Exchange rate risk and its determinants: evidence from international stock markets.
Abstract

This paper evaluates if international stock markets are exposed to fluctuation in the exchange rate and whether this exposure is related to exports, imports and inflation. Eight countries are studied: Australia, Belgium, Brazil, Hong Kong, Sweden, Switzerland, the United Kingdom and the United States. The empirical investigation covers the period from 1995 to 2004 and the estimation is conducted using the framework of Patro, D.K., Wald, J.K. and Wu, Y. (2002). The empirical findings show that all international stock markets are exposed to exchange rate risk, except for Brazil. The amount of exchange rate exposure is found to be sensitive to a country’s export, import and inflation. The results imply that there are predictable relationship between changes in the return of the national stock index return and fluctuation in the exchange rate. In addition, imports and exports as well as inflation may be useful in predicting exchange rate risks.

Keywords: International Asset Pricing Model; exchange rate risk; determinants of exchange rate risk.
Table of Contents

1. Introduction ..................................................................................................................... 1
2. Theoretical Framework ................................................................................................... 4  
   2.1 Processes for asset values and inflation ................................................................. 4 
   2.2 The investors utility function and budget constraint .............................................. 6 
   2.3 Utility maximization and demand for assets ......................................................... 7 
3. Estimation Method ........................................................................................................ 12 
4. Data ............................................................................................................................... 14 
5. Empirical Findings ........................................................................................................ 15  
   5.1 Estimation of international stock indices and currency indices .............................. 15 
   5.2 Estimation of correlations between international stock indices ............................ 17 
   5.3 Estimation of exchange rate risk .......................................................................... 17 
   5.4 Estimation of the determinants of exchange rate risk ............................................ 21 
6. Summary and Conclusion ............................................................................................. 25 
References: ........................................................................................................................ 27 
Appendix: .......................................................................................................................... 29 
   Table 1. Summary statistics for weekly excess returns on international stock indices 
   and currency indices ................................................................................................. 29 
   Table 2. Correlations among stock indices .................................................................. 30 
   Table 3. Exchange risk exposure for international stock index returns using weighted-
   basket currency index ............................................................................................... 31 
   Table 4. Autoregressive conditional heteroscedasticity (ARCH) test ............................. 32 
   Table 5. Summary statistics for macroeconomic variables and exchange rate betas.... 33 
   Table 6. Explaining exchange rate betas using macroeconomic variables: Ordinary 
   Least Square (OLS) regressions .................................................................................. 34 
   Figure 1. Plots of the confidence interval for the estimated exchange rate betas for 
   period 1995-2004 ........................................................................................................... 36
1. Introduction

The benefits of international diversification have been known for many decades. Investors holding international financial assets face three sources of risk: market risk, unsystematic risk and exchange rate risk. Market risk is the risk associated with the overall movements in the general market portfolio or economy. Unsystematic risk is the fluctuation in the stock price index that is diversified because it is uncorrelated with market risk. Exchange rate risk arises because the exchange rates between foreign currencies change over time and these changes affect the return of the investor. Exchange rate risk may in turn be systematic or unsystematic but this is generally ignored in this literature.

An investor who diversifies his portfolio eliminates the unsystematic risk. Once he achieved full diversification, the only risk left is the systematic risk. Market risk and to some degree exchange rate risk are considered systematic risks because they cannot be eliminated through portfolio diversification. An investor holding a well diversified national portfolio is only exposed to market risk, while an investor holding a well diversified international portfolio is exposed not only to market risk but also to exchange rate risk.

The standard CAPM applies in an integrated world market where investors from different countries have similar expectations about the real rate of return and risk on any given asset. By relying on the Purchasing Power Parity (PPP), the CAPM treats global market risk as the only relevant risk. On the other hand, if PPP does not hold, investors from different countries have different expectations about rates of return and risks measured in each investor's respective home currency. Therefore the standard CAPM will not constitute a correct model to price the expected return on assets traded in international markets.

To model international investments when PPP does not hold, Adler and Dumas (1983) developed the international version of the Capital Asset Pricing Model (ICAPM). The basis for PPP is the “law of one price” which implies that in the absence of transportation and other transaction costs, the real price of an identical tradable good must be the same in all countries. PPP is a theory which states that exchange rate between two currencies
are in equilibrium when their purchasing power price is the same in each of the two countries. However if PPP is violated, the price indices of the two countries when expressed or translated into a common currency will be different. Adler and Dumas (1983) develop a theory of how asset market equilibrium given that PPP does not hold.

The goal of this paper is to evaluate if international stock markets are exposed to fluctuation in the exchange rate and to investigate if the fluctuation in the exchange rate is related to exports, imports and inflation. For the study, eight countries have been selected: Australia, Belgium, Brazil, Hong Kong, Sweden, Switzerland, the United Kingdom and the United States. The empirical investigation covers the period from 1995 to 2004.

Several empirical studies have demonstrated the importance of exchange rates in stock prices. Ferson and Campbell (1994) studied the sources of risks for 18 national stock markets over the period 1970-1989. The sources of risks are returns in a world stock market portfolio, exchange rate risk, Eurodollar yield spread, U.S. Treasury bill yield spread, measures of global inflation, real interest rates and industrial production growth. Their findings show that the average rate of return on the selected national stock markets are significantly exposed to world market risk and to exchange rate risk, but not to these other sources of risk.

Allayannis (1997) found that about 22 percent of his samples of 137 U.S. manufacturing industries are exposed to exchange rate risk. Moreover the exchange rate risk for U.S. manufacturing industries varies systematic with the share of exports and imports in total industry production. On average, during this period, a 1% appreciation in the dollar reduces the value of an exporters stock value by 0.46% and increases an importers stock value by 0.37%.

De Santis and Gérard (1998) studied the markets for equity and one-month Eurocurrency deposits for four countries: Germany, Japan, the United Kingdom and the United States during the period from June 1973 to December 1994. They tested the International CAPM and assess whether exchange rate risk has a significant affect on international returns. Their evidence shows that, except for the U.S. equity market, the exchange rate risk represents a significant fraction of the total risk an investor bears. Therefore their findings
give strong support for a specification of the International CAPM that includes both worldwide market risk and exchange rate risk.

He and Ng (1998) found that about 25 percent of their samples of 171 Japanese multinationals’ stock returns experienced exposure to exchange rate risk. The exchange rate exposure was positively related to the level of the export ratio of Japanese’s firms. The greater the extent to which the firm trades internationally, the greater was their exposure to exchange rate fluctuations.

The theoretical framework used to discuss the International CAPM in this paper is taken from Adler and Dumas (1983) and the empirical section is based on a study by Patro, D.K., Wald, J.K. and Wu, Y. (2002). The latter use a two-step estimation procedure. In the first step they estimate the effects of time-varying exchange rate risk on stock market returns for 16 OECD countries. Their sample period is 1980-1997. In the second step the estimated coefficients of exchange rate risks of each year is regressed on annual country-specific macroeconomic variables.1

This paper replicates the main steps from Patro, D.K., Wald, J.K. and Wu, Y. (2002) on new data. It is important that empirical results are replicated in order to find out whether they can be generalized to other countries and to other periods. Overall, the findings indicate that there is strong statistical evidence that variation in the exchange rate affects the stock market of all countries (except for Brazil). Furthermore, exchange rate risks depend on imports and exports as well as inflation.


2. Theoretical Framework

This section presents the International Capital Asset Pricing Model of Adler and Dumas (1983).

An investor holding a well diversified international portfolio bears market risk and exchange rate risk. As result, in equilibrium, investors should be rewarded with a market risk premium and an exchange risk premium. In this case the risk premium is defined the difference between the expected returns on an asset, here the market portfolio, and a weighted-basket of foreign-currency deposits, and the risk-free rate.

The model of Adler and Dumas (1983) is developed in three steps, where the purpose is to derive an investor’s demand for internationally risky assets. First, exogenous process for asset returns and domestic inflation are specified. Second, the investor’s utility function and budget constraint are presented. Third, the investor chooses consumption and portfolio shares of the different assets to maximize expected utility. This yields the desired equation that nails down demand for international stocks as a function of (i) market risk and (ii) exchange rate risk.

2.1 Processes for asset values and inflation

There are L+1 countries and currencies in the world. An investor chooses between a risk-free asset and risky assets in any country.

Formally, if $P_i^c$ is the market price of risky asset $i$ measured in the reference currency $c$, then in a world of L+1 countries and currencies, the rate of return on risky securities in terms of the measurement currency is given by:

$$R_i^c dt = dP_i^c / P_i^c = E(R_i^c) dt + \sigma_i^c dz_i^c, \ i=1,2,\ldots,N$$ (1)
where $E(R_i^c)$ is the expected nominal rate of return on security $i$; $\sigma_i^c$ is the standard deviation of the nominal rate of return on security $i$; $z_i^c$ is a standard Brownian motion and $dz_i^c$ is the associated white noise; and $N$ is the number of nominally risky securities.

The price process for the risk-free asset, $r_f^c$, measured in the reference currency $c$ is

$$dr_f^c = r_f^c dt,$$

where $r_f^c$ is assumed to be constant over time. Risk-free assets are usually short-term treasury bills which have a rate determined by the Central Bank. The risk-free rate is therefore exogenously given from the standpoint of the investor.

The inflation rate of each country, measured in the reference currency $c$, also follows a standard Brownian motion:

$$\pi_l^c dt \equiv dI_l^c / I_l^c = E(\pi_l^c) dt + \sigma_{\pi_l}^c dz_{\pi_l}^c, \quad l = 1, 2, \ldots L + 1$$

where $I_l^c$ is the general price index in country $l$ measured in the reference currency $c$, and $E(\pi_l^c)$ and $\sigma_{\pi_l}^c$ are the expected return and standard deviation of the inflation rate.

Fluctuations in the exchange rate can influence variations in the local inflation because a depreciation (or appreciation) of local currency leads to higher (or lower) import prices. This will lead to an increase (or decrease) on the demand for domestic goods. As a result the overall price level of the economy, measured by the consumer price index (CPI), will increase (or decrease). Thus, the magnitude of variations in local inflation (changes in consumer price index) is affected by the extent to which fluctuation in the exchange rate is transmitted into the price level. This can be seen from equation (1) and (3) since residents of a country have to pay for the asset at the price available in their own countries. Therefore the real return on an asset depends on the country’s price level where the asset’s return is evaluated.

---

2 A Brownian motion is a continuous time data generating process that is similar to a random walk with drift. It has a constant average mean and a variance per unit of time.
2.2 The investors utility function and budget constraint

Investors allocate their wealth between consumption and financial investments. Therefore, the investor chooses the fraction of his wealth invested in risky \( i \)th asset \((\omega_i)\) and the consumption \((C)\) to maximize the following expected lifetime utility function:\(^3\)

\[
\max_{C, \omega} E \int_t^T U(C, I, s) ds,
\]

where \(E\) is the conditional expectation given the information available at time \(t\), and \(U(C, I, s)\) is a strictly concave utility function for the nominal consumption flow, \(C\), price index, \(I\), and time, \(s\).

We now turn to analyzing an investor’s budget constraint. Following Merton (1969), define \(W^c(t)\) as wealth measure in the reference currency \(c\) at time \(t\) and \(C(t)\) as consumption of a representative investor per unit time at time \(t\). Let \(\omega_i\) be the fraction of his wealth invested in a risky \(i\)th asset. Define \(\left(P_{t+1}^c / P_t^c\right)\) as the rate of return on risky asset \(i\) from time \(t\) to \(t+1\) and define \(r_{f,t+1}^c\) as the rate of return on risk-free asset from time \(t\) to \(t+1\). It is assumed that an investor holds \(N\) distinct risky assets and one risk-free asset \((r_f^c)\), and thus the total rate of return on the portfolio chosen by an investor from time \(t\) to \(t+1\) is denoted as \(\sum_{i=1}^{N} \omega_i \left(P_{t+1}^c / P_t^c\right) + (1 - \omega_i) r_{f,t+1}^c\). Investor’s portfolio can include assets in other countries. The value of an investor’s accumulation wealth, which is generated by return on assets, can be written as:

\[
W^c(t+1) = \sum_{i=1}^{N} \omega_i \left(P_{t+1}^c / P_t^c\right) + (1 - \omega_i) r_{f,t+1}^c \left[W^c(t) - C(t)h\right],
\]

where \((t+1) \equiv t + h\) and the time interval between periods is \(h\). By subtracting \(W^c(t)\) from both sides of equation (5) and using the fact that the rate of return on risky asset \(i\)

\( (P_{i+1}^c / P_i^c) \) is equal to \( (dP_i^c / P_i^c) \) and that the rate of return on risk-free asset \( r_{f,t+1}^c \) is equal to \( dr_f^c \), we take the limit process of \( h = \Delta t \to 0 \) and obtain the change in wealth as:

\[
dW^c = \left[ \sum_{i=1}^{N} \omega_i \frac{dP_i^c}{P_i^c} + (1 - \omega_i)dr_f^c \right] W^c - Cdt. \tag{6}
\]

By substituting \( (dP_i^c / P_i^c) \) from equation (1) and \( dr_f^c \) from equation (2) into equation (6), we can rewrite equation (6) in terms of expected international stock market returns measure in the domestic currency \( (E(R_i^c)dt) \), the risk-free rate \( (r_f^c) \), the portfolio shares \( \omega_i \), the variance of international stock returns \( (\sigma_i^c dz_i^c) \), and consumption \( (Cdt) \):

\[
dW^c = \left[ \sum_{i=1}^{N} \omega_i (E(R_i^c) - r_f^c) + r_f^c \right] W^c dt - Cdt + W^c \sum_{i=1}^{N} \omega_i \sigma_i^c dz_i^c. \tag{7}
\]

In the next step, the investor chooses portfolio shares and current consumption (which is equivalent to savings) to maximize expected utility.

### 2.3 Utility maximization and demand for assets

In each point of time, let \( J(W^c,I,t) \) denote the maximum value of the expected utility function in equation (4) subject to the budget constraint in equation (7):

\[
0 = \max_{C_t} \left\{ U(C,I,t) + J \left[ \sum_{i=1}^{N} \omega_i (E(R_i^c) - r_f^c) + r_f^c - \pi_i^c + \text{Var}(\pi_i^c) - \sum_{i=1}^{N} \omega_i \text{Cov}(R_i^c,\pi_i^c) \right] W^c - C \right\}, \tag{8}
\]

\[
+ \frac{1}{2} J \left[ \sum_{i=1}^{N} \sum_{k=1}^{N} \omega_i \omega_k \text{Cov}(R_i^c, R_k^c) - 2 \sum_{i=1}^{N} \omega_i \text{Cov}(R_i^c, \pi_i^c) + \text{Var}(\pi_i^c) \right] (W^c)^2 \right\}
\]

---

4 For a complete explanation regarding the investor’s budget constraint, see Merton, R. C., 1969, Lifetime Portfolio Selection under Uncertainty: The Continuous-Time Model, Review of Economics and Statistics 51, 247–257.

where \( J_t \) denotes the derivative of \( J \) in respect to \( t \), \( J_{W^c} \) and \( J_{W^c-W^c} \) denote the first and second derivative of \( J \) in respect to \( W^c \), respectively. \( \text{Cov}(R_i^c, \pi_i^c) \) is the covariance between the returns on \( i \)-th asset and inflation \( (\pi_i^c) \), and \( \text{Cov}(R_i^c, R_k^c) \) is the covariance between the return on \( i \)-th asset and the return on \( k \)-th asset. \( \text{Var}(\pi_i^c) \) is the variance of inflation \( (\pi_i^c) \). The covariance measures the dependence between two variables and variance measures the volatility of a variable.

The first-order conditions with respect to consumption and portfolio share derived from (8) are:

\[
0 = U_c(C, I, t) - J_{W^c}(W^c, I, t) \tag{9}
\]

\[
0 = J_{W^c} \left( E(R_i^c) - r_f - \text{Cov}(R_i^c, \pi_i^c) \right) + J_{W^c-W^c} \left( \sum_{k=1}^{N} \omega_k \text{Cov}(R_i^c, R_k^c) - \text{Cov}(R_i^c, \pi_i^c) \right) W^c \tag{10}
\]

Equation (9) shows that marginal utility of present consumption equals to marginal utility of wealth (future consumption). This equation reflects the tradeoff between a loss in marginal utility of present consumption if the investor buys one additional unit of asset \( i \) and thus consumes less at period \( t \), and the marginal gain in the marginal utility of future consumption resulting from the extra consumption the investor can afford from the positive return of asset \( i \) at period \( t+1 \).

Equation (10) contains the optimal portfolio demand as function of the expected returns on each asset \( i \) in local currency terms, their covariance with \( k \)-th asset, their covariance with the country’s domestic inflation, and changes in the marginal utility of wealth. Solving equation (10) in the form of the nominal excess return on security \( i \) required by an individual investor with identity \( l \), we obtain:

\[
E(R_i^c) - r_f = \frac{1}{\lambda_i} \sum_{k=1}^{N} \omega_k \text{Cov}(R_i^c, R_k^c) + \left( 1 - \frac{1}{\lambda_i} \right) \text{Cov}(R_i^c, \pi_i^c), \forall i \tag{11}
\]
where $\lambda_i = -J_{w^e} / J_{w^e} W^e$. This term represents the investor’s coefficient of risk aversion. It is a measure of the concavity of the utility function corrected for the investor’s wealth.

Adler and Dumas (1983) claim that individual portfolio holdings $\omega_k^l$ cannot be observed. “The only portfolio which is directly observed by reading the prices in the newspaper is the aggregate one, given by the relative market capitalization of all securities on the market: the market portfolio $\omega^m$ given by

$$\omega^m = \sum_k W_k \omega^l_k / \sum_k W^l,$$

where the summation is taken over all the investors and $W^l$ is the investor $l$’s nominal wealth.”

After deriving in equation (11) the nominal excess returns on any risky assets $i$ that each national investor $l$ requires and taking into consideration the above statement of Adler and Dumas (1983), one can derive the aggregate individual demands of all investors:

$$E(R_i^e) - r^e_i = \lambda_m \text{Cov}(R_i^e, \ R_m^e) + \sum_{l=1}^{L+1} \lambda_l \text{Cov}(R_i^e, \pi_i^e), \forall i$$

(12)

where $\frac{1}{\lambda_m} = \sum_{l=1}^{L+1} W_l^e \times \frac{1}{\lambda_l}$ and $\lambda_m = \lambda_m \left( \frac{1}{\lambda_l} - 1 \right) \frac{W_l^e}{W^e}$. The notation should be interpreted as follow: $\lambda_m$ is the world aggregate risk aversion coefficient while $\lambda_l$ is the country $l$ investor risk aversion coefficient and $W_l^e$ is country $l$’s wealth from the corresponding world aggregate wealth ($W^e$). Equation (12) states that excess returns to investment in equity denominated in local currency is a function of the covariance between equity returns and market portfolio returns as well as the covariance between equity returns and country’s domestic inflation.

---


According to De Santis and Gérard (1998) a large part of the fluctuations in domestic inflation are caused by fluctuations in the exchange rate. Therefore, for computational simplicity, \( \pi_i \) will only contain the relative change in the exchange rate between the reference currency \( c \) and the currency of \( L+1 \) countries. In this case the asset pricing model implies the following restriction for the expected return on any risky asset \( i \) in the reference currency \( c \):

\[
E(R_i^c) - r_i^c = \lambda_m \text{Cov}(R_m^c, R_i^c) + \sum_{l=1}^{L+1} \lambda_c \text{Cov}(R_l^c, \nu_l^c), \quad \forall i \tag{13}
\]

where \( \nu_l^c \) measures the change in the price value of a basket \( L+1 \)'s currencies in terms of currency \( c \). The two terms on the right-hand side of equation (13) indicates two sources of risk premium: global market risk premium and exchange rate risk premium. These risk premiums should be rewarded to an investor for his exposure to both the systematic market risk and the systematic exchange rate risk.

In equation (13), the coefficient \( \lambda_m \) can be interpreted as the market price of risk and the coefficient \( \lambda_c \) can be interpreted as the currency price of risk. The price of risk is extra return that can be gained by increasing the level of risk: market risk and exchange rate risk. Using the fact that: (i) the ratio \( \frac{E(R_m^c) - r_i^c}{Var(R_m^c)} \) and \( \frac{E(\nu_l^c) - r_i^c}{Var(\nu_l^c)} \) can be considered as price of world market risk \( (\lambda_m) \) and the price of exchange rate risk \( (\lambda_c) \), respectively and (ii) the systematic market risk and exchange rate risk are defined as \( \beta_{i,m} = \text{Cov}(R_i^c, R_m^c)/\text{Var}(R_m^c) \) and \( \beta_{i,c} = \text{Cov}(R_i^c, \nu_l^c)/\text{Var}(\nu_l^c) \), respectively. The conditional International CAPM from equation (13) can be reproduced by:

\[
(E(R_{i,t}) - r_{i,t}^c) = \beta_{i,m} (E(R_{m,t}) - r_{i,t}^c) + \beta_{i,c} E(R_{i,t}^c), \quad \forall i \tag{14}
\]

In this formula, the superscript \( c \) which denotes the measurement currency is dropped. \( E(R_{i,t}) \) is the rate of return on country \( i \)'s stock index (in local currency terms) from time
$t-1$ to $t$; $r_{i,t}^{f}$ is country’s local risk-free rate of return from time $t-1$ to $t$; $E(R_{m,t}^{x})$ is the rate of return on the world stock index (in local currency terms) from time $t-1$ to $t$; $\beta_{i,m}$ measures the systematic world market risk for country $i$’s stock index; $\beta_{i,x}$ measures the systematic exchange rate risk for country $i$’s stock index; $E(R_{j,t}^{x})$ measures the excess return from holding a weighted basket of foreign-currency deposits from time $t-1$ to $t$. $E(R_{j,t}^{x})$ is defined as:

$$E(R_{j,t}^{x}) = \sum_{j \neq i}^{4} w_{j,t} \left[ \ln \left( \frac{S_{i,j,t}}{S_{i,j,t-1}} \right) + r_{j,t}^{f} - r_{i,t}^{f} \right]$$  \hspace{1cm} (15)$$

In equation (15), $S_{i,j,t}$ is the price of one unit of currency $j$ in terms of currency $i$. In this paper, currency $j$ will be limited to the four main currencies: $\$$(US dollar), £ (sterling), € (euro) and ¥ (yen). The $w_{j,t}$ is market-capitalization index defined as the allocation of the world stock index in respect to country $j$ relative to the total allocation to all other four main currency regions (the European Union, Japan, the United Kingdom and the United States). The weight allocation for world stock index (i.e. Dow Jones World Index) which is used in this paper is 49.87% for the United States, 15.34% for the European Union, 10.81% for Japan and 9.83% for the United Kingdom.

A positive value of $E(R_{j,t}^{x})$ means that country $i$’s currency has a real depreciation relative to the weighted average of the other four main currencies. Or alternatively, a positive value of $E(R_{j,t}^{x})$ means that holding a weighted-basket of foreign currency deposits from time $t-1$ to $t$ yields a positive excess return (relative to holding domestic currency).

---

9 For a complete analysis of the weight allocation for Dow Jones World Index, see www.djindexes.com
Based on equation (14), I will access the importance of International CAPM for pricing international assets by examining whether the national stock index of eight countries are significantly exposed to the exchange rate risk, $\beta_{i,x}$.

### 3. Estimation Method

This section presents the statistical framework of Patro, D.K., Wald, J.K. and Wu, Y. (2002), which will be used to estimate the significance as well as determinants of exchange rate risk. They first estimate a coefficient on exchange rate exposure for each country and year and then these coefficients are regressed against a set of macroeconomic factors.

The first step is to study if the international stock markets of eight selected countries are significantly exposed to fluctuations in exchange rate. This is done by estimating the International CAPM from equation (14) as follows:

$$
\left( R_{i,t} - r_{i,t}^f \right) = \alpha_{i,n} + \sum_{n=1}^{9} \beta_{i,m,n} D_n + \sum_{n=1}^{9} \beta_{i,x,n} E(R_{m,t}) + e_{i,t},
$$

where $\alpha_{i,n}$ measures the risk-adjusted excess return for country $i$’s stock index; $\alpha_{i,n}$ shows how much the average excess return is above (or below) what would be expected from the return on the market portfolio’s asset as well as the weight-basket of currency deposits, $D_n$ is yearly dummies and $e_{i,t}$ is the error term. The errors may be heteroscedastic (i.e. the variance of the residual error is not necessarily the same for all observations).

For each country, the excess return on stock index and the world index is measured in local currency terms and calculated as the first difference (i.e. from time $t-1$ to $t$) of the logarithm of the index price minus the home country risk-free. The excess return on the currency index is calculated according to equation (15).

The yearly dummy variables, $D_n$, in equation (16) are defined as follow:
Equation (17) tells us that yearly dummy variable takes the value one if it belongs to a particular year and zero if it does not belong to that particular year. Thus, we will obtain a yearly dummy variable for each year. As a result, we obtain a sequence of world market risks and exchange rate risks as well as intercept terms from each year and country.

The second step is to investigate if fluctuation in the exchange rate is related to exports, imports and inflation. Exports and imports are scaled by Gross Domestic Product (GDP). Inflation is the first difference of the logarithm of CPI. The panel of estimated exchange rate risk from each year, $\beta_{i,x,n}$, are regressed on annual country-specific macroeconomic variables. To pool the information from all eight countries, a panel regression (i.e. combined country data for each variable) is used. The regression is specified as:

$$\beta_{i,x,n} = a + \sum_{n=1}^{K} b_k x_{i,k,n} + v_{i,n},$$

(18)

where $x_{i,k,n}$ is the $k$th macroeconomic variable for country $i$ in year $n$, $n = 1, 2, \ldots, 10$, $i = 1, 2, \ldots, 8$; $b_k$ measures how sensitive a country’s currency risk is to $k$th macroeconomic variables; and $v_{i,n}$ is the error term that can be heteroscedastic. To control for time-specific changes in risk, yearly dummies were added to the specification,

$$\beta_{i,x,n} = \delta_n D_n + \sum_{n=1}^{K} b_k x_{i,k,n} + v_{i,n},$$

(19)

where $D_n$, are dummy variables defined in equation (17). By using yearly time dummy variables I will control time specific effects. To allow constant differences in risk across countries, a panel regression with country-specific fixed effects is also run,

$$\beta_{i,x,n} = a_i + \sum_{n=1}^{K} b_k x_{i,k,n} + v_{i,n}.$$  

(20)
Finally both yearly dummies and country dummies are added into the regression,

\[ \beta_{i,t,n} = \alpha_i + \delta_n D_n + \sum_{n=1}^{K} b_{k} x_{i,k,n} + \nu_{i,n}. \]  

The second step regression allows an economic interpretation of the impact of these macroeconomic variables on the exchange rate exposure for the eight selected countries investigated in this paper.

4. Data

The sample covers weekly data from January 1995 to December 2004 (522 weekly observations). Weekly observations of stock index prices are obtained from EconStats™ for seven countries: All Ordinaries (Australia), Bel20 (Belgium), Bovespa (Brazil), FTSE 250 (the United Kingdom), Hang Seng (Hong Kong), Swiss Market (Switzerland), and S&P 500 (the United States). In addition, weekly observations of stock index price for OMX Stockholm 30 (Sweden) is obtained from Stockholm Stock Exchange. For the world market portfolio Dow Jones World Index in dollar currency terms was obtained from Dow Jones Indexes and all index prices are in respective local currency terms.

Following the empirical study of Dilip K. Patro, John K. Wald and Yangru Wu (2002), weekly data rather than monthly data are used to examine whether the stock market is significantly exposed to the exchange rate risk, \( \beta_{i,t,n} \), from equation (16). Exchange rate betas are estimated for each year of the sample period; therefore 52 weekly observations rather than only 12 monthly observations give a more precise estimation. Weekly observations of exchange rates for the selected countries are obtained from EconStats™ as well as from Eurostat.

For home country risk-free interest rates, Treasury Bill rates with three months maturity are used, when available, otherwise short-term interest rates are used. The risk-free interest rates data for all countries as well as for the four main currency regions (the European Union, Japan, the United Kingdom and the United States) are obtained from each country’s respective Central Bank, except for the European Union which is obtained.
from the European Central Bank, Sweden which is obtained from Ecowin and the United States which is obtained from EconStats™.

For countries whose weekly risk-free interest rates data are not available, daily data are aggregated into weekly data by taking an average of the working days of the week. Moreover, since the unit of the interest rate is per annum, all weekly risk-free interest rates are divided by 52.

All macroeconomic data are obtained at an annual frequency. The data on CPI, exports, GDP and imports are obtained from each country’s respective Central Bank, except for Hong Kong, Sweden, the United Kingdom and the United States which are obtained from the Census and Statistical Department (Government of Hong Kong), Statistical Sweden (Statistiska centralbyrån: SCB), Office of National Statistics (Government of the United Kingdom) and EconStats™, respectively.

For countries whose yearly macroeconomic data are not available, monthly or quarterly data are aggregated into yearly data by taking an average.

5. Empirical Findings

This section is subdivided into four sections. Section 5.1 presents an evaluation of the excess return for national stock indices and currency indices across countries. Section 5.2 provides a correlation matrix between international stock indices. Section 5.3 evaluates the estimated exchange rate betas across countries and considers the ability of the exchange rate risk to have an impact on the return of the national stock index. Section 5.4 shows that the time series of exports and imports as well as inflation provides strong evidence of time variation in exchange rate exposure.

5.1 Estimation of international stock indices and currency indices

Table 1 reports summary statistics for excess return in stock indices for the eight countries and their respective currency indices as well as the world market for the period January 1995 to December 2004.
The mean values of excess return on stock indices vary drastically across countries, from a high value of 0.1179% for Switzerland to a low value of -0.5910% for Brazil. Within countries there are major time-series fluctuations in weekly excess return. The standard deviations of returns are quite large compared to their respective means, for example, for Hong Kong the weekly excess return varies from a low value of -20.1318% to a high value of 13.8121%, with the standard deviation nearly 70 times as large as the mean.

The excess return of the currency indices is estimated by equation (15). It also varies greatly across countries. Furthermore, within countries, these returns change substantially from period to period, as can be seen from the wide ranges between the maximum and minimum values. The returns on currency indices across countries are generally greater than the return on stock indices.

Table 1 results indicates that an investor holding a portfolio of foreign securities from the selected countries’ national stock market, except for the national stock market of Brazil and Hong Kong, receives a high compensation (excess return) for the risk (i.e. standard deviation of the rate of return) the investor bears due to fluctuations in the stock price index. Therefore, investors would benefit more if they invest in established markets rather than emerging market due to greater dispersion in returns and return’s volatility in emerging markets. Emerging countries are extremely vulnerable to sudden swings in international capital flows. In these countries, periods of relative tranquility, characterized by substantial capital inflows and real GDP growth, are followed by periods when capital outflows due to speculative attacks, especially during international financial crises. This leads not only to economic downturns but also to great variations in the return of national stock markets.

In addition, table 1 shows that an investor would be better off holding a weighted portfolio of currency deposits of the four main currencies (i.e. Euro, US dollar, Sterling and Yen) because during the period of 1995-2004 weight-basket of currency deposits (i.e. currency indices) yield a higher excess return than the different national stock market.
5.2 Estimation of correlations between international stock indices

It has been shown that the crucial factor when determining portfolio risk for a given level of return is the correlation between returns of the securities that form the portfolio. High (or low) correlation is associated with high (or low) portfolio risk. Risk-averse investors who prefer low risk will therefore form a portfolio with the securities with the lowest correlation possible, since a low correlation means that while some securities of the portfolio will have a higher return, others will have a lower return and vice-versa.

< Table 2 here >

Table 2 presents the correlation between stock markets of the eight selected countries for the period 1995-2004. These correlations have been computed using weekly returns on national market indices. They are generally high, except for correlations with Brazil.

According with De Santis and Gérard (1997), high correlations may be explained by the increased level of integration between international markets. Therefore, as the economic of different countries become dependent of one another, stock markets tend to move in the same direction, the correlation between national stock markets increase and the potential benefits from diversification is reduced. In table 2, the high correlations between U.S. and other countries as well as the high correlations between countries within Europe can therefore be explained by the arguments from De Santis and Gérard (1997).

On the other hand, Brazil’s correlation with established market is comparatively low (average correlation of 0.27). Therefore, for this sample, Brazilian national stock index have a considerable power of diversification despite its high volatility, which make them desirable as a part of an international portfolio.

5.3 Estimation of exchange rate risk

According with the International CAPM, an investor that holds a well-diversified international portfolio should be concerned not only with the systematic market risk but also with the systematic exchange rate risk.
For the period 1995-2004, the exchange rate risk exposure over the national stock index of each one of the eight selected countries is estimated by equation (16). A null hypothesis test of no exchange rate risk exposure is performed by constructing a 95% confidence interval for the exchange rate betas.

Figure 1 illustrates the 95% confidence interval for the exchange rate betas of each one of the eight selected national stock index for the period 1995-2004. If the null hypothesis \( \beta_{i,t,r} = 0 \) falls within this confidence interval the null hypothesis is not rejected, but if it falls outside this interval, it is rejected.

Results in Figure 1 indicate that the excess return on the national stock index of Belgium is significantly exposed to exchange rate risk in years 1997, 1998 and 1999. The excess return on the national stock index of Hong Kong is significantly exposed to fluctuations in exchange rate in year 1998. The excess return on the national stock index of Switzerland is significantly exposed to exchange rate risk in year 1997, and in year 2002 the excess return on the national stock index of the United Kingdom is significantly exposed to fluctuations in the exchange rate. For all other countries the exchange rate risk is insignificant within a 95% confidence interval.

The results from figure 1 indicate that an investor that purchase assets traded in the national stock markets of Belgium, Hong Kong, Switzerland and the United Kingdom is exposed to unexpected changes in the exchange rates of the respective countries currencies (exchange rate risk).

Panel A in Table 3 reports the White’s General Heteroscedasticity Test for the regression model estimate in equation (16). White’s test is a test of the null hypothesis of no heteroscedasticity against heteroscedasticity of some unknown general form. Results in Panel A indicate that all countries’ \( p \)-values are less than a 1% significance level, except
for Brazil. Therefore, these countries regressions present an unknown general form of heteroscedasticity. This indicates that for the countries with significant White’s test, the assumptions that: (i) the linear specification of the model is correct and (ii) errors are both homoskedastic (i.e. the variance of the residual error is the same for all observations) and independent of the regressors, are not valid. If an ordinary linear regression is not corrected, the point estimates of the parameters will be consistent in the presence heteroscedasticity, but the conventional computed standard errors will no longer be valid, this will in turn affect the $t$-statistics of our point estimates. Therefore, for all countries (except Brazil) an ordinary linear regression with white heteroscedasticity consistent is performed.

Panel B in Table 3 reports the results of the distribution of estimates of exchange rate betas and the test of their significance. A Wald test on the null hypothesis that the exchange rate betas are jointly equal to zero for all ten years in the sample is performed. The Wald statistic follows an asymptotic chi-square $\chi^2_q$ distribution, where $q$ is the number of restrictions under the null hypothesis. This test statistic’s follow a chi-square ($\chi^2_{10}$) distribution. If the $p$-value for the Wald test is less than the significance level, the null hypothesis is rejected. As shown in table 3, the hypothesis that the exchange rate betas are jointly equal to zero for all ten years in the sample can be rejected at the 1% level of significance for all countries except for Brazil, Switzerland as well as for The United States. For Switzerland and the United States, this hypothesis can be rejected at 5% level of significance.

The results in table 3 show that time-varying exchange rate risk has a significant impact on the excess return on the national stock index of all selected countries, except for Brazil. These results show that movement on the return from the selected national stock markets, except for Brazil, are related to unexpected variations in the exchange rates of the respective countries currencies. This latter effect is called exchange rate risk. Therefore, an investor holding a portfolio of foreign securities from these different stock markets should be compensated with a premium (i.e. excess return) proportional to its exposure to exchange rate risk.
The maximum and minimum values of the exchange rate betas in table 3 illustrate that there is variation in exchange rate betas from year to year, giving support for a time-varying exchange rate risk exposure for stock index returns.

The simple linear regression model used to estimate the exchange rate risk that is reported in table 3 assumes that the variance of the residual error is the same for all observations and not related. However, “financial time series, such as stock prices, exchange rates, inflation rates, etc. often exhibit the phenomenon of volatility clustering, that is, periods in which their prices show wide swings for an extended time period followed by periods in which there is relatively calm.”11

As a result, regression models of financial time series are estimated by the autoregressive conditional heteroscedasticity (ARCH) model which can capture such volatility clustering. In this model, the variance of the residual error observed over different time periods may be different and autocorrelated.

Table 4 reports the $p$-values for ARCH test statistic up to four lags (i.e. time interval) for the null hypothesis that autocorrelation in the residual’s variance estimated in equation (16) is zero (i.e. not autocorrelated). If the $p$-value is less than the significance level, the null hypothesis is rejected.

Overall, at 5% and 10% significance level, the residual variance for all countries present a ARCH effect at some lag order, except for Belgium, Brazil and Switzerland. This suggests that the error variance of one time period is related to the error variance from the previous period, thus giving the impression of autocorrelation. Therefore, ARCH model should be estimated. However, only the point estimated from the linear regression on equation (16) are used so there is no reason to dwell with the error variance since they do not matter for the purpose of this paper.

---

5.4 Estimation of the determinants of exchange rate risk

After the exchange rate risk for each international stock market is estimated, I studied whether fluctuation in the exchange rate exposure is related to a country’s macroeconomic variables. Although there are many important economic variables impacting the overall economy of a country, this paper limits to study of three macroeconomics variables: exports, imports and inflation.

<Table 5 here>

Table 5 presents a summary statistics and correlations of the countries exchange rate betas and the selected macroeconomics variables: exports, imports and inflation. Note that the standard deviations and correlations are averages across countries’ standard deviations and correlations.

The remarkable maximum values of exports/GDP (i.e. 1.57) and imports/GDP (i.e. 1.65) in table 5 is due to the strong open economic of Hong Kong, which can be explained by the fact that Hong Kong imports a lot of products that they later export again “re-exports”. This can make the ratio of imports to GDP as well as the ratio of exports to GDP above 100 percent.

<Table 6 here>

Table 6 presents ordinary least square (OLS) regressions of exchange rate betas on country-specific macroeconomics variables. The columns of Table 6 provides: (1) a simple panel regression estimate by equation (18); (2) a panel regression with time-specific effects estimate by equation (19); (3) a panel regression with country-specific effects estimate by equation (20); and (4) a panel regression with both time and country-specific estimate by equation (21).

Panel A in table 6 reports the White’s General Heteroscedasticity Test for the four panel regressions. If the $p$-value is less than the significance level, the null hypothesis of no heteroscedasticity is rejected. Results in Panel A show that all regressions’ $p$-values are less than a 1% significance level, except for panel regression with time-specific effects,
where the p-value is less than a 5% significance level. Therefore, all four regressions present an unknown general form of heteroscedasticity. Hence, an ordinary linear regression with white heteroscedasticity consistent is performed for all four regressions model.

Two formal hypothesis tests are performed with the four panel regressions model. First, a null hypothesis test of no relationship between imports and/or exports and exchange rate betas are performed.

Countries that have a high value of exports (or imports) are expected to be more sensitive to the world economy than countries that do not export (or import) as much. For example, a country $i$’s export (or import) depends on the foreign income (or output) of the rest of the world as well as the exchange rate. An increase in the foreign income leads to an increase in the foreign demand for goods, some of which will fall on country $i$’s good. An increase on exchange rate followed by a depreciation of country $i$’s currency leads to an increase in country $i$’s export of goods. On the other hand, high levels of exchange rate means that foreign goods are relatively more expensive, leading to a decrease in the quantity of imports. Therefore, a depreciation of the local currency will make local exporting firms more profitable and local importing firms less profitable. As a result, stock returns will increase (or decrease) for exporting (or importing) firms.

National stock markets are composed by importing as well as exporting firms. Consequently, from a financial market perspective, returns to stock markets in countries that have a high level of exports relative to GDP are expected to have a positive correlation to the exchange rate. Returns to stock markets in countries that have a high level of imports relative to GDP are expected to have a negative correlation to exchange rate. Therefore, we expect a negative sign for the coefficient on import-driven exposure and a positive sign for the coefficient on export-driven exposure.

Results for Panel B in table 6 indicate that for the panel regression with country-specific effects, the $t$-statistics for the estimated coefficient on exports to GDP ratio exceed the $t$-statistics critical value 1.66724, and thus the estimated coefficient is positive and significant at 10% level. Therefore, fluctuation in the exchange rate exposure is
significantly affected by levels of exports. For the panel regression with both time and country-specific effects, the \( t \)-statistics on the exports to GDP ratio exceed the \( t \)-statistics critical value 2.00098, and thus the estimated coefficient is positive and significant at 5% level of significance. In addition, the \( t \)-statistics for the estimated coefficient on imports to GDP ratio exceed the \( t \)-statistics critical value 1.67095, and thus the estimated coefficient is negative and significant at 10% level of significance. Therefore, for the panel regression with both time and country-specific effects, fluctuation in the exchange rate exposure is significantly affected by levels of exports as well as imports.

A Wald test on the null hypothesis that levels of exports and imports are jointly equal to zero is estimated. This test’s statistic follows a chi-square \( \chi^2 \) distribution. For simple panel regressions the values of \( \chi^2 \) - statistics exceed the \( \chi^2 \) critical value 9.21034, and therefore these values of Wald test are jointly significant at the 1% level of significance. For panel regression with time-specific effects, the values of \( \chi^2 \) - statistics exceed the \( \chi^2 \) critical value 5.99147, and thus these values of Wald test are jointly significant at the 5% level of significance. That is, on average, fluctuation in the exchange rate exposure is significantly affected by both exports and imports levels.

Table 6 reports a significant and positive relationship between levels of exports and exchange rate betas and a significant and negative relationship between levels of imports and exchange rate betas. Because exchange rate beta is the appropriate measure of exchange rate risk, investors holding foreign securities from the selected national stock markets should be compensated with a high premium (i.e. excess return) for a high exchange rate betas (periods of high levels of exports and low levels of imports) and low premium for a low exchange rate betas (periods of low levels of exports and high levels of imports). A low exchange rate beta implies that a negative fluctuation (i.e. appreciation) in the price value of the security’s domestic currency against a weighted-basket of foreign currencies has a small effect on the security’s return. Alternatively, a high exchange rate beta implies that a positive fluctuation (i.e. depreciation) in the price value of the security’s domestic currency against a weighted-basket of foreign currencies has a large effect on the security’s return. Consequently, an investor will demand a lower excess return on a foreign security when the value of the security’s domestic currency
appreciates, because the foreign security will yield a high nominal rate of return for the investor, so the foreign security can be thought as a natural hedging against variations in the exchange rate. On the other hand, an investor will demand a higher excess return on a foreign security when the value of the security’s domestic currency depreciates because the foreign security’s nominal rate of return will be worth less.

The second null hypothesis test is to test no relationship between exchange rate betas and inflation. Inflation is likely to be related to fluctuations in exchange rate because variation in the exchange rate affects import prices that will in turn have an effect on the demand for domestic goods. As a result the overall price level of the economy, measured by the consumer price index (CPI), will be affected and inflation which is measured by changes on CPI will be affected as well. The Patro, D.K., Wald, J.K. and Wu, Y. (2002) claim that inflation is likely to be negatively related to exchange rate risk because “countries with high inflation, and therefore larger ongoing currency depreciation, may be less affected by a given percentage depreciation.”12 For regression with both time and country-specific effects in table 6, the t-statistics for the estimated coefficient on inflation exceed the t-statistics critical value 1.67095, and thus this coefficient is found to be positive and significant at the 10% level of significance. This result contradicts the arguments of Patro, D.K., Wald, J.K. and Wu, Y. (2002).

The significant and positive relationship between inflation and exchange rate betas reported in table 6 shows that high (or low) levels of inflation across countries are associated with high (or low) exchange rate betas. Because exchange rate beta is the appropriate measure of exchange rate risk, investors holding foreign securities from the selected national stock markets should be compensated with a high premium (i.e. excess return) for high levels of inflation (high exchange rate betas) and a low premium for low levels of inflation (low exchange rate betas). Therefore, risk-averse investors holding securities from the selected national stock markets will demand an excess return proportional to movements in inflation. As a result, stock market serves as a hedge against inflation because investors are fully compensated for increases in the general price level through corresponding increases in nominal stock market returns.

---

Finally, Panel C in table 6 presents the results for ARCH test for the null hypothesis that autocorrelation in the residual’s variance is zero (i.e. not autocorrelated) for the four panel regression models. The results indicate the residual variances for all regressions present ARCH effect at some lag order.

6. Summary and Conclusion

For an international investor, the return from any foreign stock fluctuates because of fluctuations in the stock price index, variations in the market and also because of unpredictable fluctuations in exchange rates. All these sources of risk can in practice have an unsystematic (diversified component) as well as a systematic (undiversified component). The unpredictable fluctuations in exchange rates are often called exchange rate risk. The practical relevance of exchange rate risk can be appropriately measured only within the context of an international asset pricing model.

The theoretical background of this paper is the International Capital Asset Pricing Model of Adler and Dumas (1983). They model returns of international equity investment given that PPP does not hold in terms of market risk (which is traditionally measured by the reaction of the asset’s return to movements in the world market index), and the exchange rate risk (measured by the reaction of the asset’s return to fluctuations in foreign currencies). Each of these risk sources is associated with a price of risk, or a risk premium, which is interpreted as the remuneration for bearing the given risk.

The empirical section of the paper studied the significance of exchange rate risk for national stock index of eight countries for the period 1995-2004. In a second step I studied whether fluctuations in exchange rate exposure are significantly related to a country’s export, import and inflation.

By using the empirical framework of Patro, D.K., Wald, J.K. and Wu, Y. (2002), the significance as well as the determinants of exchange rate risk were analyzed. Overall, there is significant evidence of time-varying exchange rate risk, except for Brazil. Furthermore, exchange rate risks across countries are sensitive to both imports and
exports. In addition, a significant relationship is found between exchange rate risk and inflation.

Hence, the conclusion is that there is a predictable relationship between changes in the return of the national stock index and fluctuations in the exchange rate. Moreover, the current state of exports, imports and inflation may be useful in predicting exchange rate risk.
References:


Massachusetts Institute of Technology.

Variables: Evidence from International Returns. *European Financial Management* 8,
421 – 477.


Internet resource:
Dow Jones Indexes, 2005-04-01,
Appendix:

Table 1. Summary statistics for weekly excess returns on international stock indices and currency indices

This table reports summary statistics for excess return on stock indices for 8 countries and the world market for the period January 1995 to December 2004. For each country, the excess return on stock index is in local currency terms, calculated as the first difference of the logarithm of the index price minus the home country risk-free. The excess return on the currency index is the excess return on the weighted portfolio of currency deposits of the four main currencies (i.e. Euro, US dollar, Sterling and Yen). The reported excess return on the world index is in US dollar terms.

<table>
<thead>
<tr>
<th>Country</th>
<th>Index</th>
<th>Weekly excess return of stock index (%)</th>
<th>Weekly excess return of currency index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Median</td>
</tr>
<tr>
<td>Australia</td>
<td>All Ordinaries</td>
<td>0.03323</td>
<td>0.15446</td>
</tr>
<tr>
<td>Belgium</td>
<td>Bel20</td>
<td>0.07853</td>
<td>0.26843</td>
</tr>
<tr>
<td>Brazil</td>
<td>Bovespa</td>
<td>-0.59100</td>
<td>0.17137</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>Hang Seng</td>
<td>-0.05285</td>
<td>0.00279</td>
</tr>
<tr>
<td>Sweden</td>
<td>OMX Stockholm 30</td>
<td>0.09871</td>
<td>0.34778</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Swiss Market</td>
<td>0.11792</td>
<td>0.32100</td>
</tr>
<tr>
<td>The United</td>
<td>FTSE 250</td>
<td>0.02882</td>
<td>0.17338</td>
</tr>
<tr>
<td>States</td>
<td>S&amp;P 500</td>
<td>0.11036</td>
<td>0.28345</td>
</tr>
<tr>
<td>World</td>
<td>Dow Jones World Index</td>
<td>0.07686</td>
<td>0.26985</td>
</tr>
</tbody>
</table>
Table 2. Correlations among stock indices

This table presents the correlation between the stock markets for eight countries for the period 1995-2004. These correlation coefficients have been computed using weekly returns on market indices.

<table>
<thead>
<tr>
<th></th>
<th>Australia</th>
<th>Belgium</th>
<th>Brazil</th>
<th>Hong Kong</th>
<th>Sweden</th>
<th>Switzerland</th>
<th>The United Kingdom</th>
<th>The United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>0.45342</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>0.33193</td>
<td>0.21492</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hong Kong</td>
<td>0.49199</td>
<td>0.35896</td>
<td>0.27449</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>0.47299</td>
<td>0.35693</td>
<td>0.22884</td>
<td>0.43360</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.44096</td>
<td>0.71393</td>
<td>0.26205</td>
<td>0.41116</td>
<td>0.44317</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The United Kingdom</td>
<td>0.54952</td>
<td>0.51586</td>
<td>0.26563</td>
<td>0.46500</td>
<td>0.59083</td>
<td>0.60696</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>The United States</td>
<td>0.50127</td>
<td>0.52699</td>
<td>0.35664</td>
<td>0.43831</td>
<td>0.46204</td>
<td>0.62985</td>
<td>0.59998</td>
<td>1</td>
</tr>
</tbody>
</table>
**Table 3. Exchange risk exposure for international stock index returns using weighted-basket currency index**

This table reports in Panel A: the White’s test which is a test of the null hypothesis of no heteroscedasticity against heteroscedasticity of some unknown general form and in Panel B: the distribution of the exchange rate betas, the absolute value of their $t$-statistics and the test for no currency exposure of stock index returns.

The Wald statistic follows a chi-square ($\chi^2_{10}$) distribution.

<table>
<thead>
<tr>
<th>Country</th>
<th>Panel A: White’s Test</th>
<th>Panel B: Estimate of exchange rate betas</th>
<th>Absolute value of t-statistics</th>
<th>Joint test: $\beta_{i,x,n} = 0, \forall n$</th>
<th>Wald stat.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>0.00001*</td>
<td>-0.19817</td>
<td>-0.20095</td>
<td>0.22179</td>
<td>-0.53209</td>
<td>-0.93667</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.00119*</td>
<td>0.65145</td>
<td>0.69722</td>
<td>1.76668</td>
<td>-0.19384</td>
<td>1.06630</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.66211</td>
<td>-0.85263</td>
<td>-1.01530</td>
<td>-0.07101</td>
<td>-1.90045</td>
<td>0.58400</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>0.00002*</td>
<td>0.23793</td>
<td>-0.36622</td>
<td>5.91447</td>
<td>-3.06825</td>
<td>0.05318</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.00005*</td>
<td>-0.60874</td>
<td>-0.53164</td>
<td>-0.16292</td>
<td>-1.53498</td>
<td>1.72813</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.00141*</td>
<td>0.63163</td>
<td>0.45667</td>
<td>1.36252</td>
<td>0.00897</td>
<td>1.13805</td>
</tr>
<tr>
<td>The United Kingdom</td>
<td>0.00018*</td>
<td>0.10549</td>
<td>0.22072</td>
<td>1.36542</td>
<td>1.45218</td>
<td>0.29755</td>
</tr>
<tr>
<td>The United States</td>
<td>0.00003*</td>
<td>-0.29247</td>
<td>-0.09457</td>
<td>0.67780</td>
<td>-1.59946</td>
<td>0.43750</td>
</tr>
</tbody>
</table>

The model estimated is as follow: $r_{i,t} - r_{i,t}' = \sum_{n=1}^{9} \alpha_{i,n} D_n + \sum_{n=1}^{9} \beta_{i,m,n} D_n (r_{m,t} - r_{m,t}') + \sum_{n=1}^{9} \beta_{i,x,n} D_n r_{i,t} + \epsilon_{i,t}$, where the year dummy variables, $D_n$, are defined as follow: $D_n = \begin{cases} 1 & \text{if } t \in \text{ year: } n = 1, 2, \ldots, 9, \\ 0 & \text{if otherwise.} \end{cases}$

$r_{i,t}$ is weekly local currency excess return on country $i$'s stock index; $r_{i,t}'$ is country’s local risk-free rate of return; $r_{m,t}$ is the rate of return of the world stock index in local currency; $r_{i,t}'$ measures the excess return on a weighted- basket of foreign-currency deposits on country $i$’s currency. The data cover the period 522 weekly observations from 1995 to 2004.

* Significance at 1% level
** Significance at 5% level
Table 4. Autoregressive conditional heteroscedasticity (ARCH) test

This table reports the p-values for (ARCH) test statistic up to 4 lags (i.e. time interval) for the null hypothesis that the autocorrelation in the residual’s variance for the model estimated in Table 3 are zero. Autocorrelation coefficients significantly (5% or 10% level) different from zero are marked with one asterisk (*) or two asterisks (**).

<table>
<thead>
<tr>
<th>Country</th>
<th>Autocorrelation</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p1</td>
<td>p2</td>
<td>p3</td>
<td>p4</td>
</tr>
<tr>
<td>Australia</td>
<td>0.43085</td>
<td>0.20002</td>
<td>0.01777*</td>
<td>0.32495</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.24262</td>
<td>0.14686</td>
<td>0.74284</td>
<td>0.58255</td>
</tr>
<tr>
<td>Brazil</td>
<td>0.95735</td>
<td>0.96467</td>
<td>0.97502</td>
<td>0.98386</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>0.74937</td>
<td>0.04301*</td>
<td>0.14271</td>
<td>0.08263**</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.08848**</td>
<td>0.75497</td>
<td>0.31983</td>
<td>0.00895*</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.12688</td>
<td>0.17534</td>
<td>0.61327</td>
<td>0.46606</td>
</tr>
<tr>
<td>The United Kingdom</td>
<td>0.00001*</td>
<td>0.07121**</td>
<td>0.00032*</td>
<td>0.67931</td>
</tr>
<tr>
<td>The United States</td>
<td>0.05751**</td>
<td>0.24380</td>
<td>0.12392</td>
<td>0.35819</td>
</tr>
</tbody>
</table>
Table 5. Summary statistics for macroeconomic variables and exchange rate betas

This table reports the summary statistic for estimated exchange rate risk (Table 1) and selected macroeconomic variables for eight countries for 1995-2004. Imports and exports are scaled by GDP as indicated. Inflation is the logarithm of CPI. The maximum (minimum) is the largest (smallest) value of that variable for all countries and all years. Average country standard deviation gives the mean between countries standard deviation for each variable. Average country correlation is the mean of the correlations between variables by country.

<table>
<thead>
<tr>
<th>Country</th>
<th>Mean</th>
<th>Average country standard deviation</th>
<th>Max.</th>
<th>Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange rate risk beta</td>
<td>-0.04069</td>
<td>0.77870</td>
<td>5.91447</td>
<td>-3.00625</td>
</tr>
<tr>
<td>Imports/GDP</td>
<td>1.64674</td>
<td>0.04082</td>
<td>1.64674</td>
<td>0.06879</td>
</tr>
<tr>
<td>Exports/GDP</td>
<td>0.44139</td>
<td>0.04320</td>
<td>1.57497</td>
<td>0.06157</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.04289</td>
<td>0.04099</td>
<td>0.71872</td>
<td>-0.04000</td>
</tr>
</tbody>
</table>

Average country correlation between variables

<table>
<thead>
<tr>
<th>Exchange rate risk beta</th>
<th>Imports/GDP</th>
<th>Exports/GDP</th>
<th>Inflation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange rate risk beta</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imports/GDP</td>
<td>-0.16167</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Exports/GDP</td>
<td>-0.09280</td>
<td>0.77468</td>
<td>1</td>
</tr>
<tr>
<td>Inflation</td>
<td>-0.06444</td>
<td>-0.14129</td>
<td>-0.07880</td>
</tr>
</tbody>
</table>
Table 6. Explaining exchange rate betas using macroeconomic variables: Ordinary Least Square (OLS) regressions

This table reports the results of regressing estimated exchange rate risk (Table 3) and on selected macroeconomic variables for 8 countries for 1995-2004. Panel A reports the White’s test which is a test of the null hypothesis of no heteroscedasticity against heteroscedasticity of some unknown general form. Panel B reports OLS regressions with White Heteroscedasticity- Consistent Standard Error & Covariance. The columns are: (1) a simple panel regression, (2) a panel regression with time-specific effects, (3) a panel regression with country-specific effects and (4) a panel regression with both time and country-specific effects. The t-statistics are in parentheses. The Wald test follows a $\chi^2$ distribution. This table reports also in Panel C the p-values for (ARCH) test statistic for the null hypothesis that the autocorrelation in the residual’s variance up to 4 lags (i.e. time interval) are zero. * Significance at 1% level; ** Significance at 5% level; ***Significance at 10% level

<table>
<thead>
<tr>
<th>Panel A: White’s General Heteroscedasticity Test</th>
<th>OLS regression with time-specific effects</th>
<th>OLS regression with country-specific effects</th>
<th>OLS regression with year and country-specific effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-value</td>
<td>0.00767*</td>
<td>0.01457**</td>
<td>0.00247*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B: OLS regression with White Heteroscedasticity- Consistent</th>
<th>OLS regression with time-specific effects</th>
<th>OLS regression with country-specific effects</th>
<th>OLS regression with time and country-specific effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imports/GDP</td>
<td>-3.46921 (-1.07199)</td>
<td>-15.66602 (-1.62971)</td>
<td>-16.16876 (-1.75243)***</td>
</tr>
<tr>
<td>Exports/GDP</td>
<td>4.319736 (1.44229)</td>
<td>16.04281 (1.95085)***</td>
<td>17.11698 (2.096597)**</td>
</tr>
<tr>
<td>Inflation</td>
<td>-0.69895 (-0.80149)</td>
<td>0.91311 (1.13204)</td>
<td>1.56401 (1.67385)***</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Wald test for joint significance of imports and exports</td>
<td>9.40283*</td>
<td>8.59916**</td>
<td>3.85748</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.08988</td>
<td>0.10457</td>
<td>0.14073</td>
</tr>
</tbody>
</table>
(Table 6. Continued)

<table>
<thead>
<tr>
<th>Panel C:</th>
<th>Autocorrelation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>p1</td>
</tr>
<tr>
<td>OLS regression</td>
<td>0.49995</td>
</tr>
<tr>
<td>OLS regression with year dummies</td>
<td>0.47688</td>
</tr>
<tr>
<td>OLS regression with country dummies</td>
<td>0.48421</td>
</tr>
<tr>
<td>OLS regression with year and country dummies</td>
<td>0.44699</td>
</tr>
</tbody>
</table>
Figure 1. Plots of the confidence interval for the estimated exchange rate betas for period 1995-2004

This figure shows the 95% confidence interval for estimated exchange rate betas \((\hat{\beta}_{i,x,n})\) under the hypothesis that \(\beta_{i,x,n} = 0\) for the eight selected countries for the period 1995-2004.