Artificial domestic currency hedge exposure

(South Korea)

Business Mathematics and Informatics

Master Paper

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Preface

This paper was written as a part of the *Business Mathematics and Informatics* master program. The goal of the BMI thesis is to encompass the following program components: *Business, Mathematics and Informatics* in practice.

In this paper we analyze the Foreign exchange exposure for South Korea. More specifically, we estimate the performance of an artificial domestic currency hedge and estimate the exposure by analyzing the FX time series.

I would like to thank my supervisor Dr. S.A. Borovkova for introducing me to the subject of artificial currency hedge exposure.

Abstract

Managing currency risk exposure within the financial markets is an important issue. Especially for the emergent markets where the currency fluctuations has a substantial effects on the economic growth due to high dependency on export. Financial derivatives can be used to insure against currency volatility and interest rate by transfer risk among market players. Most of these derivatives are traded Over The Counter (OTC) and are far from fair and orderly. Unlike risk in traditional insurance markets, most currency and interest rate risk cannot be diversified. The derivative market for such specific domestic currency could dry up due to the high demand. There will be no market player that would want to bear the risk as counterparty. This event occurred in 1997, the exchange rate and credit of number of Asian countries collapsed, resulting in a massive defaults on international bank loans.

In this paper I will analyze the exchange rate exposure of the Korean stock market and estimate the performance of a normal domestic currency hedge, semi-artificial hedge and artificial hedge during the pre and post crisis (2003-2010).

Our analysis indicates that a FWD contract with shorter maturity T, outperform a FWD with a longer maturity in all aspects. When we discount the additional transaction cost for a shorter maturity, the FWD with maturity of 3 months is the most beneficial and the FX exposure can be reduced with 10 basis point of total value.

We also observe a high FX exposure of the Korean stock market with a high dependency on the interest rate. A decrease of -0.5% in the Korean interest rate results to a 10% decrease in the FX rate. Hedging FX risk is valuable if it helps reduce the cost of financial distress, tax advantage and agency costs among different stakeholders in the firm.

Contents

1   Introduction

Managing currency risk exposure within the financial markets is an important issue. Especially for the emergent markets where the currency fluctuations has a substantial effects on the economic growth due to high dependency on export. This FX rate exposure can be reduced with FX hedge. The demand for hedging is determined mainly by three factors: the cost of financial distress, tax advantages, and agency costs among different stakeholders in the firm.

A great deal of research exits today, focusing on the emerging market exchange rate exposure. *Chue and Cook (2007)* investigated the dependency of the foreign exchange rate exposure on the Emergent stock market. They conclude that the emerging market exchange rate exposure has changed within the last few years. The emerging market crises of (1999-2002), indicated that the firms were negatively affected by the exchange rate depreciations while in the more recent years (2002-2006) this effect was reversed. *Roll and Chakrabarti (2002)* investigated the European vs. Asian stock market before and during the Asian crisis. They conclude that the correlations and the volatilities increased during the crisis and they also indicate that diversification potential was better in Asia than Europe before the crisis, but during the crisis this effect was again reversed.

In this paper I will analyze the exchange rate exposure of the Korean stock market and estimate the performance of a domestic currency hedge during the pre and post crisis (2003-2010).

First we will explain the methodology that is used in the analysis in chapter 2.

In chapter 3 we will analyze the performance of 3 types of portfolio hedge by vary the maturity T of a FX forward contract. Our main objective is to examine the performances and find an alternative hedging strategy that outperforms the normal currency hedge.

In chapter 4 we will analyze the foreign exchange exposure of a particular industrial sector by using factor analysis.

In chapter 5 we will use a stochastical simulation to examine the effects of currency fluctuations on the FX basic risk.

Finally, we will discuss our findings in chapter 6

2   Methodology

Many companies within the emerging markets have a high dependency on export. These transactions in foreign currencies will lead to foreign exchange exposure. Therefore companies want to eliminate such exposure by hedging using FX derivatives. Most of these derivatives are traded OTC and are far from fair and orderly. The involved risk premiums are often high due to high demand and illiquid market. During this paper I will analyze the performance of 3 types of hedge using forward contracts.

- Normal domestic currency hedge

- Semi-artificial domestic currency hedge

- Artificial domestic currency hedge

The analysis method and the performance of these hedges will be discussed in the following paragraph.

2.1   Portfolio hedge:

The following notations are used to describe the methodology:

i	$=$	Domestic currency	(South Korea)
j	$=$	Foreign currency Target	(U.S.)
k	$=$	Foreign currency Via	{ UK(£), EU(€), HKD(H$) and J-Yen (¥)}
$V_i(0)$	$=$	The amount of money that is at FX exposure in currency i	
$FX_{i,j}(0)$	$=$	Foreign exchange rate from i to j	
$FWD_{i,j}(0,T)$	$=$	Forward rate from i to j with maturity T	
$B_i(0,T)$	$=$	Riskless government bond yield in i	
$D_j(0,T)$	$=$	Riskless government bond yield in j	

Normal domestic currency hedge

A direct hedge from US-dollar (U$) to Korean Won (Won) using 1 Forward contracts

$$V_i(T) = V_i(0) * FX_{i,j}(0) * FWD_{j,i}(0,T)$$

Semi-artificial domestic currency hedge

A hedge from US-dollar (U$) via currency k to South Korean Won by using 1 Forward contract and 1 Foreign exchange spot rate at maturity T.

$$V_i(T) = V_i(0) * FX_{i,j}(0) * FWD_{j,k}(0,T) * FX_{k,i}(T)$$

Artificial domestic currency hedge

A hedge from US-dollar (U$) via currency k to South Korean Won by using 2 Forward contract both with maturity T.

$$V_i(T) = V_i(0) * FX_{i,j}(0) * FWD_{j,k}(0,T) * FWD_{k,i}(0,T)$$

2.2   Benchmarks

2.2.1   Performance

The performance of these 3 contracts will be calculated for the time period (2003-2010) by vary the maturity T from {1m,2m,3m,6m and 1y} .

The performance of such contract is calculated as follows:

$$Performance = \frac{V_i(T)*B_i(0,T)\big/D_j(0,T)-V_i(0)}{V_i(0)}$$

For simplicity, a transaction cost in basis point of total value given in Table 1 is used to compensate the rolling fee for the shorter maturity T.

2.2.2   Historical simulation method (VaR)

VaR is a widely used risk measure of the risk of loss on a specific portfolio. This measure is defined as a threshold value with the probability that the loss on the portfolio over time horizon exceeds this value. A certain confidence level of $(1-\alpha)$ is given such that loss l, does not exceeds L. The mathematical notation is:

$$VaR_\alpha = \inf\{l \in R : P(L > l) \leq 1 - \alpha\}$$

The VaR will be calculated with a time horizons of 1 day, to identify the risk exposure of our portfolio hedge methods.

2.3   Factor analysis

The foreign exchange exposure of a particular industrial sector can be assessed approximately using factor analysis. The method consist of regressing the stock market return of the particular industry on exchange rate changes rate changes while controlling for overall stock market movements. The econometric model specification used in the analysis is:

$$R_{i,t} = \beta_{0,j} + \beta_{1,i}\Delta s_{x,t} + \beta_{2,i}R_{m,t} + \varepsilon_{i,t}$$

Where

$R_{i,t}$ = Excess return on industry i

$\Delta s_{x,t}$ = Trade weighted exchange rate of country x (Korea)

$R_{m,t}$ = Excess return on the Korean stock market index

$\beta_{1,i}$ = Exchange rate exposure of Korean industry i

$\beta_{2,i}$ = The remaining correlation of Korean industry i

$\varepsilon_{i,t}$ = Error (IDD)

2.4   Stochastic simulation

A simulation will be used to examine the effects of currency fluctuations on the FX basic risk by vary the volatility and the interest rate. We assume that there exist dollar bonds in the US and we can trade in Won bonds in Korea. The prices of these bonds (in their respective currencies) are given by

$$D_t = e^{qt}$$

$$B_t = e^{rt}$$

The exchange rate E_t, i.e. the Won value of one dollar, is modeled as a geometric Brownian motion.

$$E_t = E_0 e^{vt+\sigma W_t}$$

Where

$$v \quad = \quad \text{Drift}$$

$$\sigma \quad = \quad \text{Volatility}$$

$$W_t \quad = \quad \text{Brownian motion}$$

We can now trade in riskless Won bond and the risky US bond which has the following price process

$$S_t = B_t E_t = S_0 e^{(q+v)t+\sigma W_t}$$

By computing 10000 simulation with each 30 sample paths, we would have a reliable estimation due to the law of large number

$$\overline{S} = {}_n\lim_\infty \frac{1}{n} * \sum_i^n S_i$$

3 Data and Results

3.1 Data

All data required for the analysis from January 1st 2003 to December 31st 2010 is obtained from Thomson DataStream. Daily FX spot rate, FWD rate and 2 years riskless government bond are used to calculate the performance and risk exposure. We examine five currencies over the globe – Hong Kong dollar, Japanese Yen, South Korea Won, United Kingdom Pound and United States Dollar. To simplify the calculations, transaction cost in basis point of total value given in table 1 is used.

3.2 Historical performance

When we analyze the FX rates, we found out that the average FX rates are small relative to their standard deviations which indicate a high volatile FX market. Our analysis also indicates an increase in volatility during the recent financial crisis. During this period, the FX rates from K-won to US$ and UK to US$ has been depreciated which made the foreign currency becomes more expensive relative to the domestic currency. In contrary, the European and Japanese FX rate increased during this period. Given our analysis, we can assume that the Euro is the most reliable and stable out the 5 currencies when we exclude the Hong Kong dollar which is a currency related to the U.S. dollar.
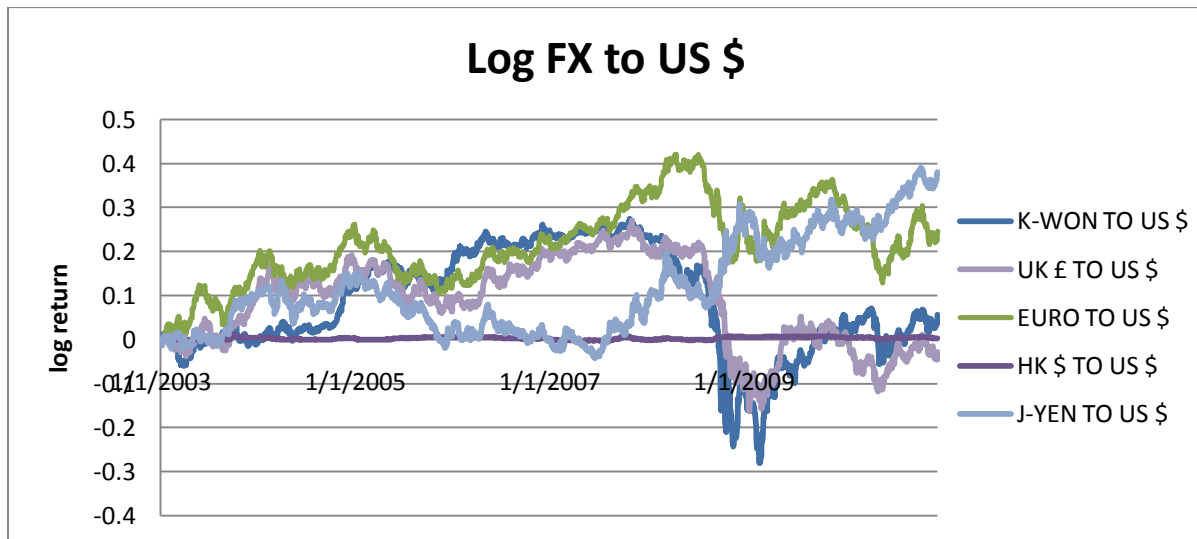

Figure 1: Log FX to US%

3.2.1 Normal hedge performance

Within the FX market, the Forward contracts are globally the most used FX derivative to reduce FX exposure. The popularity and market share of 60% of such derivative amongst market players can be explained due to its simplicity while other derivatives are much more complicated and difficult to understand. Due to its popularity, we will use this derivative to construct our hedge and analyze the FX exposure for the Korean Won-to-US Dollar FX rate.

Our analysis indicates that a forward contract with a shorter maturity has a higher performance and a lower volatility and VaR. On average, the performance can increase by 10 basis point annually and reduce the volatility and VaR by 50%. This indicate that a shorter maturity T outperform a longer maturity. To compensate the additional transaction cost/rolling cost for the shorter maturity, we will use 8 basis point of the total value per transaction. Hence, a 3 month forward contract is the most beneficial when we discount the additional transaction cost.
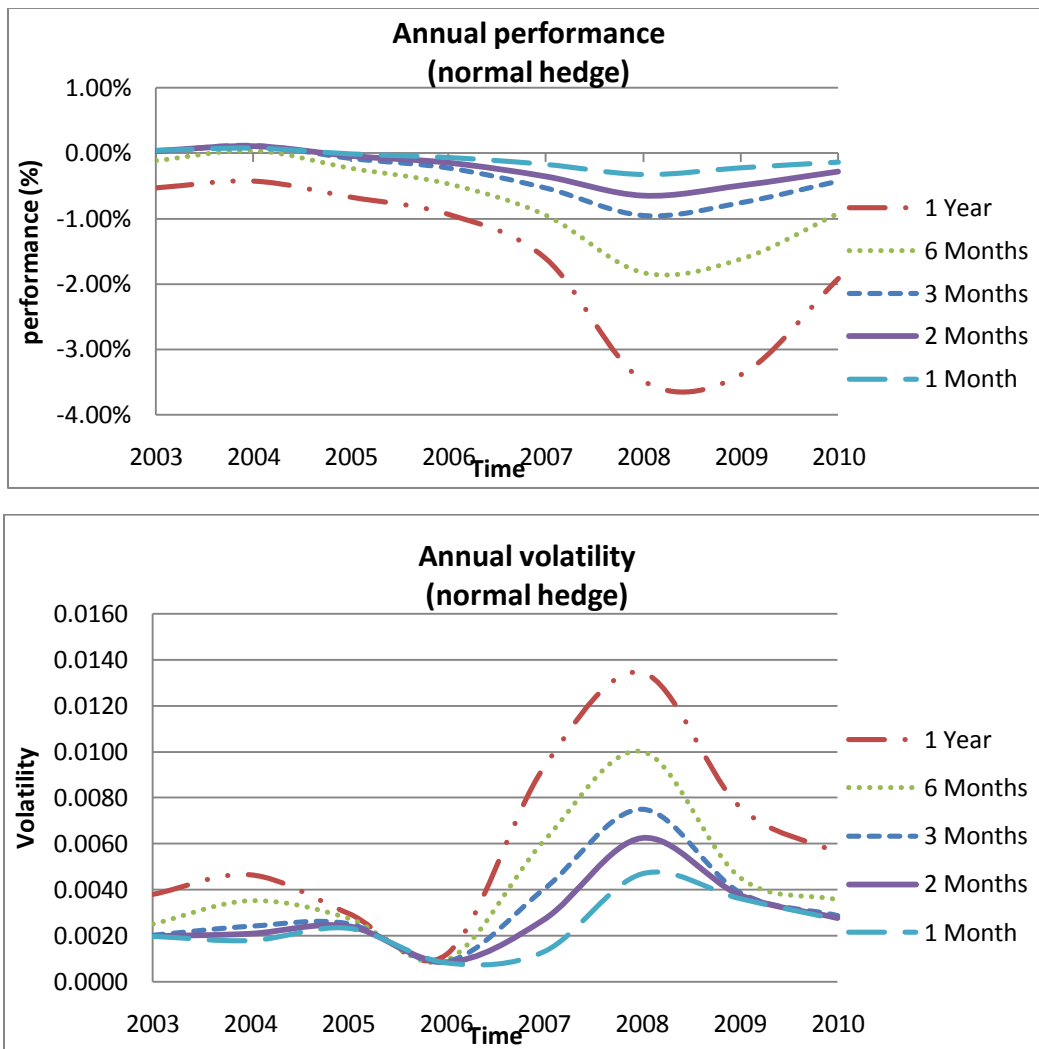

Figure 2: Annual performance and volatility

3.2.2 Artificial hedge performance

The performance and the risk exposure of the artificial hedge are identical to the normal hedge. The main difference in these two hedge methods are the transaction cost. When we compare the transaction cost, the artificial hedge will have an additional transaction cost, due to the fact that the portfolio contains 2 FWD contracts instead of 1. To compensate the shorter maturity and additional transaction cost/rolling cost, we will use transaction cost in basis point of the total value per transaction given in table 1. We can see that the Euro-Dollar has a low transaction cost in comparison with other and also the most stable FX rate, therefore we prefer an artificial hedge with the Euro which makes this artificial hedge 1.1 basis point more expensive per transaction than the normal hedge. Hence, a 3 month forward contract is the most beneficial when we discount the additional transaction cost.

Transaction cost in basis point	
Euro-Dollar	1.1
Dollar-Yen	2.3
Pound-Dollar	2.1
Dollar-HKD	1
Dollar-Won	8
Euro-Won	8
Pound-Won	8

Table 1: FX Transaction cost

3.2.3 Semi- hedge performance

On average, the semi-hedge method outperforms the normal and artificial hedge by 40 basis point, but it also has 10 times higher volatility and 3 times higher 95% VaR. This method has a high exposure to currency fluctuation which companies would like to avoid. The purpose of hedging is to reduce risk, therefore we wouldn't recommend this method for risk averse market players.
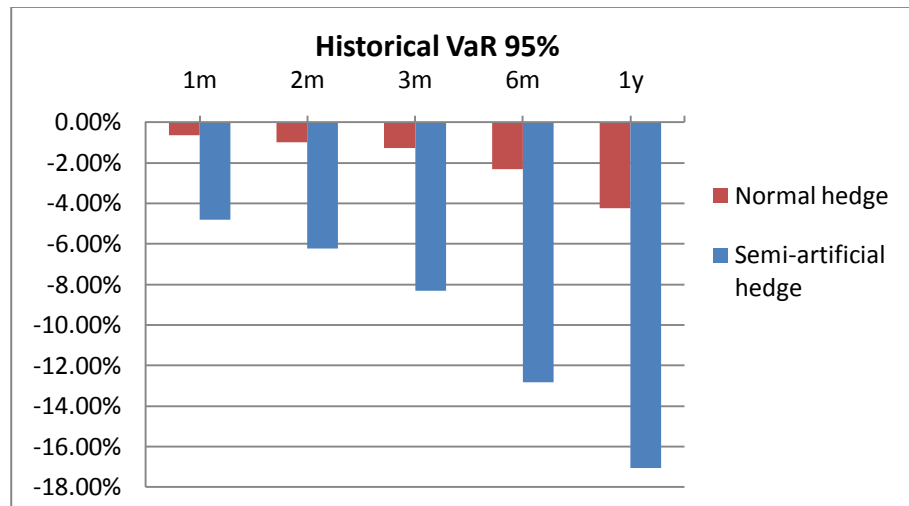

Figure 3: Historical VaR 95%

3.2.4   Performance/Loss distribution

When we look at the performance/loss distribution, Figure 4 indicates that the performance/loss is normal distributed for all hedge methods. The normal and artificial hedge is skewed on the left side which indicate a VaR of -1.28% and average of -0.35%, while the semi artificial hedge has a fat tail with a VaR -8.30% and average of +1.01%
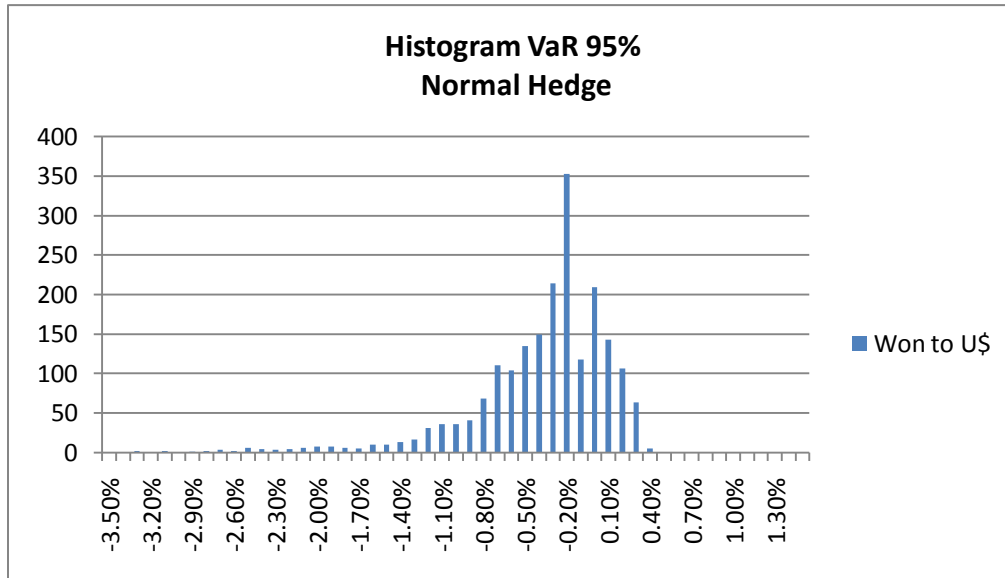

Figure 4: Histogram VaR Normal Hedge

Our analysis also indicates that when maturity T increases, the VaR also increases. The increasing factor of VaR is exponential, therefore a shorter maturity will has less FX exposure.
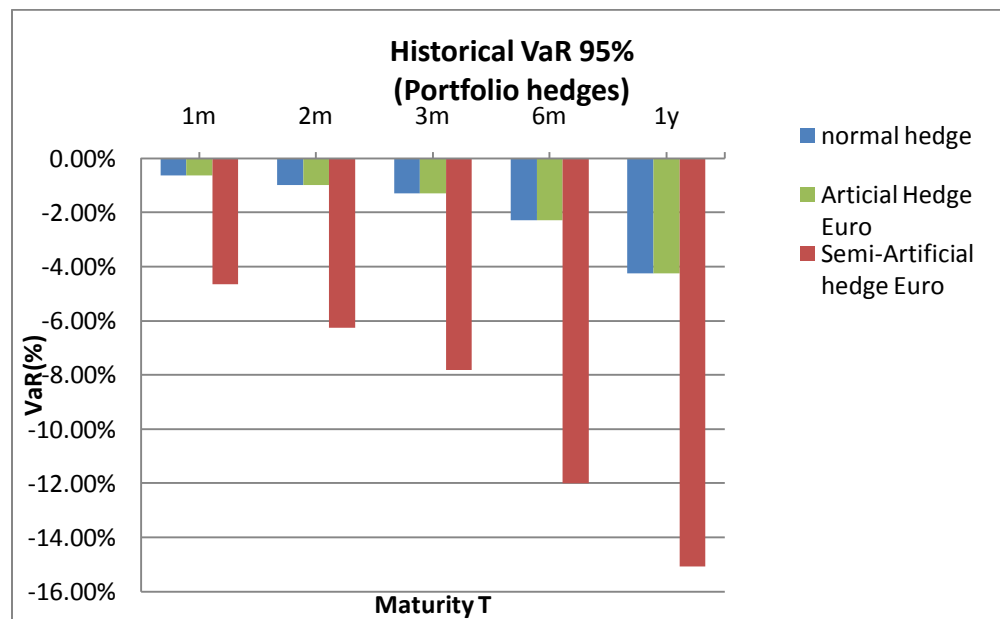

Figure 5: HS VaR value for given FWD with maturity T

4   Risk exposure (factor analysis)

When the exchange rate depreciates, the foreign currency becomes more expensive relative to the domestic currency. To measure such marginal exchange rate exposure, we will use the Factor analysis econometric model. The impact of a given local exchange rate movements on Korean industry stock return, relative to its impact on the Korean stock market index will be measured. A value of $\beta_{1,i} = 0.643$, will indicate that a 1% depreciation is associated with a 0.643% increase in stock prices and $\beta_{2,i} = 0.49$ indicate the dependency on local economic growth. The results of the factor analysis on the Korean industry are shown in table 2. Our analysis indicates that only the "Manufacture" industry has a negative impact of -1.29%, when the exchange rate depreciates by 1% and it also has high dependency of 1.95 on the economic growth of Korea. The depreciation of exchange rate has a positive impact on all other industry, especially "Electronics & Communication" which has a positive of 1.12% when the exchange rate depreciates and has a low dependency on the economic growth of Korea during the crisis. Our analysis also indicates that during financial distress, the FX exposure and the dependency of economic growth increased for all the industry except for "Services" which indicate that this industry has a low FX exposure and low dependency of economic growth.

KOS 200 Industry	$\beta_{1,i}$			$\beta_{2,i}$		
	2003-2010	2003-2006	2007-2010	2003-2010	2003-2006	2007-2010
Construction	0.643	0.814	1.099	0.489	0.344	0.284
Electronics & Communication	1.119	0.816	1.366	0.421	0.601	0.089
Services	0.111	0.283	0.197	0.224	0.288	0.144
Manufacture	-1.287	-1.007	-1.636	1.951	1.851	2.259
Financial Services	0.365	0.239	0.411	0.391	0.344	0.335

Table 2: Factor analysis results (FX exposure)

5   Simulation

A simulation will be used to examine the effects of currency fluctuations on the basic risk by vary the volatility and the interest rate. By computing 10.000 simulations each with 30 sample paths, we would have a reliable estimation due to the law of large number.

Our analysis indicates that when the volatility increases, the FX rate fluctuation also increases. The fluctuation are small between the interval [0% , 8%] , but increases drastically when sigma >8%.
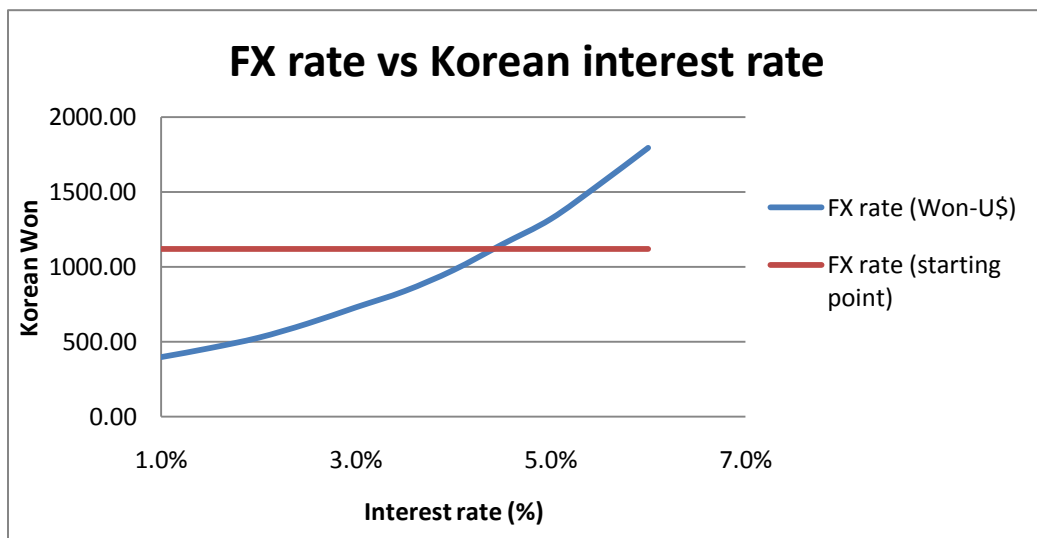

Figure 5: FX rate vs. Korean interest rate

To analyze the effects of interest rate fluctuation on the FX rate, we vary the interest rate in the simulation. We observe that there exists a high dependency between the interest rate and FX rate. When the Korean Interest rate increases relative to the US interest rate, the FX rate increases which make the Foreign currency (US$) more expensive relative to the domestic currency (Won) Figure 5. A fluctuation of - 0.5% in the interest rate results to 10% depreciation in the FX rate. When we analyze both interest rates, we observe a high volatility of 59% and low average interest rate of 2.58% for US interest rate while the Korean interest rate has a much lower volatility of 16% and higher average interest rate of 4.45%. The FX exposure of Korean stock market is high due to the unstable US interest rate.

6   Conclusion

The main research objective is to analyze the exchange rate exposure of the Korean stock market and estimate the performance of a domestic currency hedge during the pre and post crisis (2003-2010). We have analyzed the relation between the Korean stock returns and FX rate return, the performance of the widely used FWD contracts and implemented a simulation to determine the basic risk.

Our results indicates that a FWD contract with shorter maturity T, outperform a FWD with a longer maturity in all aspects. When we discount the additional transaction cost for a shorter maturity, the FWD with maturity of 3 months is the most beneficial and the FX exposure can be reduced with 10 basis point of total value. The performances of the artificial hedge are identical with the normal hedge. In comparison with the 5 currencies, the European Euro is the most suitable currency to conduct this artificial hedge due to its low transaction cost and a low volatility. This method requires an addition transaction cost of 1.1 basis point of total value. This method can be used to avoid expensive risk premium, avoid illiquid FX market and diversify the risk amongst market players. On average, the semi-artificial hedge reduces the FX exposure by 40 basis of total value but with an addition 10x higher volatility and a 3 times higher VaR. It's also worth mentioning that the VaR increases exponentially when maturity T increases. The semi-artificial hedge method has a high FX exposure which is not meant for risk averse market players.

When we look at the risk exposure analyzed with the factor analysis model, The "Manufacture" industry has a negative impact of -1.29%, when the exchange rate depreciates by 1% and it also has high dependency of 1.95 on the economic growth of Korea. The depreciation of exchange rate has a positive impact on all other industry, especially "Electronics & Communication" which has a positive of 1.12% when the exchange rate depreciates and has a low dependency on the economic growth of Korea during the crisis. Our analysis also indicates that during financial distress, the FX exposure and the dependency of economic growth increased for all the industry except for "Services" which indicate that this industry has a low FX exposure and low dependency of economic growth.

The FX basic risk can be estimated with a simulation by vary the volatility and the interest rate. When the volatility increases, the FX rate fluctuation also increases which is very logical. Our analysis also indicates that the interest rate fluctuation has a high impact on the FX rate. When we increase the Korean interest rate relative to the US interest rate, the FX rate increases respectively. A fluctuation of - 0.5% in the interest rate results to 10% depreciation in the FX rate.

We can conclude that when the FX rate of US$ becomes more expensive, the Korean stock market will increase. The FX exposure is relative high with $\beta_{1,i}$ =0.23 pre-crisis and $\beta_{1,i}$ =0.29 post-crisis. The best way to hedge this FX exposure, is to use a FWD contract with a maturity of 3 months. Hedging FX risk is valuable if it helps reduce the cost of financial distress, tax advantage and agency costs among different stakeholders in the firm. The financial distress cost can be decreased by reducing volatility of foreign currency-denominated cash flows, the likelihood of financial distress will be lower. The FX hedging can also decrease tax payments if the tax schedule is a convex function of income. In this case, smoothing pre-tax income lowers the average tax burden. Finally, hedging also helps firms to increase their leverage by reducing borrowing cost since it assures potential bond holders of a reduced probability of financial distress. Hence, it becomes easier for firms to achieve an optimal capital structure.

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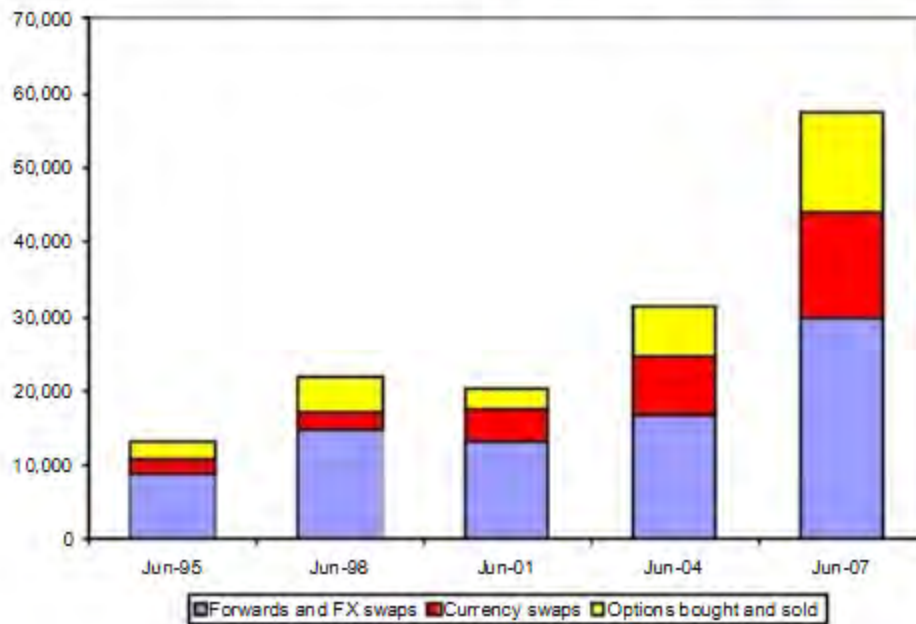
Appendix

FX Forwards Turnover by Currency, 2007
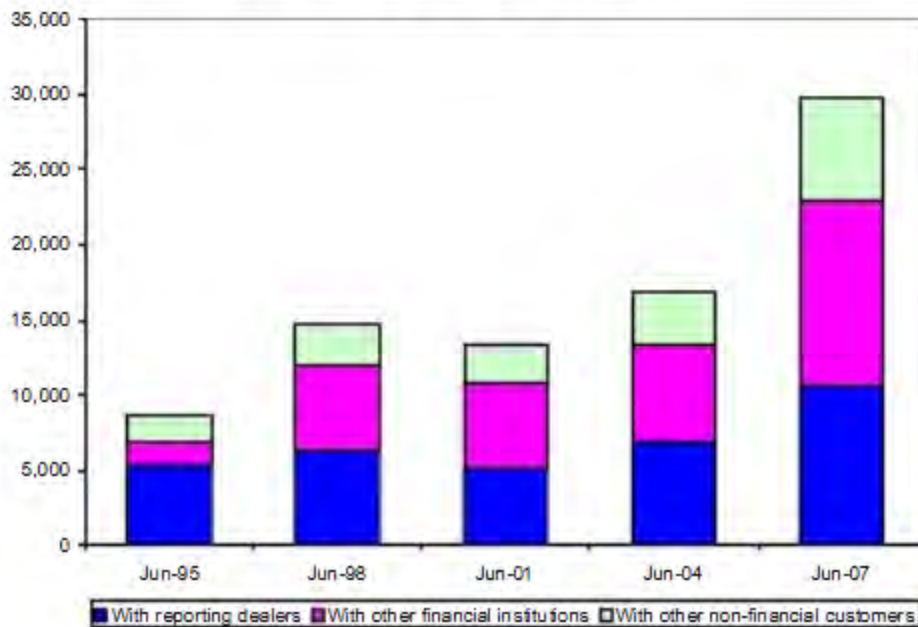**(Percentage shares of average daily turnover)**
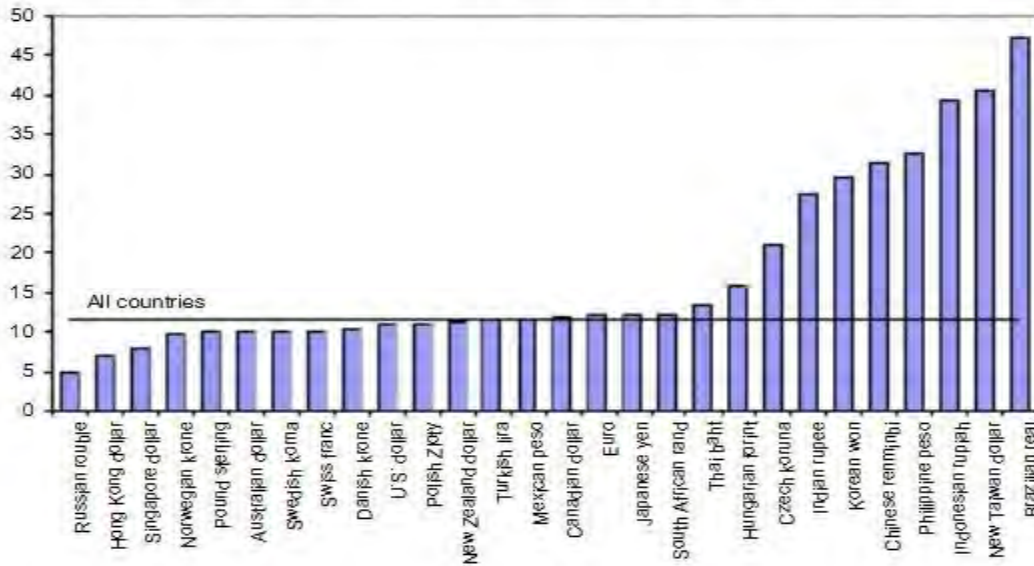
FX Spot rate Turnover by Currency, 2007
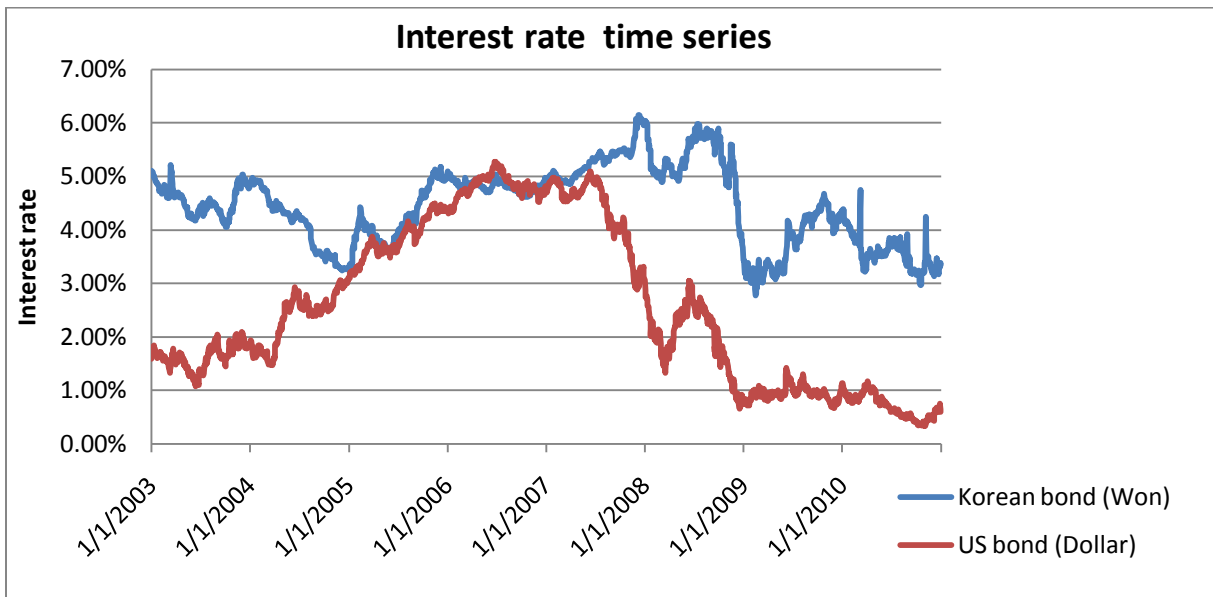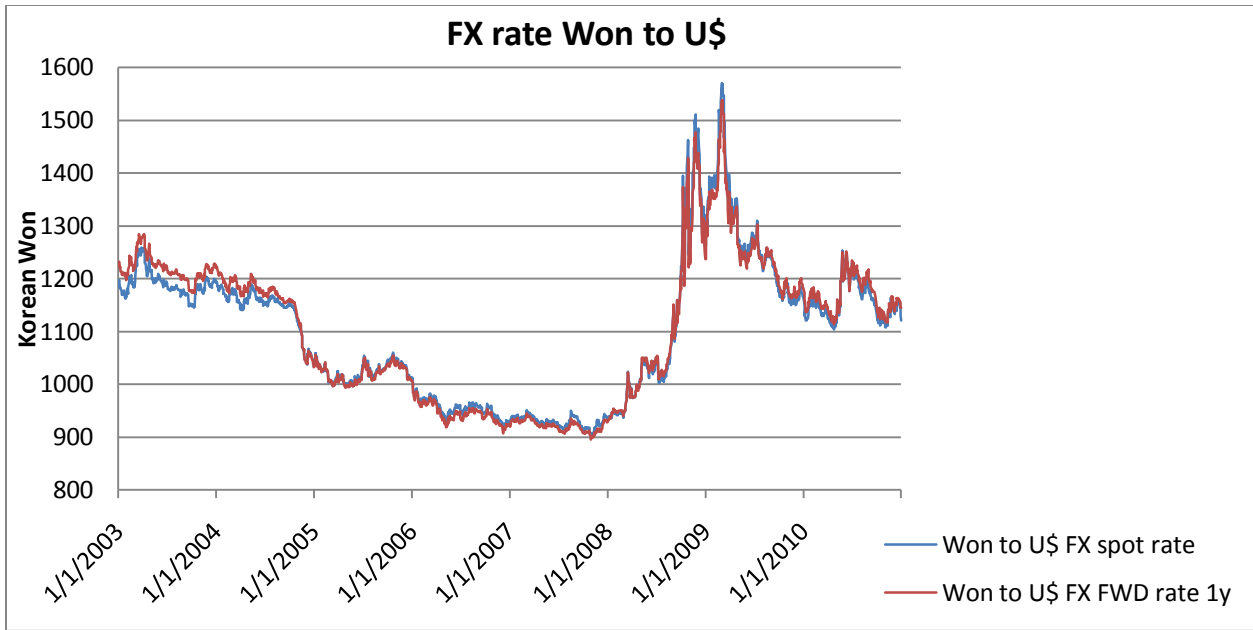**(Percentage shares of average daily turnover)**
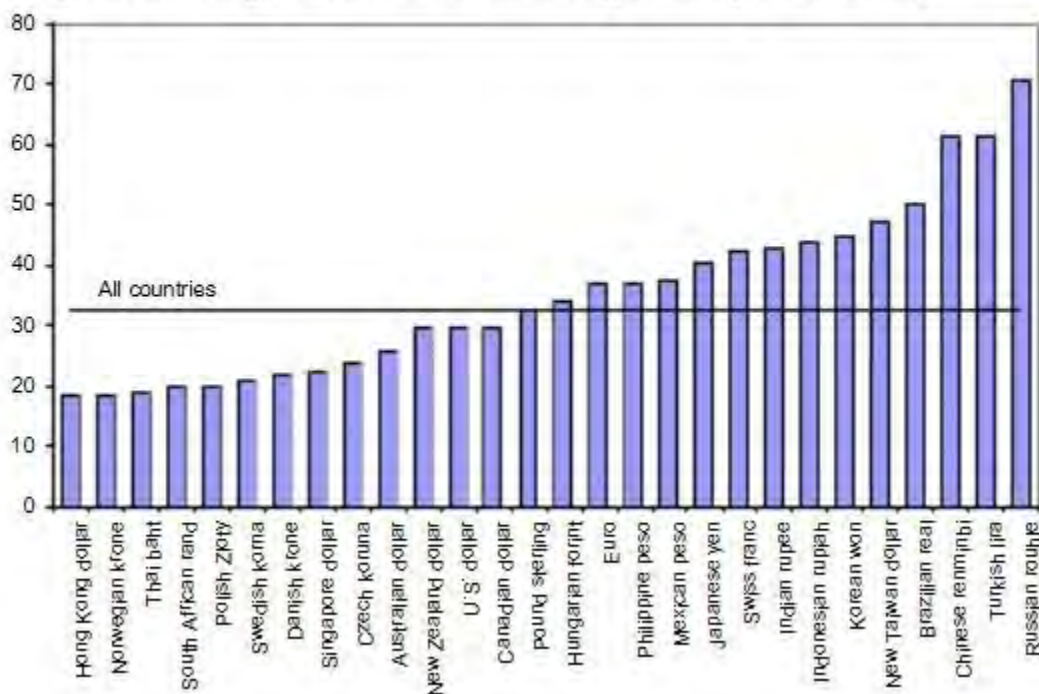
Notional Amounts Outstanding of OTC Foreign Exchange Derivatives, by Instrument
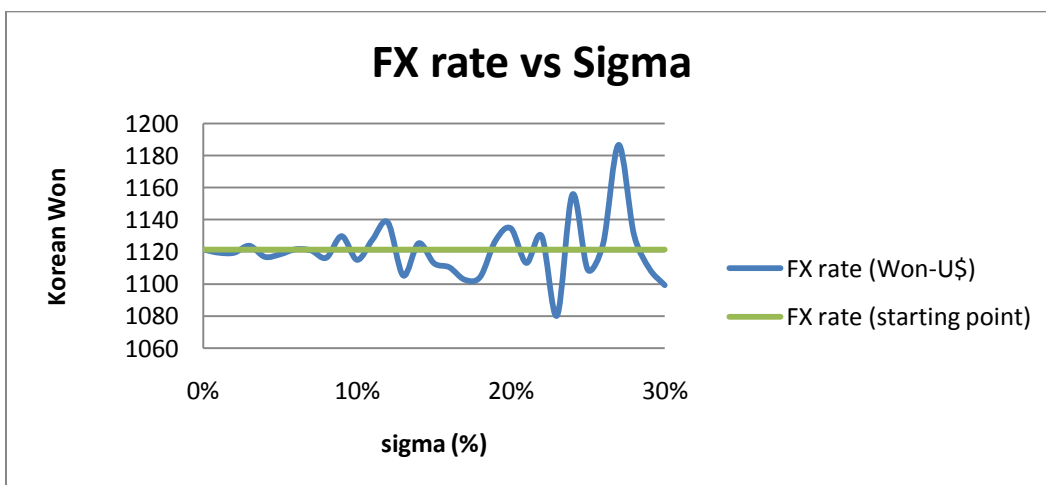## (In billions of U.S. dollars)

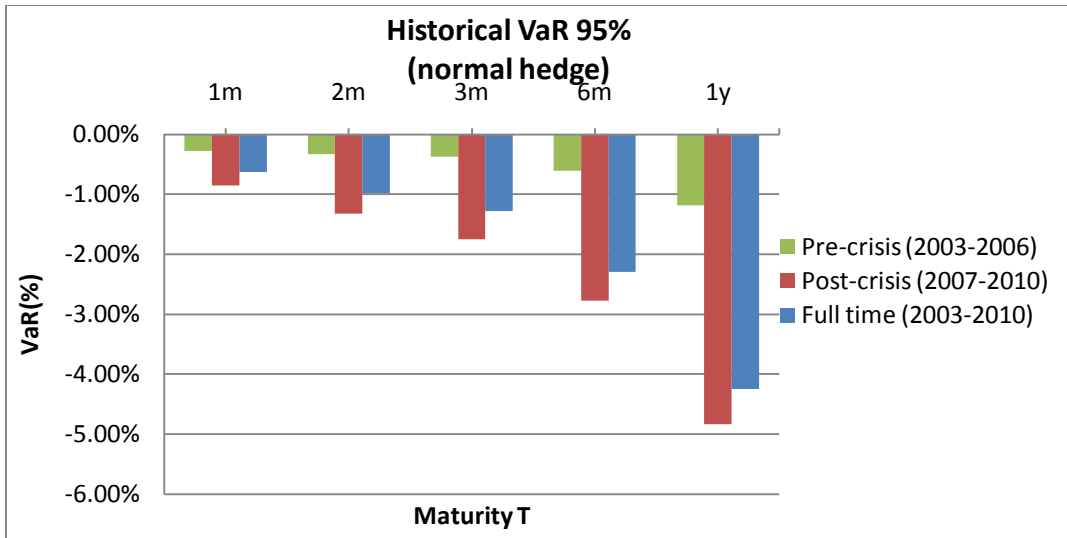Legend: Forwards and FX swaps ■Currency swaps □Options bought and sold
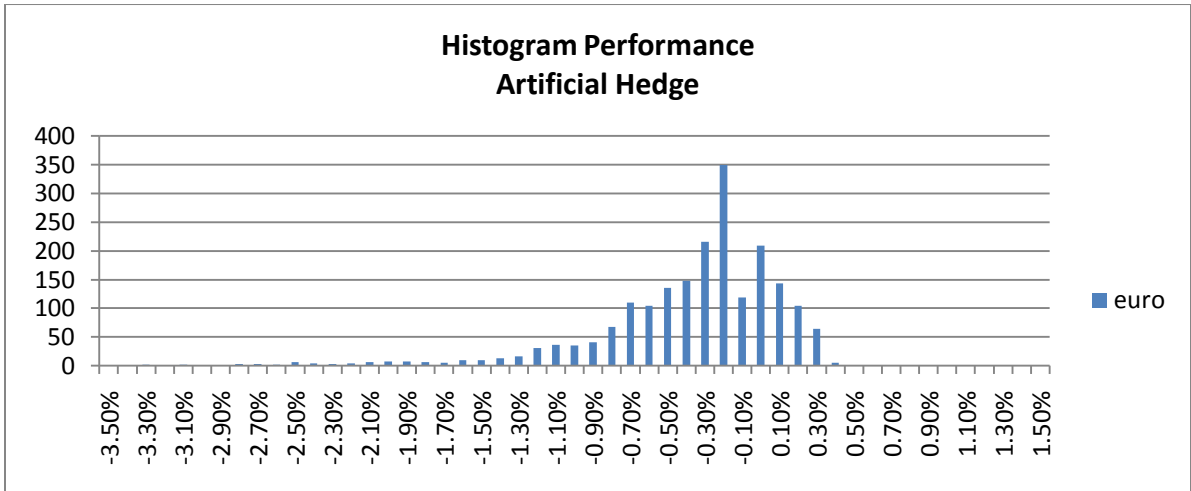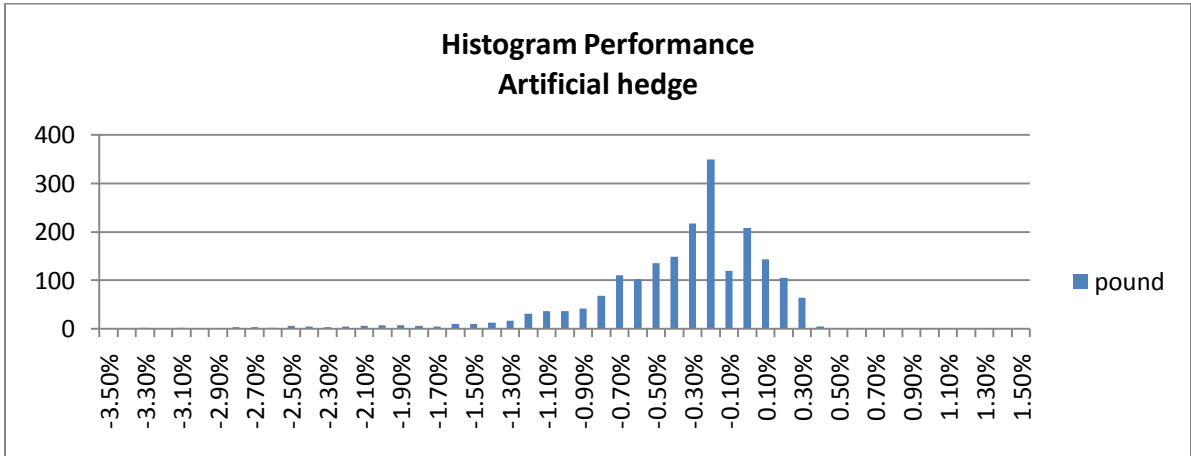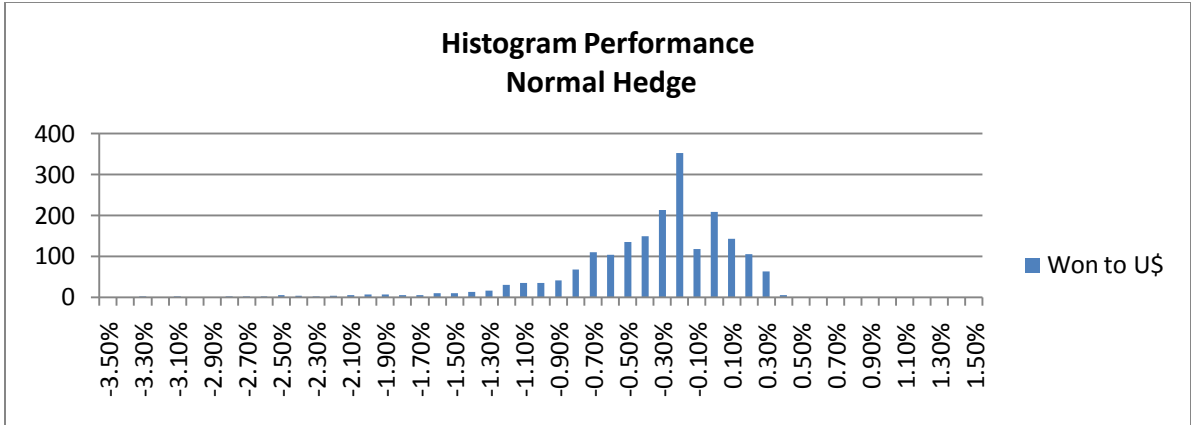
Notional Amounts Outstanding of Forwards and FX Swaps, by Counterparty
(In billions of U.S. dollars)

Legend: ■With reporting dealers ■With other financial institutions □With other non-financial customers

FX rate Won to U$

Korean Won (vertical axis): 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600

Horizontal axis: 1/1/2003, 1/1/2004, 1/1/2005, 1/1/2006, 1/1/2007, 1/1/2008, 1/1/2009, 1/1/2010

— Won to U$ FX spot rate
— Won to U$ FX FWD rate 1y

Interest rate time series

Interest rate (vertical axis): 0.00%, 1.00%, 2.00%, 3.00%, 4.00%, 5.00%, 6.00%, 7.00%

Horizontal axis: 1/1/2003, 1/1/2004, 1/1/2005, 1/1/2006, 1/1/2007, 1/1/2008, 1/1/2009, 1/1/2010

— Korean bond (Won)
— US bond (Dollar)

Increasing factor 3m (VaR)	
1m	0.49
2m	0.77
3m	1.00
6m	1.79
1y	3.31

Historical VaR 95% (normal hedge)

Historical VaR 95% (Portfolio hedges)

FX rate vs Sigma

Histogram Performance Normal Hedge — Won to U$

Histogram Performance Artificial hedge — pound

Histogram Performance Artificial Hedge — euro

Histogram Performance
Semi-artificial hedge

euro

Histogram Performance
Semi-artificial hedge

pound

Histogram Performance
Semi-artificial hedge

jap

Histogram Performance
Semi-artificial hedge

Legend: ■ hk

X-axis labels: -15.00%, -13.70%, -12.40%, -11.10%, -9.80%, -8.50%, -7.20%, -5.90%, -4.60%, -3.30%, -2.00%, -0.70%, 0.60%, 1.90%, 3.20%, 4.50%, 5.80%, 7.10%, 8.40%, 9.70%, 11.00%, 12.30%, 13.60%, 14.90%, 16.20%, 17.50%, 18.80%, 20.10%

Y-axis labels: 0, 10, 20, 30, 40, 50