Explaining exchange rate risk in world stock markets: A panel approach

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Abstract

Using a GARCH approach, we estimate a time-varying two-factor international asset pricing model for weekly equity index returns of 16 OECD countries. A trade-weighted basket of exchange rates and the MSCI world market index are used as risk factors. We find significant currency risk exposures in country equity index returns. We then explain these currency betas using several country-specific macroeconomic variables with a panel approach. We find that imports, exports, credit ratings, and tax revenues significantly affect currency risks in a way that is consistent with some economic hypotheses. Similar conclusions are obtained by using lagged explanatory variables, and thus these macroeconomic variables may be useful as predictors of currency risk exposures. Our results are robust to a number of alternative specifications.

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1. Introduction

Since the inception of the floating exchange rate system in 1973, most developed countries have allowed their currency exchange rates to float to some degree against other major currencies. In a world with perfectly integrated capital markets, if
purchasing power parity (PPP) holds between two countries, then the real return of an asset measured in either currency will be the same because exchange rate changes will simply mirror differential inflation rates. On the other hand, if PPP does not hold, the real returns for an asset denominated in different currencies will in general be different. In this case, the uncertainty associated with future exchange rate changes can affect expected returns on securities (see Adler and Dumas, 1983), and the fluctuation of exchange rates will be a source of systematic risk on stocks and bonds. This risk is typically referred to as foreign exchange risk or currency risk.1 By and large, the empirical evidence indicates that PPP is often violated, at least in the short-run, and this can therefore result in a foreign exchange risk for international equity returns.2

The primary objective of this paper is to study the significance as well as the determinants of foreign exchange risk exposures for equity index returns of 16 OECD countries for the period 1980–1997. 3 Using a GARCH specification, we find significant time-varying foreign exchange risk exposure. An important issue is what determines this exposure. Using a panel approach which allows us to pool data across countries and thus improve estimation efficiency, we find that several macroeconomic variables can help explain foreign exchange rate exposures. 4 These variables include imports, exports, credit ratings, and tax revenues. We then suggest several possible interpretations for the observed relations between exchange rate risk exposures and these macroeconomic variables.

The model that we use is grounded on the international asset pricing model of Stulz (1981) and Adler and Dumas (1983). Our definition of foreign exchange risk is based on the illustration in Adler and Dumas (1984). The international asset pricing model specifies that an asset’s expected return is associated with the covariance of the asset’s return with the returns on the world market portfolio and with the covariance of the asset’s return with the returns on foreign exchange rates. Alternatively, the model specification and the importance of a foreign exchange risk factor may be viewed within the context of arbitrage pricing theory (see Ross, 1976), where asset returns are characterized by a small number of common factors. The factors in our model are the excess return on the world market portfolio and the excess return on a country’s trade-weighted currency index.

A number of other researchers have examined the importance of foreign exchange risk in equity returns. Prior studies using US market data have had only limited suc-

1 We use the terms “foreign exchange risk” and “currency risk” interchangeably throughout this paper.

2 While a number of studies, such as Abuaf and Jorion (1990), Wu (1996) and Frankel and Rose (1996), report supporting evidence for PPP in the long run, PPP is found to be overwhelmingly violated in the short run. See the survey by Rogoff (1996).

3 We do not directly test whether currency risk is priced in this paper; rather we focus on the determinants of currency risk exposures. Dumas and Solnik (1995) and De Santis and Gerard (1998) among others study the pricing of foreign exchange risks and find that currency risks are priced. In particular, De Santis and Gerard (1998) carry out a comprehensive and robust analysis on the pricing issue for four currencies.

4 In a companion paper, we examine the determinants of world market risk for these equity index returns (Patro et al., 2001).
cess in documenting the significance of foreign exchange risk in equity returns (see, e.g., Jorion, 1990, 1991; Bartov and Bodnar, 1994). In contrast, research using international equity returns typically finds significant currency betas. Several studies find significant foreign exchange exposure using unconditional factor models and international data. For example, Roll (1992) reports that exchange rate changes explain up to 23% of the variation in equity index returns for developed countries. He and Ng (1998) find that some Japanese multinationals have significant positive exposure to foreign exchange rates. Ferson and Harvey (1994) demonstrate the importance of a foreign exchange risk premium in explaining international equity index returns for 18 developed markets. Other studies find significant exchange rate risk using conditional models. Among these, Ferson and Harvey (1993) find that the world market portfolio and a trade-weighted currency index are the two most important factors in explaining international equity returns. Dumas and Solnik (1995) and De Santis and Gerard (1998) also find that the currency risk premium is significant for international equity index returns. Choi et al. (1998) and Doukas et al. (1999) show that conditional currency risk is important in explaining the stock returns of Japanese firms. Ferson and Harvey (1997) examine the relationship between risk, mispricing, and a number of macroeconomic and financial variables and find that these variables primarily explain changes in risk exposures. In summary, previous research using international equity returns generally finds support for the significance of a foreign exchange risk premium.

Our paper differs from the existing literature in several aspects. We use a two-step estimation procedure, where in the first step the time-varying exchange rate betas (exposures) are estimated using a GARCH model. These betas are allowed to change from year to year, but a priori, they are not assumed to be a function of pre-specified variables. We use weekly data on equity indices and exchange rates to obtain relatively precise estimates of our annual betas. In the second step, the estimated betas are regressed on annual country-specific macroeconomic variables. This not only provides an econometric relation between the exchange risk betas and macroeconomic variables, but more importantly allows for a possible economic interpretation of the impacts of these variables on currency risks. We overcome the problem of small-sample size by using panel regressions, which utilize additional information on cross-country variations in returns and risks and thus provide more efficient estimates of model parameters with the available data.

The findings in this paper may have some practical implications. For example, portfolio managers interested in global asset allocation may want to understand how currency risks differ across countries and what explains these differences, and

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5 In addition to studies on developed markets, recent research also examines the importance of currency risk for emerging markets (see Bailey and Chung, 1995).

6 We choose not to run the second-step regressions using observations at higher frequencies for several reasons. First, some macroeconomic variables that we use are not available at monthly or even quarterly frequencies. Second, there exists a well-known problem of measurement errors in high frequency macroeconomic variables. And third, if we used more frequently sampled macroeconomic data, we would have too few observations of equity returns to obtain precise estimates of monthly or quarterly betas.
therefore this kind of information may be useful in their portfolio selection decisions. In order to design hedging strategies for risk exposures to different currencies, multinational corporations may be interested in predicting future exchange rate risks by employing information about the current state of the macroeconomy. Finally, the relation between currency risks and the macroeconomy may provide useful information for government policy makers.

The remainder of the paper is organized as follows. Section 2 presents some theoretical motivation, which guides our empirical work. In Section 3, we describe our estimation methodology and report results on exchange rate exposures. We provide an analysis of the determinants of exchange rate exposures using macroeconomic variables in Section 4. Concluding remarks and some implications of our findings are offered in Section 5.

2. Theoretical motivation

Our empirical work is motivated by studies on international asset pricing, such as Adler and Dumas (1983, 1984) and Dumas and Solnik (1995), among others. Within that framework, the return of a national stock market, say country $i$, which we will call the “domestic” country hereafter, is not only subject to the systematic risk of the world stock market, but also subject to a foreign exchange rate risk due to the country’s exposure to fluctuations in currency prices. Our focus will be on estimating the sensitivity of country $i$’s stock index returns to changes in the value of its currency relative to a trade-weighted basket of currencies and on studying the macroeconomic determinants of this exchange rate risk. We therefore concentrate on measuring the determinants of foreign exchange exposure and not on directly testing if currency risk is priced. 7

We specify a parsimonious two-factor model for country $i$ as follows:

$$
(r_{it} - r_{ft}) = \alpha_i + \beta_{iw}(r_{it}^w - r_{ft}^w) + \beta_{ix} r_{xt}^x + e_{it},
$$

(1)

where, $r_{it}$ is the rate of return on country $i$’s stock index (in local currency terms) from time $t-1$ to $t$; $r_{it}^w$ is country $i$’s local risk-free rate of return from time $t-1$ to $t$; $r_{it}^w$ is the rate of return on the world stock index (in local currency terms); $r_{xt}^x$ measures the excess return from holding a trade-weighted basket of foreign-currency deposits from time $t-1$ to $t$, and for the panel of 16 countries in our sample. $r_{xt}^x$ is defined as:

$$
r_{xt}^x = \sum_{j=1}^{15} w_{ixj} \left[ \ln(S_{ij,t}/S_{ij,t-1}) + r_{jt}^w - r_{jt}^w \right].
$$

(2)

In Eq. (2), $S_{ij,t}$ is the price of one unit of currency $j$ in terms of currency $i$. That is, a higher value of $S_{ij,t}$ means that currency $i$ depreciates in value relative to currency $j$. 7 See Footnote 3.
$w_{i,j,t}$ is the weight in commodity trade (imports plus exports) of country $i$ with country $j$ relative to the total trade of country $i$ with all other 15 countries in our sample. A positive value of $r^x_{i,t}$ means that country $i$’s currency has a real depreciation relative to the trade-weighted average of the other 15 currencies. Or alternatively, a positive value of $r^x_{i,t}$ means that holding a trade-weighted basket of foreign-currency deposits from time $t-1$ to $t$ yields a positive excess return (relative to holding the domestic currency).

In Eq. (1), the parameter $\beta_{i,w}$ 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; and $\epsilon_{i,t}$ is an error term. Eq. (1) says that the excess return from holding country $i$’s equity is determined by two factors: the excess return from exposure to the world stock market and the excess return from exposure to currency prices. Our initial interest is to examine whether the domestic stock market is significantly exposed to this exchange rate risk.

Notice that in principle it is possible to include the excess returns of holding these 15 foreign currency deposits as separate right-hand side variables in Eq. (1) and then estimate the exposure to each currency price separately. However, a direct cost of using such a method is that the degrees of freedom are greatly reduced, making estimation much less efficient given our moderate sample size. Furthermore, our study on the determinants of exchange risks will become much more difficult because for each country, there will be 15 different exchange rate betas instead of a single one to be explained. Because of these considerations, the use of an effective exchange rate index provides a parsimonious specification and seems to be most appropriate.

Some intuitive economic interpretation of (1) is straightforward and useful. Consider a case where domestic firms do not have foreign transactions of any kind. One simple example of such a case is when the domestic economy is closed. In this case, domestic firms will not have foreign exchange rate exposure. A change in the domestic currency prices relative to other currencies should not have any real economic impact on the operation of domestic firms. In other words, the value of a firm and hence the return on its stock, if measured in the domestic currency unit, should not be affected by currency price fluctuations. Therefore, we should expect the value of $\beta_{i,x}$ in Eq. (1) to be equal to zero if domestic firms are not subject to real currency risk.

On the other hand, in an open economy a change in currency prices can have an impact on the value of the firm. For example, consider a firm whose products are

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8 Our trade-weighted currency index is constructed in a manner similar to the J.P. Morgan currency index; however, our index is weekly which is necessary to provide efficient estimates in our GARCH model.

9 Prior researchers, such as Ferson and Harvey (1993, 1994), have primarily used the trade-weighted value of the US dollar as the global currency risk factor for all countries. In contrast, we use a country-specific trade-weighted index of currency excess returns as our currency risk factor because we want to measure the risk for an investor in any given country, rather than from a purely US perspective. Using this index allows us to capture the actual risk faced by local investors, which is the more relevant measure given our primary focus on the country-specific determinants of exchange rate risk.
A real depreciation of the domestic currency should decrease the firm’s costs relative to its foreign competitors and therefore increase the firm’s profitability and in turn its stock return. In this case, we should expect the value of $\beta_{i,x}$ to be larger than zero. Similarly, one may argue that for an importing firm, a real depreciation of the domestic currency lowers its profitability as well as its stock return and thus one should in this case expect the value of $\beta_{i,x}$ to be smaller than zero. Based on the above reasoning, our null hypothesis of no currency exposure can be stated as follows:

$$H_0 : \beta_{i,x} = 0.$$ 

A finding of $\beta_{i,x}$ significantly different from zero will imply that on average exchange rate risk has an impact on the return of the national stock index.

### 3. Exchange rate risk for international equity indices

#### 3.1. Data

Weekly observations of equity index prices are obtained from Morgan Stanley Capital International (MSCI) for 16 OECD countries: Australia (AUS), Austria (AUT), Belgium (BEL), Canada (CAN), Denmark (DEN), France (FRA), Germany (GER), Italy (ITA), Japan (JPN), Netherlands (NET), Norway (NOR), Spain (SPN), Sweden (SWE), Switzerland (SWI), the United Kingdom (UK), and the United States (USA). MSCI starts collecting weekly price data in December 1979. Therefore, our sample on returns starts in January 1980 and covers up to December 1997 for a period of 18 years. For each country, the observations are end-of-period value-weighted indices of a large sample of companies in that country. All index prices used in this paper are in respective local currency terms.

We choose to employ weekly data rather than the more commonly used monthly observations or the more frequently sampled daily data because weekly sampling seems to be an ideal compromise. One of our concerns is estimation efficiency. In our empirical specification, the betas are allowed to change from year to year. We find that it is difficult to obtain precise estimates of the betas in a given year with only 12 monthly observations. In contrast, 52 weekly observations in a year can give us much more precise estimates. \(^{10}\) While daily sampling provides more data points, it is known that daily data are subject to large biases due to infrequent trading, bid–ask spreads and asynchronous prices.

We obtain weekly dollar exchange rates for these countries from the Federal Reserve Board. For home-country risk-free interest rates, we extract from IMF’s *International Financial Statistics* (IFS) monthly Treasury bill rates for each country (line 60) or other short-term interest rates if Treasury bill rates are not available. As

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\(^{10}\) We compare the results using weekly observations with those using monthly observations and confirm this assertion.
weekly interest-rate data are not available for the entire sample period for many countries, we interpolate the monthly data into weekly observations. To construct trade-weighted exchange rate indices, we obtain pair-wise import and export data among these 16 countries from various issues of OECD’s *Monthly Statistics of Foreign Trade – Series A*. The weights are updated annually.

Table 1 presents summary statistics for the weekly excess returns on the international equity indices and currency indices. The mean values of excess returns on equity indices vary drastically across countries, from a high value of 0.198% for Sweden to a low value of −0.040% for Canada. Within countries, there in general exist vast time-series fluctuations in weekly excess returns; the standard deviations of returns are quite large compared to their respective means. For example, for Australia, the weekly excess return varies from a low value of −33.566% to a high value of 11.472%, with the standard deviation nearly 80 times as large as the mean. The excess returns on the currency indices also vary greatly across countries. Furthermore, within countries, these returns change substantially from period to period, as can be seen from the large standard deviations and wide ranges. The variability of returns on the currency indices is in general smaller than that of returns on the equity indices.

### 3.2. Measuring currency risk

The first stage of our empirical work involves estimating the two-factor model (1) equation-by-equation for the 16 OECD countries. It is well documented (see Pagan and Schwert, 1990; Chan et al., 1992, among many others) that the volatility of stock returns can change over time and that both expected returns and risks can be time varying. We explicitly incorporate these elements in our estimation. Namely, we assume that the returns follow a GARCH process. Furthermore, as in De Santis and Gerard (1998), to maintain parameter parsimony, we estimate a GARCH(1,1) model, which assumes that the time-varying variance of the residual depends only on the squared residual in the past period and an autoregressive component. 11 The world market and currency index betas as well as the intercept terms are allowed to change from year to year. 12 Specifically, given our sample of weekly observations for 18 years (1980–1997), we estimate the following two-factor model with time-varying betas using a maximum likelihood procedure:

\[
(r_{i,t} - r_{f,t}) = \sum_{n=1}^{18} \alpha_{i,n} D_n + \sum_{n=1}^{18} \beta_{i,w,n} D_n (r_{w,t}^n - r_{f,t}^n) + \sum_{n=1}^{18} \beta_{i,x,n} D_n r_{x,t}^n + \varepsilon_{i,t}, \tag{3}
\]

where the year dummy variables, \( D_n \), are defined as follows:

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11 We first estimate a GARCH-M process, but find no significant relationship between expected returns and time-varying volatility. We also estimate GARCH(1,2), GARCH(2,1), and GARCH(2,2) models, but we find the higher-order GARCH parameters are mostly insignificant. Therefore, we adopt the GARCH(1,1) model in our final estimation. For a general description of models in the GARCH family, see Bollerslev et al. (1992).

12 We test and are able to reject the hypothesis that the intercepts are constant across years.
### Table 1
Summary statistics for weekly excess returns on international equity indices and currency indices

<table>
<thead>
<tr>
<th>Country</th>
<th>Symbol</th>
<th>Weekly excess return of equity index (%)</th>
<th>Weekly excess return of currency index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
<td>Min.</td>
</tr>
<tr>
<td>Australia</td>
<td>AUS</td>
<td>-0.034</td>
<td>2.691</td>
</tr>
<tr>
<td>Austria</td>
<td>AUT</td>
<td>0.003</td>
<td>2.644</td>
</tr>
<tr>
<td>Belgium</td>
<td>BEL</td>
<td>0.051</td>
<td>2.217</td>
</tr>
<tr>
<td>Canada</td>
<td>CAN</td>
<td>-0.040</td>
<td>2.096</td>
</tr>
<tr>
<td>Denmark</td>
<td>DEN</td>
<td>0.077</td>
<td>2.301</td>
</tr>
<tr>
<td>France</td>
<td>FRA</td>
<td>0.051</td>
<td>2.639</td>
</tr>
<tr>
<td>Germany</td>
<td>GER</td>
<td>0.079</td>
<td>2.405</td>
</tr>
<tr>
<td>Italy</td>
<td>ITA</td>
<td>0.038</td>
<td>3.288</td>
</tr>
<tr>
<td>Japan</td>
<td>JPN</td>
<td>0.026</td>
<td>2.533</td>
</tr>
<tr>
<td>Netherlands</td>
<td>NET</td>
<td>0.139</td>
<td>2.210</td>
</tr>
<tr>
<td>Norway</td>
<td>NOR</td>
<td>-0.026</td>
<td>3.173</td>
</tr>
<tr>
<td>Spain</td>
<td>SPN</td>
<td>0.025</td>
<td>2.767</td>
</tr>
<tr>
<td>Sweden</td>
<td>SWE</td>
<td>0.198</td>
<td>2.986</td>
</tr>
<tr>
<td>Switzerland</td>
<td>SWI</td>
<td>0.132</td>
<td>2.120</td>
</tr>
<tr>
<td>UK</td>
<td>UK</td>
<td>0.067</td>
<td>2.202</td>
</tr>
<tr>
<td>USA</td>
<td>USA</td>
<td>0.098</td>
<td>2.058</td>
</tr>
<tr>
<td>World</td>
<td>WLD</td>
<td>0.073</td>
<td>1.820</td>
</tr>
</tbody>
</table>

This table reports summary statistics for weekly excess returns on MSCI equity indices for 16 OECD countries and the world market for the period January 1980–December 1997 (939 weeks). For each country, the excess return on the equity index is in local currency terms, calculated as the first difference of the logarithm of the index price minus the home country risk-free rate. The excess return on the currency index is the excess return on the trade-weighted portfolio of currency deposits of the other 15 currencies. The reported excess return on the world index is in US dollar terms.
\[
D_n = \begin{cases} 
1 & \text{if } t \in \text{year } n, \quad n = 1, 2, \ldots, 18, \\
0 & \text{if otherwise,}
\end{cases}
\]

the residual terms, \(e_{i,t}\), are assumed to follow a GARCH(1,1) process as follows:

\[
e_{i,t} \sim N(0, h_{i,t}),
\]

where

\[
h_{i,t} = \gamma_{i,0} + \gamma_{i,1} e_{i,t-1}^2 + \gamma_{i,2} h_{i,t-1}.
\]

The autoregressive parameter \(\gamma_{i,1}\) and moving average parameter \(\gamma_{i,2}\) capture the time-varying volatility of stock returns. Thus the conditional variance evolves over time and is related to the prior conditional variance and prior forecast error. Panel B in Table 2 reports the estimates of the GARCH model. We find that \(\gamma_{i,1}\) is significant at the 5% level for 13 out of 16 countries and \(\gamma_{i,2}\) is significant at the 1% level for all countries. These results provide strong support for our GARCH specification.

Our empirical procedure allows us to estimate a conditional risk measure for each country for each year, which we seek to explain in our panel regressions in the following section. The coefficients, \(\beta_{i,w,n}\), denote the world market betas for year \(n\), which measure the risk exposures of the excess returns on a country’s stock index on the excess return of the world market portfolio.

The parameters that we focus on are the beta coefficients on the excess return of the trade-weighted portfolio of foreign currency deposits, \(\beta_{i,x,n}\). In our specification, a value of \(\beta_{i,x,n}\) significantly different from zero signifies a systematic foreign exchange risk for equity index returns. In other words, if a country has no foreign exchange risk exposure, then its currency beta should be insignificantly different from zero. A positive beta, however, implies that a depreciation of the local currency leads to a higher return (in local currency terms) for the firms in that country, and a negative beta implies that an appreciation of the local currency leads to a higher stock return.

### 3.3. Results and discussion

If the asset pricing model of Adler and Dumas (1983) holds and there are deviations from PPP, we expect to find significant betas on the trade-weighted currency index. Panel A in Table 2 reports results on the distribution of estimates of the currency betas and the tests for their significance. We find that for eight countries (Australia, Canada, France, Italy, Japan, Sweden, UK and US), the mean values of the absolute \(t\)-statistics for the estimated exchange rate betas exceed 1.96, and thus these exchange rate betas are statistically significant at the 5% level. For Germany and Spain, the mean values of the \(t\)-statistics are significant at the 10% level. Since the currency betas are allowed to change year by year for each country, we perform a Wald test on the hypothesis that the currency betas are jointly equal to zero for all 18 years in the sample. This test statistic has an asymptotic \(\chi^2_{18}\) distribution. Test results are presented in the last two columns of Panel A in Table 2. As we show, the hypothesis that the currency betas are jointly equal to zero can be rejected at the 1% significance level for all countries except Austria, where this hypothesis can be
Table 2
Foreign exchange risk exposures for international equity index returns using trade-weighted currency index

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Panel A. Estimate of foreign exchange betas</th>
<th>Panel B. Estimate of GARCH(1,1) model parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foreign exchange beta ($\beta_{i,x,n}$)</td>
<td>Absolute value of $t$-statistic</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>Min</td>
</tr>
<tr>
<td>AUS</td>
<td>0.578</td>
<td>−0.700</td>
</tr>
<tr>
<td>AUT</td>
<td>−0.229</td>
<td>−4.729</td>
</tr>
<tr>
<td>BEL</td>
<td>0.516</td>
<td>−1.085</td>
</tr>
<tr>
<td>CAN</td>
<td>1.261</td>
<td>0.648</td>
</tr>
<tr>
<td>DEN</td>
<td>0.770</td>
<td>−0.842</td>
</tr>
<tr>
<td>FRA</td>
<td>1.700</td>
<td>−0.329</td>
</tr>
<tr>
<td>GER</td>
<td>0.783</td>
<td>−3.534</td>
</tr>
<tr>
<td>ITA</td>
<td>1.176</td>
<td>−0.785</td>
</tr>
<tr>
<td>JPN</td>
<td>0.821</td>
<td>0.417</td>
</tr>
<tr>
<td>NET</td>
<td>0.256</td>
<td>−3.112</td>
</tr>
<tr>
<td>NOR</td>
<td>1.128</td>
<td>−1.005</td>
</tr>
<tr>
<td>SPN</td>
<td>0.853</td>
<td>−0.801</td>
</tr>
<tr>
<td>SWE</td>
<td>0.881</td>
<td>−3.532</td>
</tr>
</tbody>
</table>
The model estimated is as follows:

\[(r_{it} - r_{it}^f) = \sum_{n=1}^{18} \alpha_{in}D_n + \sum_{n=1}^{18} \beta_{inw}D_n(r_{wt}^w - r_{it}^f) + \sum_{n=1}^{18} \beta_{inx}D_n r_{it}^x + \epsilon_{it},\]

where the year dummy variables, \(D_n\), are defined as follows:

\[D_n = \begin{cases} 1 & \text{if } t \in \text{year } n, \quad n = 1, 2, \ldots, 18, \\ 0 & \text{if otherwise}, \end{cases}\]

\(r_{it}\) is weekly local currency excess return on country \(i\)'s stock index, \(r_{it}^f\) is country \(i\)'s risk-free rate, \(r_{wt}^w\) is the rate of return on the world stock index in local currency terms, \(r_{ix}\) is the excess return on a trade weighted portfolio of currency deposits, in country \(i\)'s currency. A positive value of \(r_{ix}\) means country \(i\)'s currency depreciates relative to the 15 others. The residuals are assumed to follow a GARCH(1,1) process as follows:

\[\epsilon_{it} \sim N(0, h_{it}),\]

where

\[h_{it} = \gamma_{i,0} + \gamma_{i,1} \epsilon_{i,t-1}^2 + \gamma_{i,2} h_{i,t-1}.\]

The data cover the period 1980–1997. Panel A reports the distribution of the foreign exchange betas, the absolute values of their \(t\)-statistics and the tests for no currency exposure of equity index returns. The Wald statistic follows a \(\chi^2_{18}\) distribution. Panel B presents the GARCH parameter estimates with their \(t\)-statistics in parentheses. The values of the parameter \(\gamma_{i,0}\) are multiplied by \(10^3\).
rejected at the 5% level. It is also apparent that the betas exhibit substantial variation from year to year. For example, the betas for Australia vary from a low of −0.700 to a high of 1.485. Therefore, we find that there is significant evidence of time-varying currency risk exposure for equity index returns.\footnote{We also find significant time-varying world market betas. Because the main focus of this paper is on explaining exchange rate risks, results on world market beta estimates are not reported here to conserve space.}

Our results of significant betas on exchange rates and world market portfolio are consistent with findings in other studies such as Ferson and Harvey (1994, 1997). In the following section, we investigate how our estimates of foreign exchange risk relate to country-specific macroeconomic variables.

4. Determinants of exchange rate exposure

4.1. Macroeconomic variables used

Once the exchange rate betas are estimated, in the second stage, we investigate the extent to which the foreign exchange exposures can be explained by a country’s macroeconomic variables. The variables we include in our final regressions are: the exports to GDP ratio; the imports to GDP ratio; the CPI inflation rate; the government surplus to GDP ratio; the tax revenues to GDP ratio, and the change in the logarithm of the country’s credit ratings.\footnote{We use the change in the logarithm of the country’s credit ratings, rather than the level of credit ratings to ensure that, along with other variables, this variable is stationary.} We choose these variables for two main reasons. First, we believe that these variables are among the most important economic variables impacting the stock and currency market equilibrium and furthermore they are somewhat “exogenous” in the sense that they come from outside the stock market. Second, our choice of variables is also guided by existing research. For example, Jorion (1990) finds that exchange rate exposure is positively related to the ratio of foreign sales to total sales for US multinationals. Allayannis (1997) reports that time-varying currency exposures for US manufacturing industries are related to the level of imports and exports. He and Ng (1988) show that export ratios are closely related to exchange rate exposure for Japanese multinationals. Ferson and Harvey (1997) indicate that exchange rate betas are jointly related to both country-specific and global risk factors such as inflation and credit ratings for some countries.

We also consider several additional variables including money supply as a fraction of GDP, current account as a fraction of GDP, and total market capitalization, either as a fraction of GDP or as a fraction of the world market capitalization. With the exception of the current account, these variables are not significant in any of the specifications. As the current account variable is highly correlated with imports and exports, it does not add much additional explanatory power to the regressions. Hence these variables are dropped from our final regressions.
Previous studies have used financial variables to explain time-varying betas and returns. We also estimate our models with four financial variables, namely, the dividend yield, the earnings-to-price ratio, the price-to-book value ratio, and the term spread, as additional explanatory variables in our regressions. While we find that dividend yield and earnings to price ratios are occasionally individually significant in the regressions, including these variables has little effect on the coefficients of the macroeconomic variables. We therefore exclude these variables from our final regressions and focus on the macroeconomic variables.

All macroeconomic data are obtained at an annual frequency. The data on total tax revenues are obtained from IMF’s Government Finance Statistics Yearbook. Credit rating data are collected from the March and September issues of Institutional Investor. These credit ratings are based on a scale from 0 to 100. We take the average of the ratings assigned in March and September as the annual rating. The other data are obtained from IMF’s International Financial Statistics: gross domestic product (GDP, line 99), imports (line 71), exports (line 70), consumer price index (line 64), and government surplus (line 80).

Table 3 presents summary statistics and correlations of these variables and the country exchange rate risk betas that are estimated in the previous section. Note that the standard deviations and correlations are averages across countries’ standard deviations and correlations, as most of the variation occurs between countries. For example, the correlation of imports and exports varies significantly across countries, from 0.292 for Norway to 0.969 for the Netherlands, and these within-country correlations average to the mean correlation of 0.758 in Table 3.

4.2. Panel methodology

In order to determine to what extent our exchange rate betas, $\beta_{i,x,n}$, can be explained by macroeconomic fluctuations, we regress the exchange rate betas on the variables summarized in Table 3. To improve estimation efficiency, we pool data for all 16 countries and run a panel regression. Our basic regression with $K$ explanatory variables (Column (1) of Table 4) is specified as

$$\beta_{i,x,n} = a + \sum_{k=1}^{K} b_k x_{i,k,n} + v_{i,n}, \quad (5)$$

where $x_{i,k,n}$ is the $k$th macroeconomic variable for country $i$ in year $n$, $n = 1, 2, \ldots, 18$; $i = 1, 2, \ldots, 16$; $b_k$ measures how sensitive a country’s currency risk is to its $k$th macroeconomic factor; we assume that this sensitivity is common across countries; and $v_{i,n}$ is the error term which can be heteroskedastic.

To control for time-specific changes in risk, we add year dummies (Column (2) of Table 4) to the specification:

\[15\] Moreover, we also conduct a joint test and find that the four financial variables are jointly significant for only one of the regressions.
Table 3
Summary statistics for variables in panel regressions

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Average country standard deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange rate risk beta</td>
<td>0.773</td>
<td>1.073</td>
<td>−4.729</td>
<td>7.887</td>
</tr>
<tr>
<td>Imports/GDP</td>
<td>0.246</td>
<td>0.031</td>
<td>0.053</td>
<td>0.782</td>
</tr>
<tr>
<td>Exports/GDP</td>
<td>0.243</td>
<td>0.027</td>
<td>0.051</td>
<td>0.732</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.049</td>
<td>0.029</td>
<td>−0.007</td>
<td>0.193</td>
</tr>
<tr>
<td>Government surplus/GDP</td>
<td>−0.035</td>
<td>0.019</td>
<td>−0.147</td>
<td>0.045</td>
</tr>
<tr>
<td>Taxes/GDP</td>
<td>0.296</td>
<td>0.014</td>
<td>0.110</td>
<td>0.461</td>
</tr>
<tr>
<td>Δ Credit rating</td>
<td>−0.003</td>
<td>0.018</td>
<td>−0.086</td>
<td>0.054</td>
</tr>
</tbody>
</table>

Average country correlation between variables

<table>
<thead>
<tr>
<th></th>
<th>Exchange rate risk beta</th>
<th>Imports/ GDP</th>
<th>Exports/ GDP</th>
<th>Inflation</th>
<th>Government surplus/ GDP</th>
<th>Taxes/ GDP</th>
<th>Δ Credit rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange rate risk beta</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imports/GDP</td>
<td>−0.128</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exports/GDP</td>
<td>−0.026</td>
<td>0.758</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation</td>
<td>−0.071</td>
<td>0.386</td>
<td>0.136</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government surplus/GDP</td>
<td>0.186</td>
<td>0.140</td>
<td>−0.238</td>
<td>−0.075</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxes/GDP</td>
<td>0.085</td>
<td>0.124</td>
<td>−0.122</td>
<td>−0.139</td>
<td>0.332</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Δ Credit rating</td>
<td>−0.029</td>
<td>0.104</td>
<td>0.000</td>
<td>−0.363</td>
<td>0.126</td>
<td>−0.016</td>
<td>1.000</td>
</tr>
</tbody>
</table>

This table reports summary statistics for estimated exchange rate risk (Table 2) and select macroeconomic variables for 16 OECD countries for 1980–1997. Imports, exports, and government surplus are all scaled by GDP as indicated. Inflation is the difference in log of CPI. Δ Credit rating is change in the log of the credit rating given by Institutional Investor’s Country Credit Ratings. The minimum (maximum) is the smallest (largest) value of that variable for all countries and all years. Average country standard deviation gives the mean between countries of the standard deviation for each variable. Average country correlation is the mean of the correlations between variables by country.

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

(6)

where \(D_n\), as defined in Eq. (4), is a dummy variable for each year \(n, n = 1, 2, \ldots, 18\). Further, to allow for constant differences in risk across countries, we also run a panel regression with country-specific fixed effects (Column (3) of Table 4), namely

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

(7)

And lastly we add both year-specific and country-specific dummies to the regression (Column (4) of Table 4):
\[
\beta_{i,x,n} = a_i + \delta_n D_n + \sum_{k=1}^{K} b_k x_{i,k,n} + v_{i,n}.
\]

We find that tests for heteroskedasticity, especially for different variances by country and year, are significant, and therefore correcting for heteroskedasticity and estimating by feasible GLS helps improve estimation efficiency. We assume a linear exponential form for the variance. For each model specification, the residual variance is assumed to be given by \( \sigma^2 = \exp(Z'\gamma) \), where the \( Z \)'s are all the right-hand side variables and the \( \sigma^2 \)'s are estimated from a first-pass OLS regression of that specification.\(^{16}\) While the results of OLS and GLS regressions are not greatly different, GLS does noticeably increase the statistical significance in some cases, and therefore we only report the GLS results.

### 4.3. Results from contemporaneous regressions

Table 4 presents GLS regressions of exchange rate betas on contemporaneous country-specific macroeconomic variables. The columns of Table 4 provide: (1) a simple pooled regression; (2) a panel regression with year dummies; (3) a panel regression with country dummies; and (4) a panel regression with both year and country dummies. Due to missing observations, our regressions are unbalanced panels where different countries can have different time-series observations.

We test three formal hypotheses with our model. First, we expect that imports will have a negative coefficient, and exports will have a positive coefficient in our regression of currency risk. Both imports and exports are measures of the degree of openness of the country, and more openness is expected to result in higher sensitivity of stock returns to changes in foreign exchange rates. This is similar to the hypothesis tested by He and Ng (1998) for Japanese multinational firms. That is, when countries have higher exports (imports), their stock markets will reflect a more positive (negative) exposure to currency risk, and thus the currency betas will be larger (smaller). A depreciation of the local currency will make local exporting firms more profitable and local importing firms less profitable. Therefore, for exporting (importing) firms, stock returns will increase (decrease) with a depreciation of the local currency, and the exchange rate betas should be more positive (negative). Formally, we can state our null hypothesis of no relationship between imports or exports and currency risk as:

\[
H_0: \text{Currency betas are not sensitive to a country's imports and/or exports.}
\]

From Table 4, we are able to reject this hypothesis when looking between countries; that is, when country-specific dummies are not included. However, we are not

\(^{16}\) It is interesting to note that small countries have significantly higher variance than large countries in this specification.
able to reject this hypothesis when including country-specific dummies without year dummies as in Column (3) of Table 4. We report the values of the Wald test for the joint significance of imports and exports, and find that they are jointly significant except in Column (3) with country dummies. Thus, we can conclude that while exports are associated with more positive currency risk and imports are associated with more negative currency risk, most of the difference appears to be between countries, not within countries. That is, on average, countries with higher exports (imports) have more positive (negative) currency risk than countries with lower exports (imports).
Our second hypothesis is that a higher country credit rating will be associated with a lower level of currency risk. As a country’s credit ratings are highly negatively correlated with their level of foreign debt (see, Lee, 1993), we expect that countries with better credit will be less subject to foreign exchange rate risks. Countries with more foreign debt may suffer more severe economic shocks when their currency depreciates.\textsuperscript{17} We include the change in the logarithm of the country credit rating in our regressions. The formal hypothesis tested is:

$$H_0 : \text{Changes in country credit ratings are not associated with changes in currency risk.}$$

Results presented in Table 4 show that the parameter on credit ratings has the expected negative sign across all specifications. In terms of statistical significance, we are able to reject the above null hypothesis at the 1\% level when both year and country dummies are included in Column (4) of Table 4. The negative coefficient on changes in credit ratings is consistent with our prior beliefs that countries with improved credit should see a decrease in their level of currency risk. Thus, while some care must be taken in interpreting these results, we believe that the consistently negative sign in all our regressions, suggests a negative relation between country credit ratings and foreign exchange rate risk.

Our third hypothesis concerns the explanatory power of tax revenues as a fraction of GDP.\textsuperscript{18} If investors care about returns on an after-tax basis, then a higher tax rate may impact required before-tax returns. If investors demand a constant, or nearly constant, after-tax rate of return and return premium, then higher taxes may imply a higher discount rate or a higher currency beta.\textsuperscript{19} Therefore, we expect the parameter of the tax variable to be positive. The formal hypothesis tested is:

$$H_0 : \text{Taxes do not affect currency risk.}$$

The results from GLS regressions in Table 4 show that taxes have a positive impact on currency risk in three out of the four regressions, and the parameter is significant at the 5\% level in the pooled regression without dummies and in the regression with only country dummies. However, the tax parameter is insignificant for the regression with year dummies only, and it is insignificant and changes sign for the regression with both year and country dummies.

We also examine the relation between exchange rate risk and two other macroeconomic variables: inflation and government surplus as a fraction of GDP, which may have important impacts on stock and currency markets. However, we do not have strong prior beliefs as to the signs on the coefficients for these variables. We find that

\textsuperscript{17} We test the level of foreign debt as an additional right-hand side variable for a subset of countries where data are available, but find it to have little additional explanatory power.

\textsuperscript{18} The tax revenue data that we use are consolidated central government tax revenues. The tax revenue to GDP ratio is a proxy for the average tax rate in the economy. Due to data limitations, we are unable to obtain corporate and income tax rates separately for the countries in our sample.

\textsuperscript{19} For related work, see Benninga and Sarig (1999) and Wu and Zhang (2000).
the coefficient on government surplus has a positive sign in the regressions for all specifications except the one with year dummies only. Furthermore, the coefficient is significant at the 1% level for the regression with both year and country dummies (Column (4) of Table 4).

Inflation has a negative coefficient for three out of the four specifications, and it is negative and significant for the regression with both year and country dummies. A negative coefficient implies that countries with high inflation have stock markets that are less sensitive to a change in exchange rates. This suggests that countries with high inflation, and therefore probably larger ongoing currency depreciation, may be less affected by a given percentage depreciation. For example, a high inflation country with an average 20% depreciation may have its stock market less impacted by a 5% currency depreciation than a country with low inflation and little ongoing depreciation.

Ferson and Harvey (1997) provide a relevant comparison with our results. Some of our macroeconomic variables, namely inflation and credit rating, are the same as the macroeconomic variables they examine. However, we also find that imports, exports, taxes, and government surplus enter into the determination of exchange rate risk in an economically meaningful way.

We also examine the year dummies from the regressions in Columns (2) and (4) of Table 4 to see whether the German unification of 1990 or the European Monetary System (EMS) crisis of 1992 increased overall currency risk. We find that currency risk was significantly higher in 1990 and 1994, but surprisingly the 1992 EMS crisis did not appear to have a direct impact on currency betas. The increase in currency betas in 1990 may be related to the 1990 replacement of the Ostermark with the Deutsche Mark.

4.4. Results from lagged regressions

Next, we consider whether current values of these macroeconomic variables have any explanatory power for currency risks in the future. To this end, we run the same set of regressions but with the explanatory variables lagged one period. The results presented in Table 5 from the lagged GLS regressions provide many of the same conclusions as the contemporaneous regressions in Table 4. Moreover, the $R^2$ are similar, which suggests that lagged variables provide a reasonable fit and some predictive power for currency betas. The primary differences are that change in country credit ratings is no longer significant when used in lagged form. This suggests that a country’s credit rating is contemporaneously correlated with exchange rate risk, but it does not have significant predictive power for exchange rate

---

20 We also include variables lagged two periods in the regressions but find that they are never significant.

21 The sample size of 259 in the lagged regression is smaller than the 260 observations in the contemporaneous regressions because of slightly different missing macroeconomic variables. Selecting only those years without missing variables does not qualitatively change our results.
risk in the future.  Similar results are obtained when levels of credit ratings are used. Exports and imports still have the expected signs in all specifications, and they are significant in all the regressions except the one with country dummies only (Column (3) of Table 5). Thus higher exports may be used to predict higher exchange rate betas, while higher imports may be used to predict lower exchange rate betas. We also find that taxes continue to have a coefficient that has the expected positive sign and is statistically significant at the 5% or 1% level throughout all specifications.

Using the level of credit ratings rather than the difference also produces an insignificant coefficient in the lagged regressions, and gives us similar results for the other coefficients.

Table 5
Explaining exchange rate betas using lagged macroeconomic variables: GLS regressions

<table>
<thead>
<tr>
<th></th>
<th>GLS regression with year dummies</th>
<th>GLS regression with country dummies</th>
<th>GLS regression with year and country dummies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imports_1/GDP_1</td>
<td>–10.582***</td>
<td>–10.195***</td>
<td>–1.331</td>
</tr>
<tr>
<td></td>
<td>(–5.752)</td>
<td>(–5.810)</td>
<td>(–0.473)</td>
</tr>
<tr>
<td>Exports_1/GDP_1</td>
<td>8.712***</td>
<td>8.005***</td>
<td>2.381</td>
</tr>
<tr>
<td></td>
<td>(4.963)</td>
<td>(4.615)</td>
<td>(0.719)</td>
</tr>
<tr>
<td>Inflation_1</td>
<td>1.874</td>
<td>0.008</td>
<td>–0.276</td>
</tr>
<tr>
<td></td>
<td>(1.147)</td>
<td>(0.003)</td>
<td>(–0.181)</td>
</tr>
<tr>
<td>Government surplus_1/GDP_1</td>
<td>(0.146)</td>
<td>(–1.098)</td>
<td>(0.250)</td>
</tr>
<tr>
<td>Taxes_1/GDP_1</td>
<td>1.713**</td>
<td>1.829**</td>
<td>12.707***</td>
</tr>
<tr>
<td></td>
<td>(2.336)</td>
<td>(2.159)</td>
<td>(3.216)</td>
</tr>
<tr>
<td>Δ Credit rating_1</td>
<td>0.178</td>
<td>–0.959</td>
<td>-2.138</td>
</tr>
<tr>
<td></td>
<td>(0.067)</td>
<td>(–0.299)</td>
<td>(–0.877)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>259</td>
<td>259</td>
<td>259</td>
</tr>
<tr>
<td>Wald test for joint significance of lagged imports and exports</td>
<td>35.916***</td>
<td>39.222***</td>
<td>0.532</td>
</tr>
</tbody>
</table>

This table reports the results of regressing estimated exchange rate risk (Table 2) on selected lagged macroeconomic variables for 16 OECD countries for 1980–1997. Imports, exports, and government surplus are all scaled by GDP as indicated. Inflation is the difference in log of CPI. Δ Credit rating is change in the log of the credit rating given by Institutional Investor. The columns are: (1) a simple pooled regression, (2) a regression with year dummies, (3) a regression with country dummies, and (4) a regression with both year and country dummies. The results are from unbalanced panels because the countries have slightly different sample sizes. The GLS regressions are estimated through a two-stage procedure. For each model specification, the residual variance is assumed to be given by \( \sigma^2 = \exp(Z\gamma) \), where the Z’s are all the right-hand side variables and the \( \sigma^2 \)’s are estimated from a first-pass OLS regression of that specification. The results are from unbalanced panels because the countries have slightly different sample sizes. The \( t \)-statistics are in parentheses. The Wald test follows a \( \chi^2 \) distribution.

** Significance at the 5% level.
*** Significance at the 1% level.
Similar to the interpretation for the contemporaneous regressions, this result may imply that investors in higher tax countries require higher premiums as well.

In summary, we find that imports, exports, credit ratings, and tax revenues are important variables in explaining currency risk, and that these results are consistent under alternative specifications.

5. Conclusion

Using weekly exchange rates and stock index returns for a sample of 16 OECD countries, we estimate a conditional two-factor model with the world equity market index and a trade-weighted currency index as risk factors. We find significant time-varying currency betas for country equity index returns. We then explain these time-varying exchange rate betas using several country-specific macroeconomic variables, including imports, exports, credit ratings, taxes, inflation, and government surplus.

While other researchers have shown that currency risk is significant in explaining international equity returns, in this paper we investigate what determines currency risk exposures. Our findings show that equity index returns have significant exchange rate risk exposures which are related to a country’s macroeconomic aggregates. As expected, we find that higher exports are associated with a more positive exposure to exchange rate depreciation, while higher imports are associated with a more negative exposure. Furthermore, our results demonstrate that countries with an improved credit rating have a reduction in exchange rate risk exposure, and that higher taxes are associated with higher currency risk exposure. We find mixed evidence for inflation and government surplus in explaining exchange rate risk. Regressions using lagged values of the same set of right-hand side variables yield similar results, which suggest that these variables may be useful in predicting exchange rate risks in the future as well.

The significant coefficients in both the contemporaneous and lagged variables suggest that these regressions may be useful to both investors and policy makers to help predict to what degree currency price variation is a risk factor for a particular country’s stock market. The findings may also be useful for portfolio managers interested in global asset allocation or investors trying to hedge against foreign exchange risk. Similarly, corporations with significant foreign operations may be able to use a country’s macroeconomic conditions to predict currency risks. Lastly, government policy makers may play a role in influencing currency risks and equity returns through the use of macroeconomic policy.

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