STOCKHOLM SCHOOL OF ECONOMICS
MASTER'S THESIS IN FINANCE

CURRENCY HEDGED INTERNATIONAL EQUITY INVESTMENTS

– FROM THE PERSPECTIVES OF SWEDISH AND AMERICAN INVESTORS

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ABSTRACT

Using time-series data for 20 major countries over the period 1993–2004 we examine the risk performance of international equity portfolios with full and reduced amounts of exchange rate exposure. The study is performed from the perspectives of both Swedish and American investors. In line with a priori expectations we find that currency hedging using forward contracts tends to decrease the standard deviation of diversified and undiversified international investments. The findings are consistent with regards to different hedging horizons and time periods of study.

We identify two main reasons limiting the magnitude of risk reduction stemming from currency hedging when compared to unhedged investments: (1) natural hedges between single countries' equity indices and exchange rates and (2) currency diversification in a global portfolio context. Since currency hedging nonetheless appears to reduce investment volatility, we conclude that it would be beneficial to include currency hedging in an international equity investment strategy of any risk-averse investor.

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CONTENTS

1 Introduction

Modern portfolio theory – developed and popularized by Markowitz (1952) – states a trade-off between returns and risk of financial assets. Risk-averse investors demand increases in expected returns for extra risk, or equivalently, reductions in risk for a decrease in expected returns. Since price changes of financial assets are almost always less than perfectly correlated, a central result of portfolio theory is that diversification of assets significantly improves the risk–return profile for a given investor. A number of past and recent academic authors, among them McManus & Tezel (1998) and Solnik (1995), have emphasized the possible virtues of diversifying not only by investing in a vast array of domestic assets, but increasing the set of investment opportunities to the global financial market.

In association to international investments, a key issue arises around the subject of exchange rate risk. This risk is even more pronounced when investing in a single or just a few countries since simultaneous currency movements cannot cancel. In international investments, investors are primarily concerned with returns denominated in domestic currency. Situations where international investments yield high returns in terms of *foreign* currency however do not necessarily imply investment success in *domestic* currency, as is illustrated in the excample below.

1.1 Illustrative Example of Benefits from Currency Hedging

Suppose a Swedish investor invests SEK 100 in European stocks. At the commencement of the investment the SEK/EUR exchange rate is 10, i.e. EUR 10 is invested. Suppose that the position is closed one year later and that the value of the stock portfolio has appreciated 10% – it is now worth EUR 11. If however the SEK has appreciated vis-à-vis EUR, e.g. so that the exchange rate is 9, only SEK 99 will remain after the proceeds of the investment have been converted back to SEK ($11 \times 9 = 99$). Although the (EUR-denominated) return of the stocks was 10%, the return in SEK was negative (–1%). This risk of incurring losses resulting from an adverse change in exchange rates will henceforth be labeled *currency risk* or *exchange rate risk*.

The example highlights how currency risk can cannibalize returns when measured in domestic currency. Admittedly, the effect of currency movements might also be the opposite of the above – if the SEK/EUR rate would have depreciated, the Swedish investor's gain on the European investment would have been amplified. As a result, *in any situation where an investor in a given country invests in one or several other countries, the returns in domestic currency will be affected*

by changes in exchange rates. Clearly, currency risk will constitute an additional source of risk on top of the risk inherent in the investment itself. From a risk-averse investor's perspective this effect should be highly undesirable, since the extra risk will not bring about any increases in expected return.

In theory, the simplest way to alleviate this problem is *currency hedging. Hedging* generally refers to an investment position or combination of positions that reduces or cancels out the volatility/risk in another investment, whilst leaving the returns of that investment basically unchanged (Hull (2003)). In the context of currencies, the properties of the hedging instrument must therefore ensure that unfavorable exchange rate movements are met by favorable movements in the value of the hedging instrument, and vice versa. The simplest instrument fulfilling this property is a *forward contract*, which essentially is a zero net present value agreement to exchange currencies at a future date at a rate determined today.[1]

Presume that the investor in the previous example entered a forward contract upon the inception of the investment. For simplicity assume the investor could have agreed to exchange the initial investment's worth of EUR 10 to SEK at a pre-determined rate of 10 SEK/EUR one year from today. In this case only EUR 1 would have been affected by currency fluctuations. The resulting SEK proceeds would have been 109 ($10 \times 10 + 1 \times 9 = 109$), i.e. a 9% return; the major portion of the exchange rate risk was thus eliminated at zero financial cost.

1.2 Purpose

Forward contracts' potential ability to reduce international investment risk without significantly affecting average returns should be intuitively clear from the preceding section. Any investor with the aim of conducting international investments with as little foreign currency risk as possible should prefer the strategy of forward hedging over a strategy where the entire investment is exposed to foreign exchange rate movements.

The use of hedging strategies such as forward contracts is low among many institutional investors including mutual funds. A review of Swedish funds' holdings reveals that only around 4% of all examined funds currency-hedge foreign equity using forwards or other comparable instruments

[1] However, unless the investor has a perfect forecast ability there will always be a *basis risk* in terms of the mismatch between what the investor sells forward at time $t = 0$ and what the investment will be worth at the maturity of the forward contract. Thus the hedge will always be imperfect.

(futures, options etc.).[2] As has been demonstrated above, eliminating at least parts of the exchange rate risk is rather simple. From a theoretic perspective it may therefore seem puzzling that many renown financial institutions bear exchange rate risk which in theory is uncompensated by higher returns.[3] In our opinion, rational investors willing to speculate in currency risk should do so purely by investing in currencies instead of indirectly through foreign equity. Hence;

The purpose of this thesis is to examine whether currency hedging of international equity investments reduces risk.

It is of crucial importance to see whether hedging is better than no hedging at all. A priori we expect hedged investments to display less volatility in returns than unhedged investments. We also expect that hedging has a much more marked effect on a single country investment than on a well-diversified portfolio (i.e. well-diversified in terms of currency exposure).

1.3 Disposition

The remainder of the paper is organized as follows. Section 2 introduces theoretical concepts central to this paper and performs a review of previous research on the topic of currency hedging foreign investments. Limitations are accounted for in Section 3 and Section 4 presents the data and methodology employed in the study, including descriptive statistics. Section 5 outlines our empirical findings and analyses and Section 6 contains discussion and conclusions. We sum up with suggested areas for further research in Section 7.

[2] Mutual funds are obliged by Swedish law to report all holdings, including derivatives, to the Swedish Financial Supervisory Authority (FI). FI is a public authority whose role is to promote stability and efficiency for the financial system as well to ensure effective consumer protection. By manually seeking through 100 Swedish funds we only found four mutual funds with currency derivatives holdings.

[3] Three of Sweden's major banks, Skandinaviska Enskilda Banken, Handelsbanken and Föreningssparbanken, were all investigated. None had currency derivatives for a strategic purpose in any of their international portfolios.

2 Theoretic Framework and Literature Review

2.1 Theoretic Framework

2.1.1 Performance Assessment: The Standard Deviation

Risk can either be measured in standard deviations or in terms of beta. By using beta it is possible to examine how much a new investment would add to the portfolio's diversification and hence enlarge/reduce its *systematic* risk. The empirical research in our study is on the contrary determined to examine total risk. When measuring total risk, using standard deviation is more appropriate since this measurement takes into account both systematic and *idiosyncratic* risk. (Bodie et al. (2002).) By examining standard deviation we implicitly assume that the investor is investing her entire wealth in international stocks, rather than holding a fraction of wealth in international stocks.

2.1.2 Hedging Instrument: Forward Contracts

The technique of using *forward contracts* (*forwards*, for short) for hedging assets denominated in foreign currency was mentioned in the introduction. This section elaborates further on the functioning of these instruments, particularly explaining how they can be used to substantially reduce currency risk in international investments.

A forward contract is an agreement to buy or sell an underlying asset at a certain price at a certain future date. The price at which the asset will be exchanged (the *forward price*, denoted F_0) is set such that the present value of the contract is zero at inception. Because of this, no cash changes owner at contract commencement; the only monetary flows occur when the contract matures, i.e. on the future date when the contracted transaction of the asset takes place.

The underlying in the context of this paper is the exchange rate between two countries. In theory, forward prices for exchange rates are set according to the *Covered Interest Rate Parity*[4]:

$$F_0 = S_0 e^{(r-r_f)(T-t)}, \qquad (1)$$

where

F_0 = forward rate at time t;
S_0 = foreign exchange spot price at time t;
r = domestic (Swedish or American) risk free interest rate;

[4] In theory the Covered Interest Rate Parity must hold according to a simple no-arbitrage argument.

r_f = foreign risk free interest rate;
T = time of delivery (hedging horizon);
t = time 0 (date of forward contract inception).

Equation (1) states that the forward exchange rate with horizon T is determined by today's exchange rate, the risk-free interest rate differential between the two countries in question and the time to maturity. F_0 can hence be viewed as today's "best guess" of the risk adjusted exchange rate at time T. Precisely how forwards can be used as to facilitate risk reduction in international investments is outlined conceptually below:

Define exchange rates as the amount of domestic currency required to purchase one unit of foreign currency.[5] An investor holds an asset X in a foreign country with stochastic return over the period $t = 0$ to $t = 1$. Denoting by S_0 the observed exchange rate at the beginning of the investment and by S_1 the (unknown) exchange rate at the closing point, the return of an unhedged asset is:

$$r^U = \frac{S_1 X_1 - S_0 X_0}{S_0 X_0}. \qquad (2)$$

The corresponding domestic return for an investor holding a portfolio where the asset value today (X_0) is hedged is:

$$r^H = \frac{F_0 X_0 + S_1 (X_1 - X_0) - S_0 X_0}{S_0 X_0}. \qquad (3)$$

Intuitively the standard deviation of Equation (3) should be lower than that of Equation (2) when estimated over time. This is because the variation between F_0 and S_0 is expected to be lower than between S_1 and S_0.

2.1.3 Investor Characteristics

Although the act of entering forward contracts seems rather simple, it is unlikely that every single investor will be able to execute the hedging strategies developed in this paper. Currency forward contracts are typically available only for very large amounts of currency conversion, so sufficient amounts of capital are critical.[6] In addition, anyone carrying out international investments must have good access to international stock markets as to minimize transaction costs. Few private investors are expected to fulfill these criteria; the hedging strategies in this paper are applicable

[5] This convention (domestic/foreign currency) will be followed in the remainder of the paper.
[6] Accorduing to OMX, owners of the Stockholm Stock Exchange, converting less than approximately one million SEK to whatever foreign currency using forwards is not possible in practice.

primarily to major financial institutions such as mutual funds. We therefore take the perspective of large institutional investors, hereon referred to as "the investor".

2.2 Previous Studies

Jorion (1989) performs a study of how foreign assets contribute to the total portfolio of American investors during the period 1978–1988. Two well-diversified foreign portfolios of bonds and stocks are assessed; one unhedged, i.e. including exchange rate risk versus the USD, and one hedged, i.e. stripped of currency risk. The latter is hedged by selling forward foreign currency one month to the value of the investment today.

Jorion argues that American investors are likely to invest only a small fraction of their wealth in foreign assets – the focal point of his study is therefore the *incremental* risk contribution of the foreign assets (measured by the Treynor ratio). On the contrary, the *total* risk of the portfolio is pivotal in our paper, since the entire wealth is invested in single countries or in a market capitalization-weighted global index. Jorion finds that hedging is more important the larger the fraction of wealth invested in foreign securities. For an American investor holding the majority of wealth in domestic assets, the difference in *incremental* risk reduction between hedged and unhedged foreign assets is low. If however only a small fraction is held in American assets, substantial reductions in *total* volatility result from currency hedging.

Thomas (1988) investigates hedged versus unhedged investments in 15 non-US equity markets form an American investor's perspective over the period 1975–1987. The study covers both total and systematic risks on a country-by-country basis. Similarly to Jorion, the hedge is constructed such that foreign currencies are sold forward. Thomas finds that not only total volatility, but also incremental risk, is reduced when hedging is employed. Total risk – as measured by the average standard deviation of returns of all 15 markets throughout the period – was reduced by 15%.

Finally, in an essay on equity hedging from the perspective of European pension funds, Smith (2003) shows how currency hedging using forwards reduces the volatility of foreign assets. Smith argues that currency hedging should be a natural portfolio component for any investor holding assets abroad, in particular if the investment horizon is short. In a longer perspective, say, 20 or 30 years, currency risk tends to "wash out", i.e. gains and losses on currencies cancel out on average, due to the theory of Purchasing Power Parity (PPP) which states that real prices in all countries should equal.

3 Limitations

3.1 Relevance of Returns

This study examines changes in risk, defined as the standard deviation of returns, resulting from currency hedging. An effective hedging strategy should not lead to any significant changes in returns themselves. Due to a relatively short time series we will not take into account any changes in returns. This is justified by Merton (1980), who suggests that around 50 years of data is needed to estimate representative historical returns with precision. The volatility of returns is nevertheless much easier to estimate; for this a few years of high-quality data suffice. We found it to be out of the scope of this thesis to examine a data set of 50 years or more.

3.2 Costs

We believe that taking into account costs of hedging, especially transaction costs, is out of the scope of this thesis. Collecting data and calculating costs would contribute to the overall results but since we are taking the view of an institutional investor the transaction costs of buying and selling equity, costs of managers, contractual costs etc. are assumed to be negligible. Forward contracts are also one of the least costly hedging instruments, because the direct cost of entering them is zero by definition – the only cost incurred is the time taken to find and contract with a counterparty. Further support to exclude transaction costs is Smith's (2003) statement that "the costs of running a hedging program is low…" as well as a confirmation by the Executive President of the Seventh Swedish National Pension Fund, Peter Norman, during an interview[7]. According to him the cost of running a hedging program such as the one in this thesis requires approximately a quarter of a person per month in terms of human resources.

[7] Peter Norman, 8 November 2005, personal communication (interview).

4 Data and Methodology

This section delineates how the data necessary for the study have been sampled, how the hedged and unhedged portfolios have been defined and constructed and how we estimate the returns and standard deviations of these. In the quest of comparing the performance of hedged and unhedged international equity investments, we start off by investigating currency hedging on a country-per-country basis. Then all countries are weighted together in a "global portfolio" to see if any changes result from potential currency diversification. This diversified portfolio will comprise 15 of the world's major stock indices (for technical reasons to be explained in Section 4.2.3 we sampled data on 20 countries in total). Together these 15 countries are believed to constitute a well-diversified investment representative of the world stock markets in aggregate.

The hedging strategies will be explored from the perspectives of both Swedish and American investors. By doing so we check if hedging gives different findings for a small economy with a currency of minor international importance compared to the world's largest economy with the most influential currency. Analyzing an American investor's perspective moreover enables us to compare this study with Jorion's (1989) and Thomas' (1988) results.

4.1 Data

The time-series data employed in this paper spans the period 1993–2004. Prior to 19 November 1992 the Swedish Krona (SEK) was governed by a fixed exchange rate regime, under which the SEK's fluctuations were entirely tied to the fluctuations of other currencies. It therefore seems natural to exclude pre-1993 data, since a currency fluctuates in fundamentally different manners depending on whether a fixed or floating exchange rate regime is in place. No such problems are encountered in the American data set.

4.1.1 Data Collection

Equity Indices

For each of the 20 countries in the study we have chosen the broadest and most well-known stock market index available. Appendix A contains a list of the countries included and the chosen index for each country. In Appendix B each index's characteristics are given a short description. All indices are denominated in local currencies and are hence subject to full currency risk for any unhedged investor outside that index's country. Together the 15 largest indices each year compose on average 89% of the world's total stock market capitalization over the sample period.

Exchange Rates

In order to measure how foreign and domestic returns in the indices differ, foreign exchange rates for each country were sampled. A number of countries in the sample replaced their respective currencies with the Euro in 1999 – to account for this the post-1999 Euro series have been scaled up or down to match the nominal values of the pre-1999 currency. This eliminates any kinks in the data series for Euro-adopting countries yet do not change relative currency movements.

Interest Rates and Forward Prices

In the construction of the hedged portfolios, data on forward prices are pivotal. The forward prices must match the hedging horizon; if e.g. a hedge over six months is conducted, the relevant forward price must be quoted for six months. Despite considerable effort we were unable to find time-series of observed currency forward prices for any of the countries in the study – we therefore decided to calculate forward prices implied by the Covered Interest Rate Parity as per Section 2.[8] Doing so requires data on interest rates for each country. Discrete depository/interbank interest rates for one month and six months[9] were gathered for all countries throughout the sample period. These were then transformed into continuous[10] rates.

Stock Market Capitalization Figures

Stock market capitalization figures are only needed for the well-diversed portfolio. Every country's index is in this case weighted by that country's market capitalization relative to the aggregate world stock market capitalization. Yearly data on each country's stock market capitalization were taken from *Standard & Poor's* "Global Stock Markets Factbooks" (2003). Each country's year-by-year portfolio weights are exhibited in Appendices C and D, respectively.

Unless otherwise stated, all collected data are taken from Thomson Financial's *Datastream* database and a number of financial homepages that freely distribute historical data, among them the exchanges' own home sites.

[8] It should be pointed out that we introduce two crucial assumptions at this stage. Firstly, we implicitly assume that observed forward prices are exactly equal to what the Covered Interest Rate Parity would suggest. Secondly, we assume that the sampled interest rates are used by institutional market participants.

[9] We sample 1-month and 6-month data, as these are the hedging horizons we consider. Closer details are provided in Section 4.2.

[10] We use continuous rates since that form is needed in the formula used for calculating forward prices. Using discrete rates in a discrete version of the Covered Interest Rate Parity would not imply any differences in the values of the calculated forward prices.

4.1.2 Descriptive Statistics

All investment strategies constructed in the study are dependent on how both indices and exchange rates developed over the 12-year period. In Table 1 we present each country's total return and annualized standard deviation on the index together with data on how the SEK has developed relative to each country's currency (negative values translate into appreciations of SEK and vice versa):

TABLE 1 **INDEX AND CURRENCY RETURNS OVER THE TOTAL PERIOD COUNTRY-PER-COUNTRY, SWEDISH PERSPECTIVE**

Country	Total Period's Index Return (1993–2004)	Standard Deviation of Index Returns, Annualized (1993–2004)	Total Period's Currency Return (1993–2004) SEK/FX	Standard Deviation of Currency Returns, Annualized (1993–2004)
Argentina	184%	37%	*–69%*	22%
Australia	155%	13%	6%	12%
Belgium/Luxembourg	160%	17%	*–5%*	7%
Canada	176%	15%	*–2%*	10%
Finland	651%	32%	13%	6%
France	108%	24%	7%	7%
Germany	175%	24%	6%	7%
Hong Kong	286%	27%	*–7%*	10%
Italy	212%	23%	*–3%*	7%
Japan	*–32%*	23%	13%	12%
Malaysia	41%	27%	*–35%*	15%
Netherlands	318%	21%	5%	7%
Singapore	44%	21%	*–6%*	10%
Spain	287%	22%	*–12%*	8%
Sweden	330%	21%	-	-
Switzerland	242%	17%	21%	8%
Taiwan	82%	27%	*–27%*	12%
Thailand	*–25%*	28%	*–39%*	15%
United Kingdom	221%	17%	19%	9%
United States of America	249%	17%	*–7%*	10%

Table 1 gives a first indication of the essential nature of the currency component in international equity investments. Consider e.g. Malaysia: the index rose by 41% over the period, but from a Swedish perspective much of this return would not have been realizable, as a 35% SEK appreciation took place simultaneously. An opposite situation is that of Finland; the 651% index return would have been further boosted by a 13% depreciation of the SEK against the Mark/Euro. Our aim in hedging portfolios will be to eliminate these currency effects as effectively as possible.

In Figure 1 we display the index developments of each country weighted together by relative market capitalization. Each country's index has been converted to a common base of 100 as of 1 January 1993 and weighted by its relative market weight on the same date – the series can hence be viewed as a "global index" of separate countries' indices. This weighted-together global index of all countries has increased by 166% over the sample period.

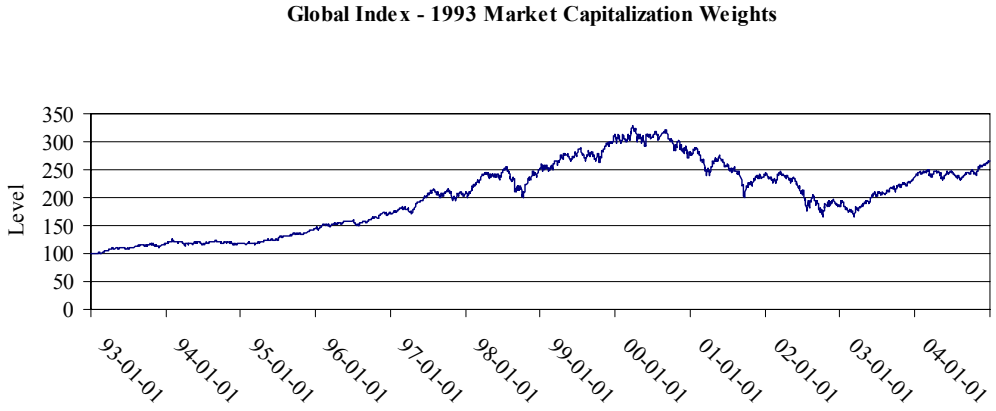

Figure 1: The market capitalization weighted global index over the total period. (Normalized series.)

To illustrate how the SEK performed over the 12 years we constructed a global currency in the same way as the global index was constructed, i.e. we set all currencies to a common base on 1 January 1993 and weighted them according to relative stock market capitalization. The same procedure was repeated for the USD. From Figure 2 it is clear that the SEK has depreciated by 8.6% over the period against all other currencies in our global index, i.e. one unit of global currency exchanges into more SEK today than 12 years ago. Likewise, USD has depreciated by 9.3%.

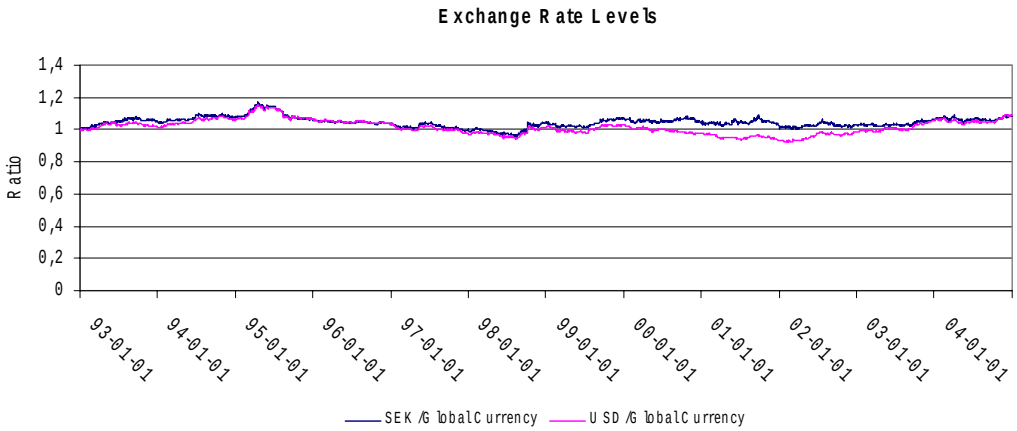

Figure 2: SEK and USD versus the market capitalization weighted global currency. (Normalized series.)

It is of interest to compare the above graph with graphs depicting single exchange rates. As can be seen in Figures 3 and 4, single currencies are significantly more risky than a basket of weighted-together currencies. It therefore seems highly important to hedge when investing in single countries and we expect that the gains from such a hedge is expected to be higher in a single country case than for a well-diversified portfolio.

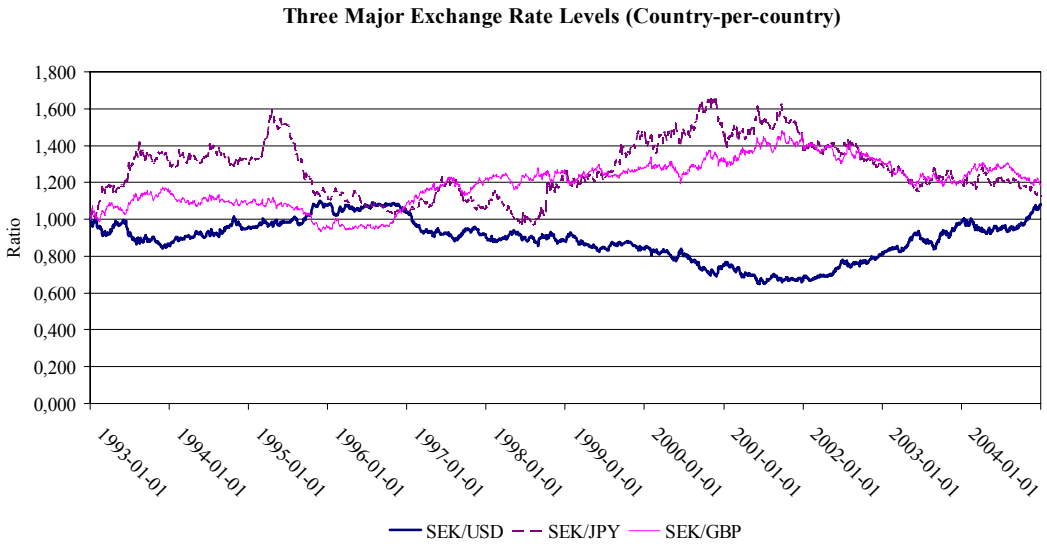

Figure 3: SEK versus American Dollar, Japanese Yen and British Pound. (Normalized series.)

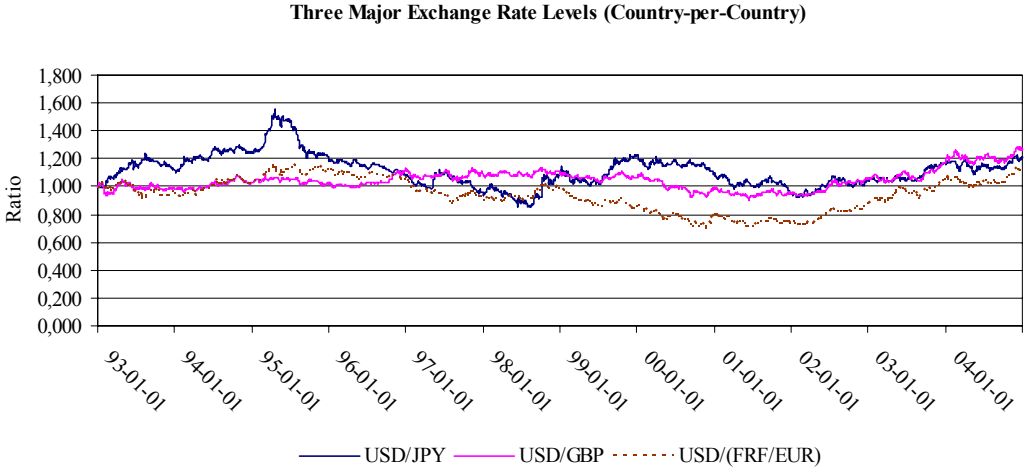

Figure 4: USD versus Japanese Yen, British Pound and French Franc/Euro. (Normalized series.)

4.2 Methodology

Here we outline the exact composition of the different foreign equity investment strategies. It is of integral importance to define the hedged and unhedged portfolios in a consistent manner, so that their risk characteristics may be compared in an equitable fashion. In sum, the following investment perspectives will be examined and compared; hedged versus unhedged, no

rebalancing versus rebalancing, 1-month versus 6-months forward horizon and total period versus sub-periods.

4.2.1 Chosen Countries

This study examines investment strategies in the world's 20 largest equity markets, insofar as data of sufficient quality exists. Finding reliable and frequently quoted time series of stock indices, exchange rates and interest rates is relatively simple for developed countries. In cases where portions of data are missing or of apparent low quality, our strategy has been to exclude the country and add the largest country following the excluded country. Countries with low data quality are typically emerging markets, e.g. Brazil, China and Russia (all of which were excluded). In the global portfolio setting the replacing country is often a small non-emerging market. As a result we focus more on developed countries in this study.

The impact on our diversified portfolios from country alterations is likely to be small. The excluded indices together constitute less than 5% of the portfolio's capitalization and more importantly, even if a bias occurs, it will affect the hedged and unhedged portfolios equally. Moreover the portfolio can still be regarded as well-diversified since it adds up to on average 89% of the world's market capitalization over the 12-year period. For the purpose of this paper – examining whether currency hedging reduces risk – the effect of excluding certain countries is unlikely to be imperative. This is further discussed in Section 6.

TABLE 2 **NEW COUNTRIES REPLACING THE EXCLUDED ONES**

Excluded Countries	*Replacing Countries*
China	Argentina
Brazil	Belgium/Luxembourg
Russia	Finland
South Africa	Singapore
South Korea	Thailand

4.2.2 Investment Strategies: No Hedging, Imperfect Hedging & Perfect Hedging

4.2.2.1 No Currency Hedging

This sub-class of portfolio represents an investor holding foreign equity index/indices with full exposure to movements in the currencies. Using the notation introduced earlier and denoting by sub-index *i* the specific country in the sample and by sub-index *t* the period of measurement, the period-to-period returns for each *i* is defined as:

$$r_{i,t}^{U} = \frac{X_{1i}S_{1i} - X_{0i}S_{0i}}{X_{0i}S_{0i}}. \tag{4}$$

Equation (4) is averaged over time for all countries in order to obtain the realized returns over the sample period:

$$\bar{r}_i^{U} = \frac{\sum_{t=1}^{n} r_{i,t}^{U}}{n} \Rightarrow \bar{r}_{i,annual}^{U} = \bar{r}_i^{U} \times \frac{n}{12}. \tag{5}$$

and the sample period standard deviation for each *i* is calculated as:

$$\mathrm{var}\left[r_{i,t}^{U}\right] = \sum_{t=1}^{n}\left(r_{i,t}^{U} - \bar{r}_i^{U}\right)^2 \Rightarrow \sigma_i^{U} \equiv \sqrt{\mathrm{var}\left[r_{i,t}^{U}\right]} \Rightarrow \sigma_{i,annual}^{U} = \sigma_i^{U} \times \sqrt{\frac{n}{12}}. \tag{6}$$

In Equations (5) and (6), *n* denotes the number of observed returns (e.g. $n = 12 \times 12 = 144$ in the 1-month case or $n = 12 \times 2 = 24$ for a 6-month horizon, when looking at the total period).

When looking at the global index portfolio the following procedure is applied. All *i*'s per-period returns in Equation (4) are multiplied with their respective portfolio weight and summed together, as to obtain the portfolio return from $t = 0$ to $t = 1$:

$$r_t^{U} = \sum_{i=1}^{15} w_i r_{i,t}^{U}, \tag{7}$$

where w_i denotes each country's weight in the portfolio,

$$w_i = \frac{Market\ Capitalization_i}{\sum_{i=1}^{15} Market\ Capitalization_i}, \tag{8}$$

using both fixed 1993 weights and annually updated weights.

Equations (4) and (7) are calculated for each intra-period in the sample (i.e. on a one or six-month basis, depending on the hedging horizon for the corresponding hedged portfolio), and finally averaged over time as to obtain the annualized average return over the period:

$$\bar{r}^{U} = \frac{\sum_{t=1}^{n} r_t^{U}}{n} \Rightarrow \bar{r}_{annual}^{U} = \bar{r}^{U} \times \frac{n}{12}. \tag{9}$$

The standard deviation of the portfolio is calculated as follows:

$$\mathrm{var}\left[r_t^{U}\right] = \sum_{t=1}^{n}\left(r_t^{U} - \bar{r}^{U}\right)^2 \Rightarrow \sigma^{U} \equiv \sqrt{\mathrm{var}\left[r_t^{U}\right]} \Rightarrow \sigma_{annual}^{U} = \sigma^{U} \times \sqrt{\frac{n}{12}}. \tag{10}$$

4.2.2.2 Imperfect Hedging Strategy

This portfolio class tries to mitigate currency volatility by selling the value of X_0 forward at F_0 for each period and country. The strategy is imperfect in the sense that it sells forward an amount corresponding to today's observed index value – unless the index does not change at all over the holding period, the difference between X_1 and X_0 will be exposed to currency fluctuations. This basis risk exposure arises since it is impossible *ex ante* to predict X_1, next period's index value. The "second-best" and perhaps most straightforward hedging strategy is instead to sell forward the value of X_0. Mathematically, each country's period-to-period return is thus expressed by:

$$r_i^H = \frac{X_{0i}F_{0i} + (X_{1i} - X_{0i})S_{1i} - X_{0i}S_{0i}}{X_{0i}S_{0i}}. \quad (11)$$

Each period's weighted global index return, the annualized average returns over the period and the standard deviations are computed in exact analogy as for the unhedged portfolio.

4.2.2.3 Perfect Hedging Strategy

This strategy is a copy of the imperfect strategy with the exception of one detail in the formula for calculating period-to-period returns – the spot price S_1, which is multiplied by the change of the index in Equation (11), is substituted for the forward price F_0. In reality this strategy would only be executable for an investor with perfect forecasting ability, as X_1 must be accurately predicted *ex ante* for every country and period in the sample. Clearly this is impossible in practice, but it is nevertheless interesting to compare the characteristics of the hedge outlined in Section 4.2.2.2 with those of this "perfect hedge".

4.2.3 Hedging Horizons, Period of Measurement & Portfolio Composition

The strategies in Sections 4.2.2.2 and 4.2.2.3 will be investigated using two distinct hedging horizons: one month and six months. According to theory, Hull (2003), the efficiency of a forward hedge is negatively related to its horizon. A priori, the 1-month horizon should thus work better than the 6-month variant, as the index difference exposed to S_1 in Equation (11) has less time to grow. In other words the forward hedge is conducted on a monthly or semiannual basis, which gives us twelve or two observations per year. To ensure comparability the unhedged portfolios are investigated for the same horizons. The unhedged portfolios' characteristics are measured on the same date as when the forward contract matures – which happens on the same date for all countries – ensuring comparability between the different classes of portfolios.[11]

[11] This is an important part of the methodology. If the hedged and unhedged portfolios were assessed in different manners with regard to observation frequency, we would in fact be "comparing apples and pears".

To check whether differences in hedged and unhedged volatility are stable over time we employ different periods of measurement. In the base case the entire 1993–2004 period is considered. Two sub-periods are also studied: Period I (1 January 1996–31 December 1999) and Period II (1 January 2000–31 December 2003).

Finally, the weighted-together global index portfolios will be examined using both fixed 1993-year weights throughout the entire 1993–2004 period and annually updated weights to account for relative changes in country market capitalization. When fixed weights are used, each country is allocated a relative weight as per equation (7) – these weights are then held constant throughout the sample period. When annual rebalancing is carried out, Equation (7) is updated on 1 January every year. This will change the relative composition of indices in the portfolio from year to year if the relative weighting of capitalization changes between the countries.[12] This also has the effect of mirroring the aggregate world stock market better than the strategy with fixed weights. The weights employed are listed in Appendices C and D.

[12] It is because of this we have sampled data for 20, rather than 15 countries. In the rebalanced portfolio the five smallest countries differ from year to year and therefore replace each other every now and then.

5 Empirical Results & Analysis

This section presents comparisons of the standard deviations of the portfolios described in Section 4. For both the Swedish and the American perspective the country-per-country results are displayed first, followed by the weighted-together global portfolio findings. If later findings do not contribute substantially to results already presented and discussed these are displayed in Appendix E and if the former do not contribute any further at all to conclusions these will not be displayed at all. (This is done in order not to take up superfluous space.)

5.1 A Swedish Investor's Perspective

Table 3 reports the calculated standard deviations country by country for all three portfolio strategies. For the convenience of the reader we only present the 1-month horizon hedging standard deviations and corresponding unhedged data.

TABLE 3 HEDGED AND UNHEDGED STANDARD DEVIATIONS, COUNTRY-PER-COUNTRY, 1-MONTH HEDGING HORIZON, ANNUALIZED VALUES

Italicized values indicate lower standard deviation for the unhedged portfolio.

Country	Standard Deviation (1993–2004)			Difference in Standard Deviations	
	Perfectly Hedged	*Imperfectly Hedged*	*Unhedged*	*Perfectly Hedged versus Imperfectly Hedged*	*Imperfectly Hedged versus Unhedged*
Argentina	41.2%	38.9%	41.3%	5.9%	–5.8%
Australia	12.4%	12.4%	18.5%	0.0%	–33.0%
Belgium/Luxembourg	17.3%	17.2%	19.7%	0.6%	–12.7%
Canada	16.0%	16.0%	19.6%	0.0%	–18.4%
Finland	33.4%	33.4%	32.1%	0.0%	*4.0%*
France	21.0%	21.0%	20.1%	0.0%	*4.5%*
Germany	23.0%	23.2%	22.0%	-0.9%	*5.5%*
Hong Kong	29.2%	29.2%	30.1%	0.0%	–3.0%
Italy	24.2%	24.2%	24.8%	0.0%	–2.4%
Japan	20.9%	21.0%	24.8%	-0.5%	–15.3%
Malaysia	32.9%	33.4%	38.9%	–1.5%	–14.1%
Netherlands	20.5%	20.6%	20.4%	-0.5%	*1.0%*
Singapore	24.5%	24.4%	25.1%	0.4%	–2.8%
Spain	23.0%	23.0%	22.6%	0.0%	*1.8%*
Switzerland	17.4%	17.7%	16.2%	–1.7%	*9.3%*
Taiwan	31.1%	31.2%	35.5%	–0.3%	–12.1%
Thailand	38.3%	37.5%	40.4%	2.1%	–7.2%
United Kingdom	14.5%	14.6%	15.3%	–0.7%	–4.6%
United States of America	14.2%	14.3%	16.6%	–0.7%	–13.9%
Average	23.9%	23.9%	25.5%		

As can be inferred from Table 3, the hedging strategies reduce the volatility of investment returns for almost all countries. To test the observed reductions statistically we employ a matched-pairs difference in means test, as outlined in Appendix F.[13] The test is one-sided and the hypotheses used are:

$$\begin{cases} H_0 = \overline{H} - \overline{U} \geq 0 \\ H_1 = \overline{H} - \overline{U} < 0 \end{cases},$$

where $\overline{H}$ is the mean of the hedged standard deviations and $\overline{U}$ is the mean of the unhedged standard deviations.[14] The null-hypothesis is rejected if the observed *t*-statistic is smaller than the critical *t*-statistic (equal to –2.55 at the 1% significance level and with 18 degrees of freedom). Our observed *t*-statistic was –3.03; in other words, there is strong statistical support of our conclusion that the hedged strategy has a lower standard deviation on average.

The petty magnitude of the *p*-value (less than 0.5%) enables us to confidently state that the hedging strategies work effectively on average. However, the fact that some single countries' hedged portfolios display *higher* standard deviations than the unhedged counterparts is very disturbing, because a currency hedge not fulfilling its chief purpose of reducing volatility is clearly not satisfactory. Intuitively, countries that have a negative correlation between index returns and currency returns should have low standard deviations already when unhedged; this effect can be viewed as a *natural hedge*. The unhedged portfolio would benefit from this effect whereas the hedged portfolio would not be able to capture this phenomenon to the same extent.[15]

Hence, for the six countries where the hedged volatility exceeds the unhedged, we expect the index returns to be negatively correlated with their currency returns. By examining these correlations we came to the results in Table 4. It indeed seems to be the case that the hedging strategies' inability to reduce volatility for these countries is explained by natural hedges. Additionally, it is clear from Tables 3 and 4 that the larger the difference in standard deviations to the advantage of the unhedged portfolio the greater the magnitude of the correlation.

[13] Even though the number of observations (19) is small we still regard the test as a reliable indicator of statistically significant differences in mean standard deviations.

[14] The means were calculated using the arithmetical approach.

[15] This is because of the hedged strategies' relatively smaller exposure to currency movements.

TABLE 4 CORRELATIONS BETWEEN INDEX RETURNS AND CURRENCY RETURNS

Correlations (index returns versus currency returns) estimated for 1-month frequency data for all countries where unhedged standard deviations fall short of the hedged.

Country	Finland	France	Germany	Netherlands	Spain	Switzerland
Correlations	–0.32	–0.30	–0.31	–0.20	–0.22	–0.41

The results for the sub-periods' standard deviations are found in Appendix E Table 11. Here the same differences in standard deviations are observed. For Period I the observed *t*-statistic (–2.36) is significant at the 5% level whereas we cannot statistically say that the hedged portfolio reduces risk in Period II. (An observed *t*-statistic of –1.00, which is statistically significant only at a 25% level.) This is likely to be caused by few observations over a short time period. Nevertheless we believe that the results are *economically* significant.

In addition to the above comparisons, the performance of the perfectly and imperfectly hedged strategies is very similar. Perfect foresight does not appear to imply greater volatility reductions. In general the small differences in the portfolios' performance are explained by the fact that the discrepant term between the imperfect and perfect portfolios' formulas are often very small:

$$\frac{S_1(X_1 - X_0) - F_0(X_1 - X_0)}{S_0 X_0} \approx 0 . \qquad (12)$$

So far we have established that the hedging strategy – be it perfect or imperfect – on average reduces investment volatility on a country-per-country basis. As mentioned in Section 1, this effect is expected to be much smaller when considering a well-diversified portfolio of indices in different countries. The results for our market capitalization-weighted global portfolio are exhibited in Table 5. (For 6-month results see Appendix E Table 12.)

TABLE 5 **FROM THE PERSPECTIVE OF A SWEDISH INVESTOR INVESTING IN THE GLOBAL PORTFOLIO, ANNUALIZED VALUES**

Numerical results are stated for the total period and the two sub-periods. For each period we report the imperfectly hedged and unhedged standard deviations for the fixed 1993-weight portfolios (No rebalancing) and for the portfolios with yearly updating of weights (Rebalanced).

Strategy			Period I (1996–1999)		Period II (2000–2003)		Total Period (1993–2004)	
1-month forward			*Imperfectly Hedged*	*Unhedged*	*Imperfectly Hedged*	*Unhedged*	*Imperfectly Hedged*	*Unhedged*
	No rebalancing							
		Standard Deviation	14.7%	17.3%	15.9%	16.0%	13.8%	15.5%
		Change	–15.0%		–0.6%		–11.0%	
	Rebalanced							
		Standard Deviation	14.8%	16.9%	16.4%	16.1%	14.0%	15.3%
		Change	–12.4%		1.9%		–8.5%	

In likeness with the country-per-country examination hedging reduces volatility when looking at the total period. The same holds true for Period I, although no material differences emerge in Period II. Over the total period the change in standard deviation stemming from the hedging strategy is –10%. Thus, Table 5 provides further evidence of the hedging strategy's ability to mitigate currency risk. The issue of fixed or changing portfolio weights does not alter any comparisons between the hedged and the unhedged portfolios. Nor does the issue of imperfect versus perfect hedging matter, see full results in Appendix E Table 13.

To be able to compare the risk reductions between the country-per-country setting and the global portfolio setting the following procedure is applied. For each country included in the global index the standard deviation difference in Table 3 is weighted with the same portfolio weights as used in Table 5 (no rebalancing). This is easily done for the portfolio with fixed weights, whereas the rebalanced setting would lead to very complex calculations. The aggregate standard deviation difference obtained is –11.2%, which is practically identical to the comparative global portfolio figure (–11.0%). This is contrary to a priori expectations, since we anticipated the former figure to be much lower than the latter. It seems like the standard deviations stemming from Period I are the driving cause behind the total period's difference. One likely factor behind this is lack of currency diversification in the global portfolio seen from a Swedish investor's perspective during Period I. For example the correlations between SEK/USD and SEK/GBP is as high as 0.96 and for SEK/USD and SEK/JPY the correlation is 0.70 (the three currencies with largest portfolio weights).

5.2 An American Investor's Perspective

As mentioned in Section 4 the imperfectly hedged and unhedged portfolio classes were also constructed from the viewpoint of an investor whose base currency is the USD, i.e. an American investor. The resulting figures for the country-per-country perspective are found in Table 6.

TABLE 6 HEDGED AND UNHEDGED STANDARD DEVIATIONS, COUNTRY-PER-COUNTRY, 1-MONTH HEDGING HORIZON, ANNUALIZED VALUES

Italicized values indicate lower standard deviation for the unhedged portfolio.

Country	Standard Deviation (1993–2004)			Difference in Standard Deviations	
	Perfectly Hedged	*Imperfectly Hedged*	*Unhedged*	*Perfectly Hedged versus Imperfectly Hedged*	*Imperfectly Hedged versus Unhedged*
Argentina	40.3%	40.1%	43.9%	0.5%	–8.7%
Australia	12.5%	13.5%	18.1%	–7.4%	–25.4%
Belgium/Luxembourg	17.5%	17.5%	23.0%	0.0%	–23.9%
Canada	16.2%	16.4%	19.3%	–1.2%	–15.0%
Finland	33.0%	33.5%	33.2%	–1.5%	*0.9%*
France	21.0%	21.2%	20.0%	–0.9%	*6.0%*
Germany	23.4%	24.2%	22.7%	–3.3%	*6.6%*
Hong Kong	28.7%	28.8%	28.9%	–0.3%	–0.3%
Italy	24.0%	23.9%	24.4%	0.4%	–2.0%
Japan	20.9%	21.3%	24.3%	–1.9%	–12.3%
Malaysia	32.7%	34.1%	37.8%	–4.1%	–9.8%
Netherlands	20.8%	21.3%	24.5%	–2.3%	–13.1%
Singapore	24.6%	25.2%	25.8%	–2.4%	–2.3%
Spain	22.9%	23.4%	23.0%	–2.1%	*1.7%*
Sweden	21.9%	22.1%	24.0%	–0.9%	–7.9%
Switzerland	17.7%	18.4%	17.2%	–3.8%	*7.0%*
Taiwan	30.5%	30.2%	32.5%	1.0%	–7.1%
Thailand	37.1%	36.1%	40.0%	2.8%	–9.7%
United Kingdom	14.6%	14.7%	17.8%	–0.7%	–17.4%
Average	24.2%	24.5%	26.3%		

When compared with Table 3, the hedging strategy leads to almost identical results for the American investor. The same difference in means test as in the previous section confirms statistical significance in averaged standard deviation. The same hypotheses were used and the corresponding observed *t*-statistic was –3.66 and highly significant at the same significance level and degrees of freedom.

The *p*-value of this test is even lower than in Section 5.1. Hedging seems to benefit the American investor too. In analogy with the Swedish perspective the index–currency correlations for the countries where hedging was not reducing risk were checked. The same consistent pattern as for

Sweden ensued, i.e. the correlation is more negative the better the relative performance of the unhedged portfolio. This is seen in Table 7:

TABLE 7 CORRELATIONS BETWEEN INDEX RETURNS AND CURRENCY RETURNS

Correlations (index returns versus currency returns) estimated for 1-month frequency data for all countries where unhedged standard deviations fall short of the hedged.

Country	Finland	France	Germany	Spain	Switzerland
Correlations	–0.17	–0.35	–0.34	–0.23	–0.37

As in the Swedish case we now move on to the global index. From the American investors point of view the volatilities in Table 8 would have been realized throughout the sample period.

TABLE 8 FROM THE PERSPECTIVE OF AN AMERICAN INVESTOR INVESTING IN THE GLOBAL PORTFOLIO, ANNUALIZED VALUES

Numerical results are stated for the total period and the two sub-periods. For each period we report the imperfectly hedged and unhedged standard deviations for the fixed 1993-weight portfolios (No rebalancing) and for the portfolios with yearly updating of weights (Rebalanced).

Strategy			**Period I (1996–1999)**		**Period II (2000–2003)**		**Total Period (1993–2004)**	
1-month forward			*Imperfectly Hedged*	*Unhedged*	*Imperfectly Hedged*	*Unhedged*	*Imperfectly Hedged*	*Unhedged*
	No rebalancing							
		Standard Deviation	14.7%	15.3%	15.9%	16.8%	13.8%	14.5%
		Change	–3.9%		–5.4%		–4.8%	
	Rebalanced							
		Standard Deviation	14.8%	14.8%	16.4%	17.0%	14.0%	14.4%
		Change	0%		–3.5%		–2.7%	
6-months forward								
	No rebalancing							
		Standard Deviation	10.2%	9.2%	15.7%	18.2%	13.4%	13.9%
		Change	10.9%		–13.7%		–3.6%	
	Rebalanced							
		Standard Deviation	9.4%	9.0%	15.5%	17.2%	13.4%	13.2%
		Change	4.4%		–9.9%		1.5%	

When compared with Table 5, the general differences between the hedged and unhedged portfolios are smaller for the American investor than for the Swedish investor. This appears rather normal, since the American holds almost half of the invested amount in the domestic index, with no resulting exchange rate risk (for the Swedish investor only 1% of the invested amount is held in Sweden).

There is a general tendency of the hedged portfolios to demonstrate lower standard deviations than the unhedged strategies – again the hedging of currencies fulfills its major purpose. However some of the 6-month hedging horizon results appear intriguing. In some cases the standard deviation of the unhedged portfolio is *lower* than that of the hedged portfolio. This is the case e.g. for Period I with changing portfolio weights (10.9%), which undoubtedly casts a dark shade on the effectiveness of the hedging program. The difference for the total period is also positive (1.5%). A partial explanation to this phenomenon is currency diversification; the unhedged portfolio is already comparatively spared from idiosyncratic risk due to different currencies cancelling one another out. Another could be index–currency correlations as in the country-per-country analysis, however a decomposition of portfolio correlations would be too mathematically involved for this study. The Period I underperformance of the hedged strategy is very difficult to explain – apart from the above arguments we see no other explanation than scarcity of observations (24).

As a broad inference the question of rebalancing portfolio weights comes across as being more important than in Table 5. We believe this effect is attributable to the American investor holding a large portion of the investment in domestic currency; changes in portfolio composition will invariably lead to larger relative changes in domestic assets than for the Swedish investor. (See Appendix D for a graphical overview.)

Finally we can establish that there is a large disparity between the differences in hedged and unhedged standard deviations depending on what setting we are analyzing. The mean difference is –12.5% for the country-per-country treatment and –4.8% for the global portfolio analysis, respectively. This is opposite to our findings for the Swedish perspective; the currency diversification effect appears to be much larger for the American investor.

6 Discussion & Conclusions

The purpose of this study has been to investigate whether risk characteristics for international equity portfolios can be improved by engaging in currency hedges. The assessment was performed over the period 1993–2004, from the perspectives of Swedish and American investors investing in single foreign countries' equity. We also investigated a market capitalization-weighted index of international equity. A priori we expected the hedging strategy to reduce volatility and we anticipated that the effect would be greater for single countries than for an aggregate global index.

Our empirical results suggest that both a Swedish and an American investor would have benefited duly from hedging in terms of lower standard deviations of returns. Where this has not been the case these divergences are believed to be explained by (1) natural hedges, i.e. negative correlation between a given country's index and currency returns and (2) currency diversification. In addition, our results appear to be in line with the findings of both Jorion (1989) and Thomas (1988). However, the reduction in standard deviation for the hedged strategy in the country-per-country analysis compared to the well-diversified setting is larger for the Swedish perspective than for the American perspective. For the Swedish perspective this is against our a priori expectations but we believe this finding to be foremost explained by currency diversification.

Continuing to assess and compare the perfectly with the imperfectly hedged strategies we draw the conclusion that perfect forecasting ability is of minor importance. The sum of gain/losses made from the residual (due to imperfect foresight) plus the total return form the hedge is not materially different from the total return of the perfectly hedged portfolio. This holds true both for our country-per-country analysis and our global index, regardless of whether rebalancing or fixed weights are used. Furthermore, rebalancing weights or keeping them fixed is of importance only for the American perspective.

In general, the choice of hedging horizon does not have any conclusive impact on the effectiveness of currency hedging. This is against our a priori expectations that the shorter the length of the forward contracts the better the hedge and provides evidence that the hedging program only has to be carried out semiannually, which in turn translates into lower transaction costs. Plausibly currency fluctuations are similar for one and six-month windows. Overall our results appear to be consistent over time, even for shorter time periods hedging reduces risk in an

economically significantly manner. Since hedging improves risk characteristics over a 12-year period we may conclude that the PPP does not seem to wash out currency fluctuations on such a time horizon.

It should be pointed out that the difficulty of constructing an effective forward hedge against currency fluctuations is further added to by the following subtle argument. In our study we have hedged the currency of the country in which the equity is bought but this equity itself is likely to be exposed to currency risk even in its domestic country. A firm with a large share of sales and production outside its own borders will quite naturally be exposed to currency fluctuations with regard to the countries in which it operates. This could be exemplified by a Swedish investor investing in a UK-listed company with all its operations in the USA. The investor would then not only be affected by movements in the SEK/GBP rate, but also indirectly by GBP/USD movements, unless the company itself hedges the GBP/USD risk. This indirect effect clearly adds complexity to the problem of hedging currency risk in international equity investments. If investors and the company behind the equity hedge simultaneously, an adverse counter-effect for the investor might emerge. Despite this possibility we still find in our study that hedging is beneficial in most cases.

The study has focused on a Swedish and an American perspective. We believe that our findings are applicable to any country, as long as there is a liquid equity and derivatives market. More specifically, it does not seem to matter if we take the perspective of an investor in a small emerging country with high volatility in returns or a large developed country with stable returns, since the hedged investment will still have a lower risk than the unhedged investment on average. Although the study adds support to currency hedging's ability to reduce investment risk, we must bear in mind that the model is assessed from historical data and might not be able to generalize over an infinite future (as is the case with any study employing historical time series).

All in all, this thesis has added understanding to currency hedging of international equity investments. Building on our results we suggest increased use of currency hedging in the global financial marketplace.

7 Further Research

Throughout the study we have encountered many possible side paths that have been tempting to embark. Yet we have been compelled to delimit our study in order to fit into the defined scope. Therefore we are happy to be able to suggest several areas for further research.

Firstly we suggest that the strategy should be evaluated using other derivatives like options and swaps or a combination of these. Furthermore it could be of interest to perform the study with different hedging ratios and look at incremental contributions to risk characteristics. Moreover we believe it to be worth to check if the hedge can be even more efficient in reducing standard deviations by taking into account correlations between index returns and exchange rates in the well-diversified global index. This could be done through hedging according to a so-called *minimum-variance hedge ratio*. We also believe it to be of interest to include a risk–reward analysis by employing data from a longer sample period (it should however be pointed out that too long a sample period might imply no benefits of currency hedging, due to the PPP argument presented in Section 2).

Finally, recent developments in derivatives markets have lead to the emergence of forwards that automatically adjust as foreign equity prices rise and fall. With these, a perfect or nearly perfect currency hedge would be possible to construct – using data on such contracts in a study similar to ours would have the potential to add understanding to the topic of currency hedging international equity investments.

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Interviews

Peter Norman. 08/11/2005 at 10.00-10.45
Executive President, The Seventh Swedish National Pension Fund.

Appendices

Appendix A: Countries & Corresponding Indices

TABLE 8

Stock Market Country	Abbreviation	Index (1993–2004)
Argentina	ARG	Merval Index
Australia	AUS	ASX All Ordinaries
Belgium/Luxembourg	BEL/LUX	BEL 20 Price Index
Canada	CAN	S&P/TSX Composite Index
Finland	FIN	HEX All Share Index
France	FRA	CAC 40
Germany	GER	DAX 30
Hong Kong	HGK	HIS
Italy	ITA	MIB 30 Index
Japan	JPN	Nikkei 225 Average Stocks
Malaysia	MAL	Composite Index
Netherlands	NLD	AEX
Singapore	SIN	STI*
Spain	ESP	IBEX 35
Sweden	SWE	SAX All Share Index
Switzerland	CHF	Swiss Performance Index
Taiwan	TWN	TAIEX
Thailand	THA	SET Index
United Kingdom	UK	FTSE 100
United States of America	USA	S&P 500

Source: Datastream and http://finance.yahoo.com (*).

Appendix B: Index Descriptions

Argentina – Merval Index
The Argentina Merval Index is the market value of a stock portfolio, selected according to participation in the Buenos Aires Stock Exchange, number of transactions and trading value.

Australia – ASX All Ordinaries
The All Ordinaries Index is Australia's premier market indicator. The index represents the 500 largest companies, in market capitalization terms, listed on the Australian Stock Exchange. The index comprised 99% of the Australian market on June 30. 2002.

Belgium/Luxembourg – BEL 20 Price Index
The BEL 20 index is the leading representative of the Brussels Stock Exchange. It comprises the 20 largest companies ranked according to their market capitalization (40%) and turnover (60%).

Canada – S&P/TSX Composite Index
The S&P/TSX Composite Index comprises approximately 71% of market capitalization for Canadian-based Toronto Stock Exchange listed companies. The size of the S&P/TSX Composite and its broad economic sector coverage has made the S&P/TSX Composite the premier indicator of market activity for Canadian equity markets.

Finland – HEX All Share Index
HEX All Share Index is a capitalization-weighted index of all listed shares on the Helsinki Stock Exchange.

France – CAC 40
The CAC 40 index is the main benchmark for Euronext Paris, tracking a sample of blue chip stocks. Its performance is closely correlated to that of the market as a whole. The index contains 40 stocks selected among the top 100 market capitalization and the most active stocks listed on Euronext Paris.

Germany – DAX 30
DAX measures the performance of the Prime Standard's 30 largest German companies in terms of order book volume and market capitalization on the Frankfurt Stock Exchange, whereas the Prime Standard is the admission segment for companies wishing to position themselves internationally.

Hong Kong – HSI
Hang Seng Index is a capitalization-weighted stock market index in the Hong Kong Stock Exchange. It covers changes of the 33 largest companies of the Hong Kong stock market and as the main indicator of the overall market performance in Hong Kong.

Italy – MIB 30
The Milan Stock Exchange 30 Index is a capitalization-weighted index. Being based on the 30 leading stocks, that is, the most liquid and most highly capitalized stocks listed on the Italian (Milan) Stock Exchange, the sample of index stocks accounts for over 70% of the total market capitalization and about 75% of total trading volume.

Japan – Nikkei 225 Average Stocks
The Nikkei 225 Average Stock Index is a stock market index for the Tokyo Stock Exchange calculated daily by the Nihon Keizai Shimbun newspaper. The index comprises the 225 largest companies on the exchange and it is price-weighted. The most watched index of Asian stocks.

Malaysia – Composite Index
The Kuala Lumpur Stock Exchange Composite Index is a broad-based capitalization-weighted index of 100 stocks designed to measure the performance of the Kuala Lumpur Stock Exchange.

Netherlands – AEX
The Amsterdam Exchange Index is generally viewed as the most representative index for the price dynamics of the Dutch stock market. The index is constructed as a capitalization-weighted arithmetic average of the 25 largest Dutch companies.

Singapore – STI
The Straits Times Index is a modified market capitalization-weighted index comprised by the most heavily weighted and active stocks traded on the Stock Exchange of Singapore, which is compiled by the Straits Times Newspaper of Singapore. The index was developed with a base value of 885.26 as of August 28. 1998

Spain – IBEX 35
The IBEX 35 is the official index for the market segment of continuously traded stocks. The index sample is composed of the 35 most actively traded stocks among the securities quoted on the Joint Stock Exchange System of the four Spanish stock exchanges during the control period.

Sweden – SAX index
The Stockholmsbörsen All-Share (SAX) Price Index is a capitalization-weighted index comprised of all shares listed on Stockholmsbörsen. The index includes all companies listed on the A-list and O-list.

Switzerland – SPI
The Swiss Performance Index is Switzerland's most closely followed performance index. It includes all Swiss Stock Exchange-traded equity securities of companies domiciled in Switzerland and the Principality of Liechtenstein.

Taiwan – TAIEX
The Taiwan Stock Exchange Capitalization Weighted Stock Index (TAIEX) is the most widely quoted of all Taiwan Stock Exchange indices. The capitalization-weighted TAIEX covers all of the listed stocks excluding preferred stocks, full-delivery stocks and newly listed stocks, which are listed for less than one calendar month.

Thailand – SET Index
The Bangkok SET Index is a capitalization-weighted index of all the stocks traded on the Stock Exchange of Thailand. This index is an exact copy of SET.

United Kingdom – FTSE 100
The index is recognized as the prime measure of the UK financial markets. It comprises the 100 most highly capitalized blue chip companies, representing approximately 80% of the UK market. Used extensively as a basis for investment products, such as derivatives and exchange-traded funds.

United States of America – S&P 500
Widely regarded as the best single gauge of the U.S. equities markets. The index includes a representative sample of 500 leading companies in leading industries of the U.S. economy. Although the S&P 500 focuses on the large-cap segment of the market, with over 80% coverage of U.S. equities, it is also an good proxy for the total market.

Appendix C: Countries with Largest Stock Market Capitalization – No Rebalancing

TABLE 9 **STOCK MARKET CAPITALIZATIONS, PORTFOLIO WEIGHTS AND GLOBAL WEIGHTS, AS OF 1993**

Country	Market Capitalization (MUSD)	Portfolio Weight (%)*	Global Weight (%)
USA	4,485,040	**45.3%**	41.0%
Japan	2,399,004	**24.2%**	21.9%
UK	927,129	**9.4%**	8.5%
France	350,858	**3.5%**	3.2%
Germany	348,138	**3.5%**	3.2%
Canada	243,018	**2.5%**	2.2%
Switzerland	195,285	**2.0%**	1.8%
Hong Kong	172,106	**1.7%**	1.6%
Australia	144,634	**1.5%**	1.3%
Netherlands	134,594	**1.4%**	1.2%
Italy	129,191	**1.3%**	1.2%
Taiwan	101,124	**1.0%**	0.9%
Spain	98,969	**1.0%**	0.9%
Malaysia	94,004	**0.9%**	0.9%
Sweden	78,376	**0.8%**	0.7%
Total Portfolio value	9,901,470		
Total Portfolio		100%	
World's total	10,932,526		91%

*Source: Standard and Poor's Global Stock Market Factbook, August 2003. *Portfolio weights are the authors' own calculations.*

Appendix D: Portfolio Weights for Countries with Largest Stock Market Capitalization – Rebalancing

TABLE 10 NUMERICAL OVERVIEW

Country	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
USA	45.3%	41.4%	38.2%	43.6%	47.5%	54.6%	54.4%	51.2%	52.1%	55.7%	53.7%	51.4%
JPN	24.2%	24.2%	28.1%	23.3%	17.3%	10.7%	10.1%	14.0%	10.9%	9.1%	10.3%	10.9%
UK	9.4%	9.3%	9.1%	8.9%	9.7%	9.6%	9.6%	9.0%	8.9%	8.9%	9.1%	8.7%
FRA	3.5%	3.7%	3.4%	3.3%	3.3%	3.3%	4.0%	4.5%	5.0%	4.7%	4.7%	4.9%
GER	3.5%	3.7%	3.5%	3.7%	3.4%	4.0%	4.4%	4.4%	4.4%	4.3%	3.3%	3.9%
CAN	2.5%	2.6%	2.8%	2.3%	2.7%	2.7%	2.2%	2.5%	2.9%	2.8%	2.8%	3.2%
CHF	2.0%	2.2%	2.1%	2.8%	2.3%	2.8%	2.8%	2.1%	2.7%	2.1%	2.7%	2.6%
AUS	1.5%	1.7%	1.7%	1.6%	1.7%	1.4%	1.3%	1.3%	1.3%	1.5%	1.8%	2.1%
HGK	1.7%	3.1%	2.0%	1.9%	2.5%	2.0%	1.4%	1.9%	2.2%	2.0%	2.2%	2.6%
NLD	1.4%	1.5%	2.1%	2.3%	2.1%	2.3%	2.4%	2.1%	2.2%	1.8%	1.9%	1.8%
ITA	1.3%	1.1%	1.4%	1.3%	1.4%	1.7%	2.3%	2.2%	2.7%	2.1%	2.3%	2.2%
TWN	1.0%	1.6%	1.9%	1.2%	1.5%	1.4%	1.1%	1.2%	0.9%	1.2%	1.3%	1.4%
MAL	0.9%	1.8%	1.5%	1.4%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ESP	1.0%	0.0%	1.2%	1.3%	1.4%	1.4%	1.6%	1.3%	1.7%	1.9%	2.2%	2.6%
SWE	0.8%	0.0%	0.0%	1.1%	1.4%	1.3%	1.1%	1.1%	1.1%	0.9%	0.9%	1.0%
ARG	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	0.0%
BEL/LUX	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	1.1%	0.0%	0.0%	0.0%	0.7%	0.8%
FIN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.1%	1.0%	0.0%	0.0%	0.0%
SIN	0.0%	1.1%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
THA	0.0%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

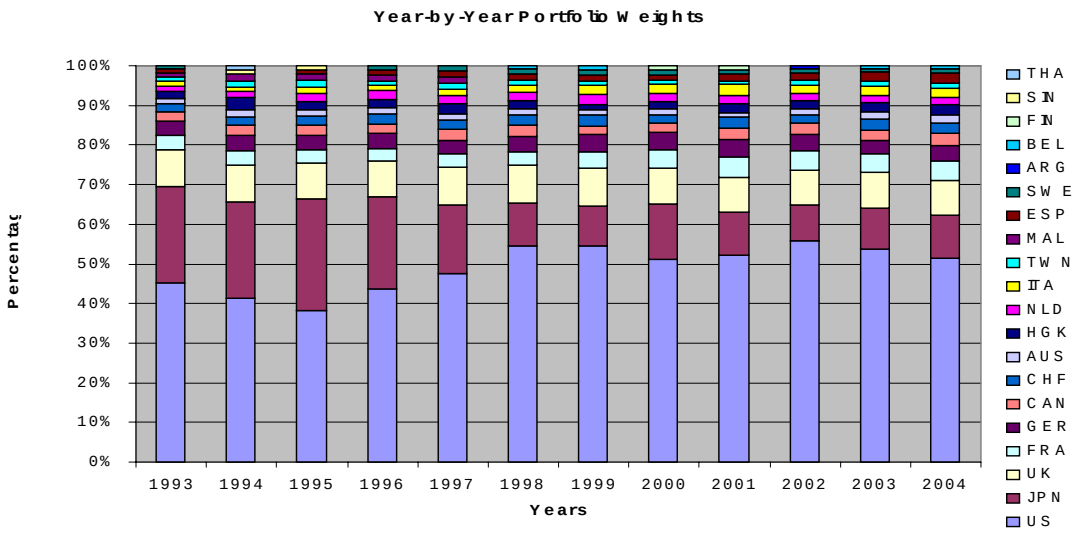

Figure 5: Graphical overview.

Appendix E: Complementing Results

TABLE 11 FROM THE PERSPECTIVE OF A SWEDISH INVESTOR, COUNTRY PER COUNTRY, 1-MONTH HORIZON, ANNUALIZED VALUES

Numerical results are stated for Period I and Period II. For each period we report the imperfectly hedged and unhedged standard deviations.

Country	Standard Deviation (1996–1999)		Standard Deviation (2000–2004)	
	Imperfectly Hedged	*Unhedged*	*Imperfectly Hedged*	*Unhedged*
Argentina	38%	41%	43%	46%
Australia	12%	20%	11%	16%
Belgium/Luxembourg	18%	21%	19%	21%
Canada	19%	23%	17%	20%
Finland	32%	30%	39%	37%
France	23%	20%	22%	20%
Germany	23%	21%	29%	27%
Hong Kong	34%	36%	22%	22%
Italy	27%	27%	23%	21%
Japan	20%	26%	22%	24%
Malaysia	48%	58%	21%	23%
Netherlands	20%	19%	26%	25%
Singapore	34%	33%	21%	22%
Spain	27%	26%	24%	22%
Switzerland	20%	20%	26%	26%
Taiwan	22%	20%	18%	16%
Thailand	28%	34%	33%	37%
United Kingdom	48%	52%	32%	34%
United States of America	13%	15%	17%	14%
Average	26.1%	28.0%	24.0%	24.6%

TABLE 12 FROM THE PERSPECTIVE OF A SWEDISH INVESTOR INVESTING IN THE GLOBAL PORTFOLIO, ANNUALIZED VALUES

Numerical results are stated for the total period and the two sub-periods. For each period we report the imperfectly hedged and unhedged standard deviations for the fixed 1993-weight portfolios (No rebalancing) and for the portfolios with yearly updating of weights (Rebalanced).

Strategy			Period I (1996–1999)		Period II (2000–2003)		Total Period (1993–2004)	
			Imperfectly Hedged	*Unhedged*	*Imperfectly Hedged*	*Unhedged*	*Imperfectly Hedged*	*Unhedged*
1-month forward								
	No rebalancing							
		Standard Deviation	14.7%	17.3%	15.9%	16.0%	13.8%	15.5%
		Change	–15.0%		–0.6%		–11.0%	
	Rebalanced							
		Standard Deviation	14.8%	16.9%	16.4%	16.1%	14.0%	15.3%
		Change	–12.4%		1.9%		–8.5%	
6-months forward								
	No rebalancing							
		Standard Deviation	14.1%	15.5%	14.6%	14.2%	13.3%	16.6%
		Change	–9.0%		2.8%		–19.9%	
	Rebalanced							
		Standard Deviation	13.4%	14.8%	14.4%	14.4%	13.3%	16.5%
		Change	–9.5%		0.0%		–19.4%	

TABLE 13 FROM THE PERSPECTIVE OF A SWEDISH INVESTOR; COMPARISON BETWEEN THE IMPERFECTLY HEDGED PORTFOLIO AND ITS BENCHMARK, A PERFECTLY HEDGED PORTFOLIO, ANNUALIZED VALUES

Numerical results are stated for the total period and the two sub-periods. For each period we report the imperfectly and perfectly hedged standard deviations for the fixed 1993-weight portfolios (No rebalancing) and for the portfolios with yearly updating of weights (Rebalanced).

Strategy			Period I (1996–1999)		Period II (2000–2003)		Total Period (1993–2004)	
			Imperfectly Hedged	*Perfectly Hedged*	*Imperfectly Hedged*	*Perfectly Hedged*	*Imperfectly Hedged*	*Perfectly Hedged*
1-month forward								
	No rebalancing							
		Standard Deviation	14.7%	14.6%	15.9%	15.8%	13.8%	13.7%
		Change	0.6%		0.6%		0.7%	
	Rebalanced							
		Standard Deviation	14.8%	14.8%	16.4%	16.3%	14.0%	14.0%
		Change	0.0%		0.6%		0.0%	
6-months forward								
	No rebalancing							
		Standard Deviation	14.1%	10.4%	14.6%	15.1%	13.3%	13.4%
		Change	35.6%		–3.3%		–0.7%	
	Rebalanced							
		Standard Deviation	13.4%	9.7%	14.4%	16.1%	13.3%	13.4%
		Change	38.1%		–10.6%		–0.7%	

Appendix F: Test for Difference in Means of Standard Deviations

Denote by $\overline{D}$ the difference in the means of all countries' standard deviations ($\overline{D} = \overline{U} - \overline{H}$) and by s_D the estimated standard deviation of the differences $\overline{U} - \overline{H}$. To test the hypotheses

$$\begin{cases} H_0 : \overline{H} - \overline{U} \geq D_0 \\ H_1 : \overline{H} - \overline{U} < D_0 \end{cases},$$

the test statistic

$$t_{obs} = \frac{\overline{D} - D_0}{s_D / \sqrt{n}}$$

is *t*-distributed with $n - 1$ degrees of freedom under the assumption that $\overline{D}$ follows the normal distribution. The decision rule is to reject H_0 if $t_{obs} < -t_{crit} = -t_{n-1;\,\alpha}$, where n is the number of observations and α is the chosen significance level.