Cross Hedging Currency Risk from Frontier/Emerging Markets: Thai Portfolio Investors' Perspectives.

Mr. Tanatuch Kujiranuwat

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การป้องกันความเสี่ยงจากสกุลเงินตลาดเกิดใหม่: มุมมองของการลงทุนจากนักลงทุนไทย

นายธนทัต คูจิรานุวัฒน์

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By	Mr. Tanatuch Kujiranuwat
Field of Study	Finance
Thesis Advisor	Assistant Professor RUTTACHAI SEELAJAROEN, Ph.D.

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INDEPENDENT STUDY COMMITTEE

..... Chairman
()

..... Advisor
(Assistant Professor RUTTACHAI SEELAJAROEN, Ph.D.)

..... Examiner
(Associate Professor VIMUT VANITCHAREARNTHUM, Ph.D.)

..... Examiner
(Assistant Professor TANAKORN LIKITAPIWAT, Ph.D.)

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The study explored performances of cross-hedging emerging/frontier market currency risk with developed market currencies from Thai investors' perspective. The results showed that Thai investors can use a cross-hedging strategy to reduce currency risk and improve risk adjusted return from their emerging market investment. Single cross hedging can reduce portfolio risk significantly as confirmed by the F-test. Multiple cross-hedging showed signs of improvement from single cross-hedging both in currency risk reduction and risk adjusted return improvement, but the statistical test failed to prove that the improvement is significant. While the portfolio return was penalized by the hedging cost. The risk reduction justified the hedging cost and improved risk adjusted return performance indicators; Sharpe ratio and Sortino ratio. The improvement was confirmed by standard paired bootstrap test of the ratios.

The study also revealed that, in some cases, Ederington hedge effectiveness and Sharpe/Sortino ratio can be contradicting, both measures must be considered before making a hedging decision. When investment risk is significantly higher than the FX risk, the improvement will not be as prominent as when investment risk and FX risk are in the same level. Thus, in this study, cross-hedging bond investment showed more significant risk adjusted return than stock investment. In our study, the rebalancing strategy affects the cross-hedging performance, 3-month rebalancing strategy produced a significantly higher risk adjusted return than 1-month rebalancing strategy. Sharpe ratio and Sortino ratio were equally effective and always went in the same direction. The results are sensitive to market conditions and situations, thus selection of recent data set and continuous monitoring in the actual implementation of currency cross-hedging will be crucial.

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Tanatuch Kujiranuwat

TABLE OF CONTENTS

Page

1. INTRODUCTION

In 2019, Thai Ministry of Finance (MOF) and the Bank of Thailand (BOT) decided to relax regulations to facilitate capital outflows to help promote capital flow balance and lessen pressure on the baht. This relaxing scheme encouraged Thai investors, whether they are corporations, financial institutions, or individual investors, to invest in foreign assets. In 2020, the BOT further relaxed regulations to allow residents to freely deposit funds in Foreign Currency Deposit (FCD) accounts, further relaxed regulations regarding investment in foreign securities and allow the listing in Thailand of foreign securities such as Exchanged Traded Funds (ETF) that track foreign securities.

Currency risk, also referred to as exchange-rate risk, arises from the change in price of one currency in relation to another. Corporations, financial institutions, or individual investors that hold foreign investment are exposed to currency risk that may create unpredictable profits and losses. Institutional investors, such as hedge funds and mutual funds, and multinational corporations use forex, futures, options contracts, or other derivatives to hedge currency risk. For developed market investors who invest in other developed markets, currency hedging instruments between hard currencies, also referred to as major currencies, are available in various forms and very liquid. Direct hedge can be a perfect tool to manage currency risk. However, for developed market investors who invest in foreign developing market such as emerging market, their concern is that currency risk hedging instruments for emerging market currency are still costly even in developed market. For fund managers in these countries, currency cross hedging with other major currency can be an alternative way to manage currency risk in their emerging country investment.

Cross hedging refers to the practice of hedging risk using two distinct assets with positively correlated price movements by taking opposite positions in each investment to mitigate the risk from market movement. Currency cross hedging is a common form of cross hedging, an investor sells short a different correlated currency, effectively but imperfectly reducing currency risk. For example, the EUR/USD exchange rate and GBP/USD exchange rate had a strong positive correlation of 0.95,

when a US investor buys EUR bond, pays EUR for the transaction, and exposes to EUR/USD exchange rate risk, the US investor can short GBP forward contract as a cross hedge. This is the case where the hedging instrument between major currencies are used to cross hedge other major currencies. Another example, when a US investor buys Thai baht bond, pays Thai baht (THB) for the transaction, and exposes to USD/THB exchange rate risk, the investor can short Japanese yen (JPY) forward contract as a cross hedge. This is the case where the hedging instrument between major currencies are used to cross hedge emerging market currencies.

Researchers conducted a few similar studies in this topic. Eaker and Grant (1987) studied how cross hedging can reduce currency risk for investors from developed countries. The studies provided empirical evidence that supports effectiveness of cross hedging. This study used hedging effectiveness, which focus only risk reduction ability of hedging strategy without considering hedging cost. Aggarwal and Demaskey (1997) documented that cross hedging by using futures and options in developed country currencies effectively reduced currency risk in investments in Asian emerging markets. Wong (2013) examined the behavior of a competitive exporting firm that exports to a foreign country and faces currency risk. This paper concluded that firms that expose themselves to less developed currencies should find cross hedging useful in managing currency risk. These studies were conducted in perspective of developed country investors, most of them focused on major currencies, either cross hedging between major currencies or cross hedging between major currencies and emerging market currencies. In these studies, the local currencies of the investors are usually major currencies. The hedging instruments between major currencies are liquid and not costly. These studies mostly focus on hedging effectiveness, not the risk adjusted return after cross hedging.

Frontier market is increasingly appealing to fund managers globally, due to the high growth opportunities. Frontier currency risk adds return volatility into investment portfolio. For fund manager from emerging market countries who would like to invest in frontier market assets, their currency risk situation is more severe. Hedging instrument between frontier market currency and emerging market currency is usually unavailable. Since hedging instruments between emerging market

currencies and major currencies, though not as liquid and in many forms as in developed countries, are more accessible in local FX market. Cross hedging can be a solution to work around the problem.

Thai fund managers also started to expand investment universe to cover frontier market as alternatives for Thai investors. As an emerging country, hedging instruments between Thai Baht and Frontier market currencies are not available, even in OTC market for institutional investors. The customized derivatives between Thai baht and frontier market currencies may be available but they are very costly. However, FX forward between Thai Baht and Major currencies are more accessible at lower cost. Cross hedge can be an answer to reduce currency risk. For example, when Thai investor buys Vietnam bond, pay Vietnam Dong (VND) for the transaction and exposes to VND/THB exchange rate risk, Thai investor may decide to sell forward contract of USD/THB which is available in the local market, as a cross hedge.

This study aims to assess effectiveness of cross hedging strategy for Thai fund manager, who invest in frontier market stocks and bonds, to reduce currency risk using major currency forward contracts.

In this study, first objective is to assess risk reduction potential of cross hedging frontier market currency risk in investment with major currency/local currency forward contract. In the earlier study, market environment can be different between developed country investors and Thai investors. Hedging tools for developed country investors are derivatives between two major currencies which are very liquid, however, for Thai investors, the hedging tools are derivatives between major currencies and THB, which are less liquid in the market. Hedging effectiveness of the available tools can be different. Hedging effectiveness can be measured as H.E. (Ederington's Hedge effectiveness). This hedge effectiveness was proposed by Ederington (1979), which is defined as a reduction in portfolio variance. The hedging technique used in this study, is the minimum variance hedge (MV hedge), that is widely used in many studies. The minimum variance hedge ratio is an important factor in determining the optimal number of futures contracts to purchase to hedge a position to minimize the variance of the position return.

In other studies, multiple cross hedging showed superior risk reduction performance to single cross hedging. Multiple cross hedging is a composite hedging strategy that employs multiple derivative hedge instruments to reduce risk associated with a position. Chen and Sutcliffe (2012) used multiple cross hedging which demonstrated a statistically significant increase in effectiveness from composite hedging of the Amex Oil Index using S&P500 and New York Mercantile Exchange crude oil futures. Multiple cross hedging concept can be applicable to currency risk hedging. For example, when a Thai investor buys Indian rupee (INR) bond, pays INR for the transaction, and exposes to INR/THB exchange rate risk, the investor can short combination of USD and Singapore dollar (SGD) forward contracts and as a cross hedge.

Álvarez-Díez et al. (2015) studied multiple currency cross hedging within mean-VAR hedge ratio framework. This framework calculates the mean-VAR hedge ratio for cross-hedging a long position with long or short positions in other currencies by solving the multi-objective problem to obtain either the smallest risk value for a given return, or the highest return for a certain risk level. The risk mentioned was defined as the value at risk (VaR) of the portfolio. This study found that multiple currency cross hedging could reduce the value at risk (VaR) and the conditional value at risk (C-VaR), also known as expected short fall, of the portfolio of loan and deposit of foreign currencies.

For frontier and emerging market countries, exchange rate management is an effective tool to stabilize their exchange rate to offset external shocks and facilitate trade. we hypothesize that, for each emerging market country, there might be relationship between local currency and basket of currencies of the trading counterparties of each country, that is strong enough to exploit in multiple cross hedging strategy. In our study, we aim to assess benefit of multiple cross hedging in reducing frontier market currency risk. The hedge ratios of multiple currencies are determined using the minimum variance concept by solving for a set of hedge ratios that minimized variance of currency portfolio returns.

The second objective of this study is to assess that multiple cross hedging frontier market currency risk, using basket of major currencies of the import/export

counterparties of frontier market country, can further reduce frontier market currency risk in investment portfolio.

As mentioned earlier, foreign exchange (FX) forward between Thai Baht and some Major currencies are available at some cost. Sharpe (1966) proposed Sharpe ratio, a simple yet theoretically meaningful measure that considers both return and risk simultaneously, to measure performance of investment portfolio. Ederington (1979) suggested hedging effectiveness (H.E.), a method that measures effectiveness as a proportionate decline in portfolio variance after being hedged. However, Hedge effectiveness alone can measure only ability to reduce risk of the cross-hedge strategy. The risk reduction for cross hedging may not justified the incurred cost. Aggarwal and Demaskey (1997) used Sharpe ratio as risk-return performance indicator. Álvarez-Díez et al. (2015) also consider return versus risk reduced by cross hedging strategy. Meier (2019) empirically analyzed the risk reduction performance of eight currency hedging strategies using a mean-variance framework and found that currency hedging succeeds in reducing the risk of global equity portfolios. Meier also used Ederington hedge effectiveness and Sharpe ratio to compare performance of hedging strategies. The last question that this research aims to answer is whether the risk reduction from multiple cross hedging, if any, worth the hedging cost.

The third objective of this study is to compare risk-return performance hedging cost included of the non-hedged, naïve hedge (fully hedged) and single/multiple cross hedged portfolios using Sharpe ratio and Sortino ratio as a risk-return performance indicator.

2. LITERATURE REVIEW

2.1 Background

The collapse of Bretton Woods exchange rate system (1973) led to significant investment from developed countries in emerging markets. Foreign portfolio investment (FPI) is one type of investment that can improve risk-return characteristics and diversify investment portfolio. However, FPI adds foreign exchange rate risk in the investment portfolios. Changing in exchange rates have been a major risk for investors and fund managers. Currency risk management became topic of interest for investor from developed countries. Eun and Resnick (2009) decomposed the variance of international securities in US dollar term. The country in the studies included Australia, Canada, Germany, Japan, U.K., and Switzerland. The decomposition results revealed that the exchange rate variance accounted for 60.90% to 87.89% variance of bond return in US dollar term, while the exchange rate variance accounted for 13.44% to 41.16% variance of stock return in US dollar term. Since currency risk can be a significant part of overall risk. Reducing currency risk can significantly improve risk-return profile of the portfolio. Compared with foreign bond markets, the risk of investing in foreign stock markets is attributable to currency risk to a lesser degree. However, stock investment was focused in many literatures but bond was less in focus.

In the earlier stage, developed country investors had a few market instruments to managing exchange rate risk such as forward and option, however they are only available for developed market currencies. When developed country investors invested in emerging market countries whose financial markets were less developed, and the currency hedging instruments were either not available or lack of liquidity and costly, cross hedging strategy was examined by researchers.

Eaker and Grant (1987) provided empirical evidence on the effectiveness of cross hedging to reduce foreign exchange risk. In the paper, single cross-hedges, multiple cross-hedges (basket of currency forward contracts) and commodity cross-hedges (gold forward contract) were examined. Those cross hedges were found to be less effective than traditional direct hedges, inter-temporal instability increased risk in

cross hedged positions instead of decreasing. However, the cross hedges, except the commodity cross hedge, were shown to be a useful risk reduction technique when direct hedge is not an option or not cost effective. The paper suggested that understanding and monitoring the underlying economic relationships between the cross-hedged currencies are essential in order that cross-hedging strategies can be implemented with good results. Aggarwal and Demaskey (1997) stated that investments in the developing and emerging markets are often difficult to hedge, as derivative markets in such currencies were nonexistent, relatively underdeveloped, and often not very liquid. They examined the effectiveness of cross-hedging portfolio investments in emerging markets by using derivatives denominated in the more liquid developed market currencies. Demaskey and Pearce (1998) presented empirical evidence on the effectiveness of currency and commodity futures cross-hedging. The study examined single, multiple, and joint currency and commodity futures cross-hedges for five Southeast Asian currencies. The performance of the cross-hedged portfolios was estimated within the mean-variance framework and was compared using the widely accepted Ederington hedge effectiveness. The results supported the cross-hedging strategies for all minor ASEAN currencies. Wong (2013) studied cross-hedging with currency forward and concluded in his study that when there are no hedging instruments between the home and foreign currencies, the third countries that have well-developed currency forward markets to which fund managers can access, can be a solution to hedge currency risk. Therefore, developed country fund managers had to exploit cross-hedging strategy using future, forward, option on developed currencies to reduce exchange rate risk in their emerging market portfolios. Cross-hedging is one technique pursued by researchers to reduce currency risk when hedging instruments are limited.

Frontier market countries are currently in spotlight for investment opportunity. Credit Suisse Research Institute forecasted that the frontier markets are to deliver superior investment growth to emerging market over the next five years (Credit Suisse Research Institute, 2016). Investment into this area has been increased in the last 3 years (2018-2020), Net ETF flow increased 8,371 USD million in Asia Pacific exclude Japan, 33,482 USD million in China and 4,247 USD million in India (Data

Source: Bloomberg Feb,2021). During early COVID situation in the first half of 2020, foreign portfolio investment FPI into emerging market has been on downward trend, however in the last quarter of 2020, FPI into the four selected countries has shown reviving sign. India Foreign Portfolio Investment increased by 2,170 USD million in Dec 2020 (all-time high), compared with an increase of 7,736 USD million in the previous quarter. Philippines Foreign Portfolio Investment increased by 3,564 USD million in Dec 2020, compared with an increase of 1,779 USD million in the previous quarter. Indonesia Foreign Portfolio Investment increased by 2,605 USD million in Dec 2020, compared with a drop of 1,708 USD million in the previous quarter. As of Mar 2021, Indonesia Foreign Portfolio Investment increased further by 5,225 USD million. However, Vietnam Foreign Portfolio Investment fell by 255 USD million in Dec 2020, compared with a drop of 16 USD million in the previous quarter (Data Source: Ceicdata).

At the same time, the bank of Thailand (BOT) relaxed rules and opened opportunity for Thai investors to invest offshore, to facilitate capital outflow and lesson pressure on the Thai baht. Thus, Thai fund managers started to look for higher return and are interested to invest in frontier and other emerging market countries. Thailand Foreign Portfolio investment abroad increased significantly from 53,191 USD million in 2017 to 79,410 USD million in 2020, which composed of equity and investment fund share 53,096 USD million, and Debt securities 26,314 USD million.

For fund manager from emerging market countries such as Thailand, the obstacle in managing frontier market currency risk is more severe than investors in developed market. Hedging instrument between frontier market currency and emerging market currency is usually unavailable, even in OTC market for institutional investors. However, FX forward between Thai Baht and major currencies are more accessible at some cost**. In this study, first objective is to assess risk reduction potential of cross hedging frontier market currency risk in investment with major currency/local currency forward contract. Cross-hedging strategy is studied in the perspective of Thai investors (fund managers) to reduce the currency risk. when forward contract of frontier market currency versus Thai baht is not accessible in the market.** For example, Thai fund managers who invest in

Vietnam stock market, want to protect the exchange rate risk, but exchange rate forward contract between Thai baht (THB) and Vietnamese Dong (VND) is not available in local market. As the emerging market perspective, Thai investors can use developed market currency exchange rate forward to cross hedge and reduce the currency risk in Vietnamese Dong (VND) investment. In this study, we aim to provide alternative solution for Thai fund managers to manage frontier market currency risk in their investment. In this study, cross hedging for both bond investment and stock investment will be studied. Return volatility of bond investment is usually lower than return volatility of stock investment, thus risk reduction from FX hedging bond investment may be more prominent in reducing overall risk than stock investment. Also, Karoui (2006) examined the relationship between the volatilities of equity indexes returns and FX rates for a set of emerging countries and found a positive relationship between the FX rate volatility and the stock return volatility in a large part of the sector indexes studied. This correlation may affect the effectiveness of FX cross hedging in reducing overall risk. Such correlation was also be examined in this study.

2.2 Hedge ratio and Multiple hedge ratio

Johnson (1960) was the first to derive the number of derivative contracts that can minimized the variance of the hedged portfolio. Since then, minimum variance (MV) strategy has been widely used, analyzed, and discussed.

Anderson and Danthine (1980) presented the theory of optimal hedging with one cash good and many futures markets and the risk minimizing position sizes of futures are given by the slopes of regressions. Chen, Lee and Shrestha (2004) showed that, under some normality and martingale conditions, most of the hedge ratios based on other criteria (e.g., expected utility, extended mean-Gini coefficient, and generalized semi variance) converge to the MV hedge ratio. Cross hedging using MV strategy was widely in focus in may studies and in practical used.

As mentioned earlier, Aggarwal and Demaskey (1997) proved that cross hedging of currency risk improves the risk-return performance of the portfolio. This

study stated that investment in Asian emerging markets can be effectively hedged by using futures and options in developed country currencies to minimize currency risk in the investment portfolio. Such hedging was shown to increase portfolio performance measured by the Sharpe performance index. Moreover, not only the single cross hedge strategy was used to manage the currency risk, but also multiple cross hedged was used and proven to be superior strategy in many situations.

Seelajaroen, R. (2000) studied hedging performance of the SPI (share price Index) futures contract with two optimal hedging models, Working's model and the Variance Minimization model and found in support of the usefulness of the SPI contract as a hedging tool for the AOI (All Ordinary Index) portfolio. On the standpoint of profit maximization, Working's strategy is found to be a viable strategy in the long run. The Variance Minimization model is found to be very applicable from the risk reduction standpoint. The study confirmed that even the simple use of the hedge ratio calculated from past data can reduce risk by up to 90%.

Chen and Sutcliffe (2012) studied the effectiveness of equity portfolio cross hedges with multiple hedging using financial and commodity futures and concluded that multiple hedging is superior to single hedging. Álvarez-Díez et al. (2015) concluded that multi-currency cross hedging is useful as a risk reducing alternatives. Also, within mean-risk framework, an optimal mean-risk hedge ratio accounting for the trade-off between return and risk, differed from the minimum risk hedge ratio, and it was more efficient as the number of currencies to hedge increased.

Foreign currency hedging has long been studied for developed market investors and fund managers. Multiple currency hedging can even improve hedging performance. In our study, basket of multiple currencies is studied as hedging instruments. However, which currencies should be selected for the hedging basket.

Bank of international settlement (BIS) (2005) concluded in BIS paper that emerging market countries do intervene exchange rate of their currency, presumably because they believe exchange rate management is an effective tool in the circumstances and for the situations they face. Emerging market countries need to stabilize their exchange rate to offset external shocks and facilitate trade. Central

banks of these countries intervene and influence their exchange rate or buying power of their currency on the market through issuing new currency, setting interest rates, and managing foreign currency reserves. Survey evidence indicates that central banks believe that exchange market intervention is an efficient tool to manage currency values and trends (Neely, 2008). Chit et al. (2010) provided evidence, for both developed and less developed countries, that exchange-rate volatility in emerging East Asia economies has a significant negative impact on their export flows. Fratzscher et al. (2019) documented that foreign exchange intervention polices are widely used, not only by countries that describe themselves as floaters but also countries that explicitly manage the value of their exchange rate within bands. In our study, we hypothesize that, for each emerging market country, there might be relationship between local currency and basket of currencies of the trading counterparties of each country, that is strong enough to exploit in multiple cross hedging strategy**. In our study, the second objective aim to improve cross hedging performance by looking into multi-currency cross hedge strategy using trade counterparty currencies.**

2.3 Measure of performance and Transaction cost

Hedging cost will be added into the hedged portfolio return through the bid/ask of the forward exchange rate. The bid-ask spread of spot rate and the bid-ask spread of forward point will add up into FX forward price. the hedging cost through the mark to market process. In Thai financial market, the US dollar is intermediary currency, forward contract of other non-USD major currency will be more expensive than the USD forward contract. In addition, for investors who are not in the interbank market, the extra cost of 1 forward point will be charged into forward point. Thus, for non-USD forward contract, this extra cost will be charged twice. The cost of the forward contract will penalize the portfolio return through the mark to market process.

Sharpe (1966) proposed Sharpe ratio, a simple yet theoretically meaningful measure that considers both return and risk simultaneously, to measure performance of investment portfolio. Since then, Sharpe ratio has been widely used. Ederington (1979) suggested hedging effectiveness, a method that measures effectiveness as

proportionate decline in portfolio variance. Ederington hedge effectiveness has been used extensively in many studies to compare effectiveness of hedging strategies. Sortino and Price (1994) came up with an improved measure for risk-adjusted returns. The Sortino ratio is a modified version of the widely used Sharpe index. This new ratio uses only the negative portion of the standard deviation as the measure for volatility. Some investors argue that we should only concern with downside risk, not the upside volatility. By using only, the downside volatility, Sortino ratio can be a solution for this group of investors.

Aggarwal and Demaskey (1997) used Sharpe ratio as risk-return performance indicator in hedging performance study. Álvarez-Díez et al. (2015) also considered return versus risk reduced by cross hedging strategy. Meier (2019) empirically analyzed the risk reduction performance of eight currency hedging strategies using a mean-variance framework and found that currency hedging succeeds in reducing the risk of global equity portfolios.

Efron (1979) introduced bootstrapping which is a non-parametric resampling methods for estimating the sampling distribution of an estimator. The method was inspired by the previous success of the Jackknife procedure which is used to estimate the variance and bias of a large population. It was the earliest resampling method, introduced by Quenouille (1949) and named by Tukey (1958). Efron and Tibshirani (1986) examined the theoretical basis of bootstrap approximate confidence interval for complicated situations developed by Efron (1984 and 1985). The study included the application for ratio estimation. Kunsch (1989) extended the jackknife and the bootstrap method of estimating standard errors in case of the observations came from a general stationary sequence. Kunsch proposed the moving block bootstrap method, an alternative approach that does not require fitting a parametric model to deal with dependent time series data.

Daniel and Titman (1999), in their study about market efficiency in an irrational world, they assumed that the empirical distribution represents the true distribution of returns, and assuming that returns are serially uncorrelated. Standard bootstrap was used with 100,000 bootstrap iterations to study the return of portfolio. They included an additional robustness check by performing a block-bootstrap of the

returns with nearly identical results. Cogneau and Zakamouline (2010) stated that the common obstacles to estimate the risk and return of an asset, are a lack of sufficient data and the uncertainty in the nature of the data generating process, and researchers rely on statistical bootstrap methods to overcome the obstacles.

Lo (2002) stated that the building blocks of the Sharpe ratio are expected returns and volatilities, both are unknown quantities that must be estimated statistically and are subjected to estimation error. The Sharpe ratios could not be compared naively. Ledoit and Wolf (2008) suggested to a subsampling simulation technique to statistical test difference of two Sharpe ratios by constructing a studentized time series bootstrap confidence interval. If zero is not contained in the obtained interval, the difference of the two Sharpe ratios can be declared different.

In this study, the improvement of Sharpe ratio after cross-hedging investment portfolio is statistically test the ratio using standard bootstrap method, the simplest method which assumes no serial correlation within observations.

Because both risks and returns of a portfolio change when the portfolio is hedged, both dimensions should be used in evaluating performance of the hedging strategies. To add cost perspective into this study, Sharp ratio is used to compare the cost effectiveness of naïve hedged, minimum variance single cross hedged and minimum variance multiple cross hedged portfolios with non-hedged portfolio. FX dealers include their margin into forward price, thus return performance of the hedged portfolio already price in the hedging cost. Thus, Sharpe ratio of hedge portfolio already take the hedging cost into account. The Sortino ratio, which is improved version of Sharpe ratio but uses downside deviation rather than standard deviation as a measure of risk, is also used. The significance of the difference between ratio is statistical tested using the standard bootstrapping simulation technique proposed by Efron to test the difference of performance ratio between each strategy. **The third objective of this study is to compare risk-return performance (hedging cost included) of the non-hedged, naïve hedge (fully hedged) and single/multiple cross hedged portfolios using Sharpe ratio as a risk-return performance indicator.**

2.4 Further studies related to this topic.

Opiea and Riddiough (2020) developed a new method to dynamically hedge foreign currency risk in international equity and bond portfolios. The method exploits the time-series predictability of currency returns, exploiting a forecastable component in global factor returns. The hedging strategy outperforms leading alternative approaches delivered a high risk-adjusted return. This method employed currency carry, value, and momentum investment strategies, to timing hedging positions. This innovative method went beyond traditional hedging method by using currency exchange rate prediction to improve hedging timing.

Álvarez-Díez (2015) conducted study using multi-currency cross hedging within mean-risk framework, an optimal mean-risk hedge ratio accounting for the trade-off between return and risk, which differs from the minimum risk hedge ratio. The results showed that the optimal hedge strategy can be achieved by minimizing VaR given level of return, through a multi-objective genetic algorithm (GA). This study went on to employ optimization algorithm to improve risk adjusted return of hedging ratio.

3 RESEARCH QUESTION AND HYPOTHESIS

From the literature review, we found a few studies related to our area of interest. However, those study were conducted more than a decade and most of them were conducted from perspective of developed market investors who invested in emerging market countries. The hedging instrument used was derivative between major currencies which was liquid, while hedging instruments available to Thai fund manager, will be derivatives between Thai baht and major currencies which are less liquid and more expensive. When hedging cost is substantial, risk reduction alone may not be sufficient in making hedging decision. The overall risk-return profile of the portfolio must be considered. We should include risk adjusted return measures such as Sharpe ratio into our study. For some investors, downside risk may be their major concern. We will add Sortino ratio into this study for comparison. Since currency risk can be a significant part of overall risk. The risk of investing in foreign stock markets is attributable to currency risk to a lesser degree than in foreign bond

markets. We should also add bond investment into this study for comparison. We would like to add contributions into this area of interest as the followings.

1. This study is conducted from the perspective of an emerging country investor (Thai fund managers) who invested in frontier market. For developed country investor, the hedging instruments use exchange rate between two developed currencies as underlying. In this study, the hedging instruments use exchange rate between developed currencies and emerging market currency (THB) as underlying, which are more expensive. The cost of hedging will be included in the risk adjusted return performance indicators, such as Sharpe ratio and Sortino ratio, will be used and statistically compared by standard paired bootstrap test.
2. This study is conducted in different time frame, and the idea of choosing hedging currencies in the basket, from import export trade counterparties of our target investment, will be examined.
3. In this study, both stock investment and bond investment will be studied since return volatility of stock is generally higher than bond. It is expected that overall risk adjusted return improvement from hedging FX in bond investment should be more prominent than the stock investment.

As discussed in the introduction and literature review section, the main question of this paper is conducted as follows.

Can Thai fund managers use a basket of major currencies of import and export trade counterparties to hedge their currency risk in their investment portfolios investing in frontier/emerging market stocks or bonds? Results of our study aims to provide an evidence whether risk adjusted return of frontier market investment can be improved by cross-hedging with single and/or multiple forward contracts of trade counterparty's currencies.

To answer research question, we determine three hypotheses with supporting reasons as follows.

In the first hypothesis, we conjecture that variance of the frontier/emerging market equity/bond portfolio can be reduced by cross-hedging with single FX forward contracts of import-export counterparties 'currencies.

In earlier study, when an investor from developed country invests in emerging country asset and exposes to FX risk and uses FX forward, between two major currencies, which is very liquid to cross hedge the position, there is sufficiently high correlation between investing FX rate and hedging instrument that we can exploit to significantly reduce currency risk in the investment portfolio.

The alternative hypothesis is that when Thai investor invests in frontier market country asset and exposes to FX risk and uses FX forward, between a major currency and the Thai baht which is emerging market currency, which is less liquid to cross hedge the position, there is no sufficiently high correlation between investing FX rate and hedging instrument that we can exploit to significantly reduce currency risk in the investment portfolio.

Second hypothesis, we conjecture that cross hedging the frontier/emerging market equity/bond portfolio using multiple FX forward contracts of import-export counterparties 'currencies, can outperform single currency cross hedging, in reducing currency risk.

In some case in earlier study, multiple cross hedging currency risk forward contract can further improve hedge effectiveness. We expected that we can also use a basket of import-export counterparties 'currencies as a multiple hedging tools and improve hedge effectiveness comparing to single hedging strategy.

Alternatively, we cannot find significant improvement in hedge effectiveness when we increase to more than one hedging instruments.

Third hypothesis, we conjecture that the risk reduction provided by cross hedging the frontier/emerging market equity/bond portfolio using single/multiple FX forward contracts of import-export counterparties 'currencies, is sufficiently significance to improve risk-return of the portfolio when hedging cost is considered.

We also conjecture that the risk reduction from the first or second hypothesis, if any, is significant enough to justify the cost incurred from taking hedge position. In this case, not only the hedge effectiveness has to be improved, but also the risk adjusted return measures; Sharpe ratio and Sortino ratio.

Alternatively, the cost incurred from taking hedge position outweighs the risk reduction from the first or second hypothesis and the risk adjusted return measures; Sharpe ratio and Sortino ratio, cannot be significantly improved.

4 DATA

To reflect the most recent situation as possible, the most recent data was selected and went back for a period of ten years. This data was right after the last global financial crisis in 2008. The data used in this study are collected from August 26, 2010, to Dec 30, 2020**.** The 10-year data that covered the QE effect was split into two 5-year data sets to examine the consistence of the strategy throughout the study period. The first half data covered August 26, 2010, to April 27, 2016, the second half data covered April 28, 2016, to Dec 30, 2020. The second half data started after the ECB announced its non-standard monetary policy measures buying assets from commercial banks known as quantitative easing or QE in March 2015 to support economic growth across the euro area. Also, the data started after the end of Chinese stock market turbulence in early February 2016. There may be changes in monetary policies in both developed markets and Asian markets that may affect the exchange rates in the second half of the data of this study.

We set up investment portfolios, one for bond investment and one for stock investment in each of the four countries, investing in Stock and Bond index of those countries. We select Asian countries with GDP growth higher than Thailand. High growth countries in focus includes Vietnam (GDP growth 7.02% in 2019), India (4.20% in 2019), Indonesia (5.03% in 2019) and Philippines (6.04% in 2019) (Data Source: World Bank)

We identify major trading counterparties by ranking both import and export counterparties by trade amount in 2019 (only for Vietnam, 2018 data is used instead). Trade counterparties that use EURO as national currency, are counted as euro trade counterparties. The euro is the national currency of the EU member states who have adopted it, including Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Cyprus, Estonia, Latvia, Lithuania, Malta, Slovakia, and Slovenia.

Table 1: Investing countries versus major import/export counterparties.

Country	**Top 4 Trading Counterparty**			
1. Vietnam	China	USA	Japan	Euro zone
2. India	China	USA	Euro Zone	Singapore
3. Indonesia	China	Singapore	USA	Japan
4. Philippines	China	USA	Japan	Euro zone

Appendix 1 Data source: https://tradingeconomics.com/ * we rank counterparty according to import/export amount (only currency that is major currency and FX forward is available in the Thai FX market).

The top four of export/import trading counterparties are selected into the above list. The counterparty that their currencies forward contract is not available in Thai FX market will be excluded and replaced by the next counterparty in the list.

Table 2: List of investing and trading currencies

Investing Currency	**Hedging Currency**
1. Vietnamese Dong (VND)	1. US Dollar (USD)
2. Indian Rupee (INR)	2. European Currency (EUR)
3. Philippine peso (PHP)	3. Japanese Yen (JPY)
4. Indonesian rupiah (IDR)	4. Chinese Yuan (CNH)
-	5. Singapore dollar (SGD)

Daily market data of exchange rate and forward point are retrieved from Bloomberg Database including last mid-price, bid- price, ask-price, forward point, spot rate, interest rate and equity portfolios. The last mid-price stands for the exchange rate in the mid between the bid and ask price at the end of the day. Bid price is the exchange rate that quoted by the dealer, ask price is the exchange rate accepted by buyer. Forward point is the mark up on the spot exchange rate, in basis point basis form, to become forward exchange rate. The spot-rate represents current exchange rate that settled in two business days. The Bloomberg database also provides the forward point in the basis form. Then, we can calculate the outright forward rate, as shown in the following formula.

$$Ask\ forward\ exchange\ rate_t = Ask\ spot\ rate_t + Ask\ forward\ point_{t,m}$$

$$Bid\ forward\ exchange\ rate_t = Bid\ spot\ rate_t + Bid\ forward\ point_{t,m}$$

The above formula reflects the hedging cost for interbank market. The bid-ask spread of spot rate and the bid-ask spread of forward point will add up into the hedging cost through the mark to market process. Hedging cost will penalize the hedged portfolio return.

Since US dollar is the intermediary currency, the USD forward contract will be cheaper than forward contract of other non-USD major currency. For example, to sell SGD/THB forward contract, we must sell SGD/USD forward contract and sell USD/THB forward contract. The total spread will make the transaction more costly.

For fund manager that is not in the interbank market, the extra cost of 1 forward point will be charged into forward point. Thus, for non-USD forward contract, this extra cost will be charged twice.

Currency return is calculated as shown below and will be used for volatility calculation and Hedge ratio calculation. The mid exchange rate is used in the formula.

$$\text{Currency return } (\%) = \left(\frac{Exchange\ rate_{t+1}}{Exchange\ rate_t} - 1\right) \times 100$$

Portfolios return from investment are calculated by investment total return Index in each country, data are collected from Bloomberg database.

Table 3: Investment Asset and Definitions.

Investment Asset	Definition Index name (Bloomberg Ticker)
1. Vietnam stock	Vietnam Ho Chi Minh Stock Index / VN-Index (VNINDEX Index)
2. Philippine stock	Philippines Stock Exchange PSEi Index (PCOMP Index)
3. Indonesia stock	Jakarta Stock Exchange Composite Index (JCI Index)
4. India stock	NSE Nifty 50 Index**:** The Index tracks the behavior of a portfolio of blue-chip companies, the largest and most liquid Indian securities domiciled in India and listed on the NSE (NIFTY INDEX)
5. Vietnam Bond	Bloomberg Barclays EM USD Aggregate: Vietnam Total Return Index Unhedged USD*(I01438US Index)
6. Philippine Bond	Bloomberg Barclays EM Local Currency: Philippines Total Return Index Unhedged PHP (I20284PH Index)
7. Indonesia Bond	Bloomberg Barclays EM Local Currency: Indonesia Total Return Index Unhedged IDR (I20283ID Index)
8. India Bond	Bloomberg Barclays EM Local Currency: India Total Return Index Unhedged INR (I20280IN Index)

* I01438US Index was converted from USD to VND by daily spot exchange rate.

Investment Total Return Index is collected in every trading day, and the Investment return in each period is calculated as the following formula.

$$\text{Investment return (\%)} = \left(\frac{Investment\ Total\ Return\ Index_{t+1}}{Investment\ Total\ Return\ Index_{t}} - 1\right) \times 100$$

$$\text{Foreign Investment return into THB(\%)} = \left(\frac{Investment\ Total\ Return\ Index_{t+1} \times Spot\ rate_{t+1}}{Investment\ Total\ Return\ Index_{t} \times Spot\ rate_{t}} - 1\right) \times 100$$

Spot rate is the foreign exchange bid rate of Thai baht per Investment currency unit.

Table 4: Interest rate and Definitions.

Interest rate	Definition
1. Thai Baht (THB)	THBFIX rate 1,3 and 6-month
2. European Currency (EUR)	Euribor rate ACT/360 1,3 and 6-month
3. Japanese Yen (JPY)	ICE LIBOR JPY 1,3 and 6-month
4. Chinese Yuan (CNH)	CNH Deposit 1,3 and 6-month
5. Singapore dollar (SGD)	SGD Deposit 1,3 and 6-month
6. US Dollar (USD)	ICE LIBOR USD 1,3 and 6-month

5 METHODOLOGY

In this study, we mostly follow methodology used in Meier (2019). Our portfolio follows return of stock/bond indexes, single/multiple forward contracts of currencies are used for hedging position. Cross-hedging performance measures by hedging effectiveness (HE) proposed by Ederington (1979), Sharpe ratio proposed by Sharpe (1966) and Sortino ratio proposed by Sortino (1994). Standard paired bootstrapping method proposed by Efron (1979) is used in statistical test for ratio differences.

However, the objectives of our study follow are different from Meier (2019). Instead of multi-currency investment position, our study focuses on single currency investment position but hedged with both single currency forward contract and basket of currency forward contracts as in the studies by Eaker and Grant (1987) and Aggarwal and Demaskey (1997). We also include the Sortino ratio proposed by Sortino (1994) as risk return measure.

5.1 Construction of stock and bond investment portfolio

We setup four types of portfolios, non-hedged, naïve hedged (Full hedge), single cross hedged, and multiple cross hedged. Risk and risk adjusted return of each portfolio are measured for performance comparison. The details of each portfolio are shown as the followings.

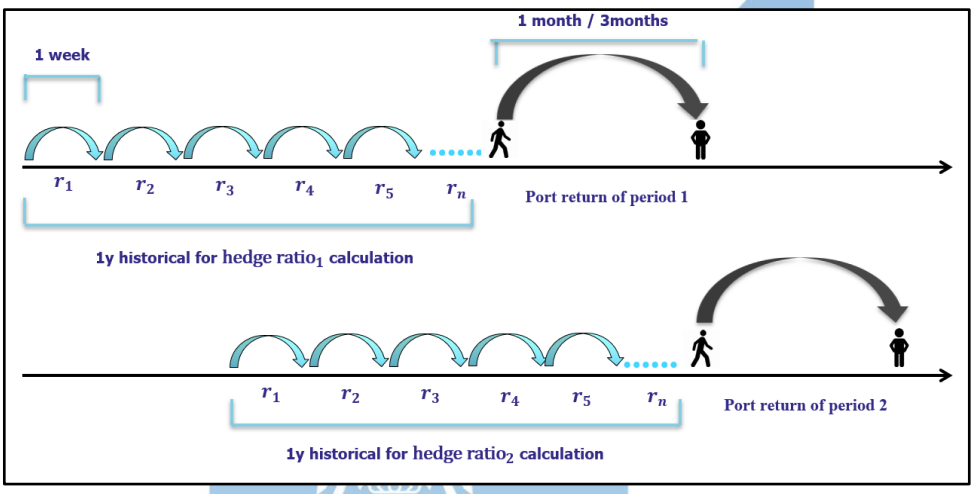
Initial position of each portfolio is stock/bond index investment position in one of each country of interest (Vietnam, India, Philippines, and Indonesia) with value of one billion THB, marked to the market (MTM) at the t_0. Growth of these portfolios in local currency are assumed to be according to stock/bond index return. Then, these portfolios are marked to market into THB every day. Details of each portfolio are as the following.

1. Non hedged portfolio assumes that investment in target market is not hedged for currency risk. The portfolio does not contain any position of forward contract in hedging currency (Hedge ratio = 0).
2. Naïve hedged (Full hedge) assume that investment in target market is fully hedged for currency risk. The portfolio always contains a position of forward contract in hedging currency. Notional amount of forward contract at the beginning of every rebalancing period, equals to the MTM value in THB of the stock/bond of the portfolio. The hedging position are rebalanced every month and every three months (Hedge ratio = 1).
3. Single cross hedged assumes that investment in target market is minimum variance (MV) hedged for currency risk. The portfolio always contains a position of forward contract in hedging currency with notional amount of forward contract at the beginning of every rebalancing period, equals to the amount according to the MV hedge ratio. The hedging position are rebalanced every month and every three months (Hedge ratio = MV hedged ratio).
4. Multiple cross hedged assumes that investment in target market is MV hedged for currency risk. The portfolio always contains multiple position of forward contracts in hedging currencies with notional amount of each currency forward contract at the beginning of every rebalancing period equals to the MV hedge ratio of each currency. The hedging position are rebalanced every month and every three months.

In ours study, fund managers are assumed to rebalance their hedge at the beginning of rebalancing period, if hedging ratio for rebalancing is required, each hedging ratio is estimated using weekly returns from previous one year period as

explained by figure (1). Formula for hedge ratio calculation is as shown in equation (7). Return of the portfolio, calculated during each rebalancing period composes of return from stock/bond investment and return from exchange rate change. Calculation details are as shown in equation (5). Portfolio risk is estimated by return volatility of the portfolio as shown in equation (8). Sharpe ratio and Sortino ratio are used to estimate risk return performance of the portfolio, formula is provided in equation (11) and (12).

Figure1: Visual explanation of how historical data is used to estimate hedge ratio.



5.2 Mark to market formula

As in the process explained above, monthly mark to market formular is as the following.

Mark to market according to investment movement in target currency is calculated in equation (1)

$$MTM_{t+1}\ in\ target\ currency = MTM_t\ in\ target\ currency \times (1 + Investment\ return_{t+1}(\%)) \quad (1)$$

Mark to market according to exchange rate movement in THB is calculated in equation (2)

$$MTM_{t+1} in\ THB = (MTM_{t+1} target\ currency \times \frac{USD}{THB_{t+1,bid}} \div \frac{USD}{target\ currency}_{t+1,ask}) \quad (2)$$

Notional of hedging position in hedging currency unit is calculated in equation (3)

$$N_b = \frac{MTM_t in\ THB \times hedge\ ratio_{t,m}}{forward\ price\ in\ hedging\ currency_{t,m}^{mid}} \quad (3)$$

Mark to market from hedging is calculated in equation (4)

$$MTM\ hedging_t = N_b D_b(t,T) X_0 - N_q D_q(t,T) \quad (4)$$

Where, t = valuation date

T = payment date

X_0 = spot FX rate: base/quote

$D_b(t,T)$= discount factor of base currency from valuation date to forward date

$D_q(t,T)$= discount factor of quote currency from valuation date to forward date

N_q= notional principal amount for quote currency

Return of hedged portfolio (%) is calculated in equation (5)

$$Return\ of\ hedged\ portfolio(\%)_{t+1} = (\frac{MTM_{t+1}\ in\ THB + MTM\ hedging_{t+1} + Realize_{t+1}}{MTM_t in\ THB + MTM\ hedging_t + Realize_t} - 1) \times 100 \quad (5)$$

5.3 Minimum variance hedge ratio and Portfolio value calculation

$$\sigma^2_{weekly\ currency\ return} = \frac{\sum_{i=1}^{n}(weekly\ currency\ return_i - Avg(weekly\ currency\ return))^2}{n-1} \quad (6)$$

where,

n = number of weeks to calculate variance (52)

Hedge ratio can be calculated by varying parameter h to minimize variance according to the following equation.

$$\sigma^2_{p,t} = \sum_{i=1}^{n} h^2_{i,t}\sigma^2_{i,t} + \sum_{i=1}^{n}\sum_{j=1\ j\neq i}^{n} h_{i,t}h_{j,t}Cov_{ij,t} \quad (7)$$

where,

$\sigma^2_{p,t}$ = the currencies portfolio variance during period t

$\sigma^2_{i,t}$ = the currency variance returns during period t

$Cov_{ij,t}$ = the Co-variance of currency (i , j) during period t

$h_{j,t}$ = the hedge ratio of currency j during period t

$h_{i,t}$ = the hedge ratio of currency i during period t

hedge ratio h < 0 representing a short position and h > 0 representing a long position in currency. By nature, the exchange rate of target currencies and the exchange rate of hedging currencies relative to baht should go in the same direction. We expect to see h <= 0, for h >0 that we do not have any rational explanation for the occurrence. We use h equal to zero.

In this study, Visual Basic for Application (VBA) program is developed to be used in combination with EXCEL spreadsheets to generate the back test results of each cross-hedging strategy for each investment portfolio. The test will be realistic, using out-of-sample test concept, hedge ratio will be calculated using 1-year data and

will be used to hedge the investment position throughout the next rebalancing period (1-month or 3-month).

Within VBA program, solver tool in EXCEL will vary a set hedge ratio as shown in equation (7) until variance of currency hedge position is minimized. This concept is in line with the least square principle in linear regression analysis where the sum square of error is minimized. In the case that the hedge ratio (HR) is positive the result will be the same. Since we force the HR to be non-negative, the solution will be the same as non-negative least square regression (NNLS). This minimization problem has quadratic objective function that is convex, the generalized reduced gradient (GRG) method in EXCEL solver will be able to find the global minima which is unique.

5.4 Performance indicators

Two performance indicators are used to compare hedging performance of each hedging strategy. Hedging effectiveness, as shown in the following formula, indicates risk reduction of each strategy. Sharp ratio also shown as in the following formula, indicates risk adjusted return performance of each strategy.

$$\sigma_{portfolio\ return} = \sqrt{\frac{\sum_{i=1}^{n}(Return\ of portfolio(\%)_i - Avg(Return\ of portfolio(\%))^2}{n-1}} \quad (8)$$

where,

n = number of portfolio return

$$\text{Variance of portfolio} = (\sigma_{portfolio\ return})^2 \quad (9)$$

$$Hedging\ effectiveness = 1 - \frac{variance\ of\ hedged\ portfolio}{variance\ of\ nonhedged\ portfoio} \quad (10)$$

Hedging effectiveness is interpreted according to the following concepts.

1. Negative hedging effectiveness means the cross-hedging strategy is fail
2. Positive hedging effectiveness means the cross-hedging strategy can reduce portfolio currency risk.
3. If the full hedged, single cross hedge and multiple cross hedged are positive, the one with higher hedging effectiveness will be more efficient to reduce portfolio currency risk.

$$Sharpe\ ratio\ = \frac{Avg(Return\ of portfolio(\%)) - Risk\ free\ return(\%)}{\sigma_{portfolio\ return}(\%)} \quad (11)$$

$$Sortino\ ratio\ = \frac{Avg(Return\ of\ portfolio(\%)) - Risk\ free\ return(\%)}{\sigma_{down\ side\ portfolio\ return}(\%)} \quad (12)$$

$$\sigma_{down\ side\ portfolio\ return}(\%) = \sqrt{\frac{\sum_{i=1}^{n} Min(0, Return\ of\ portfolio(\%) - Risk\ free\ return(\%))^2}{n-1}} \quad (13)$$

Sharpe/Sortino ratio represents the additional amount of return that fund manager receives per unit of increase in risk. Higher Sharpe/Sortino ratio means better risk adjusted performance.

We calculate Sharpe ratio and Sortino ratio for both non-hedged portfolios and hedged portfolios. For the hedged portfolios, the Sharpe ratio and Sortino ratio will reflect the hedging cost. It is market practice for dealers to include profit margin to calculate short forward price as explained in the previous section. Since the forward price which includes profit margins for dealer is used in calculation of the hedged portfolio return, the return performance of the hedged portfolio will be penalized by the hedging cost included in the forward price. If the risk reduction justifies the

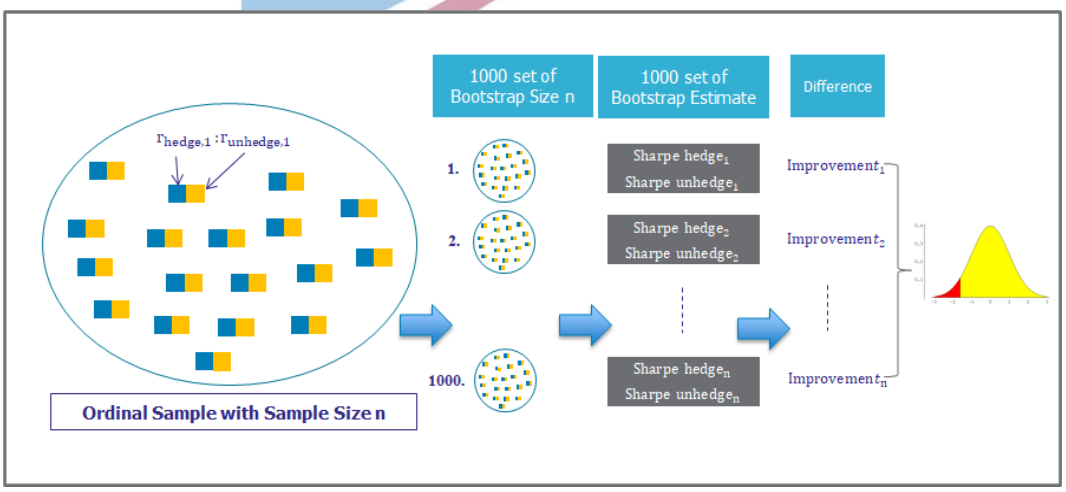
hedging cost, we will see the improvement of the Sharpe ratio and Sortino ratio of the hedged portfolio over the non-hedged portfolio.

5.5 Standard paired bootstrap test

This standard bootstrap method was the first introduced by Efron (1979). More formally, this method consists in drawing random resamples with replacement, $X^* = (x_1^*, x_2^*, \ldots, x_n^*)$ from $X = (x_1, x_2, \ldots, x_n)$ sample. Note that the number of data points in a bootstrap resample is equal to the number of data points in the original sample. By doing this several times and computing for each resample the $\hat{\theta}(X^*)$ which is the estimator of interest, we can obtain an approximate probability distribution of the estimator $\hat{\theta}(X)$. The number of boot strap samples is supposed to be as many as possible, in this study we used 1,000 bootstrap samples to estimate the distribution of the estimator.

In our case, the daily returns for hedged and non-hedged portfolio are paired data with bivariate distribution. We define X as a sample set of vector daily return of hedged and non-hedged portfolio. The estimator of interest $\hat{\theta}(X)$ in this study is the difference between Sharpe ratio of the hedged and non-hedged portfolio.

Figure2: Visual explanation of Standard Paired Bootstrap Test



The standard paired bootstrapping procedure in this study is as the followings.

1. Calculate the daily return of both hedged and non-hedged portfolio, pair them into return vectors and use them as paired bootstrap samples. The population sample set for 10-year analysis contains 2,284 samples (n=2,284).
2. Randomly draw 2,284 bootstrap samples from the data in the population sample set with replacement to form a re-sampled sample set (n equals to the number of data points in the original sample). Each re-sampled sample set is called a Bootstrap Sample set. Then, repeat this step for 1,000 times to generate the total of 1,000 Bootstrap Sample sets.
3. Evaluate the statistic of interest (θ) which in our case is difference between Sharpe ratio of non-hedged and hedged portfolio for each Bootstrap Sample set. There will be totally 1,000 estimates of θ.
4. Construct distribution of the statistic of interest with these 1,000 Bootstrap statistics and use it to make our statistical inference, that is a confidence interval for $\theta>0$. To declare the two Sharpe ratios difference is significant from zero, zero must not be contained in the confidence interval.

5.6 Limitations of Methodology

1. In this study, the hedge ratio is limited to non-negative to preserve the hedging position as a short position. Allowing the hedge ratio to be positive implies that speculation is allowed. In some case, this can improve hedging performance.
2. The correlation between stock index returns and FX returns is studied. The results are presented in the next section. However, the correlation between stock index returns and FX returns is ignored in this study. The same with the correlation between bond index returns and FX returns.
3. Serial correlation within daily returns is ignored. The serial correlation may exist and require more advanced method. For example, the block bootstrap or a studentized time series bootstrap may improve accuracy of standard paired bootstrap test.

6 EMPIRICAL RESULTS

The empirical results will be presented in four sections. The first section is general analysis results which explains the general observations and some noticeable key points. The second is the analysis of hedging results. The third section is the answer to the research question and the three hypotheses in this study. The fourth section covers the analysis related to this study in addition to the research questions and hypotheses.

6.1 General analysis

Preliminary analysis of the data revealed that FX risk in foreign bond portfolio investment was larger portion in overall risk than in foreign stock investment. Correlation between stock index returns and FX returns was generally low. The correlation between bond index returns, and FX returns was also low.

FX risk in foreign bond portfolio investment was larger portion in overall risk than in foreign stock investment. From the data the data set collected from August 26, 2010, to Dec 30, 2020, Volatility of exchange rate of investment currencies to Thai Baht ranged from 5.13% per year to 7.23% per year, while the stock index volatility ranged significantly higher from 16.82% per year to 18.66% per year and the bond index ranged from 3.87% per year to 6.07% per year. After mark to market with FX, stock investment risk in THB term increased only 4.83% per year to 19.53% per year. However, the bond investment risk increased more after marking to the market with FX, the investment risk increase ranged from 30.13% to 125.24% (as shown to Table 5).

Thus, reducing FX risk in bond investment should have more prominent effect in improving overall risk. As shown in Table 6, Ederington hedge effectiveness (H.E.) from cross-hedging currency risk in bond investment is always higher than in stock investment in all currency pairs. The paired t-test was applied to confirm the difference and it was confirmed statistically (as shown to Table 7).

Table 5: Investment volatility and FX volatility (% per year).

Country	Vietnam	India	Indonesia	Philippines
Stock Volatility	17.06	17.06	16.82	18.66
Bond Volatility	6.07	3.87	5.94	4.83
FX(CCY/THB) Volatility	5.13	7.23	7.20	5.74
Stock MTM THB Volatility	17.89	20.39	19.90	20.19
Bond MTM THB Volatility	7.90	8.72	10.67	8.11
Stock Volatility increase*	4.83	19.53	18.32	8.22
Bond Volatility increase*	30.13	125.24	79.86	67.92

*Investment Volatility increase (%) $= \left(\frac{Investment\ MTM\ THB\ Volatility}{Investment\ Volatility} - 1\right) \times 100$

Table 6: Hedge effectiveness of single cross-hedging currency risk in Bond vs Stock investment (%).

Hedge effectiveness	Bond	Stock
VND USD	43.17	3.43
VND EUR	9.32	-0.32
VND CNH	12.43	3.38
VND JPY	10.14	-0.84
INR USD	19.02	-2.99
INR EUR	5.34	-1.28
INR SGD	14.91	1.24
INR CNH	9.87	-0.38
IDR USD	1.36	-3.33
IDR SGD	3.13	1.51
IDR JPY	1.52	-0.19
IDR CNH	2.13	-0.63
PHP USD	15.54	0.44
PHP EUR	0.50	-0.28
PHP CNH	6.96	1.10
PHP JPY	2.20	-1.06

Table 7: Hedge effectiveness Paired t-test.

Paired t- test between H.E. Stock vs. Bond		
	Stock	Bond
Mean	-0.0001	0.0985
Variance	0.0004	0.0112
Observations	16	16
P(T<=t) one-tail	0.0006***	
P(T<=t) two-tail	0.0011***	

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Correlation between stock index returns and FX returns was generally low. **The correlation between bond index returns, and FX returns was also low.** Karoui (2006) found strong correlation between return of some stock sector indexes in the emerging market and return of FX between local currencies and the USD, as high as 80 % or more. We examined whether there exists any natural relationship between stock index returns and FX returns, in both local currency to USD, and local currency to Thai Baht. However, in this study, no such strong relationship was found (as shown to Table 8). We also examined the correlation between bond index returns and the FX returns in the same way, we also did not find such strong relationship (as shown to Table 9). However, in this study, we only study market indexes not the sector indexes as in the previous study. We decided to ignore such correlation in our study.

Table 8: Correlation between Stock Total index Return and FX Return

	2011-2020		2011-2015		2016-2020	
Country	**Local CCY/THB**	**Local CCY/USD**	**Local CCY/THB**	**Local CCY/USD**	**Local CCY/THB**	**Local CCY/USD**
Vietnam	-0.010	0.060	-0.005	0.044	-0.015	0.080
India	0.298	0.419	0.395	0.469	0.192	0.387
Indonesia	0.236	0.381	0.157	0.322	0.327	0.451
Philippines	0.108	0.191	0.159	0.236	0.062	0.153

Table 9: Correlation between Bond Total index Return and FX Return

	2011-2020		2011-2015		2016-2020	
Country	**Local CCY/THB**	**Local CCY/USD**	**Local CCY/THB**	**Local CCY/USD**	**Local CCY/THB**	**Local CCY/USD**
Vietnam	-0.083	-0.089	-0.060	-0.107	-0.142	-0.059
India	0.094	0.122	0.113	0.125	0.062	0.118
Indonesia	0.253	0.352	0.201	0.314	0.370	0.450
Philippines	0.073	0.109	0.124	0.148	-0.007	0.038

6.2 Analysis of cross-hedging results

In this section, we first show the examples of cross-hedging analysis result table. The rest of this section provides analysis from cross-hedging results. We examined results from cross hedging stock investment first, found that the risk adjusted return for stock investment in Vietnam, Indonesia and Philippines can be improved by cross hedging with Japanese Yen, but the improvement was from return rather than risk reduction. The same observation was found in India stock investment with Singapore dollar. We analyzed the results of cross-hedging bond investment and found that currency risk reduction from cross-hedging was more prominent in bond investment than in stock investment. We also found that, throughout the study period, the average hedge ratios between currency pairs are all less than 1. After we split the data into two halves, we found that the results depended on the economic and market conditions. Another observation is that the improvement from using baskets of currencies as cross hedging tools is not statistically significant.

We first show the examples of cross-hedging analysis result table. From the procedures explained in research methodology section, we obtained the cross-hedging Vietnam stock index investment results and tabulated them as shown in Table 10. The first column of the table shows the standard deviation of the returns, Sharpe ratio and Sortino ratio of the non-hedged portfolio, while the subsequent columns show the standard deviation of the returns of the hedged portfolio, hedge effectiveness, Sharpe ratio and Sortino ratio for each hedge strategy of single cross hedge. Table 11 shows

results of the multiple hedging strategy of the same format. We show these Table as a sample of our full results only. The rest of the results, tabulated in this format, will be available in the appendix (2-27). However, significant results will be retabulated into more concise table format for discussion.

Table 10: Performance indicators of Vietnam stock portfolio from single hedging strategies (1-month rebalancing)

VND	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	EUR	JPY	CNH	USD	EUR	JPY	CNH
S.D. (%)	17.889	17.498	19.303	20.244	17.614	17.509	17.898	17.949	17.558
H.E. (%)		4.321	-16.434	-28.073	3.103	4.198	-0.106	-0.682	3.664
Sharpe ratio	0.729	0.765	0.864	0.895	0.624	0.748	0.762	0.801*	0.631
Sortino ratio	0.257	0.272	0.320	0.346*	0.218	0.266	0.696	0.284**	0.220

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Table 11: Performance indicators of Vietnam stock portfolio from multiple hedging strategies (1-month rebalancing)

VND	Multiple cross hedged										
	USD EUR	USD JPY	USD CNH	EUR JPY	EUR CHN	CNH JPY	USD EUR JPY	USD EUR CNH	USD JPY CNH	EUR JPY CNH	USD EUR JPY CNH
S.D. (%)	17.511	17.513	17.515	17.962	17.566	17.636	17.519	17.158	17.525	17.648	17.515
H.E. (%)	4.174	4.151	4.139	-0.822	3.576	2.808	4.087	4.098	4.024	2.672	4.128
Sharpe ratio	0.753	0.749	0.740	0.816**	0.626	0.639	0.755	0.746	0.744	0.644	0.750
Sortino ratio	0.268	0.266	0.263	0.290**	0.219	0.224	0.268	0.265	0.264	0.226	0.266

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Risk adjusted return for stock investment in Vietnam, Indonesia and Philippines can be improved by cross hedging with Japanese Yen, but the improvement was from FX return rather than risk reduction. The same observation was found in India stock investment with Singapore dollar. Table 12 shows the results of performance indicators of Vietnam portfolios from nonhedged, 1-month rebalancing and 3-month rebalancing, cross hedging Vietnam stock with Japanese Yen improved risk adjusted return. Both Sharpe ratio and Sortino ratio improvement was statistically significance. With Japanese Yen cross-hedging (1-month rebalancing), Sharpe ratio and Sortino ratio, from the investment in Vietnam stock, increased from 0.729 and 0.257 respectively for non-hedging portfolio, to 0.801 and 0.284 after cross hedging. We also observed the same direction when we cross hedged Philippines Peso and Indonesia Ringgit with Japanese Yen. For Indonesia stock investment as shown in Table 13, Japanese Yen cross-hedging (1-month rebalancing) increased Sharpe ratio and Sortino ratio from 0.087 and 0.033 for non-hedging portfolio, to 0.260 and 0.048 after cross hedging. For Philippine stock investment as shown in Table 14, Japanese Yen cross-hedging increased Sharpe ratio and Sortino ratio from 0.317 and 0.121 for non-hedging portfolio to 0.351 and 0.134 after cross hedging. We did not use Japanese Yen to cross hedge Indian Rupee because Japanese Yen is not major trade counterparty to India.

However, we noticed that the hedge effectiveness between these currencies; Vietnam Dong, Indonesian Ringgit and Philippine Peso to Japanese Yen are all negative, for 1-month rebalancing. The hedge effectiveness between Japanese Yen and those three currencies; Vietnam Dong, Indonesian Ringgit and Philippine Peso, were -0.682, -0.242 and -0.242 respectively. We also observed the same pattern for 3-month rebalancing strategy, the hedge effectiveness was also negative, -0.836, -0.187 and -1.055 respectively.

Table 12: Performance indicators of Vietnam stock portfolio hedged by Japanese Yen.

Country	Vietnam		
Hedge Strategy	Non-hedged	1-month Rebalancing	3-month Rebalancing
S.D. (%)	17.889	17.949	17.584
H.E. (%)	-	-0.682	-0.836
Sharpe ratio	0.729	0.801*	0.815**
Sortino ratio	0.257	0.284**	0.289**

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Table 13: Performance indicators of Indonesia stock portfolio hedged by Japanese Yen.

Country	Indonesia		
Hedge Strategy	Non-hedged	1-month Rebalancing	3-month Rebalancing
S.D. (%)	19.898	19.922	19.917
H.E. (%)	-	-0.242	-0.187
Sharpe ratio	0.087	0.260**	0.130**
Sortino ratio	0.033	0.048**	0.049**

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Table 14: Performance indicators of Philippines stock portfolio hedged by Japanese Yen.

Country	Philippines		
Hedge Strategy	Non-hedged	1-month Rebalancing	3-month Rebalancing
S.D. (%)	20.190	20.254	20.296
H.E. (%)	-	-0.635	-1.055
Sharpe ratio	0.317	0.351*	0.351
Sortino ratio	0.121	0.134*	0.135

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Cross-hedging Vietnam, Indonesia and Philippines stock investment with Japanese Yen, significantly improved the risk adjusted return performance indicators; Sharpe ratio and Sortino ratio statistically, while the hedge effectiveness showed negative result. The hedge effectiveness contradicted the risk adjusted return performance indicators. After examined into the details as shown in Table 15, we found that the correlations between these currencies to Japanese Yen are low and the cross hedging could not reduce risk, but the improvement came from the return from hedging position due to depreciation of Japanese Yen during the period. This extra return drove the improvement of risk adjusted return indicators from the return side. Depreciation of Japanese Yen during the period depended on the market direction and would not be sustainable. Making hedging decision from risk adjusted return performance indicator alone may lead to mistake. It is recommended that investors should take both hedging effectiveness and the risk adjusted return measures into consideration when making cross hedging decision. Otherwise, the risk adjusted return improvement from direction return of the hedging currency can vanish when market direction changes.

Table 15: Correlation between investing currency and hedging currency (2011-2020).

	USD	EUR	JPY	CNH	SGD
VND	0.83	0.16	0.27	0.58	-
PHP	0.46	0.12	0.13	0.35	-
IDR	0.44	-	0.11	0.36	0.25
INR	0.37	0.10	-	0.32	0.25

For India stock investment, cross-hedging with Singapore dollar (3-month rebalancing) produced the marginally positive hedging efficiency, but significantly improved risk adjusted return performance indicators statistically, both Sharpe ratio and Sortino ratio (as shown in Table 16). Thus, risk adjusted return performance may

also not be sustainable, because the improvement came from market direction return instead of the risk reduction.

Table 16: Performance indicators of India stock portfolio hedged by Singapore dollar.

Country	India		
Hedge Strategy	Non-hedged	1-month Rebalancing	3-month Rebalancing
S.D. (%)	20.390	20.222	20.263
H.E. (%)	-	1.638	1.238
Sharpe ratio	0.404	0.472	0.480*
Sortino ratio	0.156	0.182	0.185*

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

We analyzed the results of cross-hedging bond investment and found that currency risk reduction from cross-hedging was more prominent in foreign bond investment than in stock investment. Table 17 - 18 are summary of the results of cross-hedging currency risk in the bond investment. As expected, since return volatility of bond investment is usually lower than stock, the improvement of the risk adjusted return performance indicators from cross-hedging bond investment should be more prominent than the improvement in cross hedging stock investment. Both Sharpe ratio and Sortino ratio from investment in Vietnam bond significantly increased from 0.662 and 0.152 in non-hedging portfolio to 0.866 and 0.202 after being cross hedged by Japanese Yen using MV (minimum variance) hedge ratio. Also, the Sharpe ratio and Sortino Ratio of the India bond investment increased from 0.324 and 0.070 respectively for the non-hedging portfolios, to 0.507 and 0.111 respectively, after being cross hedged by Singapore dollar using MV hedge ratio.

For Vietnam bond investment, cross hedging with Japanese Yen significantly improved both the risk adjusted return performance indicators; Sharpe ratio and Sortino ratio, but it still could not substantially reduce portfolio risk. The hedging efficiency was marginally positive at 2.862%. However, the confidence levels of significance of the improvement were higher in the case of bond investment than in the case of stock investment, up to 95% and 99%. For India bond investment, cross-

hedging with Singapore dollar (3-month rebalancing) produced the marginally positive hedging efficiency, and significantly improved risk adjusted return performance indicators statistically, both Sharpe ratio and Sortino ratio.

Table 17: Performance indicators of Vietnam bond portfolio from single hedging strategies (3-month rebalancing, 2011-2020)

VND	Non-hedged	Single MV cross hedged			
		USD	EUR	JPY	CNH
S.D. (%)	7.898	6.706	7.877	7.785	7.302
H.E. (%)	-	27.921	0.554	2.862	14.531
Sharpe ratio	0.662	0.835	0.740	0.866**	0.541
Sortino ratio	0.152	0.218	0.171	0.202***	0.125

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Table 18: Performance indicators of India bond portfolio from single hedging strategies (3-month rebalancing, 2011-2020)

INR	Non-hedged	Single MV cross hedged			
		USD	EUR	SGD	CNH
S.D. (%)	8.717	8.413	8.728	8.609	8.554
H.E. (%)	-	6.862	-0.239	2.473	3.701
Sharpe ratio	0.324	0.351	0.413	0.507*	0.227
Sortino ratio	0.070	0.077	0.089	0.111*	0.049

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

We went further into more details by examining the details of hedge ratios used the hedging process. On average, the hedge ratios between currency pairs are all less than 1. The naïve hedging strategy tend to over-hedge the position in the long run. Theoretically, the MV hedge ratio should be more effective than Naïve hedge strategy in the long run one (as shown in Table 19).

Table 19: MV Hedge ratio of 3-month Rebalancing (2011-2020)

	USD			EUR			JPY			CNH			SGD		
	Avg.	Max	Min	Avg.	Max	Min	Avg.	Max	Min	Avg.	Max	Min	Avg.	Max	Min
VND	0.96	1.28	0.80	0.18	0.47	0.00	0.19	0.44	0.00	0.74	1.25	0.43	-	-	-
PHP	0.66	1.04	0.27	0.21	0.66	0.00	0.15	0.51	0.00	0.52	0.85	0.31	-	-	-
IDR	0.34	0.87	0.00	-	-	-	0.05	0.31	0.00	0.39	0.82	0.00	0.50	1.25	0.00
INR	0.46	0.99	0.00	0.19	0.60	0.00	-	-	-	0.40	1.10	0.00	0.63	1.34	0.04

Analysis of the spilt data revealed that the results depended on the economic and market conditions. In the next step, the 10-year data (2011 to 2020) was split into two 5-year data sets (2011-2015 and 2016-2020) to examine the consistence of the strategy throughout the study period. As shown in Table 22– 23, for Vietnam bond investment, only in the first half of the data, Japanese Yen could statistically improve the risk return performance indicators; both Sharpe ratio and Sortino ratio. In the second half of the data, cross-hedging bond investment with Japanese Yen no longer improve risk adjusted return performance indicator. However, cross hedging Vietnam bond position with US dollar showed positive hedge effectiveness and statistically significance in improving Sharpe ratio and Sortino ratio. In the Table 23, in the second half, hedge effectiveness from cross hedging Vietnam bond investment by the US dollar using MV hedge effectiveness were positive at 43.17% and significantly increased both Sharpe ratio and Sortino ratio from 0.214 and 0.039 to 0.794 and 0.160, respectively. The improvement was statistically significant. For Vietnam bond position, cross hedged with US dollar showed robustness in reducing risk and improving Sharpe ratio and Sortino Ratio at the same time. The correlation between VND/THB and USD/THB was as high as 0.91, as shown in the Table 20.

For India bond investment in the first half, Euro showed negative hedge effectiveness while significantly improved the risk adjusted return performance indicators (as shown in Table 24). However, in the second half, although each correlation between currency pairs is moderate, as shown in Table 20. The correlation between INR/THB and USD/THB is 0.56, while the correlation between INR/THB

and SGD/THB is only 0.36, both US dollar and Singapore dollar were shown to be effective cross hedging tools, which could reduce risk (positive hedge effectiveness) and improved risk adjusted return performance indicators. Using 10-year data and 5-year data can lead to different decision. The too-long time series data that may not represent the recent market condition, may lead to wrong cross hedging decision. Cross hedging decision can depend on conditions, and it is prudent to closely monitor hedging performance closely in order that hedging strategy can be adjusted in timely manner. As shown in Table 25, in the second half, hedge effectiveness from cross hedging India bond investment by the SGD dollar were positive at 14.91% and significantly increased both Sharpe ratio and Sortino ratio from 0.310 and 0.060 to 0.646 and 0.120, respectively. The MV hedge ratio in the second half, still showed the average less than one, as shown in Table 21.

Table 20: Correlation between investing currency and hedging currency (2016-2020).

	USD	EUR	JPY	CNH	SGD
VND	0.91	0.24	0.27	0.47	-
PHP	0.68	0.20	0.17	0.39	-
IDR	0.43	-	0.12	0.31	0.34
INR	0.56	0.18	-	0.38	0.36

Table 21: MV Hedge ratio of 3-month Rebalancing (2016-2020)

	USD			EUR			JPY			CNH			SGD		
	Avg.	Max	Min	Avg.	Max	Min	Avg.	Max	Min	Avg.	Max	Min	Avg.	Max	Min
VND	0.93	1.02	0.80	0.20	0.47	0.00	0.16	0.44	0.00	0.59	0.93	0.43	-	-	-
PHP	0.78	1.04	0.47	0.26	0.66	0.00	0.17	0.51	0.00	0.55	0.85	0.38	-	-	-
IDR	0.34	0.87	0.00	-	-	-	0.05	0.31	0.00	0.39	0.68	0.00	0.68	1.25	0.00
INR	0.70	0.99	0.44	0.25	0.60	0.00	-	-	-	0.51	1.10	0.27	0.79	1.34	0.29

Table 22: Performance indicators of Vietnam bond portfolio from single hedging strategies (3-month rebalancing, 2010-2015)

VND	Non-hedged	Single MV cross hedged			
		USD	EUR	JPY	CNH
S.D. (%)	9.420	8.337	9.559	9.420	8.669
H.E. (%)	-	21.679	-2.968	0.007	1.304
Sharpe ratio	0.990	0.917	1.091	1.292***	0.698
Sortino ratio	0.262	0.268	0.296	0.352***	0.191

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Table 23: Performance indicators of Vietnam bond portfolio from single hedging strategies (3-month rebalancing, 2016-2020)

VND	Non-hedged	Single MV cross hedged			
		USD	EUR	JPY	CNH
S.D. (%)	5.998	4.521	5.711	5.682	5.612
H.E. (%)	-	43.166	9.325	10.140	12.433
Sharpe ratio	0.214	0.794*	0.247	0.276	0.337
Sortino ratio	0.039	0.160*	0.043	0.049	0.060

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Table 24: Performance indicators of India bond portfolio from single hedging strategies (3-month rebalancing, 2010-2015)

INR	Non-hedged	Single MV cross hedged			
		USD	EUR	SGD	CNH
S.D. (%)	9.924	9.911	10.085	10.135	9.907
H.E. (%)	-	0.252	-3.271	-4.294	0.347
Sharpe ratio	0.340	0.200	0.443*	0.431	0.171
Sortino ratio	0.080	0.047	0.106*	0.103	0.040

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Table 25: Performance indicators of India bond portfolio from single hedging strategies (3-month rebalancing, 2016-2020)

INR	Non-hedged	Single MV cross hedged			
		USD	EUR	SGD	CNH
S.D. (%)	7.319	6.586	7.121	6.751	6.949
H.E. (%)	-	19.024	5.342	14.908	9.865
Sharpe ratio	0.310	0.592*	0.388	0.646*	0.315
Sortino ratio	0.060	0.114*	0.073	0.120*	0.059

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Another observation is that the improvement from using baskets of currencies as cross hedging tools is not statistically significant. Using more than one currency can improve the hedge effectiveness. Theoretically, adding more currencies must further reduce risk, and the variance must be minimized, however in practice, the minimum variance hedge ratio is calculated using historical data and is used to hedge future FX movement. The out of sample calculation of hedge ratio, in practice, cannot guarantee the risk reduction. On the contrary, multiple hedging can increase hedging cost. The multiple hedging tools comprised of collective of smaller notional forward contracts. They cost more, especially for non-USD hedging tools. However, in this study, multiple hedging is proven to be an effective tool for cross hedging foreign investment in this case. Multiple cross hedging can improve both hedge effectiveness and risk adjusted return indicators for both Vietnam and India. For, Vietnam bond portfolio, the best performance of multiple cross hedging portfolio was from using all of four currencies that related import/export counterparty trading (USD, EUR, JPY and CNH), the Sharpe ratio and Sortino ratio were highest of all at 0.8184 and 0.1631 (as shown in Table 26). While the highest Sharpe ratio and Sortino ratio of India bond portfolio came from multiple hedging using the two currencies; US dollar and Singapore dollar, this hedge strategy produced the highest Sharpe ratio and Sortino ratio of 0.8690 and 0.1628 (as shown in Table 27), but the F-test failed to conclude that the improvement from multiple currency hedging over single currency hedging (USD cross-hedge) was can statistically significant (p-value 1-tail < 0.4529).

For Indonesian (as shown in Table 28), no single currency cross-hedging can significantly improve the risk adjusted return ratio, only multiple cross hedging can improve Sharpe ratio statistically. None of any multiple currency combination can improve risk adjusted return ratio significantly for Philippines (as shown in Table 29). In implementing multiple cross hedged, investors should take the complexity of hedging process into consideration together with the unclear benefit over single cross hedge before implementing the multiple hedging strategy.

Table 26: Performance indicators of Vietnam bond portfolio from Multiple hedging strategies (3-month rebalancing, 2016-2020)

VND	Non-hedged	Single MV cross hedged				Multiple cross hedged
		USD	EUR	JPY	CNH	USD EUR JPY CNH
S.D. (%)	5.998	4.521	5.711	5.682	5.612	4.506
H.E. (%)	-	43.166	9.325	10.140	12.433	43.566
Sharpe ratio	0.214	0.794*	0.247	0.276	0.337	0.818*
Sortino ratio	0.039	0.160*	0.043	0.049	0.060	0.163*

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Table 27: Performance indicators of India bond portfolio from Multiple hedging strategies (3-month rebalancing, 2016-2020)

INR	Non-hedged	Single MV cross hedged		Multiple cross hedged
		USD	SGD	USD SGD
S.D. (%)	7.319	6.586	6.751	6.456
H.E. (%)	-	19.024	14.908	22.202
Sharpe ratio	0.310	0.592*	0.646*	0.869**
Sortino ratio	0.060	0.114*	0.120*	0.163**

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Table 28: Performance indicators of Indonesia bond portfolio from Multiple hedging strategies (3-month rebalancing, 2016-2020)

IDR	Non-hedged	Single MV cross hedged		Multiple cross hedged
		USD	SGD	USD SGD
S.D. (%)	9.499	9.301	8.956	8.837
H.E. (%)	-	4.136	11.109	13.452
Sharpe ratio	0.343	0.339	0.518	0.582*
Sortino ratio	0.083	0.083	0.121	0.138

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Table 29: Performance indicators of Philippine bond portfolio from Multiple hedging strategies (3-month rebalancing, 2016-2020)

PHP	Non-hedged	Single MV cross hedged		Multiple cross hedged
		USD	EUR	USD EUR
S.D. (%)	7.010	5.990	6.806	5.945
H.E. (%)	-	26.974	5.712	28.077
Sharpe ratio	0.052	0.269	0.063	0.262
Sortino ratio	0.010	0.048	0.011	0.046

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

6.3 Research question and hypotheses

Can Thai fund managers use a basket of major currencies of import and export trade counterparties to hedge their currency risk in their investment portfolios investing in frontier/emerging market stocks or bonds? This study provided strong evidence that risk adjusted return of frontier market investment can be improved by cross-hedging with single and/or multiple forward contracts of trade counterparty's currencies. Table 26 to 28 show currencies or basket of currencies that show significant risk reduction performance with positive H.E. and significant improvement in risk adjusted return indicators; Sharpe ratio and Sortino ratio, we performed the F-test and confirmed that the return variances between non-hedged and hedged portfolio are significantly different. Sharpe ratio and Sortino ratio were significantly improved by the cross-hedging. Only for Philippines, there is no

currency can be used to improve risk adjusted return by cross-hedging investment in Philippines (as shown in Table 29).

For the first hypothesis, we conjecture that variance of the frontier/emerging market equity/bond portfolio can be reduced by cross-hedging with single FX forward contracts of import-export counterparties 'currencies. There exists a strong evidence (as shown in Table 26) to support that using USD as hedging instrument can significantly reduce currency risk from investing in Vietnam bond index. There also exists a strong evidence to support that using USD as hedging instrument can significantly reduce currency risk from investing in Indian bond index (as shown in Table 27). For both countries, the H.E. were high, and we used F-test to confirm that the variances before hedging and after hedging are statistically significant. The p-value for Vietnam bond investment cross hedged by USD was < 0.000^{***}. The p-value for Indian bond investment cross hedged by USD was < 0.000^{***}.

For the second hypothesis, we conjecture that cross hedging the frontier/emerging market equity/bond portfolio using multiple FX forward contracts of import-export counterparties 'currencies, can outperform single currency cross hedging, in reducing currency risk. There exists an evidence to support that using USD and SGD as hedging instrument can significantly reduce currency risk from investing in Indian bond index (as shown in Table 27). H.E. was higher. The F-test to confirm that the variance before hedging and after hedging is statistically significant (p-value 1-tail < 0.0032***). However, The F-test failed to conclude that the improvement from multiple currency hedging over single currency hedging (USD cross-hedge) was can statistically significant (p-value 1-tail < 0.2495). For Vietnam (as shown in Table 26), the combination of all four currencies can be used to cross-hedged the Vietnam investment with significant risk reduction (F-test p value 1-tail < 0.000^{***}) but failed to prove that the return variance is significantly lower than single cross-hedging (F-test p value 1-tail < 0.453). Indonesian (as shown in Table 28), no single currency cross-hedging can significantly improve the risk adjusted return ratio, only multiple cross hedging can improve Sharpe ratio statistically (F-test p value 1-tail < 0.007***) but failed to prove that the return

variance is significantly lower than single cross-hedging (F-test p value 1-tail < 0.326).

Third hypothesis, we conjecture that the risk reduction provided by cross hedging the frontier/emerging market equity/bond portfolio using single/multiple FX forward contracts of import-export counterparties 'currencies, is sufficiently significance to improve risk-return of the portfolio when hedging cost is considered. There exists a strong evidence to conclude that the risk reduction from currency cross-hedging is sufficiently significance to justify the hedging cost and significantly improve risk-return of the portfolio. Sharpe and Sortino ratio between nonhedged portfolio and cross hedged portfolio are statistically different in many scenarios.

From the analysis of results, there exists a strong evidence that investors can use major currencies of import and export trade counterparties to hedge their currency risk in their investment portfolios investing in frontier/emerging market for both stock and bond investment. Reduction in currency risk is statistically significant. The improvement on risk adjusted return from currency hedging is also statistically significant (as shown in Table 26 to 29).

6.4 Additional analysis

Two analyses were performed in addition to those related to research question and hypotheses. We observed that Sharpe ratio and Sortino ratio always go into the same direction. We performed another analysis to compare the two ratios and found that Sharp ratio and Sortino ratio worked similarly in our study. The performance of 1-month and 3-month rebalancing strategy was compared, and we found that in general, the 3-month rebalancing strategy produced higher risk adjusted return than 1-month rebalancing strategy.

We observed that Sharpe ratio and Sortino ratio always go into the same direction. We performed another analysis to compare the two ratios and found that Sharp ratio and Sortino ratio worked similarly in our study. Return distributions of both hedged and nonhedged portfolio were examined. The return

distributions were found to be symmetry; thus, it is not expected that Sharpe ratio and Sortino ratio will work differently. As shown in Figure 3, return distribution of Vietnam stock index after marked to the market and return distribution of the Vietnam stock after being cross hedged by Japanese Yen showed symmetrical distribution. We found the same observation for stock investments in other countries as well.

In the next step, we examined the difference between the resulted Sharpe ratio and Sortino ratio in all scenarios. As shown in Figure 4, the scatter plotting between Sharpe ratio and Sortino Ratio of each scenario of stock investment showed linear relationship without any outlier and confirmed the similarity between the two ratios. We applied linear regression to confirm the close relationship between Sharpe ratio and Sortino ratio. The regression analysis confirmed the close relationship with R-square close to 1 (as shown in Table 30).

In our case, where the portfolio returns are symmetry for both downside and upside, Sharpe ratio and Sortino ratio worked equally well.

Figure 3: Return distribution of Vietnam stock index.

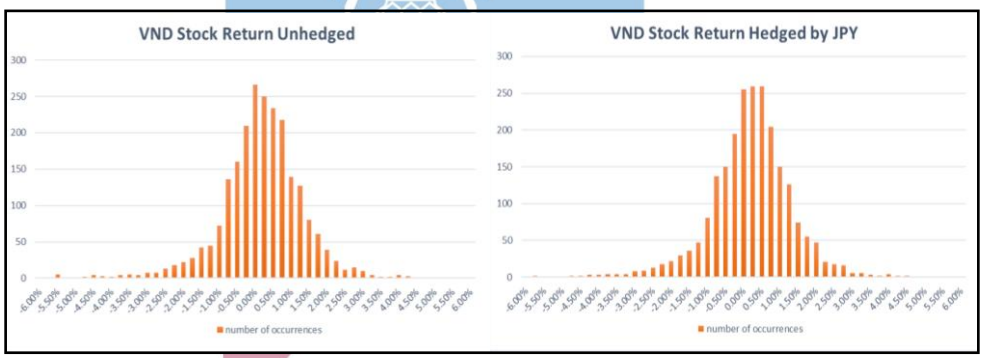


Figure 4: Scatter plot between Sharpe and Sortino ratio

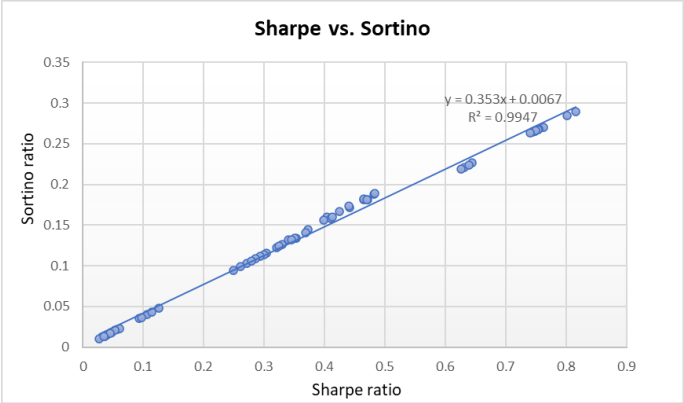


Table 30: Linear regression statistics between Sharpe and Sortino ratio

Regression Statistics	
Multiple R	0.9973
R Square	0.9947
Observations	60

We found that in general, the 3-month rebalancing strategy produced higher risk adjusted return than 1-month rebalancing strategy. This step of our study was to examine the differences in risk adjusted return performances between rebalancing period of 1-month and 3-month. Firstly, the results of scatter plotting showed linear relationship without any outlier, as shown in Figure 5. Secondly, we applied linear regression between Sharpe ratio of 1-month rebalancing and Sharpe ratio of 3-month rebalancing for all hedging scenarios. The R-square between the two rebalancing strategies was almost close to 1. The slope coefficient between the two was also close to one (as shown in Table 31). The average of Sharpe ratios of the 3-month rebalancing strategy was 0.392, it was 0.009 higher than the average of Sharpe ratios of the 1-month rebalancing strategy, which was 0.383. The difference of averages of the Sharpe ratios between the two strategies also confirmed by the positive linear regression intercept, which was also statistically significant. As shown in Table 33, the difference was confirmed by paired t-test with high level of

confidence (p value < 0.000*). The same test process was applied to Sortino ratio, and the results went into the same direction.

Figure 5: Scatter plot between Sharpe ratio 1m rebalancing vs. 3m rebalancing.

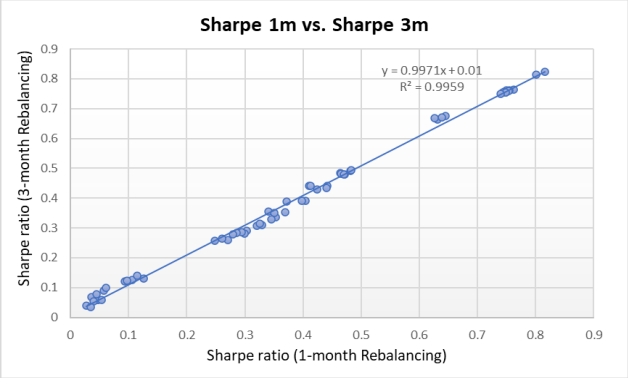


Table 31: Linear regression statistics between Sharpe ratio 1m rebalancing vs. 3m rebalancing.

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.0100	0.0038	2.6223	0.0111**
1-month Sharpe	0.9971	0.0084	118.0174	0.0000***
	R Square	0.9959	**Observations**	60

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Figure 6: Scatter plot between Sortino 1m rebalancing vs. Sortino 3m rebalancing.

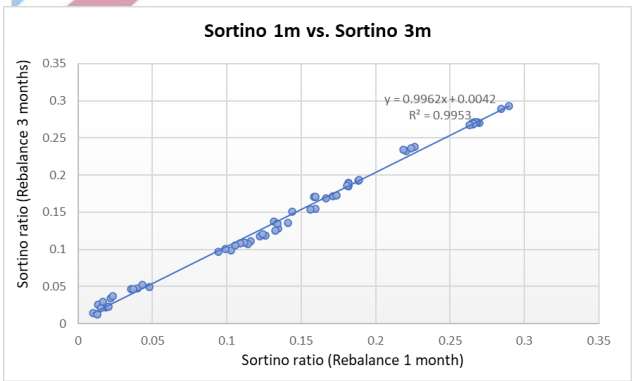


Table 32: Linear regression statistics between Sortino ratio 1m rebalancing vs. 3m rebalancing.

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.0042	0.0015	2.8183	0.0066***
1-month Sortino	0.9962	0.0089	111.3653	0.0000***
	R Square	0.9953	**Observations**	60

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Table 33: Paired T-test of Sharpe ratio between 1m and 3m rebalancing.

Paired T-test of Sharpe ratio between 1m and 3m rebalancing.		
	Sharpe 1m	Sharpe 3m
Mean	0.3833	0.3923
Variance	0.0596	0.0595
Observations	60	60
t Stat	-4.4003	
P(T<=t) one-tail	0.0000***	
P(T<=t) two-tail	0.0000***	

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Table 34: Paired T-test of Sortino ratio between 1m and 3m rebalancing.

Paired T-test of Sortino ratio between 1m and 3m rebalancing.		
	Sortino 1m	Sortino 3m
Mean	0.1420	0.1457
Variance	0.0075	0.0074
Observations	60	60
t Stat	-4.7795	
P(T<=t) one-tail	0.0000***	
P(T<=t) two-tail	0.0000***	

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

7 CONCLUSION

Cross-hedging strategy can be beneficial for Thai investors to reduce currency risk and improve risk adjusted return in their emerging market investment. The hedging currency can be selected by trade counterparties.

Single cross hedging can reduce portfolio risk significantly as measured by Ederington hedge effectiveness and confirmed by the F-test.

Multiple cross-hedging shows sign of improvement from single cross-hedging both in currency risk reduction and risk adjusted return improvement in some case, but the statistical test failed to prove that improvement is statistically significant. Investors should assess their situation before implementing multiple cross-hedging strategy.

Bid-ask spread from FX forward contract incurs hedging cost. However, the risk reduction from cross hedging justified the hedging cost and improved risk adjusted return. Cross-hedging currency risk using developed currency as hedging instruments, reduces currency risk in frontier market investment and improves risk-return as measured by Sharpe ratio and Sortino ratio. The improvement was confirmed by standard paired bootstrap test of the ratios.

This study revealed a few points that should be mentioned. The risk adjusted return measures such as Sharpe ratio or Sortino ratio can be improved by either reducing risk or increasing return or both. The study shows that in some cases, cross hedging can increase portfolio risk because the hedging ratio calculated from the historical data may not match the actual beta and correlation in the future (out of sample). However, the improvement came from increasing return due to cross hedging position generated higher return than the loss from FX in the investment position. The extra return could drive the improvement of the risk adjusted return performance indicators into significant. This extra return depends on market direction of the cross-hedging currencies and may not be sustainable in the future. Historical market direction may not be repeating. It is recommended that fund manager should take both hedging effectiveness and the risk adjusted return measures into consideration when making cross hedging decision.

In our case, 3-month rebalancing strategy can produce higher risk adjusted return than 1-month rebalancing strategy, as measured by both Sharpe ratio and Sortino ratio. More frequent rebalancing can increase cost, also shorter hedging period may increase risk since market shock can be more prominent in shorter period. Rebalancing strategy can make difference in risk adjusted return improvement. The 3-month rebalancing strategy producing higher average of both Sharpe ratio and Sortino ratio than 1-month strategy. However, it is recommended that fund manager should re-evaluated situation before making decision, since risk reduction and cost of rebalancing may be different in different circumstances.

The return of the portfolios, both hedged and non-hedged, are symmetry. We also observed that Sharpe ratio and Sortino ratio are highly correlated and always go in the same direction. It is recommended that either Sharpe ration or Sortino ratio can be used as risk adjusted return measures. Since Sharpe ratio is more widely used as measurement tool for risk adjusted return, can be equally effective and can be easily calculated, this study recommended that Sharpe ratio should be used in further study. However, if any nonlinear hedging instruments such as option, are used, Sortino ratio should be considered.

When risk of the investment is higher than the currency risk, as shown in the stock investment cases, it is more difficult to improve the overall risk adjusted return by reducing currency risk. When the investment risk and FX risk is at the same level, as shown in bond investment cases. The improvement from cross hedging FX risk can significantly improve the risk adjusted return.

The cross-hedging decisions are sensitive to market conditions and situations. Currency market condition changed over time and affected the decision-making process. We separated the 10-year data set into two of 5-year data sets. The data led to difference conclusions; both were still statistically significant. The too-long time series data may not represent the recent market condition and may lead to wrong cross hedging decision. It is also recommended that investors should continuously monitor both the market condition and the cross-hedging performance and make strategy adjustment in timely manner.

8 APPENDIX

Appendix 1: Import/Export in (Indonesia, India, Vietnam, and Philippines)

No	Indonesia Imports By Country	Value	Year	No	Indonesia Exports By Country	Value	Year
1	China*	$44.93B	2019	1	China	$27.96B	2019
2	Singapore*	$17.59B	2019	2	United States*	$17.87B	2019
3	Japan*	$15.66B	2019	3	Japan	$16.00B	2019
4	Thailand	$9.47B	2019	4	Singapore	$12.92B	2019
5	United States	$9.32B	2019	5	India	$11.82B	2019
6	South Korea	$8.42B	2019	6	Euro Zone	$11.09B	2019
No	**India Imports By Country**	**Value**	**Year**	**No**	**India Exports By Country**	**Value**	**Year**
1	China*	$68.40B	2019	1	United States*	$54.29B	2019
2	United States	$34.92B	2019	2	Euro Zone*	$38.53B	2019
3	United Arab Emirates	$30.31B	2019	3	United Arab Emirates	$29.54B	2019
4	Saudi Arabia	$27.00B	2019	4	China	$17.28B	2019
5	Iraq	$22.09B	2019	5	Hong Kong	$11.48B	2019
6	Euro Zone	$21.62B	2019	6	Singapore*	$10.74B	2019
No	**Vietnam Imports By Country**	**Value**	**Year**	**No**	**Vietnam Exports By Country**	**Value**	**Year**
1	China*	$65.52B	2018	1	United States*	$47.58B	2018
2	South Korea	$47.58B	2018	2	China	$41.37B	2018
3	Japan*	$19.04B	2018	3	Euro Zone*	$29.67B	2018
4	United States	$12.76B	2018	4	Japan	$18.83B	2018
5	Thailand	$12.04B	2018	5	South Korea	$18.24B	2018
6	Euro Zone	$8.72B	2018	6	Hong Kong	$7.96B	2018
No	**Philippines Imports By Country**	**Value**	**Year**	**No**	**Philippines Exports By Country**	**Value**	**Year**
1	China*	$26.76B	2019	1	United States*	$11.57B	2019
2	Japan*	$11.22B	2019	2	Japan	$10.67B	2019
3	South Korea	$8.76B	2019	3	China	$9.81B	2019
4	United States	$8.56B	2019	4	Hong Kong	$9.62B	2019
5	Euro Zone*	$7.43B	2019	5	Euro Zone	$6.43B	2019
6	Indonesia	$7.30B	2019	6	Singapore	$3.83B	2019

Appendix 2: Performance indicators of India stock portfolio from single hedging strategies (1-month rebalancing)

INR	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	EUR	SGD	CNH	USD	EUR	SGD	CNH
S.D. (%)	20.390	21.076	22.152	20.413	20.709	20.621	20.466	20.222	20.409
H.E. (%)		-6.851	-18.035	-0.233	-3.158	-2.285	-0.754	1.638	-0.196
Sharpe ratio	0.404	0.403	0.529	0.462	0.303	0.404	0.441	0.472	0.341
Sortino ratio	0.156	0.163	0.215	0.179	0.119	0.160	0.171	0.182	0.132

Appendix 3: Performance indicators of India stock portfolio from multiple hedging strategies (1-month rebalancing)

INR	Multiple cross hedged										
	USD EUR	USD SGD	USD CNH	EUR SGD	EUR CHN	CNH SGD	USD EUR SGD	USD EUR CNH	USD SGD CNH	EUR SGD CNH	USD EUR SGD CNH
S.D. (%)	20.634	20.413	20.482	20.234	20.430	20.326	20.428	20.517	20.431	20.344	20.447
H.E. (%)	-2.414	-0.234	-0.909	1.520	-0.402	0.619	-0.037	-1.256	-0.406	0.443	-0.568
Sharpe ratio	0.440	0.483*	0.398	0.470	0.372	0.413	0.481*	0.425	0.465	0.410	0.465
Sortino ratio	0.174	0.189*	0.156	0.181	0.144	0.156	0.188*	0.167	0.182	0.158	0.182

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Appendix 4: Performance indicators of Indonesia stock portfolio from single hedging strategies (1-month rebalancing)

IDR	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	SGD	JPY	CNH	USD	SGD	JPY	CNH
S.D. (%)	19.898	20.540	20.041	22.884	20.246	20.149	19.713	19.922	19.910
H.E. (%)		-6.559	-1.439	-32.268	-3.525	-2.540	1.856	-0.242	-0.119
Sharpe ratio	0.087	0.089	0.138	0.270	-0.015	0.048	0.106	0.260**	0.027
Sortino ratio	0.033	0.035	0.052	0.114*	-0.006	0.018	0.0340	0.048**	0.010

Appendix 5: Performance indicators of Indonesia stock portfolio from multiple hedging strategies (1-month rebalancing)

IDR	Multiple cross hedged										
	USD SGD	USD JPY	USD CNH	SGD JPY	SGD CHN	CNH JPY	USD SGD JPY	USD SGD CNH	USD JPY CNH	SGD JPY CNH	USD SGD JPY CNH
S.D. (%)	19.867	20.141	19.980	19.750	19.777	19.946	19.878	19.847	19.988	19.810	19.859
H.E. (%)	0.317	2.456	-0.821	1.479	1.215	-0.480	0.206	0.515	-0.909	0.883	0.388
Sharpe ratio	0.098	0.053	0.040	0.114	0.045	0.034	0.093	0.061	0.046	0.036	0.057
Sortino ratio	0.037	0.021	0.015	0.043	0.017	0.013	0.036	0.023	0.018	0.014	0.022

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Appendix 6: Performance indicators of Philippines stock portfolio from single hedging strategies (1-month rebalancing)

PHP	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	EUR	JPY	CNH	USD	EUR	JPY	CNH
S.D. (%)	20.190	20.229	21.681	22.624	20.208	20.078	20.184	20.254	20.055
H.E. (%)		-0.383	-15.32	-25.560	-0.179	1.111	0.058	-0.635	1.338
Sharpe ratio	0.317	0.324	0.449	0.494	0.217	0.304	0.353	0.351*	0.249
Sortino ratio	0.121	0.124	0.179	0.204*	0.082	0.116	0.134	0.134*	0.094

Appendix 7: Performance indicators of Philippines stock portfolio from multiple hedging strategies (1-month rebalancing)

PHP	Multiple cross hedged										
	USD EUR	USD JPY	USD CNH	EUR JPY	EUR CHN	CNH JPY	USD EUR JPY	USD EUR CNH	USD JPY CNH	EUR JPY CNH	USD EUR JPY CNH
S.D. (%)	20.096	20.100	20.018	20.243	20.066	20.103	20.128	20.042	20.046	20.132	20.080
H.E. (%)	0.933	0.894	1.693	-0.554	1.223	0.865	0.613	1.457	1.423	0.571	1.092
Sharpe ratio	0.330	0.325	0.271	0.369*	0.279	0.261	0.346	0.299	0.294	0.286	0.320
Sortino ratio	0.126	0.124	0.103	0.141*	0.106	0.099	0.132	0.114	0.112	0.109	0.122

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Appendix 8: Performance indicators of Vietnam stock portfolio from single hedging strategies (3-month rebalancing)

VND	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	EUR	JPY	CNH	USD	EUR	JPY	CNH
S.D. (%)	17.889	17.565	19.363	20.303	17.646	17.579	17.917	17.584	17.963
H.E. (%)		3.587	-17.166	-28.817	2.689	3.432	-0.323	-0.836	3.382
Sharpe ratio	0.729	0.770	0.886	0.901	0.653	0.754	0.765	0.815**	0.663
Sortino ratio	0.257	0.275	0.329	0.349*	0.229	0.269	0.271	0.289**	0.232

Appendix 9: Performance indicators of Vietnam stock portfolio from multiple hedging strategies (3-month rebalancing)

VND	Multiple cross hedged										
	USD EUR	USD JPY	USD CNH	EUR JPY	EUR CHN	CNH JPY	USD EUR JPY	USD EUR CNH	USD JPY CNH	EUR JPY CNH	USD EUR JPY CNH
S.D. (%)	17.582	17.584	17.578	17.989	17.599	17.672	17.585	17.576	17.574	17.683	17.581
H.E. (%)	3.398	3.381	3.442	-1.096	3.208	2.411	3.365	3.465	3.492	2.286	3.406
Sharpe ratio	0.760	0.755	0.750	0.825**	0.667	0.671	0.761	0.757	0.753	0.675	0.761
Sortino ratio	0.271	0.269	0.268	0.293**	0.234	0.236	0.271	0.270	0.268	0.239	0.272

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Appendix 10: Performance indicators of India stock portfolio from single hedging strategies (3-month rebalancing)

INR	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	EUR	SGD	CNH	USD	EUR	SGD	CNH
S.D. (%)	20.390	21.177	22.274	20.487	20.780	20.692	20.520	20.263	20.428
H.E. (%)		-7.870	-19.336	-0.957	-3.863	-2.993	-1.282	1.238	-0.380
Sharpe ratio	0.404	0.401	0.539	0.480	0.319	0.392	0.441	0.480*	0.355
Sortino ratio	0.156	0.162	0.220	0.186	0.125	0.155	0.172*	0.185*	0.138

Appendix 11: Performance indicators of India stock portfolio from multiple hedging strategies (3-month rebalancing)

INR	Multiple cross hedged										
	USD EUR	USD SGD	USD CNH	EUR SGD	EUR CHN	CNH SGD	USD EUR SGD	USD EUR CNH	USD SGD CNH	EUR SGD CNH	USD EUR SGD CNH
S.D. (%)	20.728	20.482	20.551	20.277	20.485	20.314	20.502	20.614	20.483	20.328	20.504
H.E. (%)	-3.350	-0.909	-1.592	1.099	-0.936	0.736	-1.102	-2.216	-0.915	0.599	-1.124
Sharpe ratio	0.435	0.493*	0.392	0.481*	0.389	0.441	0.492*	0.429	0.482*	0.442	0.483*
Sortino ratio	0.172	0.193*	0.154	0.186*	0.151	0.170	0.193*	0.169	0.189*	0.171	0.190*

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Appendix 12: Performance indicators of Indonesia stock portfolio from single hedging strategies (3-month rebalancing)

IDR	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	SGD	JPY	CNH	USD	SGD	JPY	CNH
S.D. (%)	19.898	20.686	20.137	23.083	20.344	20.227	19.748	19.917	19.961
H.E. (%)		-8.081	-2.416	-34.571	-4.537	-3.329	1.507	-0.187	0.630
Sharpe ratio	0.087	0.092	0.160	0.279*	0.005	0.058	0.126	0.130**	0.039
Sortino ratio	0.033	0.037	0.061	0.119*	0.002	0.022	0.048	0.049**	0.015

Appendix 13: Performance indicators of Indonesia stock portfolio from multiple hedging strategies (3-month rebalancing)

IDR	Multiple cross hedged										
	USD SGD	USD JPY	USD CNH	SGD JPY	SGD CHN	CNH JPY	USD SGD JPY	USD SGD CNH	USD JPY CNH	SGD JPY CNH	USD SGD JPY CNH
S.D. (%)	19.884	20.212	20.032	19.784	19.811	20.013	19.903	19.864	20.057	19.853	19.907
H.E. (%)	0.141	-3.175	-1.350	1.143	0.871	-1.158	-0.054	0.338	-1.600	0.449	-0.087
Sharpe ratio	0.123	0.060	0.054	0.140	0.079	0.034	0.122	0.098	0.060	0.068	0.090
Sortino ratio	0.047	0.023	0.021	0.053	0.030	0.013	0.047	0.037	0.023	0.026	0.034

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Appendix 14: Performance indicators of Philippines stock portfolio from single hedging strategies (3-month rebalancing)

PHP	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	EUR	JPY	CNH	USD	EUR	JPY	CNH
S.D. (%)	20.190	20.314	21.784	22.760	20.250	20.145	20.218	20.296	20.079
H.E. (%)		-1.231	-16.42	-27.083	-0.599	0.444	-0.278	-1.055	1.099
Sharpe ratio	0.317	0.322	0.456	0.495	0.231	0.290	0.336	0.351	0.257
Sortino ratio	0.121	0.124	0.182	0.206*	0.088	0.111	0.128	0.135	0.097

Appendix 15: Performance indicators of Philippines stock portfolio from multiple hedging strategies (3-month rebalancing)

PHP	Multiple cross hedged										
	USD EUR	USD JPY	USD CNH	EUR JPY	EUR CHN	CNH JPY	USD EUR JPY	USD EUR CNH	USD JPY CNH	EUR JPY CNH	USD EUR JPY CNH
S.D. (%)	20.155	20.171	20.082	20.304	20.103	20.186	20.185	20.109	20.130	20.223	20.176
H.E. (%)	0.351	0.187	1.063	-1.135	0.862	0.041	0.046	0.800	0.590	-0.323	0.142
Sharpe ratio	0.310	0.314	0.260	0.354	0.278	0.365	0.328	0.281	0.285	0.285	0.307
Sortino ratio	0.119	0.120	0.099	0.135	0.105	0.101	0.126	0.107	0.109	0.109	0.118

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Appendix 16: Performance indicators of Vietnam bond portfolio from single hedging strategies (3-month rebalancing, 2011-2020)

VND	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	EUR	JPY	CNH	USD	EUR	JPY	CNH
S.D. (%)	7.898	6.733	10.632	11.239	7.562	6.706	7.877	7.785	7.302
H.E. (%)		27.330	-81.199	8.331	-102.476	27.921	0.554	2.862	14.531
Sharpe ratio	0.662	0.872	0.843	0.914	0.514	0.835	0.740	0.866**	0.541
Sortino ratio	0.152	0.230	0.217	0.249	0.118	0.218	0.171	0.202***	0.125

Appendix 17: Performance indicators of Vietnam bond portfolio from multiple hedging strategies (3-month rebalancing, 2011-2020)

VND	Multiple cross hedged										
	USD EUR	USD JPY	USD CNH	EUR JPY	EUR CHN	CNH JPY	USD EUR JPY	USD EUR CNH	USD JPY CNH	EUR JPY CNH	USD EUR JPY CNH
S.D. (%)	6.732	6.706	6.708	7.849	7.279	7.234	6.731	6.730	6.704	7.244	6.728
H.E. (%)	27.348	27.924	27.872	1.241	15.066	16.111	27.382	27.403	27.954	15.878	27.449
Sharpe ratio	0.847	0.839	0.827	0.879**	0.554	0.572	0.851	0.840	0.834	0.583	0.852
Sortino ratio	0.222	0.219	0.215	0.206**	0.127	0.132	0.223	0.219	0.216	0.134	0.222

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Appendix 18: Performance indicators of India bond portfolio from single hedging strategies (3-month rebalancing, 2011-2020)

INR	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	EUR	SGD	CNH	USD	EUR	SGD	CNH
S.D. (%)	8.717	8.828	11.443	9.167	8.994	8.413	8.728	8.609	8.554
H.E. (%)		-2.545	-72.302	-10.578	-6.442	6.862	-0.239	2.473	3.701
Sharpe ratio	0.324	0.383	0.563	0.496	0.164	0.351	0.413	0.507*	0.227
Sortino ratio	0.070	0.087	0.142	0.112	0.036	0.077	0.089	0.111*	0.049

Appendix 19: Performance indicators of India bond portfolio from multiple hedging strategies (3-month rebalancing, 2011-2020)

INR	Multiple cross hedged										
	USD EUR	USD SGD	USD CNH	EUR SGD	EUR CHN	CNH SGD	USD EUR SGD	USD EUR CNH	USD SGD CNH	EUR SGD CNH	USD EUR SGD CNH
S.D. (%)	8.438	8.426	8.358	8.621	8.579	8.548	8.436	8.426	8.432	8.561	8.443
H.E. (%)	6.306	6.568	8.078	2.209	3.138	3.843	6.342	6.563	6.447	3.548	6.184
Sharpe ratio	0.452	0.571**	0.342	0.510*	0.308	0.424	0.570**	0.428	0.546*	0.427	0.549**
Sortino ratio	0.010	0.126**	0.074	0.114*	0.067	0.092	0.126**	0.094	0.120**	0.093	0.121**

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Appendix 20: Performance indicators of Vietnam bond portfolio from single hedging strategies (3-month rebalancing, 2011-2015)

VND	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	EUR	JPY	CNH	USD	EUR	JPY	CNH
S.D. (%)	9.420	8.373	12.906	12.818	8.794	8.337	9.559	9.420	8.669
H.E. (%)		20.998	-87.703	-85.147	12.855	21.679	-2.968	0.007	1.304
Sharpe ratio	0.990	0.927	1.542	1.288	0.640	0.917	1.091	1.292***	0.698
Sortino ratio	0.262	0.276	0.320	0.392	0.175	0.268	0.296	0.352***	0.191

Appendix 21: Performance indicators of Vietnam bond portfolio from multiple hedging strategies (3-month rebalancing, 2011-2015)

VND	Multiple cross hedged										
	USD EUR	USD JPY	USD CNH	EUR JPY	EUR CHN	CNH JPY	USD EUR JPY	USD EUR CNH	USD JPY CNH	EUR JPY CNH	USD EUR JPY CNH
S.D. (%)	8.382	8.338	8.341	9.578	8.696	8.684	8.381	8.377	8.340	8.704	8.380
H.E. (%)	20.819	21.662	21.590	-3.285	14.786	15.007	20.852	20.922	21.608	14.615	20.855
Sharpe ratio	0.935	0.921	0.899	1.311**	0.730	0.753	0.939	0.922	0.902	0.774	0.932
Sortino ratio	0.275	0.269	0.261	0.363**	0.200	0.206	0.276	0.270	0.262	0.212	0.273

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Appendix 22: Performance indicators of Vietnam bond portfolio from single hedging strategies (3-month rebalancing, 2016-2020)

VND	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	EUR	JPY	CNH	USD	EUR	JPY	CNH
S.D. (%)	5.998	4.537	7.712	9.392	6.089	4.521	5.711	5.682	5.612
H.E. (%)		42.784	-65.355	-145.208	-3.067	43.166	9.325	10.140	12.433
Sharpe ratio	0.214	0.884*	0.583	0.465	0.356	0.794*	0.247	0.276	0.337
Sortino ratio	0.039	0.179**	0.113	0.109	0.065	0.160*	0.043	0.049	0.060

Appendix 23: Performance indicators of Vietnam bond portfolio from multiple hedging strategies (3-month rebalancing, 2016-2020)

VND	Multiple cross hedged										
	USD EUR	USD JPY	USD CNH	EUR JPY	EUR CHN	CNH JPY	USD EUR JPY	USD EUR CNH	USD JPY CNH	EUR JPY CNH	USD EUR JPY CNH
S.D. (%)	4.516	4.519	4.520	5.605	5.510	5.409	4.514	4.519	4.510	5.403	4.506
H.E. (%)	43.302	43.216	43.211	12.981	15.790	18.921	43.339	43.241	43.456	19.093	43.566
Sharpe ratio	0.800*	0.799*	0.803*	0.273	0.320	0.332	0.802*	0.801*	0.818*	0.326	0.818*
Sortino ratio	0.165*	0.161*	0.161*	0.047	0.056	0.058	0.161*	0.160*	0.163*	0.057	0.163*

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Appendix 24: Performance indicators of India bond portfolio from single hedging strategies (3-month rebalancing, 2011-2015)

INR	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	EUR	SGD	CNH	USD	EUR	SGD	CNH
S.D. (%)	9.924	10.510	13.514	10.882	10.383	9.911	10.085	10.135	9.907
H.E. (%)		-12.156	-85.436	-20.235	-9.462	0.252	-3.271	-4.294	0.347
Sharpe ratio	0.340	0.164	0.542	0.367	-0.028	0.200	0.443*	0.431	0.171
Sortino ratio	0.080	0.041	0.152	0.092	-0.007	0.047	0.106*	0.103	0.040

Appendix 25: Performance indicators of India bond portfolio from multiple hedging strategies (3-month rebalancing, 2011-2015)

INR	Multiple cross hedged										
	USD EUR	USD SGD	USD CNH	EUR SGD	EUR CHN	CNH SGD	USD EUR SGD	USD EUR CNH	USD SGD CNH	EUR SGD CNH	USD EUR SGD CNH
S.D. (%)	9.947	10.019	9.843	10.152	9.970	10.039	10.033	9.945	10.019	10.056	10.036
H.E. (%)	-0.475	-1.934	1.612	-4.658	-0.930	-2.344	-2.219	-0.424	-1.928	-2.688	-2.281
Sharpe ratio	0.314	0.402	0.177	0.443	0.272	0.367	0.407	0.269	0.381	0.383	0.391
Sortino ratio	0.075	0.097	0.041	0.106	0.064	0.088	0.098	0.064	0.091	0.092	0.094

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

Appendix 26: Performance indicators of India bond portfolio from single hedging strategies (3-month rebalancing, 2016-2020)

INR	Non-hedged	Naïve hedge				Single MV cross hedged			
		USD	EUR	SGD	CNH	USD	EUR	SGD	CNH
S.D. (%)	7.319	6.741	8.909	7.051	7.350	6.586	7.121	6.751	6.949
H.E. (%)		15.158	-48.153	7.176	-0.850	19.024	5.342	14.908	9.865
Sharpe ratio	0.310	0.751*	0.624	0.725*	0.446	0.592*	0.388	0.646*	0.315
Sortino ratio	0.060	0.145*	0.130	0.137*	0.086	0.114*	0.073	0.120*	0.059

Appendix 27: Performance indicators of India bond portfolio from multiple hedging strategies (3-month rebalancing, 2016-2020)

INR	Multiple cross hedged										
	USD EUR	USD SGD	USD CNH	EUR SGD	EUR CHN	CNH SGD	USD EUR SGD	USD EUR CNH	USD SGD CNH	EUR SGD CNH	USD EUR SGD CNH
S.D. (%)	6.596	6.456	6.547	6.755	6.920	6.739	6.460	6.570	6.470	6.747	6.474
H.E. (%)	18.775	22.202	19.978	14.829	10.611	15.213	22.086	19.416	21.848	15.008	21.749
Sharpe ratio	0.683*	0.869**	0.609*	0.636*	0.370	0.528	0.858**	0.692*	0.834**	0.512	0.825**
Sortino ratio	0.130*	0.163**	0.115	0.118	0.070	0.098	0.161**	0.131*	0.157**	0.095	0.155**

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1

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VITA

NAME	Tanatuch Kujiranuwat
DATE OF BIRTH	10 May 1993
PLACE OF BIRTH	Bangkok
HOME ADDRESS	22 onnut20 Suan-luang Bangkok 10250