Expected Returns, Risk and the Integration of International Bond Markets

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Abstract

In this paper we model the expected returns and risk of international bond markets. We make no assumptions about the extent of bond market integration and thus allow national bond market to be partially integrated into world bond markets. Using a conditional asset pricing model which allows for variation in the prices and quantities of risk, we ¯nd strong evidence that bond markets are only partially integrated into world bond markets. Around one quarter of total expected returns is due to time-varying expected return that is related to local market risk. The remaining expected return is due to time-varying world bond market risk. A number of robustness checks con¯rm our main results. Given the importance of measuring expected returns, we illustrate the di®erence in expected returns that can be generated from models that make di®ering assumptions about the extent of integration. These di®erence can be quite substantial.

Keywords: Partial Integration, expected returns, conditional asset pricing, bond markets.

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1 Introduction

There is a substantial body of empirical evidence that indicates returns on tradable assets are predictable. While US stock returns have been the focus of initial investigations, more recent evidence has indicated that this phenomenon is common across US bond markets and international stock and bond markets.[1] These results are usually interpreted in terms of predictable risk premia, and numerous studies have attempted to explain predictability by considering asset pricing models that allow expected returns to vary over time. It is also widely accepted that returns in domestic stock and bond markets can be predicted not only by domestic instruments but by a set of world instruments as well.[2] The significant role of world instruments is usually explained in terms of financially integrated capital markets. However, international asset pricing models, in which the world is treated as a single integrated market, have generated mixed results (see, for example, Campbell and Hamao (1992), Harvey (1991), and Bekaert and Harvey (1995)).

The relatively poor performance of international asset pricing models may be due to overly restrictive specifications. To date, tests of models with time-varying expected returns have concentrated on either of two polar cases: capital markets are assumed to be either completely segmented, or completely integrated (for interesting exceptions to this see Bekaert and Harvey (1995, 1997) and Errunza and Losq (1985)). Such restrictive specifications contradict the established evidence that returns can be predicted by both local and world instruments. Predictability by both sets of instruments would seem to suggest that the appropriate asset pricing model should allow for the influence of both local and world information. Uncovering the appropriate asset pricing model is important since an adequate account of the way in which expected returns in the major international markets are generated is important for, amongst other things, the calculation of the cost of

[1] See Campbell (1987, 1991), Campbell and Shiller (1988), Fama and French (1988, 1989), and Keim and Stambaugh (1986) on US stock returns and Evans (1994), Fama and French (1989), and Keim and Stambaugh (1986) on US bond returns. Harvey (1991), Bekaert and Harvey (1995) and Solnik (1990) provide evidence that various non-US stock returns are predictable.

[2] For stock returns see Harvey (1991), Bekaert and Harvey (1995) and for bond returns see Ilmanen (1995).

capital, for asset allocation, and for performance measurement. Failure to model expected returns in these markets adequately can have important and far reaching implications.

The bond market is an extremely important asset class with a aggregate market value signi¯-cantly greater than that of the stock market. However, much less attention has been paid to the risk and return structure of bond markets, especially with respect to the increasingly important area of international asset pricing. The recent relaxation of many barriers to international investment and consequent diversi¯cation opportunities available to investors makes the assessment of risk and return in international bond markets an important area of research that, to date, has to a large extent been ignored. Ilmanen (1995) approaches the issue of assessing international bond market risk and return by assuming that local bond markets are completely integrated. Our approach is di®erent in that we do not impose this restrictive assumption on the data, but rather, allow for an empirically richer speci¯cation of the risk return relationship. As we shall see, this is an important development in fully understanding the risk return relationship of bond markets.

The contribution of this paper is to develop a relatively simple empirical model that allows for conditional time-varying expected returns from both local and world sources of risk. We develop an empirical conditional asset pricing model with time-varying expected returns that nests the polar cases of complete integration and complete segmentation. Focusing on data from a number of bond markets (Canada, Germany, Japan, the U.K. and the U.S.), we allow sources of risk associated with world bond markets to compete with local sources of risk in explaining expected returns.

We present a number of new results. First, we show that the local bond markets are less than fully integrated into world markets. On average local risk accounts for around 25% of total expected returns. Second, time variation in expected returns appears to be driven by variation in the price of risk and by changes in the conditional second moments of returns. We clearly reject a version of the model that assumes prices of risk are constant. Third, we present a number of robustness tests of the estimated model which indicate that our preferred empirical model out-performs a number of alternatives. Fourth, a comparison of expected returns from the partially integrated model and a model that assumes complete integration illustrates the substantial differences that can be generated between the two series depending on the assumption made regarding the extent of integration. This is clearly important for issues such as asset allocation, risk-return measurement and portfolio performance measurement.

The rest of the paper is organised as follows. Section 2 discusses the theoretical foundations of the models we estimate and describes our strategy for investigating them. Section 3 describes the data and examines the predictability of local bond markets using small sets of local and world instruments. Section 4 reports estimates of our empirical model and a range of diagnostic test. Section 5 concludes.

2 Methodology

2.1 The asset pricing framework

We assume that observed excess returns, $\tilde{r}_{i,t}$, can be represented by the following equation:

$$\tilde{r}_{i,t} = a_i + b_i^W Z_{t-1}^W + b_i^L Z_{i,t-1}^L + \epsilon_{i,t} \quad (1)$$

where Z^W represents world variables, Z_i^L represents local variables for country i and $\epsilon_{i,t}$ is an error term. Thus we assume that excess returns are linearly related to sets of world and local variables, and that the relationship is not time varying, that is, that the coefficients a, b are constant.

This equation is consistent with a wide range of asset pricing models, and we use it to test some of these below. At this level of generality, however, we can distinguish integrated from segmented markets' equations. If a market is fully integrated the local variables should be absent from equation (1). Similarly, if it is completely segmented, the world variables should be absent. Clearly, if the two sets of variables are not mutually orthogonal we are likely to find it difficult to obtain statistically insignificant coefficient estimates where we expect them. Similarly, simply estimating the equation with either set of variables omitted can tell us nothing about the level of integration, see Campbell and Hamao (1992). We address this problem when we test the robustness of our preferred model.

We estimate equation (1) for a number of countries and find that there are sets of variables that can account for significant amounts of the variation in observed returns. Furthermore, we find that both world and local variables appear to play a role in determining local returns. The challenge for asset pricing theory is to explain the presence of these variables in equation (1) in as simple a way as possible without doing significant damage to the statistical properties of the estimated equation (1). Our strategy is to place restrictions on our estimated versions of this equation and to check their validity by testing for orthogonality between the regressors and residuals of the restricted equations. The regressors and residuals in the unrestricted equations are orthogonal by construction. If they are not orthogonal in the restricted equations, there is clearly some useful information in the regressors that has been forced out of the equation by the restrictions.

There are many asset pricing theories that can be used to account for the presence of explanatory variables in markets that are fully integrated; all single-market CAPM, ICAPM and APT models fall loosely into this category. Thus we can set up simple domestic models to account for returns on domestic portfolios, and world models to account for returns on world portfolios with domestic returns determined by their correlation with returns on the world portfolio. The theoretical foundations of these models do not, however, allow them to be extended in a simple way to partially integrated markets.

A number of papers have attempted to develop more or less ad hoc explanations for the presence of both world and local variables in (1). In this paper we adopt the model of Bekaert and Harvey (1995) which is based loosely on the CAPM. As those authors acknowledge, their model "is not directly implied by any current asset pricing theory". Thus our results inherit the same theoretical limitations as theirs. The contribution of our results is to show that a relatively simple model, with the ad hoc assumptions of Bekaert and Harvey, is capable of explaining a significant proportion of the variation in bond returns. Thus our results suggest that, for bond markets at least, a valuable avenue for future research would be to investigate the relationship between their assumptions and generally accepted theory.

We assume that if markets were fully integrated, and if exchange rates were fixed (or purchasing power parity holds), the returns in country i will be generated by the following version of the conditional international CAPM model

$$\tilde{r}_{i;t} = \lambda_{b;t-1} \mathrm{cov}_{t-1}(\tilde{r}_{b;t}; \tilde{r}_{i;t}) + e_{i;t} \tag{2}$$

where $\lambda_{b;t-1}$ represents the conditional world price of covariance risk, cov_{t-1} is the conditional-covariance operator, $\tilde{r}_{b;t}$ is the excess return on the world bond market portfolio and $e_{i;t}$ is an error term. Conversely, if market i were completely segmented we would then have

$$\tilde{r}_{i;t} = \lambda_{i;t-1} \mathrm{var}_{t-1}(\tilde{r}_{i;t}) + e_{i;t} \tag{3}$$

where $\lambda_{i;t-1}$ is the local bond market price of risk. It is intuitively plausible, though not established theoretically as yet, that if market i is partially integrated, its return will be governed by

$$\tilde{r}_{i;t} = \theta_{i;t-1} \lambda_{b;t-1} \mathrm{cov}_{t-1}(\tilde{r}_{b;t}; \tilde{r}_{i;t})) + (1 - \theta_{i;t-1}) \lambda_{i;t-1} \mathrm{var}_{t-1}(\tilde{r}_{i;t})) + e_{i;t} \tag{4}$$

where θ_i is interpreted as a measure of the degree of integration.

In the CAPM, the market portfolio should contain all assets. In tests of the CAPM using stock market data a stock index is chosen as a proxy for the market portfolio. Ilmanen (1995) shows that a version of the CAPM with a stock portfolio proxying the market portfolio performs poorly when measuring the risk and return of international bond markets. The interpretation placed on this finding is that bond markets are either segmented from stock markets and therefore a stock market portfolio is inappropriate, or alternatively bond markets are driven by a multifactor model in which bonds have zero sensitivity to the stock market portfolio and significant sensitivity to the bond portfolio which captures interest rate risk. Another explanation may be that a stock market portfolio is simply no longer mean-variance efficient when bonds are included in the investment opportunity set, whereas a world bond market portfolio is mean-variance efficient for local bond markets. Furthermore, if bond and stock markets are segmented then a separate CAPM for bonds, with a mean-variance efficient proxy for the bond market portfolio would be required. In our empirical work we estimate a version of the CAPM using a bond index to proxy the market portfolio. This captures a number of potential versions of the asset pricing model. Later, we test the robustness of the result to the use of a stock market proxy for the market portfolio.

2.2 Estimation strategy

There are several parameters that require estimation in order for us to uncover the price of risk, quantity of risk and the level of integration. Let r_t be a N vector of individual country bond excess returns and the N^{th} excess return is the excess return on the world bond index:

$$r_t = [r_{i,t}, r_{b,t}]' . \tag{5}$$

$$\tilde{r}_{i,t} = \theta_i(\lambda_{b,t-1}\mathrm{cov}(\tilde{r}_{b,t}, \tilde{r}_{i,t})) + (1-\theta_i)\lambda_{i,t-1}\mathrm{var}(\tilde{r}_{i,t}) + e_{,t} \tag{6}$$

$$\tilde{r}_{b,t} = \lambda_{b,t-1}\mathrm{var}(\tilde{r}_{b,t}) + e_{b,t} \tag{7}$$

$e_t = [e_{i,t}, e_{b,t}] \mid X_{t-1} \sim N(0, H_t)$ is the vector of error terms and H_t is the conditional variance-covariance matrix of excess returns. When markets are completely integrated the final term in (6) disappears and aggregation leads to equation (7). A common assumption made in the finance literature is that the conditional second moments of excess returns follow a GARCH(1,1) process (see Baba, Engle, Kraft and Kroner (1989) (BEKK)):

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B \tag{8}$$

where C is a $(N \times N)$ symmetric matrix and A and B are $(N \times N)$ matrices of constant coefficients. It is common to place restrictions on H_t in order to ease computations. Following Bollerslev, Engle and Wooldridge (1988) and De Santis and Gerard (1997, 1998) for example, we assume that the variances depend only on lagged squared errors and lagged conditional variance, and the covariances depend upon cross-products of lagged errors and lagged conditional covariances. That is, we impose the assumption that A and B are diagonal matrices.[3]

The final step in completing the model is to specify a process for the evolution of conditional prices of risk. There is now extensive evidence that prices of risk time vary according to a set of instrumental variables (see, for example, Campbell (1987), Harvey (1991), Bekaert and Harvey (1995) and De Santis and Gerard (1997, 1998)). Consequently, we let:

$$\lambda_{b;t-1} = \exp\left(\kappa_W' Z^W_{t-1}\right) \tag{9}$$

$$\lambda_{i;t-1} = \exp\left(\delta_i' Z^L_{i;t-1}\right) \tag{10}$$

The functional form of $\lambda_{b;t-1}$ and $\lambda_{i;t-1}$ is dictated by the implications of the theoretical model. Under risk aversion, the prices of risk $\lambda_{b;t-1}$ and $\lambda_{i;t-1}$ are positive (see Merton (1980)). In order to ensure that this restriction is satisfied, we assume that $\lambda_{b;t-1}$ and $\lambda_{i;t-1}$ are exponential functions of the instruments.

The parameters of interest are estimated first using the SIMPLEX algorithm and then by maximum likelihood (ML) assuming conditional normally distributed errors. The log-likelihood function is:

$$\ln L(\theta) = -\frac{TN}{2}\ln 2\pi - \frac{1}{2}\sum_{t=1} \ln |H_t(\theta)| - \frac{1}{2}\sum_{t=1} \varepsilon_t(\theta)' H_t(\theta)^{-1} \varepsilon_t(\theta) \tag{11}$$

where θ is a vector of parameters to be estimated. If there is evidence of non-normality in the model's residuals we can provide Quasi-ML (QML) estimates, as proposed by Bollerslev and Wooldridge (1992), which are robust to departures from normality.

[3] De Santis and Gerard (1997) find strong support for this parameterisation of the matrices A and B.

2.3 Measures of market integration.

In investigating bond market integration we test whether the integration weights for each country are significantly different from zero (the value which implies completely segmentation). An estimate of 1 implies that the market is completely integrated. Where $0 < \mu_i < 1$ we conclude that the local bond market is partially integrated into the world market. We hold the county-specific values of the integration parameter μ_i constant across sample periods in all models.

We also test for orthogonality between the local residuals and the two sets of information variables. A rejection of orthogonality with respect to either set would indicate a deficiency in the model as a whole. As an additional test of the model we estimate a version of the model that assumes $\mu_i = 1$; that is, that local markets are completely integrated. Under the assumption that local bond markets are completely integrated the models' residuals should be orthogonal to the local instruments. Failure of this condition implies some segmentation, conditional on our having found the correct set of world instruments.

In order to examine the relative performance of the integrated and partially integrated models we examine the statistical properties of their implied expected returns. Also, for each model, we perform a number of diagnostic tests of the models residuals.

3 Data and Predictability

3.1 Bond Returns

Our sample consists of local bond market data from Germany (BD), Canada (CN), Japan (JP), the UK and the US. For local bond returns we use J.P. Morgan Government Bond Return Indices which are based on weighted portfolios of liquid bonds. For the world bond market, we use data from the Salomon Brothers World Weighted Index. Excess returns are calculated relative to the appropriate 1-month Euro-deposit rate quoted in London.[4] The predictability of international

[4] Euro-deposit rates are used as a proxy for the risk free rate due to the lack of a liquid treasury bill market in some of the countries. The excess return on the world index is calculated with reference to the rate on $US deposits.

stock returns is usually analysed in terms of US dollars. The predictability of bond returns, however, is usually analysed using local-currency returns since the volatility of exchange rates greatly exceeds that of interest rates (see Dumas and Solnik (1995), Chan, Karolyi and Stulz (1992)). Analysing predictability of dollar adjusted bond returns may produce more evidence on the predictability of exchange rates than of bond returns. Therefore we measure returns in home-currency units.[5]

Panel A of table 1 reports summary statistics for excess returns over the period January 1986 to June 1996. The mean excess return, in percent per month, ranges from 0.0761% in Germany to 0.1982% for the world index. With the exception of the UK and Germany, the means and standard deviations are very similar; the average mean excess return is around 0.2% per month with a standard deviation just over 1%. In contrast, the UK has a standard deviation of over 2% and a mean excess return of 0.132%. A similar picture emerges for Germany which, while having a lower mean excess return, has a relatively high standard deviation. Normality tests indicate that, unlike the general case of stock returns, the excess bond returns are normally distributed.

These patterns in the excess returns are reflected in both the autocorrelation coefficients and the correlations across countries. The highest correlation is between Canada and the US, which have similar summary statistics and show no evidence of first order autocorrelation. The UK and Germany have the second highest inter-country correlation, and both exhibit evidence of significant first order autocorrelation. All the local excess returns are fairly highly correlated with the world excess return, the cross sectional average correlation is 0.74 providing weak evidence of integration. Interestingly, the world bond market unconditionally dominates all of the local markets in terms of the level of return given the level of risk.

[5] Using local currency excess returns provides perfectly hedged portfolios and as such, even in the presence of deviations from purchasing power parity and exchange rate risk premiums significantly different from zero, we can ignore potential exchange rate risk in the estimation.

3.2 The Instruments

There have been many empirical studies of predictability in stock returns (see references in footnote 1). Significantly less attention has been paid to bond returns. Fama and French (1989) and Kiem and Stambaugh (1986) however, document the presence of common predictability in both US stock and bond markets. This common predictability implies that instruments found to be useful in predicting stock market returns should be useful in predicting bond market returns (see Ilmanen (1995)).

The local instruments for our study are the difference between the yield on long term government bonds and the equity market dividend yield, the stock market excess return, the spread between the yield on long term and short term interest rates, past bond returns and a constant. The world instruments are the difference in the world bond market yield and the world equity market dividend yield, the returns on the world bond and stock market indices, the yield spread between world bond market and the $US deposit rate and a constant.[6] Panel B of table 1 reports summary statistics for the world instrument set. As would be expected given the difference in standard deviations, the stock market excess return is greater than the bond market excess return. The spread between the long bond and the short rate is positive as is the difference in the yield on equity and the yield on bonds. The correlation matrix of the instruments indicates that the correlations are reasonably low and, therefore, that the instruments are not redundant.[7]

3.3 Predictability

We investigate the extent and sources of predictability in local bond markets by estimating equations that include both local and world instruments:

[6] Details of the instruments are as follows. Bond yields are the J.P. Morgan redemption yields on the bond indices used to calculate excess returns. Stock market returns and dividend yields are from Datastream total market indices (these are preferable to the Morgan Stanley indices because, unlike the Morgan Stanley indices, they have total market coverage). All short term rates are 1 month eurocurrency rates quoted in London. All data are collected from Datastream International.

[7] The summary statistics for the local instruments have similar characteristics as the global instruments. Corresponding tables for the local instruments are available on request.

$$\tilde{r}_{i,t} = a_i + b_i^W Z^W_{t-1} + b_i^L Z^L_{i,t-1} + \epsilon_{i,t} \tag{12}$$

We test first the hypothesis that the coefficients associated with the local and world variables respectively are zero, then the hypothesis that the coefficients are jointly zero. The results are reported in Table 2.[8]

For all countries we can reject the null hypotheses that both sets of instruments can be excluded, that is, we should include at least one set. Adjusted R^2 ranges from 4% in the US to 14% in Germany. For Japan we cannot reject the hypothesis that the local instruments should be omitted conditional on the world instruments being included although in this case it is marginal. For the US we can reject both sets of instruments conditional on the other remaining.

We also report estimated equations for local returns based on the world and local subsets of instruments separately. The evidence indicates clear patterns of predictability in all the local bond markets using local instruments. The $\bar{R}^2$s range from 3.672% in Canada to 11.194% in the UK. The instruments in Germany, Japan, the UK and the US are jointly significant at conventional levels while the Canadian instruments are significant at the 7% level. In contrast to the local predictor models, the $\bar{R}^2$s of the world models are generally lower (2% to 9%). The F-tests reveal that the instruments are jointly significant at 5% in Germany, Japan and the US, and at the 15% in the UK and Canada. Overall, this section of the paper demonstrates that a small set of both local and world instruments is able to predict local bond returns. The regression $\bar{R}^2$s range from 2% to 14% and the models appear to be well specified. To summarise, there appears to be time variation in expected returns in all markets, and there is informal evidence of incomplete integration in all markets.

[8] Likelihood ratio and Lagrange multiplier tests confirm the results from the F-test, these are available on request. The lack of heteroscedasticity, ARCH effects and the apparent normal distribution of the returns (and residuals, available on request) does not require that we use a correction to the variance-covariance matrix in these regressions. Consequently, inferences based on F-tests are reliable.

4 Estimation Results

The first model we estimate includes both local and world sources of risk, that is, we allow for zero, partial and full integration. We allow the quantities of risk to vary over time but we constrain the prices of risk to be constant. We then relax the constant restriction on the prices of risk. A number of robustness tests are carried out as well as comparisons of expected returns from various models.

4.1 Constant Price of Risk, Time-Varying Quantities of Risk

We estimate of the system of equations given in equations (6)-(8) for each of the local bond markets and the world bond market in two steps.[9] We first estimate the world equation and then impose these world estimates on the individual countries in a set of 5 bivariate regressions. We restrict the estimates of the world bond market price of risk, λ_b and the estimate of the coefficients in the conditional variance of the world market variance to be the same for all countries.

Maximum likelihood estimates and asymptotic standard errors are reported in panel A of table 3.[10] The world price of risk is estimated to be 15.707 and is statistically different from zero. There appears to be some variation in the world conditional variance. The second column of panel A reports the estimated integration weights which range from 0.714 in Germany to 0.952 in Canada. Thus all of the markets appear to be extensively integrated into world markets. The third column of panel A reports estimates of the local market price of risk. In no case is this significantly different from zero. It is, however, generally large with a large standard error. The remaining column of panel A report the estimates from the conditional variance and covariance

[9] Ideally we would like to estimate a system of six equations (5 countries and 1 world equation) jointly. Relative to a two-step estimator this would lead to more efficient estimates. Such procedures have been followed in models that assume complete integration (see, for example, Gerard and De Santis (1997, 1998)). However, in models that have both local and global instruments in the mean equations joint estimation becomes increasingly difficult. The number of parameters that would need to be estimated jointly in our model of partial integration, assuming a GARCH process in the conditional variance using Gerard and De Santis's specification would be 47. Their completely integrated model requires the estimation of only 17 parameters.

[10] Throught the estimation we report asymptotic standard errors since there appears to be no evidence of non-normality in the models residuals (see panel B of table 3). Consequently quasi maximum likelihood estimates are not necessary.

equations. There appears to be some variation in variances and covariances.[11] Overall, it appears from this model that local bond markets are reasonably well integrated into world markets, with no reward for bearing local risk. Some caution should be exercised in interpreting this result. The standard errors on the estimated local prices of risk are large which may be a result of time variation in the local prices of risk. In the light of this, residual analysis and diagnostic testing are extremely important.

Panel B of table 3 reports a set of diagnostic tests and residual analysis. The R^2s (defined as the fraction of total variation in excess returns explained by the model) range from 5.252 % in the world equation to a low of 1.084% in Japan, with an average of 3.016%. Tests for normality and serial correlation of the standardised and squared standardised residuals indicate that the residuals are normally distributed, serially uncorrelated and homoscedastic. Furthermore, using the positive and negative size and sign bias tests of Engle and Ng (1993) which search for asymmetries in conditional variances, we cannot reject the null hypothesis that the symmetric GARCH model fits the data well.

The final two columns of panel B report orthogonality tests of the models' residuals against the instruments. If the specified asset pricing model has adequately captured the risk-return relationship then each countrys' residuals should be orthogonal to both sets of instruments. To test this we estimate the following OLS regression:

$$e_{i;t} = a_{i0} + b_i Z^M_{t-1} + u_{it} \tag{13}$$

where the $e_{i;t}$ are residuals from the local-market regressions and M indicates local or world instruments. It is clear from these two columns that many of the residuals are not orthogonal to the instruments. The world residuals are not orthogonal to Z^W, suggesting that a constant price of risk model for the world market price of risk may be too restrictive. Of the individual countries

[11] Visual inspection of the conditional variances and covariances over time clearly reveals time variation. These plots are available on request.

residuals, 5 out of ten orthogonality tests reject at the 1% level and a further one rejects at the 9% level. This provides very strong evidence against the estimated model. One potential explanation for this rejection is the assumption that the price of risk is constant. Predictable behaviour in the residuals may simply be symptomatic of variations in the price of risk which have not been allowed in this section.

4.2 Time-Varying Price of Risk, Time-Varying Quantities of Risk

In order to account for more variation in the expected returns we now turn to estimation of the model with time-varying prices of risk. We now include, along with equations (6)-(8), equations (9) and (10) which model the prices of risk. The two-step estimation procedure then follows as in the previous model and the result are presented in table 4. The second row of panel A reports the estimates from the world equations. Several of the world instruments appear to be important in explaining world bond market expected returns suggesting time-varying expected returns. This is confirmed in Figure 1 which plots the time-varying price of risk for the world bond market. The estimates for the price of risk associated with the world bond market are often very high.[12]

The world price of risk is clearly time-varying. The time-varying nature of the price of risk is important to rationalise if the asset pricing model is to have empirical content. Fama and French (1989) argue that predictability is related to time variation in the price of risk because the instruments may pick up variations in the business cycle. Risk averse investors should require higher expected returns at times of high risk in the economy. Therefore, at times of recession the price of risk should be higher than at times of economic growth. Examination of figure 1 does reveal a counter-cyclical pattern with the business cycle. In Figure 2 we proxy the world business cycle using monthly year-on-year change in G7 industrial production; comparison with Figure 1 does indeed suggest a counter-cyclical pattern. The correlation coefficient between the two series is -0.41 providing clear evidence for the notion that investors preferences for consumption and

[12] However, the average of 21.12 is close to the estimate from the constant price of risk model discussed earlier (see table 3).

investment vary over the business cycle.

In all countries the estimated integration weight is greater than 0 and less than 1 suggesting partial integration. The integration weights range from 0.573 in the UK to 0.963 in Japan. These estimates are quite similar to those in table 3 for the constant price of risk model. This evidence suggests less than full integration of bond markets. Furthermore, examination of panel A reveals that in all countries some of the local instruments are important in forecasting the local market price of risk. Therefore, panel B appears to reflect two observations that lead to the conclusion that markets are only partially integrated; namely estimates of integration weights less than one and statistically significant local instruments in the prediction of local prices of risk. Finally, from panel A the coefficients in the conditional variances and covariances reveals evidence of time-varying quantities of risk.

Panel B reports a series of residual diagnostics and tests of the estimated model. The R^2s are relatively high (compared with the constant price of risk model estimated in table 3, and with previous work on stock markets, see, for example, Harvey (1991) and De Santis and Gerard (1997)) ranging from 14.786 % in Japan to a low of 7.579% in the UK, with an average of 10%. This is substantially higher than the constant price of risk model. As in the case of the constant price of risk model, tests for normality and serial correlation of the standardised and squared standardised residuals indicate that the residuals are normally distributed, serially uncorrelated and homoscedastic. There is no evidence (except in the case of the US) of asymmetries in the conditional variance. Also reported in panel B is a test for a constant price of world and local risk and also a test of zero world and local price of risk. In all cases we reject the hypothesis of constant and zero prices of risk in favour of a time-varying positive price of risk for both the world bond market and the local bond markets. The final two columns of panel B report orthogonality tests of the models' residuals against the instruments. Unlike the constant price of risk model where there are six rejections of the orthogonality tests, we reject orthogonality in only 1 case - the local instruments in the UK's residuals.

The model presented in this subsection with time-varying prices of risk, according to the tests in panel B, clearly provides a better description of returns than the constant price of risk model. Furthermore, from the statistics and tests presented it is reasonable to suggest that these bond markets are not fully integrated into world bond markets. We attempt to assess the contribution of both local and world risk to total expected returns in each local bond market. To do this we decompose expected returns into that due to local risk and that due to world risk. The ratio of local risk to total risk is reported in panel C of table 4. This ratio is always greater than 0 indicating less than full integration (the average value amongst the five countries is 26%). Therefore, around one quarter of the variation in local bond markets seems to be driven by local market conditions than impact on either, or both, local quantities of risk and local prices of risk. Whatever the source of this variation in expected returns due to local risk, it clearly effects total expected returns and hence decision making that is conditioned on such measures of expected returns. Given the importance of calculating expected returns in decision making the next section addresses the robustness of our results.

4.3 Robustness-Tests for Partial Integration

4.3.1 A Model of Complete Integration

The inability of the local instruments to predict the local residuals has been interpreted as evidence that their influence is adequately captured by allowing them to enter the model through the local price of risk. An alternative explanation for the orthogonality results is simply that the local markets make no marginal contribution to the model at all, and that their presence is due to their correlation with the world instruments, combined with potential small sample inefficiencies of the estimation.

To assess this we estimate a version of the model that assumes complete integration. The estimation process involves two steps as above. The first step has already been completed: we have the estimates from the world equation in table 4. We now take these estimates and estimate

5 bivariate equations:

$$\tilde{r}_{i,t} = \lambda_{b,t-1} \mathrm{cov}_{t-1}(\tilde{r}_{b,t}, \tilde{r}_{i,t}) + e_{us,t} \tag{14}$$

$$\tilde{r}_{b,t} = \hat{\lambda}_{b,t-1} \widehat{\mathrm{var}}_{t-1}[\tilde{r}_{b,t}] + e_{b,t} \tag{15}$$

where $\hat{x}$ denotes an estimate of x. We estimated the variance-covariance matrix as in equation (8). If this single-factor version of the model is correct, and local markets are completely integrated into world markets, the residuals from the local markets should be orthogonal to the local instruments. Results from estimating the fully integrated model are reported in table 5. Panel A reports estimates from the mean equation, panel B reports the residual analysis and tests of the model. Estimates of the parameters in the conditional variance and covariance are little changed. However, the diagnostic tests are somewhat sensitive to the assumption of full integration. The average R^2 for the 5 bond market falls to 7.13%, almost a third less than the average for the partially integrated model. In addition, considering the orthogonality tests, three of the local markets now fail the residual orthogonality test with respect to the local instruments. The fact that the performance of the fully integrated model decreases, coupled with the increase in rejections of orthogonality tests, reinforces the previous suggestion that partial integration is important.

4.3.2 Using a Stock Portfolio as the World Market Portfolio

We now assess whether a simple CAPM model with a stock portfolio can explain bond excess returns. In the estimation of the partially integrated model we replace the world bond portfolio with a world stock portfolio in equation (7) and estimate the equivalent model with time-varying prices of risk and quantities of risk. We briefly report some results from this estimation (detailed results, as set out in table 4 are available on request). Interestingly the impact of using the stock index as a proxy for the market portfolio has the greatest effect on the orthogonality tests. The equivalent model with a bond market portfolio led only to one rejection of the orthogonality tests.

Now, at a 10% level of significance we reject in 6 out of the 10 cases. This is mirrored in the R^2 which fall on average by 20%. Clearly, the model with a bond market portfolio provides a better description of the risk-return relationship than the same theoretical structure with a stock-based market portfolio.

4.4 A Comparison of Expected Returns from Fully and Partially Integrated Models

In this section of the paper we illustrate further the difference between models that assume full integration and those that assume partial integration. In a fully integrated bond market the expected returns, while having different means and variances, should be perfectly correlated. Figure 3 plots the expected returns from the fully integrated model. The correlations amongst the expected returns are 0.99 between the US, Japan, Germany and Canada whilst the correlations with the UK are all around 0.60. In contrast to these results, figure 4 plots the expected returns from the partially integrated model. There is clearly much less correlation between these markets because of the influence of local risk on the expected returns. Table 6 confirms this by producing the correlation coefficients between the expected returns from the partially integrated model. The highest correlation is 0.797 between Canada and Germany and the lowest is 0.156 between the UK and Japan and the average is 0.4. It is evident that the partially integrated expected returns have substantial amounts of variation unrelated to each other which is due to local risk. This particularly important feature of the data is not picked up by a model that assumes perfect integration.

5 Conclusion

This paper has provided the first attempt to assess the extent of integration in international bond markets. Using a model originated in Bekaert and Harvey (1995) to examine integration in stock markets, we find clear evidence in favour of partial integration, and against the two alternatives of zero or complete integration in bond markets. We find clear evidence that sets of local and world instruments can influence local bond returns. We believe that our model provides an intuitively plausible mechanism by which the instruments can influence returns, and find that this mechanism cannot be statistically rejected. These results imply that diversification among local bond markets is a conditionally optimal strategy.

We provide a battery of diagnostic tests and robustness tests of our model. Whilst we find numerous rejections for models that assume constant prices of risk or complete integration or use a stock market index as the benchmark portfolio, rejections of these tests are very rare for the partially integrated model. We find approximately 25% of the total expected return of local bond markets is due to local risk whilst the remainder is due to world risk. We show that there are significant differences in the time variation of expected returns derived from the model that assumes partial integration and one that assumes complete integration. Clearly this will have important implications for those who require measures of expected returns in order to make decisions.

Our results suggest several avenues for future research. In particular, while the model appears to provide a good description of the data, is intuitively plausible, and is closely related to others in the literature, it's theoretical foundations have still to be developed: the model's empirical performance provide an incentive for this development to take place. Also, we have not attempted to investigate the way in which integration may change over time: with more data this should prove to be a straightforward and interesting exercise.

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Table 1

Summary Statistics

Panel A: Excess Bond Returns

	WD	US	UK	JP	BD	CN
Mean	0.1982	0.1754	0.1192	0.1921	0.0586	0.2036
Standard Deviation	1.1317	1.3584	2.1396	1.4850	1.1400	1.8681
Max	3.4003	3.3731	6.3541	4.2443	2.1591	3.4000
Min	-2.0476	-2.9943	-7.3622	-4.2418	-3.9374	-2.4768
ρ_1	0.2121*	0.1345	0.1818*	0.1632**	0.1683*	0.0700
N $\chi^2(2)$	0.859 [0.65]	0.089 [0.96]	2.514 [0.28]	2.693 [0.26]	5.481 [0.06]	0.556 [0.76]

Correlation Matrix

WD	1.0000					
US	0.8905	1.0000				
UK	0.6883	0.4419	1.0000			
JP	0.6501	0.3842	0.4125	1.0000		
BD	0.7083	0.4801	0.6325	0.4992	1.0000	
CN	0.7541	0.7415	0.5260	0.3884	0.4487	1.0000

Panel B: World Instruments

	WD	WERSM	WBSP	WGEYR
Mean	0.1982	0.5423	0.0972	0.4346
Standard Deviation	1.1317	4.1703	1.1789	0.0690
Max	3.4003	10.3317	3.2311	0.6058
Min	-2.0476	-16.2311	-1.5111	0.3061
ρ_1	0.2121*	0.1345	0.1818*	0.1632**
	Correlation Matrix			
WD	1.0000			
WERSM	0.2937	1.0000		
WBSP	0.0200	-0.0171	1.0000	
WGEYR	-0.2256	-0.1924	-0.4783	1.0000

Notes: The statistics are based on monthly data from 1986:02 to 1996:06. The returns are calculated in local currency at the end of month in excess of the individual countries beginning of 1 month euro-deposit rate. The returns for the individual countries are from J.P. Morgan bond return indices. The return for the world bond index is from Salomon Brothers. WD denotes the world bond index, JP denotes Japan, BD denotes Germany and CN denotes Canada. WERSM denotes the excess return on the world stock market, WBSP denotes the spread between the yield on long term world bonds and the 1 month US euro dollar rate, WGEYR is the spread between the world stock market dividend yield and the world long term bond market yield. ρ_1^* denotes the first order autocorrelation coefficient. $N\chi^2(2)$ denotes the Bera-Jarque test statistic for normality. * indicates statistically significant at the 5% level, ** indicates statistically significant at the 10% level.

Table 2

Predicting Local Bond Returns Using Local and world Instruments

	BD	CN	JP	UK	US	WD
world and local instruments						
$\bar{R}^2$	14.247	12.793	8.930	10.573	4.265	
F-test exclude Z^L_{t-1}	2:754 [0:02]	4:227 [0:00]	1:827 [0:12]	3:411 [0:01]	1:575 [0:17]	
F-test exclude Z^G_{t-1}	2:824 [0:03]	4:709 [0:00]	2:225 [0:05]	3:591 [0:01]	1:097 [0:36]	
F-test exclude Z^L_{t-1} and Z^G_{t-1}	3:246 [0:00]	3:136 [0:00]	2:527 [0:01]	2:589 [0:01]	1:814 [0:07]	
world instruments only						
$\bar{R}^2$	9.032	2.009	7.309	2.849	3.952	8.29
F-test exclude Z^L_{t-1} and Z^G_{t-1}	3:378 [0:01]	1:671 [0:15]	3:264 [0:01]	1:645 [0:15]	2:379 [0:04]	4:404 [0:00]
Local instruments only						
$\bar{R}^2$	7.358	3.671	7.761	11.194	4.05	
F-test exclude Z^L_{t-1} and Z^G_{t-1}	2:884 [0:02]	2:114 [0:07]	3:397 [0:01]	4:054 [0:00]	2:408 [0:04]	

Notes: The results are from the following OLS regression:

$$r_{it} = a + b_i^L Z^L_{i,t-1} + b_i^W Z^W_{t-1} + e_{it}$$

where r_{it} is a vector of local bond market returns, a is a constant, b_i^L is a vector of estimated coefficients associated with the local instruments, b_i^W is a vector of estimated coefficients associated with the world instruments, $Z^L_{i,t-1}$ is a vector of local instrumental variables specific to country i, Z^W_{t-1} is a vector of local instrumental variables and e_{it} is a vector of residuals. The world instruments include the spread between the yield on a portfolio of world long term government bonds and the 1 month US euro-deposit rate, the first lag of the world bond market return, the first lag of the world stock market return and the yield on long term government bonds minus the yield on the equity market. The local instruments include the spread between the yield on long term government bonds and the 1 month euro-deposit rate, the first lag of the local bond market return, the first lag of the local stock market return and the yield on long term government bonds minus the yield on the equity market. Statistics and test reported are: $\bar{R}^2$ which is the adjusted R^2; F-test is a test of the significance of the instruments. Probability values are in brackets.

Table 3

Partially Integrated Bond Markets:

Constant Price of Risk, Time-Varying Quantities of Risk

Panel A: Model Estimates

		¸b	a_0	a_1	a_2	
WD	-	15.707¤¤	1.1 E-4¤	0.008	0.3187¤¤	
	-	(8.15)	(1.2 E-5)	(1.31)	(0.14)	
	μ_i	¸i	c_0	c_1	c_2	d
US	0.761¤	3.416	1.5 E-4¤	0.026	0.463¤	1.1 E-4¤
	(0.23)	(9.38)	(2.7 E-6)	(0.14)	(0.03)	(3.1 E-6)
CN	0.952¤	-12.511	1.5 E-4¤	0.262¤	0.7236¤	1.3 E-4¤
	(0.16)	(7.75)	(1.6 E-6)	(0.05)	(0.05)	(4.8 E-6)
BD	0.714¤	-11.598	1.0 E-4¤	0.279¤	0.261	8.0 E-5¤
	(0.19)	(21.43)	(2.0 E-5)	(0.09)	(0.22)	(9.5 E-6)
JP	0.896¤¤	8.930	1.6 E-4¤	0.017	0.505¤	8.9 E-5¤
	(0.41)	(15.69)	(1.1 E-5)	(0.09)	(0.06)	(5.6 E-6)
UK	0.875¤	17.817	3.4 E-4¤	0.259¤	0.421¤	1.4 E-4¤
	(0.15)	(32.27)	(3.2 E-5)	(0.09)	(0.08)	(1.3 E-5)

Panel B: Residual Analysis

	Ŕ	N $\chi^2(2)$	H $\chi^2(12)$	S.C. $\chi^2(12)$	EN $\chi^2(3)$	OG	OL
WD	5:252	2:436	6.686	6.547	3.378	18.088	
		[0.30]	[0.88]	[0.89]	[0.34]	[0.00]	
US	5:128	1.099	8.633	9.376	3.915	6.066	4.893
		[0.58]	[0.74]	[0.67]	[0.27]	[0.30]	[0.43]
CN	1.867	0.483	11:856	7.649	1.722	4.125	5.174
		[0.78]	[0.46]	[0.81]	[0.63]	[0.53]	[0.40]
BD	2.444	1.549	12.709	7.909	2.574	17.180	18.138
		[0.46]	[0.39]	[0.39]	[0.46]	[0.00]	[0.00]
JP	1.084	3.489	11.765	5.185	2.866	17.881	17.534
		[0.18]	[0.46]	[0.95]	[0.41]	[0.00]	[0.00]
UK	2.318	1:084	15.025	6.029	0.520	9.360	27.353
		[0.58]	[0.24]	[0.91]	[0.91]	[0.09]	[0.00]

Notes: Panel A reports results from estimating the world bond market constant price of risk which is then imposed on each country and a bivariate model is estimated with the world and country i. The estimated model is a two step procedure. Step 1 estimates

$$\tilde{r}_{b,t} = \lambda_{b,t-1} var(\tilde{r}_{b,t}) + e_{b,t}$$

$$h_{b,t} = a_0 + a_1^2 e_{b,t-1}^2 + a_2^2 h_{b,t-1}$$

Step 2 estimates

$$\tilde{r}_{i,t} = \theta_i (\hat{\lambda}_{b,t-1} cov(\tilde{r}_{b,t}; \tilde{r}_{i,t})) + (1 - \theta_i) \lambda_{i,t-1} var(\tilde{r}_{i,t}) + e_{i,t}$$

$$\tilde{r}_{b,t} = \hat{\lambda}_{b,t-1} \widehat{var}(\tilde{r}_{b,t}) + e_{b,t}$$

where $\hat{x}$ is an estimate of x; $r_{i,t}$ is the excess return on the bond market of country i, $r_{b,t}$ is the excess return on the world bond index, θ_i is the level of integration of country i into world bond markets, λ_b is the world bond market price of risk, λ_i is the local market price of risk, cov and var are the variance and covariance operators, $e_t = [e_{i,t}, e_{b,t}] \mid X_{t-1} \sim N(0, H_t)$ is the vector of error terms and H_t is the conditional variance-covariance matrix of excess returns. The conditional second moments of excess returns are assumed to follow a GARCH(1,1) process:

$$h_{i,t} = c_0 + c_1^2 e_{j,t-1}^2 + c_2^2 h_{j,t-1}$$

$$h_{b,t} = a_0 + a_1^2 e_{b,t-1}^2 + a_2^2 h_{b,t-1}$$

$$h_{i,b,t} = d + c_1 a_1 e_{j,t-1}^2 + c_2 a_2 h_{j,t-1}$$

Panel B reports residual analysis and tests of the model. R^2 is the fraction of total variation in excess returns explained by the model, N is the Bera-Jarque test statistic for normality of the residuals, H is a test statistic for 12th order serial correlation of the squared standardised residuals, S.C. is a test statistic for 12th order serial correlation of the standardised residuals, EN is the Engle-Ng joint test for asymmetries in the conditional variance, OG is a Wald test that the residuals are orthogonal to the world instruments and OL is a Wald test that the residuals are orthogonal to the local instruments. * denotes statistically significant a the 1% level, ** denotes statistically significant a the 5% level, *** denotes statistically significant a the 10% level. Asymptotic standard errors are in parenthesis and probability brackets are in square brackets.

Table 4

Partially Integrated Bond Markets:

Time-Varying Price of Risk, Time-Varying Quantities of Risk

Panel A: Model Estimates

		$\cdot_0$	$\cdot_1$	$\cdot_2$	$\cdot_3$	$\cdot_4$	c_0	c_1	c_2	
WD	-	0.556¤¤¤	1.146	3.234¤	73.279¤	5.853¤	1.0E-4¤	0.006	0.355¤	
	-	(0.31)	(4.46)	(0.79)	(13.47)	(2.03)	(1.1E-5)	(0.29)	(0.13)	
	μ_i	$\pm_0$	$\pm_1$	$\pm_2$	$\pm_3$	$\pm_4$	c_0	c_1	c_2	d
US	0.692¤	-7.374¤	-14.759¤¤	26.416¤	-65.706¤	-27.446¤	1.4E-4¤	0.002	0.465¤	1.1E-4'
	(0.07)	(0.27)	(7.21)	(0.65)	(21.19)	(3.76)	(2.7E-6)	(0.86)	(0.03)	(1.1E-6
CN	0.754¤	-16.087¤	15.187¤	31.049¤	79.511¤	12.197¤	1.4E-4¤	0.161¤¤¤	0.739¤	1.1E-4'
	(0.21)	(4.88)	(5.85)	(8.03)	(25.07)	(4.16)	(2.9E-5)	(0.09)	(0.06)	(8.1E-6
BD	0.895¤	-3.478¤	-23.515¤	-3.280	-52.818	39.021¤	9.4E-5¤	0.2778¤	0.354¤	7.0E-5'
	(0.09)	(0.84)	(6.10)	(2.72)	(59.70)	(4.16)	(6.3E-6)	(0.07)	(0.15)	(4.1E-6
JP	0.963¤	-2.028¤	-39.707¤	4.092	5.775	85:827¤	6.0E-5	0.034	0.815¤	6.1E-4'
	(0.03)	(0.74)	(5.27)	(2.66)	(15.62)	(4.78)	(3.8E-5)	(0.19)	(0.13)	(1.0E-6
UK	0.469¤¤	-9..107	326.1¤	-322.1¤	407.3¤	6841:9¤	4.0E-4¤	0.023	0.116	1.5E-4'
	(2.17)	(6.72)	(123.6)	(107.8)	(114.3)	(2271.4)	(4.3E-5)	(0.41)	(0.27)	(1.8E-5

Panel B: Residual Analysis

	$\bar{R}^2$	N $\chi^2(2)$	H $\chi^2(12)$	S:C: $\chi^2(12)$	EN $\chi^2(3)$	C.P.R.	Z.P.R.	OG	OL
WD	12.125	0:609	1.721	5.141	4.849	104:44	183.86	4.912	
		[0.74]	[0.99]	[0.95]	[0.18]	[0.00]	[0.00]	[0.43]	
US	8:558	0.109	12.339	6.050	9.137	1746.18	2143.02	3.898	3.175
		[0.95]	[0.42]	[0.91]	[0.03]	[0.00]	[0.00]	[0.56]	[0.67]
CN	7.579	1.854	14:246	10.924	2.685	27:85	27.87	2.422	3.397
		[0.39]	[0.28]	[0.54]	[0.44]	[0.00]	[0.00]	[0.78]	[0.64]
BD	8.622	4.038	8.308	8.351	0.415	27.53	46.05	6.776	8.314
		[0.13]	[0.76]	[0.76]	[0.94]	[0.00]	[0.00]	[0.24]	[0.14]
JP	14.786	0.699	11.786	2.256	2.448	208.62	3185.62	5.471	6.656
		[0.70]	[0.46]	[0.99]	[0.48]	[0.00]	[0.00]	[0.36]	[0.25]
UK	14.904	4.239	9.853	11.654	3.610	19.225	149.55	2.568	17.917
		[0.17]	[0.63]	[0.47]	[0.31]	[0.00]	[0.00]	[0.76]	[0.00]

Panel C: Where Do Expected Returns Come From?

Ratio of Local to Total Expected Return	United States	Canada	Germany	Japan	United Kingdom
$\frac{\text{Local E(r)}}{\text{Total E(r)}}$	22.6%	29.3%	11.7%	39.2%	24.9%

Notes: Panel A reports results from estimating the world bond market price of risk which is then imposed on each country and a bivariate model is estimated with the world and country i. The estimated model is a two step procedure. Step 1 estimates

$$r_{b,t} = \lambda_{b,t-1} var(r_{b,t}) + e_{b,t}$$

$$\lambda_{b,t-1} = \exp\left(\delta_W' Z_{t-1}^W\right)$$

$$h_{b,t} = a_0 + a_1^2 e_{b,t-1}^2 + a_2^2 h_{b,t-1}$$

Step 2 estimates

$$\tilde{r}_{i,t} = \theta_i(\hat{\lambda}_{b,t-1}\mathrm{cov}(\tilde{r}_{b,t}, \tilde{r}_{i,t})) + (1-\theta_i)\lambda_{i,t-1}\mathrm{var}(\tilde{r}_{i,t}) + e_{i,t}$$

$$\lambda_{i,t-1} = \exp\left[\delta_i' Z^L_{i,t-1}\right]$$

$$\tilde{r}_{b,t} = \hat{\lambda}_{b,t-1}\widehat{\mathrm{var}}(\tilde{r}_{b,t}) + e_{b,t}$$

where $\hat{x}$ is an estimate of x; $\tilde{r}_{i,t}$ is the excess return on the bond market of country i, $\tilde{r}_{b,t}$ is the excess return on the world bond index, θ_i is the level of integration of country i into world bond markets, λ_b is the world bond market price of risk, λ_i is the local market price of risk, cov and var are the variance and covariance operators, exp denotes exponentiation, Z^W_{t-1} is a vector of predetermined world instruments where the coefficient vector is related to the instruments as follows: κ_0 is a constant, κ_1 is the excess return on the world stock market, κ_2 is the world stock market dividend yield minus the long term world bond yield, κ_3 is the excess return on the world bond market and κ_4 is the spread between the long term world bond market yield and the 1 month US euro dollar rate. $Z^L_{i,t-1}$ is a vector of predetermined local instruments specific to country i where the coefficient vector is related to the instruments are follows: δ_0 is a constant, δ_1 is the excess return on the local stock market, δ_2 is the local stock market dividend yield minus the long term local bond yield, δ_3 is the excess return on the local bond market and δ_4 is the spread between the long term local bond market yield and the 1 month local euro dollar rate. $e_t = [e_{i,t}, e_{b,t}] \mid X_{t-1} \sim N(0, H_t)$ is the vector of error terms and H_t is the conditional variance-covariance matrix of excess returns. The conditional second moments of excess returns are assumed to follow a GARCH(1,1) process:

$$h_{i,t} = c_0 + c_1^2 e^2_{j,t-1} + c_2^2 h_{j,t-1}$$

$$h_{b,t} = \hat{a}_0 + \hat{a}_1^2 e^2_{b,t-1} + \hat{a}_2^2 h_{b,t-1}$$

$$h_{i;b;t} = d + c_1 \hat{a}_1 e^2_{j;t-1} + c_2 \hat{a}_2 h_{i;b;t-1}$$

Panel B reports residual analysis and tests of the model. R^2 is the fraction of total variation in excess returns explained by the model, N is the Bera-Jarque test statistic for normality of the residuals, H is a test statistic for 12th order serial correlation of the squared standardised residuals, S.C. is a test statistic for 12th order serial correlation of the standardised residuals, EN is the Engle-Ng joint test for asymmetries in the conditional variance, C.P.R. is a Wald test for a constant price of risk, Z.P.R. is a test for a zero price of risk. OG is a Wald test that the residuals are orthogonal to the world instruments and OL is a Wald test that the residuals are orthogonal to the local instruments. Panel C reports the ratio of local expected returns to total expected returns. The local expected returns are calculated as $(1 - \theta_i)\lambda_{i;t-1} var(\tilde{r}_{i;t})$: * denotes statistically significant a the 1% level, ** denotes statistically significant a the 5% level, *** denotes statistically significant a the 10% level. Asymptotic standard errors are in parenthesis and probability brackets are in square brackets.

Table 5

Fully Integrated Model

Time-Varying Price of Risk, Time-Varying Quantities of Risk

Panel A: Model Estimates

	$\cdot_0$	$\cdot_1$	$\cdot_2$	$\cdot_3$	$\cdot_4$	c_0	c_1	c_2	d
WD	0.556¤¤¤	1.146	3.234¤	73.279¤	5.853¤	1.0E-4¤	0.006	0.355¤	
	(0.31)	(4.46)	(0.79)	(13.47)	(2.03)	(1.1E-5)	(0.29)	(0.13)	
US						1.4E-4¤	0.018	0.418¤	1.1E-4¤
						(3.5E-6)	(0.15)	(0.08)	(1.7E-6)
CN						2.4E-4¤	0.128	0.505¤	1.2E-4¤
						(1.1E-5)	(0.13)	(0.06)	(4.7E-6)
Bd						9.3E-5¤	0.265¤	0.356¤	6.9E-5¤
						(5.6E-6)	(0.08)	(0.11)	(4.4E-6)
JP						6.3E-5	0.049	0.876¤	6.3E-4¤
						(5.1E-5)	(0.32)	(0.02)	(3.8E-6)
UK						3.7E-4¤	0.287¤	0.356¤	6.9E-4¤
						(3.9E-4)	(0.19)	(0.11)	(4.4E-6)

Panel B: Residual Analysis

	$\bar{R}^2$	N $\chi^2(2)$	H $\chi^2(12)$	S.C. $\chi^2(12)$	E N $\chi^2(3)$	OG	OL
US	6:973	0.088	9.438	9.328	5.586	3.919	4.692
		[0.96]	[0.67]	[0.67]	[0.13]	[0.56]	[0.45]
CN	4.379	3.561	14:144	14.475	0.881	1.206	5.257
		[0.17]	[0.29]	[0.27]	[0.83]	[0.94]	[0.38]
BD	7.810	4.418	10.502	11.874	2.574	8.912	15.431
		[0.11]	[0.57]	[0.46]	[0.46]	[0.11]	[0.01]
JP	4.348	3.561	9.926	4.648	3.446	8.677	13.770
		[0.17]	[0.62]	[0.97]	[0.33]	[0.12]	[0.02]
UK	12.140	3.823	10.427	6.220	0.528	2.936	19.438
		[0.15]	[0.58]	[0.90]	[0.91]	[0.71]	[0.00]

Notes: Panel A reports results from estimating the world bond market price of risk which is then imposed on each country and a bivariate model is estimated with the world and country i. The estimated model is a two step procedure. Step 1 estimates

$$\tilde{r}_{b,t} = \lambda_{b,t-1} var(\tilde{r}_{b,t}) + e_{b,t}$$

$$\lambda_{b,t-1} = \exp\left(\kappa'_w Z^w_{t-1}\right)$$

$$h_{b,t} = a_0 + a_1^2 e^2_{b,t-1} + a_2^2 h_{b,t-1}$$

Step 2 estimates

$$\tilde{r}_{i,t} = (\hat{\lambda}_{b,t-1} cov(\tilde{r}_{b,t}, \tilde{r}_{i,t})) + e_{i,t}$$

$$\tilde{r}_{b,t} = \hat{\lambda}_{b,t-1} \widehat{var}(\tilde{r}_{b,t}) + e_{b,t}$$

where $\hat{x}$ is an estimate of x; $\tilde{r}_{i;t}$ is the excess return on the bond market of country i, $\tilde{r}_{b;t}$ is the excess return on the world bond index, θ_i is the level of integration of country i into world bond markets, λ_b is the world bond market price of risk, λ_i is the local market price of risk, cov and var are the variance and covariance operators, exp denotes exponentiation, Z^W_{t-1} is a vector of predetermined world instruments where the coefficient vector is related to the instruments as follows: κ_0 is a constant, κ_1 is the excess return on the world stock market, κ_2 is the world stock market dividend yield minus the long term world bond yield, κ_3 is the excess return on the world bond market and κ_4 is the spread between the long term world bond market yield and the 1 month US euro dollar rate. $e_t = [e_{i;t}; e_{b;t}] \mid X_{t-1} \sim N(0; H_t)$ is the vector of error terms and H_t is the conditional variance-covariance matrix of excess returns. The conditional second moments of excess returns are assumed to follow a GARCH(1,1) process:

$$h_{i;t} = c_0 + c_1^2 e^2_{j;t-1} + c_2^2 h_{j;t-1}$$

$$h_{b;t} = a_0 + a_1^2 e^2_{b;t-1} + a_2^2 h_{b;t-1}$$

$$h_{i;b;t} = d + c_1 a_1 e^2_{j;t-1} + c_2 a_2 h_{i;b;t-1}$$

Panel B reports residual analysis and tests of the model. R^2 is the fraction of total variation in excess returns explained by the model, N is the Bera-Jarque test statistic for normality of the residuals, H is a test statistic for 12th order serial correlation of the squared standardised residuals, S.C. is a test statistic for 12th order serial correlation of the standardised residuals, EN is the Engle-Ng joint test for asymmetries in the conditional variance, OG is a Wald test that the residuals are orthogonal to the world instruments and OL is a Wald test that the residuals are orthogonal to the local instruments. * denotes statistically significant a the 1% level, ** denotes statistically significant a the 5% level, *** denotes statistically significant a the 10% level. Asymptotic standard errors are in parenthesis and probability brackets are in square brackets.

Table 6

Correlations of Expected Returns: Partially Integrated

	United States	United Kingdom	Japan	Germany	Canada
United States	1.000				
United Kingdom	0.300	1.000			
Japan	0.196	0.156	1.000		
Germany	0.525	0.321	0.453	1.000	
Canada	0.596	0.443	0.426	0.797	1.000

Notes: This table reports the correlation coe±cients amongst the expected returns from the partially integrated model.

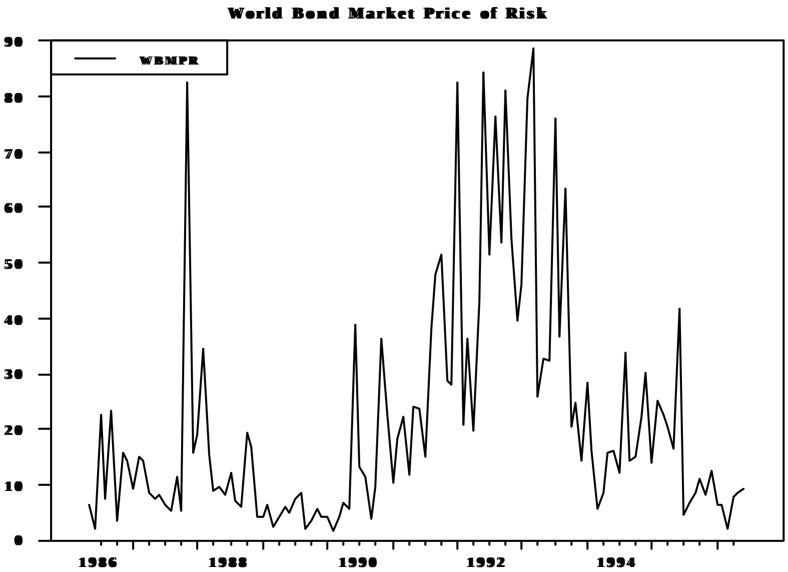

Figure 1:

This figure shows the estimated time-varying price of risk associated with world bond markets, λ_{wb}

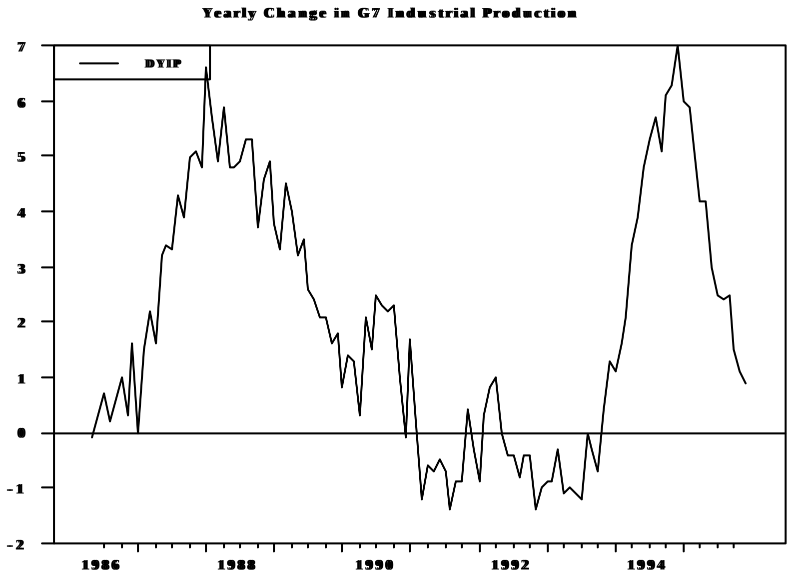

Figure 2:

This ¯gure plots the change in industrial production of the G7 (monthly year-on-year) in order to provide a proxy for the business cycle.

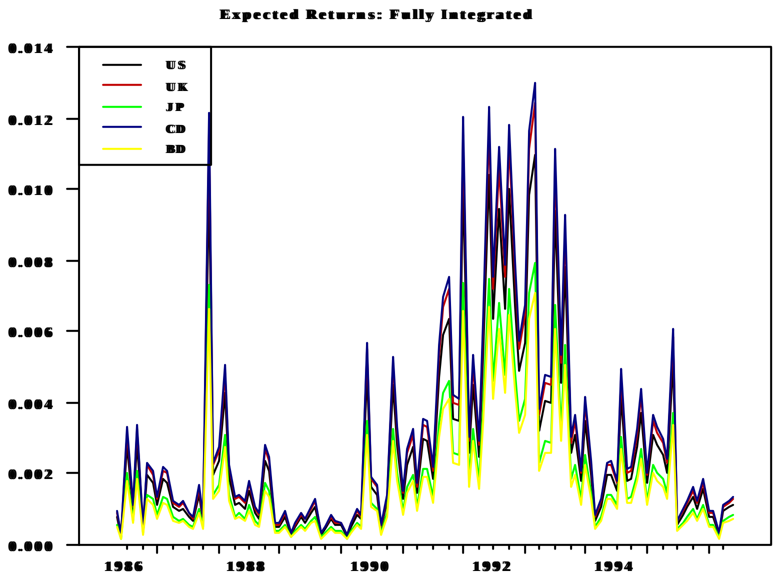

Figure 3:

Expected Returns: Full Integration

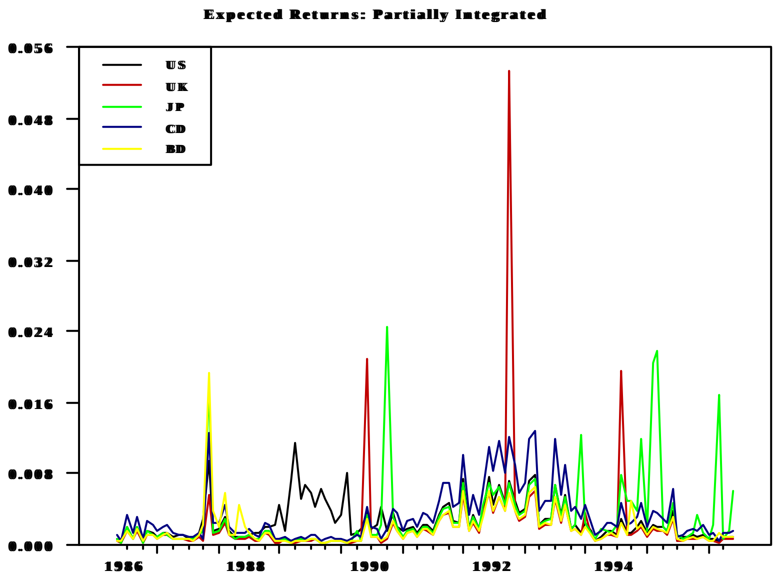

Figure 4:

Expected Returns Partially Integrated