Inflation Risk and International Asset Returns

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Abstract
We show that inflation risk is priced in international asset returns. We analyze inflation risk in a framework that encompasses the International Capital Asset Pricing Model (ICAPM) of Adler and Dumas (1983). In contrast to the literature, we relax the assumption that inflation rates are constant. We estimate and test a conditional version of the model for the G5 countries (France, Germany, Japan, the U.K., and the U.S.) over the period 1975-2003. We find evidence of statistically significant prices of inflation risk (in addition to priced nominal exchange rate risk). Inflation risk premia are an economically important component of international asset returns. Our results can be interpreted as a rejection of the ICAPM. Moreover, we show that even after the termination of nominal exchange rate fluctuations in the euro area after 1999, differences in inflation rates across countries entail non-trivial real exchange rate risk premia.

JEL Subject Codes
C32; F30; G12

Keywords
International asset pricing; Inflation risk; Exchange rate risk

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1. Introduction

As investors are concerned with asset returns expressed in real terms, uncertainty about inflation is a potentially important source of risk. Since the work of Bodie (1976) and Fama and Schwert (1977), a large literature has developed studying whether various asset classes provide a hedge against inflation. Furthermore, a substantial body of research is dedicated to inflation risk premia in bond returns.[1] However, the issue whether inflation is a priced risk factor in equity returns has received limited attention. Theoretical research by Elton, Gruber, and Rentzler (1983) and Stulz (1986) studies the impact of inflation on equity returns in domestic asset pricing models. Empirical work by Chen, Roll, and Ross (1986) and Ferson and Harvey (1991) shows that, among other economic risk factors, expected and unexpected inflation capture some of the variation in return on portfolios of U.S. equities in a domestic asset pricing context.

It is natural to investigate the impact of inflation risk on asset prices in an international context. Inflation risk may be at least partially diversifiable internationally. Moreover, theoretical models suggest a close link between inflation risk and exchange rate risk. However, the existing literature on international asset pricing generally assumes inflation rates to be constant. And empirical asset pricing research that does incorporate inflation risk in multifactor models merely examines inflation risk factors aggregated over many countries, jointly with a substantial number of other global economic risk variables, and/or in an unconditional framework.[2] The purpose of this study is a comprehensive examination of the role of uncertain inflation in different countries on international asset returns. Our approach is characterized by a strong theoretical motivation, as opposed to an empirically inspired multifactor model. The methodology we employ not only enables testing the conditional version of asset pricing models, but also takes account of important characteristics of asset returns (such as heteroskedasticity) that other methodologies leave unmodeled. Moreover, as we estimate a fully parameterized model, we can recover the conditional risk premia of market, exchange rate, and inflation risk in asset returns.

International asset pricing models study how expected asset returns are formed when investors differ in their country of residence. When investors from different countries have identical investment and consumption opportunity sets, the domestic Capital Asset Pricing Model

1 For example, recent theoretical term structure models by e.g. Buraschi and Jiltsov (2003) and Ang and Bekaert (2004) explicitly take account of priced inflation risk. Evans (1998) strongly supports the presence of time-varying inflation risk premia in U.K. index-linked bonds.

2 See Ferson and Harvey (1993, 1994) and Vassalou (2000).

(CAPM) can be straightforwardly generalized to an International CAPM (ICAPM) in which the global market portfolio is the only priced risk factor (see Grauer, Litzenberger, and Stehle (1976)). When purchasing power parity (PPP) does not hold, however, investors from different countries have different consumption opportunity sets.[3] This implies that investors evaluate the (real) returns from the same security differently. In that case, the market portfolio is no longer the only priced risk factor. In the ICAPM of Adler and Dumas (1983), asset returns depend on their covariance with both global market returns and real exchange rate returns. Other international asset pricing models under heterogeneous consumption opportunity sets are developed by Solnik (1974), Sercu (1980), and Stulz (1981).[4]

Empirical evidence indicates that exchange rate risk is priced in international asset returns. Dumas and Solnik (1995) estimate a conditional ICAPM and report evidence of exchange rate risk premia in the returns on the stock markets of Germany, Japan, the U.K., and the U.S. over the period 1970-1991. De Santis and Gérard (1998) employ a more comprehensive econometric methodology to test the ICAPM for the same four countries over the period 1973-1994. Their analysis supports a conditional ICAPM that includes both global market risk and three currency risk factors related to the German mark, the Japanese yen, and the British pound.

These studies exclusively test the version of the ICAPM developed by Solnik (1974) and Sercu (1980). Their model is a special case of the Adler and Dumas (1983) model in which all domestic inflation rates expressed in local currency are assumed to be non-stochastic. Consequently, the real exchange rate risk factors in the model of Adler and Dumas (1983) are replaced by nominal exchange rate risk factors in the Solnik-Sercu ICAPM. The implications of the restriction that inflation rates are constant have not been investigated to date. While inflation rates are known to be substantially less volatile than nominal exchange rates, it is far from obvious that this implies that uncertainty about future inflation is relatively unimportant to investors. It is also unclear what this simplification buys, as the literature on measuring inflation is well-developed. Furthermore, investors who hedge their exposure to nominal exchange rate risk may be left exposed to inflation risk, which is much more complicated to hedge. Finally, the ICAPM of Solnik-Sercu neglects the possibility that *real* exchange rate risk is priced when

[3] Deviations from PPP occur either because of differences in preferences across countries or due to deviations from the law of one price. We refer to Adler and Dumas (1983) for an exposition of this point.

[4] See Dumas (1994) and Stulz (1995) for an overview of international asset pricing.

nominal exchange rate fluctuations are absent. This may be relevant in the context of European currency risk. Nominal exchange rate fluctuations within the European Monetary Union (EMU) ceased to exist at the introduction of the euro in 1999. However, European inflation risk may still be priced in asset returns.

Our contribution is four-fold. First, as far as we know we are the first to test the ICAPM of Adler and Dumas (1983) with real exchange rate risk factors.[5] This version of the ICAPM is intuitively more appealing than the model of Solnik (1974) and Sercu (1980). Second, we investigate whether the distinction between real and nominal exchange rates matters for the inferences drawn from asset pricing tests. We show that prices of risk related to some currencies are no longer significant when real instead of nominal exchange rates are used as risk factors, indicating that previous studies have overstated the significance of currency risk. Third, these findings suggest that inflation risk partially offsets nominal exchange rate risk and raises the question whether inflation risk constitutes a distinct source of priced risk. In the model of Adler and Dumas (1983), the prices of inflation and nominal exchange rate risk are restricted to be equal. Relaxing this restriction leads to a model in which asset returns depend on their sensitivity to both inflation risk and nominal exchange rate risk. This approach allows for an assessment of the significance of inflation risk premia in security returns and offers a new empirical test of the ICAPM. Our results indicate that inflation risk is an important and independent priced risk factor in international asset returns. Fourth, we examine whether real exchange rate risk is priced within the euro area after 1999.

We estimate and test a conditional version of the ICAPM of Adler and Dumas (1983) for the equity markets of France, Germany, Japan, the U.K., and the U.S. Following De Santis and Gérard (1998), we employ a parsimonious multivariate GARCH process to test the pricing implications of the model. We confirm the results of previous studies that the (time-varying) prices of nominal exchange rate risk related to all four exchange rates in the sample are significantly different from zero. However, the prices of real exchange rate risk are only significant for the exchange rates of Germany versus Japan and the U.K. This signifies that the choice of real versus nominal exchange rates does matter in international asset pricing tests.

[5] Carrieri, Errunza, and Majerbi (2006) also examine whether real exchange rate risk is priced. However, they employ exchange rate indices and hence deviate from the theoretical setting of Adler and Dumas (1983). In addition, they focus on exchange rate risk of emerging markets, for which the restriction of constant inflation is clearly violated. Our study demonstrates the importance of risk factors related to uncertain inflation in developed capital markets.

Releasing the restriction that the prices of nominal exchange rate risk and inflation risk are equal, we report evidence in favor of priced inflation risk for all countries in the sample (in addition to significant prices of risk for all four nominal exchange rates). The hypothesis that the world prices of inflation risk are constant over time and the hypothesis that they are equal to zero are rejected at any conventional statistical significance level. We show that inflation risk is not only statistically significant, but also has an economically important contribution to expected returns on international securities. Inflation risk premia in asset returns are generally of the same order of magnitude as nominal exchange rate risk premia. Our results can be interpreted as evidence against the restrictions imposed by the ICAPM.

An interesting and relevant application of the model concerns the post-euro period. While nominal exchange rate fluctuations have terminated within the euro area in 1999, differences in inflation may entail nontrivial real exchange rate risk. Our evidence indicates that the risk premium related to the German-French inflation differential is still important in the post-euro period. This suggests that even for closely integrated countries with a common currency, investors demand a risk premium for their exposure to inflation risk.

The paper is organized as follows. In section 2 we review the literature on international asset pricing models and we discuss the ICAPM employed in our asset pricing tests. Section 3 provides a description of the methodology. Section 4 discusses the data and presents summary statistics. In section 5 we present the results of our empirical analysis of the modified ICAPM, while section 6 applies the framework of the international asset pricing model including inflation risk to the post-euro area. Section 7 concludes.

2. The model

Our study starts out with the ICAPM of Adler and Dumas (1983). The model can be constructed as follows. Consider a world economy with $L + 1$ countries (currencies), numbered $l = 0, 1, \ldots, L$, with currency 0 as the measurement or numeraire currency.[6] Apart from the measurement

[6] As is pointed out by e.g. Adler and Dumas (1983, footnote 3) and Stulz (1995, p. 219), the ICAPM is not specifically international in the sense that consumption opportunity sets can also differ within a country. "International" asset pricing models may therefore also apply to a single currency zone such as the U.S. Stulz (1995) contends that governments affect savings and lending decisions of investors by (i) defining the rights and obligations of the holders of financial assets issued within a country, (ii) defining the rights and obligations of the residents of a country (for instance in relation to taxation and the trading of assets), and (iii) defining legal tender within a country. This distinguishes "international" finance from "domestic" finance.

currency deposit, there are $M = N + L + 1$ securities, comprising of N equities or portfolios of equities, L non-measurement currency deposits, and the world portfolio of equities which is the M^{th} and last security. All returns are measured in the numeraire currency and in excess of the risk-free rate, which corresponds to the short-term deposit rate in the numeraire currency. The pricing restrictions on asset i imposed by the conditional version of the ICAPM of Adler and Dumas (1983) can be expressed as follows:

$$E[r_{it} \mid \Omega_{t-1}] = \delta_{m,t-1} \operatorname{cov}[r_{it}, r_{mt} \mid \Omega_{t-1}] + \sum_{l=0}^{L} \delta_{l,t-1} \operatorname{cov}[r_{it}, \pi_{l0t} \mid \Omega_{t-1}] \quad i = 1, \ldots, M \tag{1}$$

where

$$\delta_{m,t-1} = \theta_{t-1} \equiv \frac{1}{\sum_{l=0}^{L} \frac{W_{l,t-1}}{W_{t-1}} \times \frac{1}{\theta_l}} \qquad \text{and} \quad \delta_{l,t-1} = \theta_{t-1}\left(\frac{1}{\theta_l} - 1\right)\frac{W_{l,t-1}}{W_{t-1}}$$

In equation (1) r_{it} denotes the nominal return on security or portfolio i from time $t - 1$ to t in excess of the risk-free rate, Ω_{t-1} is the information set that investors use in choosing their portfolios, r_{mt} is the nominal return on the world market portfolio in excess of the risk-free rate, and π_{l0t} is the domestic inflation rate of country l measured in the numeraire currency. These domestic inflation rates can be decomposed as $\pi_{l0t} = s_{lt} + \pi_{lt}$, where s_{lt} denotes the nominal exchange rate change of currency l in terms of currency 0 and π_{lt} is the domestic inflation rate of country l measured in currency l from time $t - 1$ to t. Furthermore, θ_l is the coefficient of relative risk aversion for investors from country l, θ_{t-1} is an average of the risk aversion coefficients of all countries, weighted by its relative wealth at time $t - 1$ as represented by $W_{l,t-1}/W_{t-1}$. Dumas and Solnik (1995) refer to the time-varying coefficient $\delta_{m,t-1}$ in equation (1) as the "world price of market risk."[7] They call the time-varying coefficients $\delta_{l,t-1}$ the "world prices of exchange rate risk."

The ICAPM of Solnik (1974) and Sercu (1980) is a special case of equation (1). In the Solnik-Sercu model, the domestic inflation rates expressed in local currency π_{lt} ($l = 0, 1, \ldots, L$) are assumed to be non-stochastic. Therefore, the $L + 1$ covariance terms in equation (1) collapse into L covariance terms with the nominal exchange rates. The only two empirical studies we are aware of that empirically test the ICAPM, i.e. Dumas and Solnik (1995) and De Santis and

7 Other authors, e.g. Harvey (1991), use the term "the world price of covariance risk" for $\delta_{m,t-1}$.

Gérard (1998), also adopt the restriction that inflation rates are constant over time. No research has been done on the validity of this restriction. When we relax the assumption that inflation rates are non-stochastic and only assume that the domestic inflation rate in the numeraire country (expressed in the numeraire currency) is constant, we obtain an intuitively appealing representation of the ICAPM:[8]

$$E[r_{it} \mid \Omega_{t-1}] = \delta_{m,t-1} \operatorname{cov}[r_{it}, r_{mt} \mid \Omega_{t-1}] + \sum_{l=1}^{L} \delta_{l,t-1} \operatorname{cov}[r_{it}, q_{lt} \mid \Omega_{t-1}] \quad i = 1,\ldots,M \tag{2}$$

where $q_{lt} \equiv \pi_{l0t} - \pi_{0t} = s_{lt} + \pi_{lt} - \pi_{0t}$ is the real exchange rate change of currency l in terms of currency 0. Hence, this version of the ICAPM incorporates the world price of market risk and L "world prices of real exchange rate risk." This specification is consistent with investors maximizing their wealth in real terms and thus holding portfolios that provide a hedge against real (not nominal) exchange rate changes. The model in equation (2) is less restrictive than the Solnik-Sercu version of the ICAPM and allows for the possibility of priced real exchange rate risk when nominal exchange rates are fixed.

The covariance between r_{it} and q_{lt} reflect two sources of risk that may be independent: nominal exchange rate risk and inflation risk. An interesting and germane issue is the relative importance of these risk factors. A related question is whether they reinforce each other or partially cancel each other out. The distinction between these two distinct sources of risk may become especially relevant when we study inflation risk in the euro area. Within the euro area, real exchange rate risk contains both the nominal exchange rate and inflation risk components before the introduction of the euro in 1999 and only the inflation risk component after 1999. If inflation risk is priced in international asset returns, this is also likely to constitute a relevant priced risk factor in the post-euro era. Therefore, we extend the model specified in equation (2) by allowing the prices of nominal exchange rate risk and inflation risk to differ:

$$\begin{aligned} E[r_{it} \mid \Omega_{t-1}] = {} & \delta_{m,t-1} \operatorname{cov}[r_{it}, r_{mt} \mid \Omega_{t-1}] + \sum_{l=1}^{L} \varphi_{l,t-1} \operatorname{cov}[r_{it}, s_{lt} \mid \Omega_{t-1}] \\ & + \sum_{l=1}^{L} \gamma_{l,t-1} \operatorname{cov}[r_{it}, (\pi_{lt} - \pi_{0t}) \mid \Omega_{t-1}] \qquad i = 1,\ldots,M \end{aligned} \tag{3}$$

[8] Note that the number of risk premia in this model is reduced to L, as the domestic inflation rate in the numeraire country is assumed to be non-stochastic. Without loss of generality, we can subtract this inflation rate from the domestic inflation rates of the other L countries expressed in the numeraire currency.

We refer to the time-varying coefficients $\varphi_{l,t-1}$ as the world prices of nominal exchange rate risk and to $\gamma_{l,t-1}$ as the "world prices of inflation risk." Estimates and tests of this model are presented in section 5. This specification allows for an alternative statistical test of the ICAPM of Adler and Dumas (1983). A rejection of the hypothesis that $\varphi_{l,t-1}$ and $\gamma_{l,t-1}$ are equal can be interpreted as evidence against the ICAPM.

3. Empirical methodology

We want to estimate the conditional version of models (2) and (3). We employ the parsimonious multivariate generalized autoregressive conditionally heteroskedastic (GARCH) approach of De Santis and Gérard (1997, 1998).[9] Our starting point is the conditional ICAPM with real exchange rate risk factors as depicted in equation (2). This equation states the moment conditions for the excess returns of the assets under consideration. Adding a disturbance term orthogonal to the information available at the end of time $t-1$ yields the econometric representation of the model that can be used to estimate the risk premia:

$$r_t = \delta_{m,t-1} h_{m,t} + \sum_{l=1}^{L} \delta_{l,t-1} h_{n+l,t} + \varepsilon_t \qquad \varepsilon_t \mid \Omega_{t-1} \sim N(0, H_t) \tag{4}$$

where H_t is the $(M \times M)$ covariance matrix of the excess returns at time t and $h_{i,t}$ is the i^{th} column of the covariance matrix H_t. The world prices of market and real exchange rate risk are time-varying and are functions of a number of instrumental variables Z_{t-1} that represent the information set Ω_{t-1}.

If all investors are risk averse, the world price of market risk is positive (see equation (1)). Following De Santis and Gérard (1997), we force the price of market risk to satisfy this restriction by modeling the risk premium as an exponential function of the information variables. The real exchange rate risk premia are not restricted to be positive and hence the prices of real exchange rate risk are modeled as a linear function of the information variables:

$$\delta_{m,t-1} = \exp(\kappa'_m \cdot Z_{t-1}) \tag{5}$$

$$\delta_{l,t-1} = \kappa'_l \cdot Z_{t-1} \qquad l = 1,\ldots,L \tag{6}$$

The data section covers in detail which instrumental variables are used.

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[9] This methodology has been widely adopted in the literature, see e.g. Carrieri (2001), Carrieri, Errunza, and Majerbi (2006), and De Santis, Gérard, and Hillion (2003).

An important and well-documented characteristic of security returns is the heteroskedasticity in their innovations. This feature has to be taken into account when estimating the world prices of risk. Therefore, we follow the approach of De Santis and Gérard (1997, 1998) by imposing a diagonal GARCH process on the conditional second moments of the assets. In other words, the variance in H_t depend only on past squared residuals and an autoregressive component, while the covariances depend on past cross-products of residuals and an autoregressive component. Furthermore, we assume that the process is covariance stationary. The process for H_t can then be written as follows:

$$H_t = H_0 * (\iota\iota' - aa' - bb') + aa' * \varepsilon_{t-1}\varepsilon'_{t-1} + bb' * H_{t-1} \tag{7}$$

where H_0 is the unconditional variance-covariance matrix of the residuals, ι is a $(M \times 1)$ vector of ones, a and b are $(M \times 1)$ vectors containing the unknown parameters and * denotes the Hadamard product (element by element matrix multiplication). H_0 is not directly observable, but can be consistently estimated using the iterative procedure developed by De Santis and Gérard (1997). In the first iteration of this estimation procedure, H_0 is set equal to the sample covariance matrix of the returns. In subsequent steps, H_0 is updated using the estimated residuals at the end of the previous iteration. For a detailed discussion of the properties of the GARCH parameterization we refer to De Santis and Gérard (1997).[10]

Under the assumption that the errors are conditionally normally distributed, we can express the log-likelihood function as follows:

$$\ln L(\Psi) = -\frac{TM}{2}\ln 2\pi - \frac{1}{2}\sum_{t=1}^{T}\ln|H_t(\Psi)| - \frac{1}{2}\sum_{t=1}^{T}\varepsilon_t(\Psi)' H_t(\Psi)^{-1}\varepsilon_t(\Psi) \tag{8}$$

where Ψ is the vector of all unknown parameters. We use quasi-maximum likelihood (QML) standard errors obtained with the estimation methodology proposed by Bollerslev and Wooldridge (1992), because the restriction of conditional normality is often violated. The model parameterization described above is also employed for the model that incorporates nominal

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10 A possible extension of this methodology would be to add an asymmetric component in the variance equation, see e.g. Engle and Ng (1993) and Glosten, Jagannathan, and Runkle (1993) for the univariate case and Kroner and Ng (1998) for the multivariate case. Bekaert and Wu (2000) employ an asymmetric GARCH methodology in a GARCH-in-mean context. Introducing asymmetries in the volatility dynamics in our methodology would increase the number of parameters to be estimated substantially, however, which would seriously hamper our estimation procedure.

exchange rate and inflation risk factors separately (equation (3)). The econometric specification of this model can be expressed by:

$$r_t = \delta_{m,t-1} h_{m,t} + \sum_{l=1}^{L} \varphi_{l,t-1} h_{n+l,t} + \sum_{l=1}^{L} \gamma_{l,t-1} h_{n+L+l,t} + \eta_t \qquad \eta_t \mid \Omega_{t-1} \sim N(0, H_t) \tag{9}$$

where the process for H_t is given in equation (7) and the risk premia are modeled as a function of the instrumental variables Z_{t-1} in the following way:

$$\delta_{m,t-1} = \exp(\kappa'_m \cdot Z_{t-1}) \tag{10}$$

$$\varphi_{l,t-1} = \lambda'_l \cdot Z_{t-1} \qquad l = 1, \ldots, L \tag{11}$$

$$\gamma_{l,t-1} = \mu'_l \cdot Z_{t-1} \qquad l = 1, \ldots, L \tag{12}$$

4. Data

We use monthly returns on stock indices for the G5 countries (France, Germany, Japan, the U.K., and the U.S.) in addition to a value-weighted world index over the period 1975:01-1998:12. For our analysis of the post-euro period we also consider data over the period 1999:01-2003:12. All stock index data are obtained from Morgan Stanley Capital International (MSCI) and include dividends. We collect nominal end-of-period exchange rates against the U.S. dollar from International Financial Statistics (IFS). Returns on both equity indices and exchange rates are discrete and expressed in terms of the German mark. We use consumer price index (CPI) data from IFS to compute inflation rates. Inflation rate differentials are defined as the difference between the inflation rate of the four remaining countries (France, Japan, the U.K., and the U.S.) and the German inflation rate. For the conditionally risk-free asset we take the return on the one-month euro-mark deposit quoted in London (extracted from Datastream). Monthly excess returns are computed by subtracting the risk-free rate from the monthly return on each security.

The choice of instrumental variables is potentially very important in conditional tests of asset pricing models. However, the model does not provide any guidance as to the choice of the information variables and the number of instrumental variables is limited by the econometric methodology. Our selection of instruments builds on previous empirical research (notably Harvey (1991), Ferson and Harvey (1993), Dumas and Solnik (1995) and De Santis and Gérard (1997, 1998)). We include the dividend yield on the world equity index (in excess of the risk-free rate), the U.S. default premium measured by the yield differential between Moody's Baa and Aaa rated bonds, and the change in the U.S. term premium calculated as the difference between the yield on the ten-year U.S. Treasury note and the Federal Funds Rate.[11] The dividend yield is obtained from Datastream and the bond yields are taken from the website of the Federal Reserve System.[12]

Table 1 presents summary statistics over the period 1975:01-1998:12. Panel A, B, and C depict information on the summary statistics for the equity indices and the real exchange rates, the instrumental variables, and the nominal exchange rates and inflation differentials, respectively. The stock indices earn monthly excess returns ranging from 59 basis points for Japan to 117 basis points for the U.K. The skewness and especially the kurtosis generally show large deviations from the values of the normal distribution. The distribution of the excess returns on the U.K. stock index in particular exhibit very fat tails, which is primarily due to several extreme returns in 1975 (also documented by De Santis and Gérard (1998)). The Jarque-Bera test strongly rejects the assumption of normally distributed returns for all series. Real exchange rate returns are fairly close to zero over the sample period, except for the Japanese yen which showed a substantial appreciation against the German mark in real terms. The standard deviation of all real exchange rates in the sample is substantial. As is noted by a number of previous studies (e.g. Rogoff (1996)), inflation differentials are considerably less volatile than nominal exchange rates (see Panel C). Panel D of Table 1 contains the unconditional correlations between stock index returns and real exchange rate returns. Correlations between equity returns are all positive and range from 0.283 to 0.550. Correlations between real exchange rates are all positive and smaller than 0.5. Stock index returns and real exchange rates are generally negatively correlated and assume values of up to –0.609. Unconditional correlations between equity returns and nominal exchange rate returns are negative and generally substantial, as indicated by Panel E. Equity returns do not strongly correlate with inflation differentials. Correlations are generally very close to zero, except for the inflation differential between Germany and the U.S. Finally, correlations between nominal exchange rate returns and inflation differentials are remarkably low, amounting to less than 0.1 in absolute value (with only one exception).

[11] In line with De Santis and Gérard (1998), we also estimated our model with the change in yield on the one-month euro-dollar deposit as an additional instrumental variable. Our optimization procedure becomes considerably less efficient due to the addition of this variable and hence we decided to omit it. However, the inclusion of this instrument in the information set does not materially affect our estimation results and does not statistically improve our specification. Unreported evidence on this issue is available from the authors.

[12] Federal Reserve System, homepage, http://www.fed.gov/ (accessed April 27, 2004).

5. Empirical results

This section presents estimates and tests of two different models. Section 5.1 presents estimation results of the model presented by equation (2). In this version of the ICAPM, the assumption that domestic inflation rates expressed in local currency are non-stochastic is relaxed, and asset returns depend on their covariance with the global market portfolio and real exchange rate risk factors. In section 5.2 we provide estimates and statistical tests of the model in equation (3). This model posits that asset returns depend on global market risk, nominal exchange rate risk, as well as inflation risk. Both model specifications are considered in their conditional version, implying that covariances are allowed to vary over time. Testing the hypothesis of time-variation of the prices of risk is straightforward within our framework.

5.1 Conditional ICAPM with real exchange rate risk

Table 2 presents the estimation results for the ICAPM with real exchange rate risk, as denoted by equation (4). We examine the period 1975:01-1998:12, as the adoption of the euro in January 1999 instigated a structural break in the (real) exchange rates between Germany and France. Section 6 addresses this issue in more detail. Panel A of Table 2 shows the point estimates and the standard errors of the mean equation parameters and Panel B depicts the estimates of the (conditional) covariance equation parameters. Several of these parameters (all of the covariance process) are significant in isolation. More interesting, however, are the specification tests that assess the significance of a number of parameters simultaneously. For each of the five world prices of risk, we performed a likelihood-ratio test in order to investigate (i) whether the prices of risk are constant or time-varying and (ii) whether the prices of risk are significantly different from zero. Concerning the world prices of real exchange rate risk, we apply the tests to all prices of risk simultaneously as well as separately for each real exchange rate in the sample. The results of the specification tests are reflected in Panel C of Table 2.

The first two tests in Panel C focus on the world price of market risk. This price of risk is significantly different from zero at the 1% significance level, while we reject the hypothesis that the world price of market risk is constant at the 10% level. This is in line with the results of Dumas and Solnik (1995) and De Santis and Gerard (1998). All other specification tests in Panel C assess the prices of real exchange rate risk. The tests show that these prices of risk are jointly time-varying (*p*-value of 0.016) and reject the hypothesis of no real exchange rate risk at the 5%

level (*p*-value of 0.041). A more detailed perspective on the importance of real exchange rate risk is given by the specification tests for each real exchange rate separately. The evidence indicates that only the real exchange rate of Japan and the U.K. have a significant impact on the pricing of the assets under consideration. The prices of the real exchange rates of the French franc and the U.S. dollar versus the German mark are insignificant. The null-hypothesis that the prices of real exchange rate risk are constant is strongly rejected for Japan and the U.K., but not for the other countries.

Previous empirical tests of the ICAPM assume that the inflation rate is non-stochastic and hence only incorporate nominal exchange rate risk. The world prices of nominal exchange rate risk are typically highly significant in these studies. Table 2 shows, however, that the prices of exchange rate risk related to France, and, more surprisingly, the U.S. are not significantly different from zero.[13] In our empirical study, these prices of risk are associated with real exchange rate risk and hence consist of two components: nominal exchange rate risk and inflation risk. A relevant issue is whether these components of the price of currency risk partially offset each other, notably for France and the U.S. In order to establish the sign and relative magnitude of inflation risk and nominal exchange rate risk premia, section 5.2 extends our analysis to include both sources of risk separately.

5.2 Conditional asset pricing model with nominal exchange rate and inflation risk

Table 3 presents the estimation and test results for the model with nominal exchange rate risk factors as well as inflation risk factors. The estimates of the mean equation are depicted in Panel A. Comparing the nominal exchange rate risk parameter estimates with the inflation rate risk parameters, we observe a number of differences. First, the parameters corresponding to the inflation rate risk factors are generally higher in absolute terms than the value of the corresponding nominal exchange rate risk parameters. Second, the prices of nominal exchange rate and inflation risk often exhibit opposite sensitivities to the instruments. Only the coefficients on the world dividend yield have the same sign for all nominal exchange rate – inflation rate combinations (negative for France and Japan and positive for the U.K. and the U.S.). The estimates of the variance equation are presented in Panel B of Table 3. The parameter estimates

[13] These results are not directly comparable to those of De Santis & Gerard (1998) and Dumas and Solnik (1995), because they estimate the model with nominal exchange rates. Unreported results (available from the authors) of estimations and tests of a model with nominal exchange rates are in line with the literature.

of *a* are consistently higher for the nominal exchange rates than for the inflation risk factors. It is also clear that the standard errors for the inflation risk factors are lower than the standard errors for the nominal exchange rate risk factors. Finally, inflation risk factors exhibit a very high persistence as indicated by an estimate for *b* that is very close to 1.

Panel C of Table 3 displays the results of a number of specification tests that assess the significance and time-variation of the prices of risk. In line with the results in Table 2, we strongly reject the hypotheses that the price of market risk is constant over time and equal to zero. The prices of nominal exchange are also highly significantly different from zero, both jointly and for each individual nominal exchange rate in the sample. In contrast to our findings in Table 2, French and U.S. currency risk thus also carry a significant price of risk in this model. This is consistent with previous empirical research detecting priced nominal exchange rate risk factors. The most striking results in Table 3, however, concern inflation risk. For all inflation risk factors (jointly and separately), the hypothesis that their prices of risk are equal to zero is rejected at any conventional significance level. This signifies that, despite the fact that the variance of the inflation differentials is substantially lower than the variance of the nominal exchange rates, inflation risk constitutes a significant priced risk factor in international equity returns. Finally, we find strong evidence against a specification of the model in which the prices of nominal exchange rate and inflation risk are constant.

While both the prices of nominal exchange rate risk and the prices of inflation risk in our model are significant in statistical terms, the contribution of either or both sources of risk to asset returns could be small in economic terms. Figure 1 presents plots of the nine different prices of risk in over the period 1975-1998. (Note that the scaling differs for the graphs of the prices of market, nominal exchange rate, and inflation risk.) The graphs also contain a line representing the average price of risk over the sample period as well as the Hodrick-Prescott filtered prices. The latter can be used to obtain an insight in the general trend over time, as the point estimates are subject to estimation error. All prices of risk exhibit substantial variation over time. The graph of the world price of market risk is very similar to the plot depicted in Figure 1 of De Santis and Gérard (1998), with peaks in the mid 1970s, in the year 1980, and around 1983. The average price of market risk in our model is 0.075, which is substantially higher than the estimate of De Santis and Gérard. A plausible explanation for this is that the world market portfolio in the ICAPM without inflation risk factors partially absorbs the prices of inflation risk, which are generally negative in our sample. The graphs of the prices of nominal exchange rate risk resemble the general patterns observed by De Santis and Gérard (1998). All exchange rate risk prices seem to matter for international asset pricing. The sample means are equal to 0.154 for France, –0.021 for Japan, 0.066 for the U.K., and 0.0087 for the U.S. While the mean values are relatively close to zero, all four prices of risk attain considerable higher values in some periods and all assume both positive and negative values over the sample period (although the price of nominal exchange rate risk related to the French franc is virtually always positive). The prices of inflation risk are strikingly large. Averages over the sample period amount to –0.752 for France, 0.842 for Japan, -0.687 for the U.K., and –0.725 for the U.S. However, these large prices of risk are to a large extent counterbalanced by very small covariances between asset returns and inflation risk factors. As a comparison, the unconditional covariance between German equity returns and the U.S. inflation risk factor is equal to 0.145, while the covariance between German equity returns and the world market returns is 12.743. Nevertheless, despite the limited (co)variance of inflation differentials, the high prices of risk are likely to produce substantial inflation risk premia in asset returns.

In order to assess the importance of inflation and nominal exchange rate risk premia relative to each other and relative to the global market factor, we decompose the expected asset returns in our sample into the risk premia related to the various sources of risk. The (time-varying) premium for market risk for asset *i* can be computed as the product of the price of market risk $\delta_{m,t-1}$ and the conditional covariance $cov[\, r_{it}\, ,\, r_{mt} \mid \Omega_{t-1}\,]$. Similarly, the *l* nominal exchange rate risk premia for asset *i* can be estimated with $\varphi_{l,t-1} \times cov[\, r_{it}\, ,\, s_{lt} \mid \Omega_{t-1}\,]$ and the term $\gamma_{l,t-1} \times cov[\, r_{it}\, ,\, \pi_{lt} - \pi_{0t} \mid \Omega_{t-1}\,]$ constitutes an estimate of the inflation risk premia for asset *i*. Figure 2 depicts the development of the risk premia for the German equity index over time. The top panel gives an overview of the aggregate contributions of market, nominal exchange rate, and inflation risk to expected Germany equity returns. The middle and bottom panel depict individual nominal exchange rate and inflation risk premia related to France, Japan, the U.K., and the U.S. (Note that the scaling of the middle and bottom panels is different from the top panel.) A number of important observations emerge. Global market risk is the dominant component of the total risk premium on Germany equity, amounting to around 90 basis points per month on average over the period 1975-1998. This risk premium is strongly time-varying as both the price of market risk and the conditional covariance between German equity returns and returns on the global market index exhibit considerable fluctuations.

The aggregate premium for nominal exchange rate risk is generally negative. The average value computed over the entire sample is –0.104. As the sample averages of conditional risk premia can be expected to approximate their unconditional values, this suggests that an unconditional analysis of nominal exchange rate risk would indicate that the premium for currency risk is relatively modest. However, the premium was markedly negative in most of the 1970s and 1990s, but strongly positive in the early and mid 1980s. The sample average of the absolute value of the premium is almost 20 basis points per month or roughly 2.4 percent per annum, while occasionally values of up to 70 basis points per month are reached (both positive and negative). Moreover, the aggregate currency risk premium disregards possible offsetting effects across the four nominal exchange rates in the sample. The middle panel of Figure 2 demonstrates that the contribution of every individual nominal exchange rate has been economically substantial for prolonged periods of time.

The top panel of Figure 2 clearly shows that the aggregate inflation risk premium in the returns in the MSCI Germany index was economically substantial over the period 1975-1998. The sample average of –4.6 basis points per month is relatively small, but the mean absolute value is equal to 26 basis points, which is even higher than the aggregate premium for currency risk. The aggregate inflation risk premium was negative for most of the 1970s and 1990s, but substantial and positive in the 1980s (averaging more than 30 basis points per month in the years 1982-1988). In the mid 1970s and 1980s the (aggregate) premia for inflation risk and nominal exchange rate risk generally had opposite signs, but both turned negative around 1990. The bottom panel of Figure 2 illustrates the cross-sectional differences in inflation risk premia. The U.K. premium assumed small negative values for almost the entire sample period. The inflation risk premium for Japan was positive in most months with an average absolute value of 13 basis points over the sample period. Investors in the German equity index generally received a positive risk premium for inflation risk related to France, but the premium was negative in 1975-1977 and especially in the early 1980s. It is interesting to see that the French inflation risk premium has picked up in the late 1990s. The most important source of inflation risk in German equity returns clearly was the risk associated with the inflation differential with the U.S. The sample mean of the absolute premium amounts to no less than 22 basis points on a monthly basis, or more than

2.5 percent per year. Since the mid 1980s, the premium for U.S. inflation risk has generally been negative and relatively steady around –0.2. U.S. inflation risk carried a large and positive premium in the mid 1970s and was large and volatile in the first half of the 1980s. In this time period, the U.S. inflation risk component in expected returns on the MSCI Germany index was occasionally of the same order of magnitude as global market risk.

Figure 3 depicts the market risk, nominal exchange rate risk, and inflation risk components in the expected returns on equity indices in France, Japan, the U.K., the U.S., as well as the world market index. Although the total equity premia for the equity indices is to a large extent explained by the premium for market risk, both aggregate nominal exchange rate risk premia and aggregate inflation risk premia are generally substantial. For France the average market risk premium was 1.249 percent per month and the mean absolute nominal exchange rate and inflation risk premia amounted to 0.562 percent and 0.565 percent, respectively. The nominal exchange rate risk premium was always negative, while inflation risk generally bears a positive risk premium. There are considerable differences in the relative importance of currency and inflation risk among the other countries in the sample. For the U.K. in particular nominal exchange rate risk and inflation risk represent very significant parts of the total risk premium. The average absolute risk premium for inflation risk equals more than 35 basis points per month for U.K. equity. For Japan and the U.S. these risk premia are less important, but nevertheless nontrivial (mean absolute values of, respectively, 27 and 22 basis points per month). The graph for the world market index reflects the characteristics of all markets. The exchange rate and inflation risk premia are generally of opposite sign for France and the U.K., while they often reinforce each other for Japan and the U.S. It is important to note that the graphs in Figure 3 do not give insight in the magnitude and development of individual currency and inflation risk premia. As an example, the aggregate inflation risk premium for the U.S. is relatively small, but individual inflation risk premia are substantial. Sample averages of absolute inflation risk premia incorporated in U.S. equity returns are equal to, respectively, 0.273 percent per month for France, 0.203 for Japan, 0.121 for the U.K., and 0.292 for the U.S.

The evidence in Table 3 and in Figures 1-3 indicates that inflation differentials between countries entail nontrivial priced risk factors in asset returns. This constitutes important evidence against the Solnik-Sercu assumption that domestic inflation is non-random. A relevant issue is why inflation risk premia are comparable in size to nominal exchange rate risk premia, while the time-series volatility of inflation differentials is notably smaller than nominal exchange rate volatility. A plausible answer to this question is that hedging inflation risk is much more complicated than hedging against nominal exchange rate fluctuations. Currency risk can be hedged easily and cheaply using exchange-traded financial products (such as options and futures) on generally very liquid markets. The most straightforward way to hedge inflation risk is through index-linked bonds. However, as noted by e.g. Evans (1998), these bonds do not form a perfect hedge against inflation risk. Moreover, they are only available in a small number of countries and have not been available during most of our sample period (with the exception of inflation-linked bonds in the U.K.). The findings presented in this section suggest that, as a result, inflation risk can be identified as a distinct and significant source of systematic risk in asset returns. This conclusion could have important implications for asset pricing in countries between which no nominal exchange rates exist, but inflation rates do differ. The next section assesses the significance of inflation risk in Europe after the introduction of the euro in 1999.

6. The termination of nominal exchange risk in the euro area

The asset pricing model introduced in section 2 can also be applied in a setting in which nominal exchange rates between countries are fixed. While this obviously implies that nominal exchange rate risk between these countries does not carry a price, inflation differentials may still imply non-zero prices of inflation risk.[14] Since the establishment of the EMU at the beginning of 1999, nominal exchange rates have been frozen among euro area countries. This section analyzes whether asset returns still contain a risk premium for risk related to euro area inflation differentials.[15] This would have important implications for asset pricing. We present estimates and tests of the model incorporating nominal exchange rate and inflation risk depicted in equation

[14] Angeloni and Ehrmann (2004) show that inflation differences among euro area countries are still prominent five years after the introduction of the euro. Koedijk, Tims, and van Dijk (2004) presents evidence against the hypothesis of PPP for individual country pairs within the euro area.

[15] Several empirical studies indicate that substantial real exchange rate changes (i.e. inflation differentials) occur within a single currency zone. Parsley and Wei (1996) report half-lifes of price discrepancies for 51 goods and services in 48 U.S. cities amounting to 1 to 4 years. Cecchetti, Mark, and Sonora (2002) consider consumer price indices for 19 U.S. cities over the period 1918-1995. They estimate the half-life of PPP deviations to be approximately 9 years. Differences in inflation rates measured over ten-year intervals can differ by as much as 1.6 percent per annum. Rogers (2001) constructs price indices for 26 European cities over the period 1990-1999 and concludes that "… deviations from the law of one price are large," although price dispersion across cities has been reduced over the past decade. Lutz (2002) analyzes four different data sets of final goods prices in European countries and finds limited evidence that price dispersion has decreased in the past decade.

(3) for asset returns in France, Germany, Japan, the U.K., and the U.S. over the period 1975:01-2003:12. As studying the euro area in isolation could lead to biases due to the fact that non-EMU sources of currency risk are neglected, we also include other countries and currencies in the analysis. At the same time, we need to restrict the total number of countries analyzed, because the incorporation of more assets and risk factors hampers the estimation procedure considerably. Hence, our analysis focuses on the price of inflation risk related to inflation differentials between France and Germany.[16] Unfortunately, estimating the model over the post-euro period is not feasible as the number of parameters to be estimated requires a substantial time-series length. Estimating the model over the full period 1975-2003 raises a challenge for the empirical implementation of the model, because the nominal exchange rate of the French franc versus the German mark experiences a structural break in 1999. This holds especially for estimating the covariance matrix, as the volatility of the concerning variable becomes zero by definition after 1998. We apply an adaptation of the methodology of De Santis and Gérard (1998) in order to deal with this issue. A detailed description of the methodology is given in Appendix A.

Table 4 presents the results of several specification tests of the model estimated over the period 1975-2003.[17] The world price of market risk is highly significant, although the hypothesis that this price of risk is constant over time is no longer rejected. We find some evidence for statistically significant prices of risk for all four nominal exchange rates in the sample. The evidence is strong for the exchange rate of the French franc versus the German mark, but slightly weaker for the other currencies in the sample. A specification of the model in which the prices of nominal exchange rate risk are unconditional is clearly rejected. Consistent with the results in the previous section, inflation risk factors carry highly significant prices of risk, both jointly and individually. Both the hypotheses that the prices of inflation risk are equal to zero and that the prices are constant over time are rejected at any conventional significance level. Most interesting, however, is to examine the price of risk related to the inflation differential of France versus Germany as shown in Figure 4. The absolute level of the price of inflation risk in 1999-2003 does

16 Unreported results show that similar findings are obtained when we estimate the model with data for other European countries (e.g. Italy or the Netherlands) instead of France. We bias our results against finding significant intra-EMU inflation risk after the introduction of the euro by choosing a country that is economically closely integrated with Germany. More exhaustive results are available from the authors.

17 Naturally, the estimation results are very similar to those reported in table 3, as the samples largely overlap. In order to conserve space, the parameter estimates of the model are not included in the table. They are available from the authors.

not appear to be notably lower than in the period before the introduction of the common currency (except for the high prices in the early 1980s). During the post-euro period the price of inflation risk remains substantial. The price of risk is positive in the first three years after 1999 and becomes negative in 2002 and 2003. Overall, these findings suggest that even when nominal exchange rates do not fluctuate, differences in inflation rates across countries may lead to non-zero risk premia.

7. Conclusions

This paper analyzes whether inflation risk is priced in international asset returns. We test two assumptions commonly made in the international asset pricing literature. First, the Solnik-Sercu version of the ICAPM as well as the empirical tests of the ICAPM by Dumas and Solnik (1995) and De Santis and Gérard (1998) assume that domestic inflation rates expressed in local currency are non-stochastic and hence inflation risk is not priced. An empirical analysis of the specification of the ICAPM with real exchange rate risk presented in this paper provides an assessment of the validity of this assumption. Second, the ICAPM does not allow for a specification in which inflation risk and nominal exchange rate risk are independent sources of risk. The finding that inflation risk is priced has important consequences in light of the introduction of the euro in 1999. While nominal exchange rate fluctuations within the euro area have been brought to an end, differences in inflation rates between European countries may entail nontrivial inflation risk.

Using the methodology of De Santis and Gérard (1997, 1998), we estimate and test an international asset pricing model including inflation risk factors using asset returns from Germany, France, Japan, the U.K., and the U.S. over the period 1975-1998. We find clear evidence in favor of the hypothesis that inflation risk is priced in international security returns. Inflation risk prices are highly significant, both jointly and for all four individual countries in the sample vis-à-vis Germany. The prices of inflation risk vary considerably over time and the hypothesis that the price of inflation risk is constant is rejected at any conventional significance level. As the prices of inflation and nominal exchange rate risk are significantly different, our results imply a rejection of the ICAPM.

The impact of inflation risk on asset returns is also economically important. The magnitude of inflation risk premia is generally of the same order as nominal exchange rate risk premia. The average contribution of the aggregate inflation risk premium in equity returns (in absolute value) ranges from 26 basis points per month for Germany to more than 56 basis points for France. During some periods (notable the early 1980s) aggregate inflation risk premia assumed values that were considerably higher. Even the inflation risk associated with inflation differentials between the closely integrated economies of France and Germany is substantial. The mean absolute value of this risk premium amounts to 12 (35) basis points per month in German (French) equity returns over the period 1975-1998. These findings can be explained by the fact that even though variances of and covariances with inflation differentials are low compared to nominal exchange rates, the price of risk is significantly higher for the inflation risk component.

We examine the importance of EMU inflation risk after the introduction of the euro by extending our analysis to 2003. We show that inflation risk related to French-German inflation differential still has a considerable effect on expected security returns after 1999.

Our findings have direct implications for portfolio and risk managers (especially in the context of asset and liability management). Pension funds in particular are interested in the issue whether inflation risk is priced, as they often have fixed future financial liabilities (defined benefits) that are tied to price levels.

Appendix A: Empirical methodology for section 6

The termination of nominal exchange rate risk in the euro area

This Appendix contains a detailed description of the methodology used to estimate the conditional model in section 6 of this paper. Because this analysis covers both the pre-euro and the post-euro period and we include both Germany and France, our estimation procedure has to take into account that the nominal exchange rate between these countries has been frozen after they adopted the euro. This implies a structural break in the nominal exchange rate series, as a result of which we cannot use the same specification for this risk factor before and after 1999. In general, the structural break leads to two versions of equation (3):

$$E[r_{it} \mid \Omega_{t-1}] = \delta_{m,t-1} \operatorname{cov}[r_{it}, r_{mt} \mid \Omega_{t-1}] + \sum_{l=1}^{L} \delta_{l,t-1} \operatorname{cov}[r_{it}, s_{lt} \mid \Omega_{t-1}] + \sum_{l=1}^{L} \gamma_{l,t-1} \operatorname{cov}[r_{it}, (\pi_{lt} - \pi_{0t}) \mid \Omega_{t-1}] \qquad i = 1,\dots,M \qquad t < Jan\ 1999 \tag{A1}$$

Equation (A1) is exactly the same as equation (3) and holds as long as the nominal exchange rates are not frozen (the euro was adopted on January 1, 1999). Suppose, without loss of generality, that the euro area exchange rates are the last *N* excess returns in r_{it}, then as the model for the second part of the sample period can be expressed as follows:

$$E[r'_{it} \mid \Omega_{t-1}] = \delta_{m,t-1} \operatorname{cov}[r'_{it}, r_{mt} \mid \Omega_{t-1}] + \sum_{l=1}^{L-N} \delta_{l,t-1} \operatorname{cov}[r'_{it}, s_{lt} \mid \Omega_{t-1}] + \sum_{l=1}^{L} \gamma_{l,t-1} \operatorname{cov}[r'_{it}, (\pi_{lt} - \pi_{0t}) \mid \Omega_{t-1}] \qquad i = 1,\dots,M-N \qquad t \geq Jan\ 1999 \tag{A2}$$

where *N* is the number of frozen nominal exchange rates and r'_{it} denotes the vector of *(M – N)* excess returns. In our empirical application, all parameters in the mean equation of (A2) are estimated using the full sample period, while the parameters concerning the frozen exchange rates are based on data until December 1998 only.

The structural break also has consequences for the estimation of the conditional covariance matrix. Because the number of elements in the return vector decreases as of January 1999, the size of covariance matrix is reduced. This means that after 1999 we only use the upper *(M – N)* × *(M – N)* part of the original covariance matrix. The same holds for the parameters, as only the first *(M – N)* values of the vectors *a* and *b* apply after 1999. The new covariance matrix equation is as follows (with new notation for all symbols to denote the difference with equation (7)):

$$
\begin{aligned}
H'_t = H'_0 * (\iota\iota' - cc' - dd') + cc' * \eta_{t-1}\eta'_{t-1} + dd' * H'_{t-1} \\
c = a[1:M-N] \\
d = b[1:M-N] \\
\eta_{t-1} = \varepsilon_{t-1}[1:M-N]
\end{aligned}
\qquad \text{(A3)}
$$

where H'_t is the $(M-N) \times (M-N)$ covariance matrix at time t and H'_0 is the $(M-N) \times (M-N)$ unconditional covariance matrix. The unconditional covariance matrix H'_0 is set equal to the sample covariance matrix of the returns over the full sample, while the H_0 of equation (7) is based on the sample until December 1998. This is necessary in order to provide a plausible estimate of the covariances with the nominal exchange rates that disappear after January 1999. While we reckon that this approach is the best solution to the structural break problem within this framework, our results should be interpreted with care.

References

Adler, M., and B. Dumas, 1983, "International Portfolio Choice and Corporation Finance: A Synthesis," *Journal of Finance*, 38, 925–984.

Ang, A., and G. Bekaert, 2004, "The Term Structure of Real Rates and Expected Inflation," working paper, Columbia University.

Angeloni, I., and M. Ehrmann, 2004, "Euro Area Inflation Differentials," European Central Bank working paper, no. 452.

Bekaert, G., and G. Wu, 2000, "Asymmetric Volatility and Risk in Equity Markets", *Review of Financial Studies*, 13, 1–42.

Bodie, Z., 1976, "Common Stocks as a Hedge Against Inflation," *Journal of Finance*, 31, 459–470.

Bollerslev, T., J. Wooldridge, 1992, "Quasi-Maximum Likelihood Estimation and Inference in Dynamic Models with Time-Varying Covariances," *Econometric Reviews*, 11, 143–172.

Buraschi, A., and A. Jiltsov, 2003, "Time-Varying Inflation Risk Premia and the Expectations Hypothesis: A Monetary Model of the Treasury Yield Curve," *Journal of Financial Economics*, forthcoming.

Carrieri, F., 2001, "The Effects of Liberalization on Market and Currency Risk in the European Union," *European Financial Management*, 7, 259–290.

Carrieri, F., V. Errunza, and B. Majerbi, 2006, "Does Emerging Market Exchange Risk Affect Global Equity Prices?," *Journal of Financial and Quantitative Analysis*, forthcoming.

Cecchetti, S.G., N.C. Mark, and R.J. Sonora, 2002, "Price Index Convergence among United States Cities," *International Economic Review*, 43, 1081–1099.

Chen, N.-F., R. Roll, and S.A. Ross, 1986, "Economic Forces and the Stock Market," *Journal of Business*, 59, 383–403.

De Santis, G., and B. Gérard, 1997, "International Asset Pricing and Portfolio Diversification with Time-varying Risk," *Journal of Finance*, 52, 1881–1912.

De Santis, G., and B. Gérard, 1998, "How Big is the Premium for Currency Risk?," *Journal of Financial Economics*, 49, 375–412.

De Santis, G., B. Gérard, and P. Hillion, 2003, "The Relevance of Currency Risk in the EMU," *Journal Economics and Business*, 55, 427–462.

Dumas, B., 1994, "Partial Equilibrium versus General Equilibrium Models of the International Capital Market," in F. van der Ploeg (ed.), *The Handbook of International Macroeconomics*, 9, Blackwell, 301–347.

Dumas, B., and B. Solnik, 1995, "The World Price of Exchange Rate Risk," *Journal of Finance*, 50, 445–479.

Engle, R.F., and V.K. Ng, 1993, "Measuring and Testing the Impact of News on Volatility," *Journal of Finance*, 48, 1749–1778.

Elton, E., M. Gruber, and J. Rentzler, 1983, "The Arbitrage Pricing Model and Returns on Assets Under Uncertain Inflation," *Journal of Finance*, 38, 525–536.

Evans, M.D.D., 1998, "Real Rates, Expected Inflation, and Inflation Risk Premia," *Journal of Finance*, 53, 187–218.

Fama, E.F., and G.W. Schwert, 1977, "Asset Returns and Inflation," *Journal of Financial Economics*, 5, 115–146.

Ferson, W.E., and C.R. Harvey, 1991, "The Variation of Economic Risk Premiums," *Journal of Political Economy*, 99, 385–415.

Ferson, W.E., and C.R. Harvey, 1993, "The Risk and Predictability of International Equity Returns," *Review of Financial Studies*, 6, 527–566.

Ferson, W.E., and C.R. Harvey, 1994, "Sources of Risk and Expected Returns in Global Equity Markets," *Journal of Banking and Finance*, 18, 775–803.

Glosten, L.R., R. Jagannathan, and D.E. Runkle, 1993, "Relationship Between the Expected Value and the Volatility of the Nominal Excess Return on Stocks," *Journal of Finance*, 48, 1779–1801.

Grauer, F.L.A., R.H. Litzenberger, and R.E. Stehle, 1976, "Sharing Rules and Equilibrium in an International Capital Market under Uncertainty," *Journal of Financial Economics*, 3, 233–256.

Harvey, C.R., 1991, "The World Price of Covariance Risk," *Journal of Finance*, 46, 111–157.

Koedijk, C.G., B. Tims, and M.A. van Dijk, 2004, "Purchasing Power Parity and the Euro Area," *Journal of International Money and Finance*, 23, 1081–1107.

Kroner, K.F., and V.K. Ng, 1998, "Modeling the Time Varying Comovement of Asset Returns," *Review of Financial Studies*, 11, 817–844.

Lutz, M., 2002, "Price Convergence under EMU? First Estimates," working paper, University of St. Gallen.

Parsley, D.C., and S.-J. Wei, 1996, "Convergence to the Law of One Price without Trade Barriers or Currency Fluctuations," *Quarterly Journal of Economics*, 111, 1211–1236.

Rogers, J.H, 2001, "Price Level Convergence, Relative Prices, and Inflation in Europe," *International Finance Discussion Papers*, 699, Board of Governors of the Federal Reserve System.

Sercu, P., 1980, "A Generalization of the International Asset Pricing Model," *Revue de l'Association Française de Finance*, 1, 91–135.

Solnik, B., 1974, "An Equilibrium Model of the International Capital Market," *Journal of Economic Theory*, 8, 500–524.

Stulz, R.M., 1981, "A Model of International Asset Pricing," *Journal of Financial Economics*, 9, 383–406.

Stulz, R.M., 1986, "Asset Pricing and Expected Inflation," *Journal of Finance*, 41, 209–223.

Stulz, R.M., 1995, "International Portfolio Choice and Asset Pricing: An Integrative Survey," in R.A. Jarrow, V. Maksimovic, and W. T. Ziemba (eds.), *Handbooks in Operations Research and Management Science*, 9, North-Holland, Amsterdam, 201–223.

Vassalou, M., 2000, "Exchange Rate and Foreign Inflation Risk Premiums in Global Equity Returns," *Journal of International Money and Finance*, 19, 433–470.

Table 1
Summary statistics (1975-1998)

This table reports summary statistics for the asset excess returns expressed in German marks over the period 1975:01-1998:12. Equity indices are from Morgan Stanley Capital International (MSCI). Real exchange rates versus the German mark are constructed from nominal exchange rates and CPI indices obtained from International Financial Statistics (IFS). The one-month euro-mark deposit quoted in London is taken as the conditionally risk-free asset. All returns are in expressed in a percentage per month. J-B is the Jarque-Bera test statistic for normality. Q_{12} denotes the *p*-value of the Ljung-Box test statistic of order 12. *, **, *** denote significance at the 10%, 5%, and 1% significance levels, respectively.

	Mean	Median	St.Dev.	Skewness	Kurtosis	J-B	Q_{12}
PANEL A: SUMMARY STATISTICS OF EQUITY RETURNS AND REAL EXCHANGE RATE RETURNS							
MSCI Germany	0.698	0.803	5.380	-0.507	5.130	66.8***	15.4
MSCI France	0.874	0.918	6.459	0.007	4.177	16.6***	10.1
MSCI Japan	0.593	0.744	6.519	0.137	3.928	11.2***	10.0
MSCI U.K.	1.169	1.519	6.957	1.124	12.861	1227.5***	14.7
MSCI U.S.	0.854	1.028	5.429	-0.533	5.051	64.1***	9.3
MSCI World	0.710	0.894	4.570	-0.646	5.070	71.5***	19.0*
Real exchange rate France	-0.002	-0.094	1.178	1.247	9.654	606.0***	13.2
Real exchange rate Japan	-0.149	0.147	3.122	-0.409	3.857	16.2***	15.5
Real exchange rate U.K.	-0.073	-0.082	2.739	0.292	4.337	25.5***	12.2
Real exchange rate U.S.	0.019	0.072	3.286	-0.084	3.968	11.6***	12.6
PANEL B: SUMMARY STATISTICS OF INSTRUMENTS							
Dividend yield MSCI World	-0.349	-0.318	0.217	-1.104	4.759	95.6***	2095.2***
U.S. default premium	1.152	1.080	0.480	0.940	3.313	43.6***	2254.7***
Change in U.S. term premium	0.006	0.000	0.679	1.708	21.283	4151.0***	84.7***

Table 1 - *continued*
Summary statistics (1975-1998)

This table reports summary statistics for the excess returns over the period 1975:01-1998:12. J-B is the Jarque-Bera test statistic for normality. Q_{12} denotes the Ljung-Box test statistic of order 12. *, **, *** denote significance at the 10%, 5%, and 1% significance levels, respectively.

	Mean	Median	St.Dev.	Skewness	Kurtosis	J-B	Q_{12}
PANEL C: SUMMARY STATISTICS OF NOMINAL EXCHANGE RATES AND INFLATION DIFFERENTIALS							
Nominal exchange rate France	0.215	0.083	1.158	1.845	10.741	882.4***	25.1**
Nominal exchange rate Japan	-0.158	0.030	3.067	-0.449	3.821	17.7***	15.1
Nominal exchange rate U.K.	0.282	0.191	2.677	0.394	4.505	34.6***	11.0
Nominal exchange rate U.S.	0.181	0.244	3.291	-0.041	3.941	10.7***	11.2
Inflation differential France	-0.216	-0.194	0.414	-0.260	4.847	44.1***	404.5***
Inflation differential Japan	0.009	0.008	0.633	-0.544	4.027	26.9***	167.5***
Inflation differential U.K.	-0.353	-0.277	0.679	-1.118	9.135	511.7***	197.3***
Inflation differential U.S.	-0.161	-0.156	0.371	-0.209	6.462	146.0***	161.4***

Table 1 - ***continued***
Summary statistics (1975-1998)

This table reports unconditional correlations of the (excess) returns over the period 1975:01-1998:12.

	MSCI Germany	**MSCI France**	**MSCI Japan**	**MSCI U.K.**	**MSCI U.S.**	**r.e.r. France**	**r.e.r. Japan**	**r.e.r. U.K.**	**r.e.r. U.S.**	**MSCI World**
PANEL D: UNCONDITIONAL CORRELATIONS BETWEEN EQUITY RETURNS AND REAL EXCHANGE RATE RETURNS										
MSCI Germany	1	0.550	0.283	0.412	0.414	0.006	-0.022	-0.081	-0.131	0.529
MSCI France		1	0.362	0.520	0.467	-0.281	-0.142	-0.153	-0.148	0.597
MSCI Japan			1	0.352	0.343	-0.092	-0.555	-0.206	-0.194	0.686
MSCI U.K.				1	0.535	-0.239	-0.179	-0.471	-0.233	0.674
MSCI U.S.					1	-0.163	-0.220	-0.258	-0.609	0.880
Real exchange rate France						1	0.229	0.314	0.256	-0.170
Real exchange rate Japan							1	0.263	0.401	-0.365
Real exchange rate U.K.								1	0.401	-0.343
Real exchange rate U.S.									1	-0.494
MSCI World										1

	n.e.r. France	**n.e.r. Japan**	**n.e.r. U.K.**	**n.e.r. U.S.**	**infl. diff. Fra**	**infl. diff. U.K.**	**infl. diff. Jap**	**infl. diff. U.S.**
PANEL E: UNCONDITIONAL CORRELATIONS BETWEEN EQUITY RETURNS, NOMINAL EXCHANGE RATE RETURNS, AND INFLATION DIFFERENTIALS								
MSCI Germany	-0.008	-0.028	-0.092	-0.142	0.040	0.029	0.032	0.096
MSCI France	-0.281	-0.145	-0.141	-0.150	-0.017	0.000	-0.064	0.015
MSCI Japan	-0.090	-0.566	-0.213	-0.204	-0.011	0.007	0.007	0.088
MSCI U.K.	-0.252	-0.183	-0.461	-0.244	0.021	0.002	-0.090	0.101
MSCI U.S.	-0.189	-0.239	-0.275	-0.623	0.061	0.068	0.037	0.121
MSCI World	-0.190	-0.384	-0.355	-0.509	0.044	0.053	0.011	0.138
Nominal exchange rate France					-0.121	-0.030	0.019	0.000
Nominal exchange rate Japan					0.023	-0.018	-0.032	-0.011
Nominal exchange rate U.K.					-0.042	-0.053	-0.019	0.046
Nominal exchange rate U.S.					-0.036	-0.087	-0.093	-0.051

Table 2
QML estimates of the conditional ICAPM with time-varying prices of market and real exchange rate risk (1975-1998)

This table depicts quasi-maximum likelihood estimation results of the conditional ICAPM with time-varying prices of risk over the period 1975:01-1998:12. Equity indices are from Morgan Stanley Capital International (MSCI). Real exchange rates versus the German mark are constructed from nominal exchange rates and CPI indices obtained from International Financial Statistics (IFS). The one-month euro-mark deposit quoted in London is taken as the conditionally risk-free asset. Each mean equation relates the asset excess return r_{it} to the covariance with global equity returns cov(r_{it}, r_{mt}) and the covariance with *nominal* exchange rate returns cov(r_{it}, s_{lt}). The prices of risk are functions of instruments in Z_{t-1}, which proxy for the information set that investors use in choosing their portfolios. The instruments include a constant, the dividend yield on the MSCI world index in excess of the one-month euro-dollar rate (WorldDY), the default premium in the U.S. (USDP), and the change in the U.S. term premium (ΔUSTP).

PANEL A: PARAMETER ESTIMATES – MEAN EQUATIONS

	C	**s.e.**	**WorldDY**	**s.e.**	**USDP**	**s.e.**	**ΔUSTP**	**s.e.**
a. Price of market risk								
κ_m	-3.706	0.127	1.490	0.164	1.091	0.082	0.111	0.022
b. Prices of real e.r. risk								
κ_{FRA}	-0.140	0.161	-0.162	0.294	0.058	0.132	0.001	0.068
κ_{UK}	-0.132	0.073	0.286	0.147	0.202	0.063	-0.088	0.036
κ_{JAP}	0.023	0.060	-0.285	0.106	-0.119	0.050	0.054	0.033
κ_{US}	0.129	0.052	0.139	0.120	-0.039	0.046	0.006	0.033

PANEL B: PARAMETER ESTIMATES – COVARIANCE PROCESS

	MSCI Ger	**MSCI Fra**	**MSCI U.K.**	**MSCI Jap**	**MSCI U.S.**	**r.e.r. Fra**	**r.e.r. U.K.**	**r.e.r. Jap**	**r.e.r. U.S.**	**MSCI World**
a	0.186	0.172	0.233	0.213	0.232	0.145	0.182	0.208	0.193	0.206
s.e.	0.032	0.028	0.020	0.021	0.021	0.023	0.072	0.041	0.038	0.017
b	0.965	0.981	0.960	0.957	0.950	0.988	0.822	0.926	0.932	0.958
s.e.	0.014	0.009	0.008	0.010	0.010	0.007	0.089	0.025	0.028	0.008

Table 2 - *continued*

QML estimates of the conditional ICAPM with time-varying prices of market and real exchange rate risk (1975-1998)

Panel C of this table depicts the results of a number of specification tests of the conditional ICAPM with time-varying prices of risk over the period 1975:01-1998:12. *, **, *** denote significance at the 10%, 5%, and 1% significance levels, respectively.

PANEL C: SPECIFICATION TESTS				
Hypothesis	**LR-test**	**df**	***p*-value**	
H_0: The price of market risk is constant	7.579	3	0.056	*
H_0: The price of market risk is equal to zero	19.602	4	0.001	***
H_0: The price of real exchange rate risk is constant	24.818	12	0.016	**
Real exchange rate France	1.072	3	0.784	
Real exchange rate U.K.	13.757	3	0.003	***
Real exchange rate Japan	10.472	3	0.015	**
Real exchange rate U.S.	3.761	3	0.289	
H_0: The price of real exchange rate risk is equal to zero	27.049	16	0.041	**
Real exchange rate France	1.073	4	0.899	
Real exchange rate U.K.	13.762	4	0.008	***
Real exchange rate Japan	10.778	4	0.029	**
Real exchange rate U.S.	5.973	4	0.201	

Table 3
QML estimates of the conditional model with time-varying prices of market, nominal exchange rate, and inflation risk (1975-1998)

This table depicts quasi-maximum likelihood estimation results of the conditional model with time-varying prices of risk over the period 1975:01-1998:12. Equity indices are from Morgan Stanley Capital International (MSCI). Real exchange rates versus the German mark are constructed from nominal exchange rates and CPI indices obtained from International Financial Statistics (IFS). The one-month euro-mark deposit quoted in London is taken as the conditionally risk-free asset. Each mean equation relates the asset excess return r_{it} to the covariance with global equity returns cov(r_{it}, r_{mt}) and the covariance with *nominal* exchange rate returns cov(r_{it}, s_{lt}). The prices of risk are functions of instruments in Z_{t-1}, which proxy for the information set that investors use in choosing their portfolios. The instruments include a constant, the dividend yield on the MSCI world index in excess of the one-month euro-dollar rate (WorldDY), the default premium in the U.S. (USDP), and the change in the U.S. term premium (ΔUSTP).

PANEL A: PARAMETER ESTIMATES – MEAN EQUATIONS

	C	s.e.	WorldDY	s.e.	USDP	s.e.	ΔUSTP	s.e.
a. Price of market risk								
κ_m	-3.150	0.105	1.072	0.162	0.747	0.072	0.091	0.020
b. Prices of nominal e.r. risk								
λ_{FRA}	-0.125	0.116	-0.136	0.277	0.201	0.124	0.015	0.083
λ_{UK}	-0.083	0.069	0.232	0.150	0.200	0.060	-0.076	0.038
λ_{JAP}	0.017	0.055	-0.241	0.117	-0.106	0.047	0.068	0.036
λ_{US}	0.161	0.048	0.113	0.121	-0.098	0.042	-0.021	0.037
c. Prices of inflation risk								
μ_{FRA}	3.912	0.610	-0.150	1.224	-4.081	0.645	-0.358	0.400
μ_{UK}	-0.825	0.243	0.035	0.594	0.131	0.291	-0.364	0.212
μ_{JAP}	0.315	0.350	-0.494	0.607	0.307	0.335	-0.245	0.138
μ_{US}	-3.226	0.633	3.891	1.361	3.338	0.647	0.911	0.312

Table 3 - *continued*

QML estimates of the conditional model with time-varying prices of market, nominal exchange rate, and inflation risk (1975-1998)

Panel B of this table depicts quasi-maximum likelihood estimation results of the conditional model with time-varying prices of risk over the period 1975:01-1998:12. Panel C of this table depicts the results of a number of specification tests of the conditional model with time-varying prices of risk over the period 1975:01-1998:12. *, **, *** denote significance at the 10%, 5%, and 1% significance levels, respectively.

PANEL B: PARAMETER ESTIMATES – COVARIANCE PROCESS

	MSCI Ger	MSCI Fra	MSCI U.K.	MSCI Jap	MSCI U.S.	n.e.r. Fra	n.e.r. U.K.	n.e.r. Jap	n.e.r. U.S.	infl. Fra	infl. U.K.	infl. Jap	infl. U.S.	MSCI World
a	0.188	0.138	0.216	0.196	0.215	0.168	0.264	0.200	0.186	0.080	0.058	-0.078	0.024	0.189
s.e.	0.033	0.015	0.020	0.020	0.021	0.026	0.080	0.038	0.034	0.012	0.029	0.022	0.030	0.016
b	0.956	0.992	0.963	0.961	0.953	0.981	0.663	0.938	0.932	0.994	0.991	0.995	0.916	0.960
s.e.	0.016	0.004	0.008	0.009	0.011	0.008	0.121	0.022	0.025	0.004	0.018	0.006	0.170	0.008

PANEL C: SPECIFICATION TESTS

Hypothesis	**LR-test**	**df**	***p*-value**	
H_0: The price of market risk is constant	10.003	3	0.019	**
H_0: The price of market risk is equal to zero	24.170	4	0.000	***
H_0: The price of nominal exchange rate risk is constant	36.511	12	0.000	***
H_0: The price of nominal exchange rate risk is equal to zero	53.957	16	0.000	***
Nominal exchange rate France	15.146	4	0.004	***
Nominal exchange rate U.K.	23.388	4	0.000	***
Nominal exchange rate Japan	11.584	4	0.021	**
Nominal exchange rate U.S.	13.468	4	0.009	***
H_0: The price of inflation risk is constant	118.495	12	0.000	***
H_0: The price of inflation risk is equal to zero	227.076	16	0.000	***
Inflation differential France	87.439	4	0.000	***
Inflation differential U.K.	41.219	4	0.000	***
Inflation differential Japan	60.208	4	0.000	***
Inflation differential U.S.	58.831	4	0.000	***

Table 4

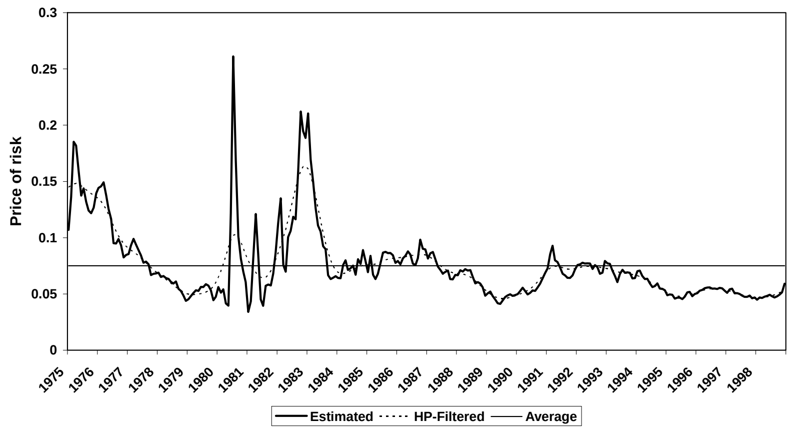
QML estimates of the conditional model with time-varying prices of market, nominal exchange rate, and inflation risk (1975-2003)

This table depicts the results of a number of specification tests of the conditional model with time-varying prices of risk over the period 1975:01-1998:12. The model is estimated using quasi-maximum likelihood estimation. Equity indices are from Morgan Stanley Capital International (MSCI). Real exchange rates versus the German mark are constructed from nominal exchange rates and CPI indices obtained from International Financial Statistics (IFS). The one-month euro-mark deposit quoted in London is taken as the conditionally risk-free asset. Each mean equation relates the asset excess return r_{it} to the covariance with global equity returns cov(r_{it}, r_{mt}) and the covariance with *nominal* exchange rate returns cov(r_{it}, s_{lt}). The prices of risk are functions of instruments in Z_{t-1}, which proxy for the information set that investors use in choosing their portfolios. The instruments include a constant, the dividend yield on the MSCI world index in excess of the one-month euro-dollar rate (WorldDY) , the default premium in the U.S. (USDP), and the change in the U.S. term premium (ΔUSTP). *, **, *** denote significance at the 10%, 5%, and 1% significance levels, respectively.

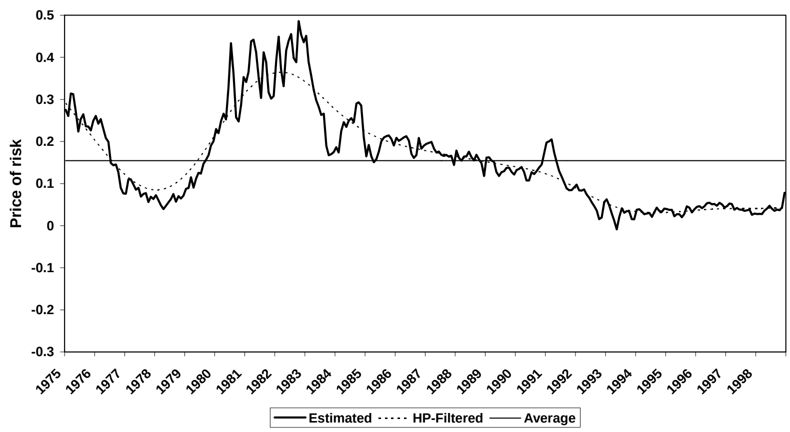
Hypothesis	**LR-test**	**df**	***p*-value**	
H_0: The price of market risk is constant	2.321	3	0.508	
H_0: The price of market risk is equal to zero	15.868	4	0.003	***
H_0: The price of nominal exchange rate risk is constant	30.488	12	0.002	***
H_0: The price of nominal exchange rate risk is equal to zero	46.215	16	0.000	***
Nominal exchange rate France	18.358	4	0.001	***
Nominal exchange rate U.K.	11.414	4	0.022	**
Nominal exchange rate Japan	7.878	4	0.096	*
Nominal exchange rate U.S.	10.271	4	0.036	**
H_0: The price of inflation risk is constant	111.840	12	0.000	***
H_0: The price of inflation risk is equal to zero	232.662	16	0.000	***
Inflation differential France	84.849	4	0.000	***
Inflation differential U.K.	45.276	4	0.000	***
Inflation differential Japan	70.047	4	0.000	***
Inflation differential U.S.	56.932	4	0.000	***

Figure 1
The prices of market, nominal exchange rate, and inflation risk

The Price of Market Risk



The Price of Nominal Exchange Rate Risk France



The Price of Nominal Exchange Rate Risk Japan

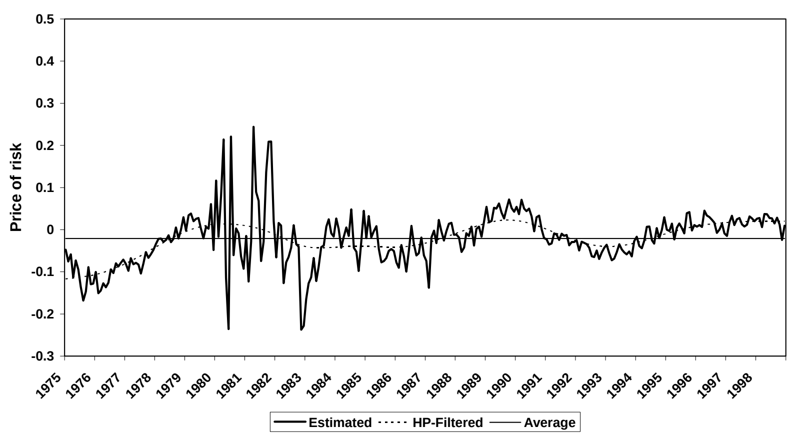
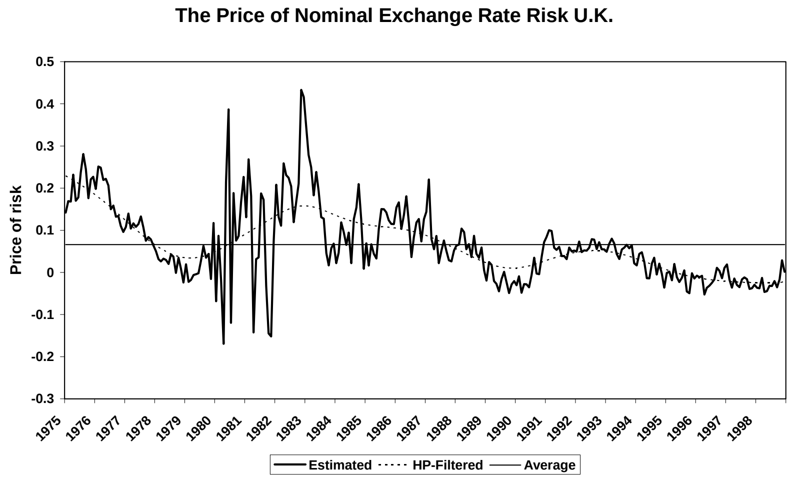
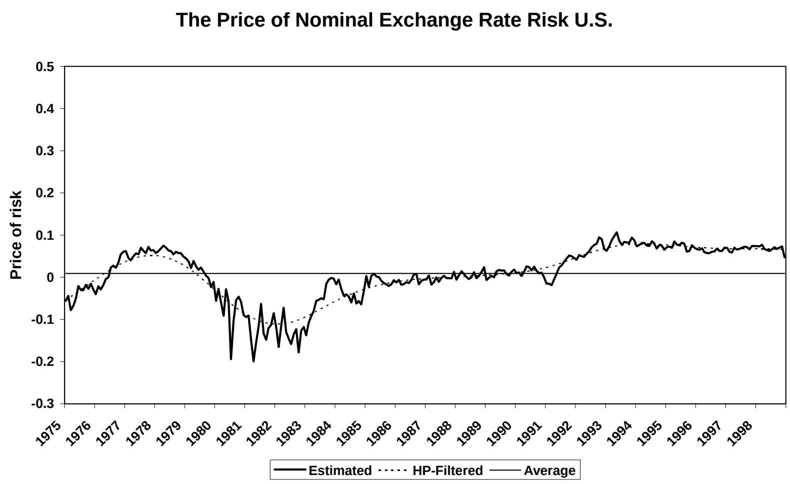


Figure 1 - *continued*
The prices of market, nominal exchange rate, and inflation risk





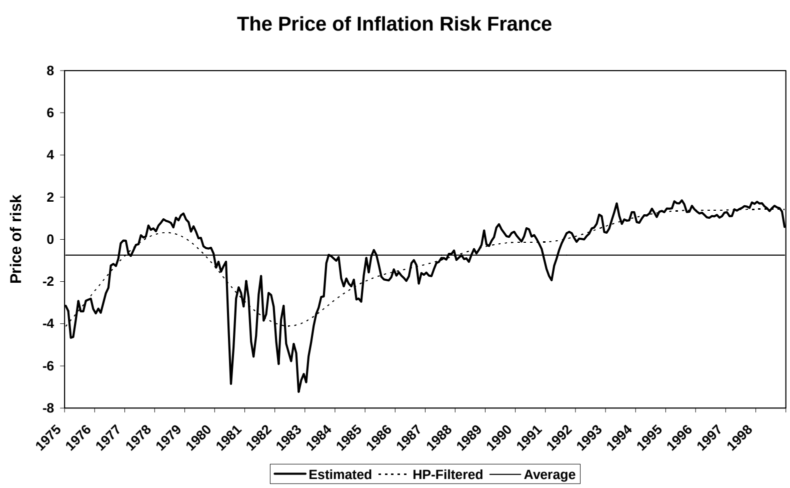
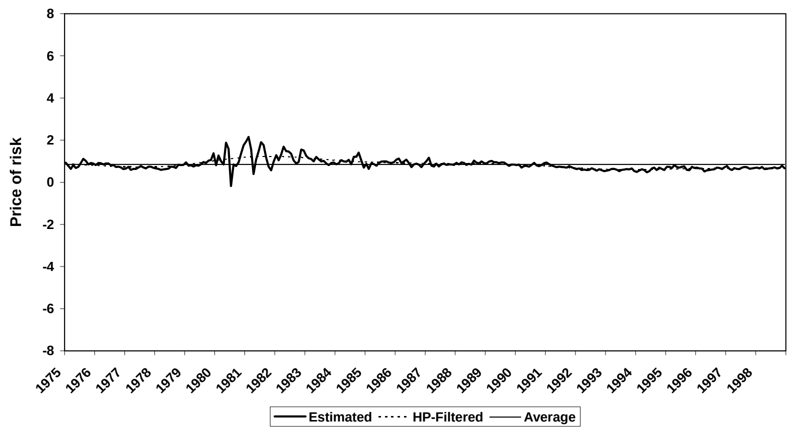
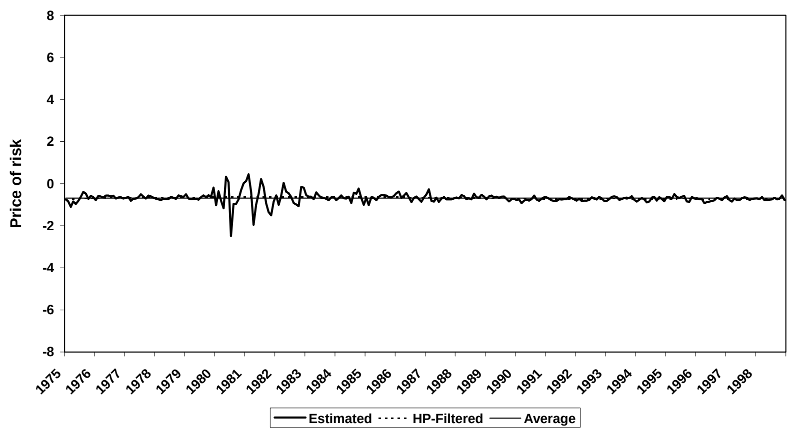


Figure 1 - ***continued***
The prices of market, nominal exchange rate, and inflation risk

The Price of Inflation Risk Japan



The Price of Inflation Risk U.K.



The Price of Inflation Risk U.S.

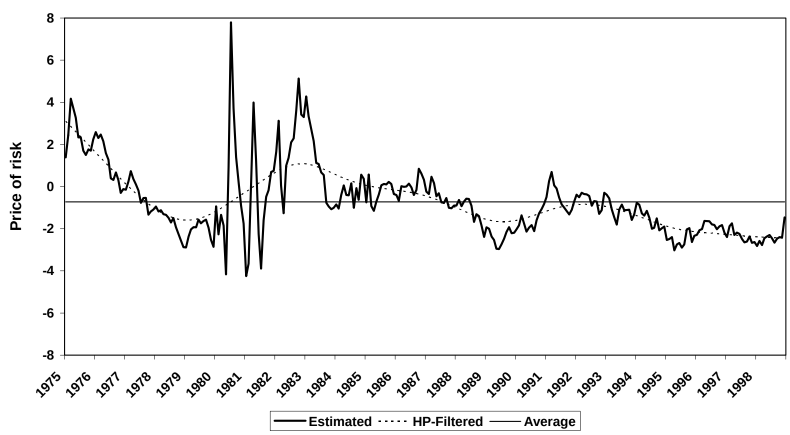


Figure 2
Estimated risk premia decomposition: MSCI Germany

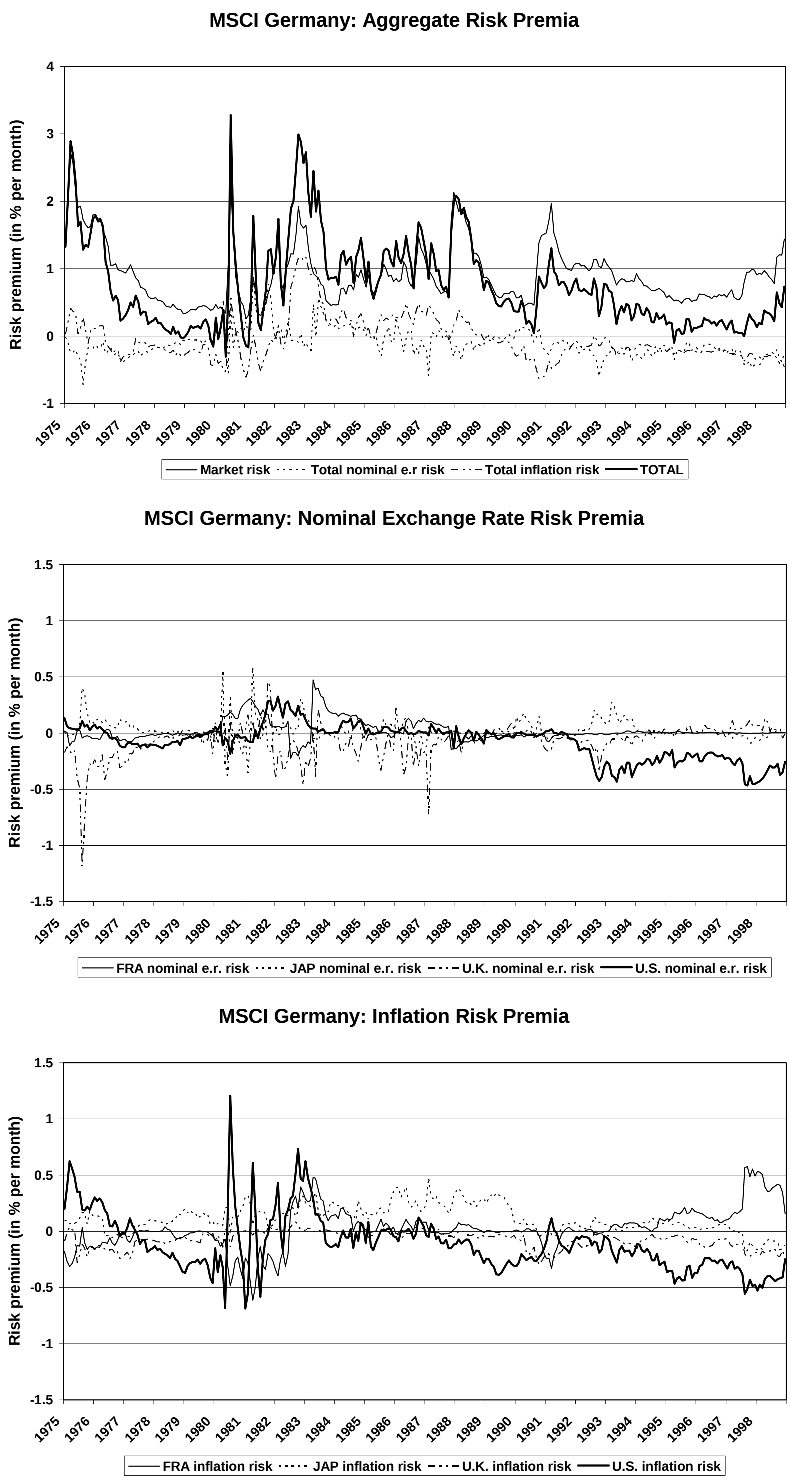
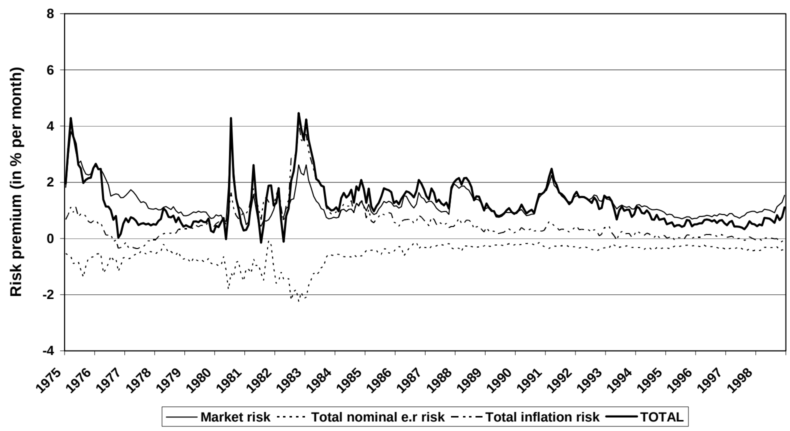
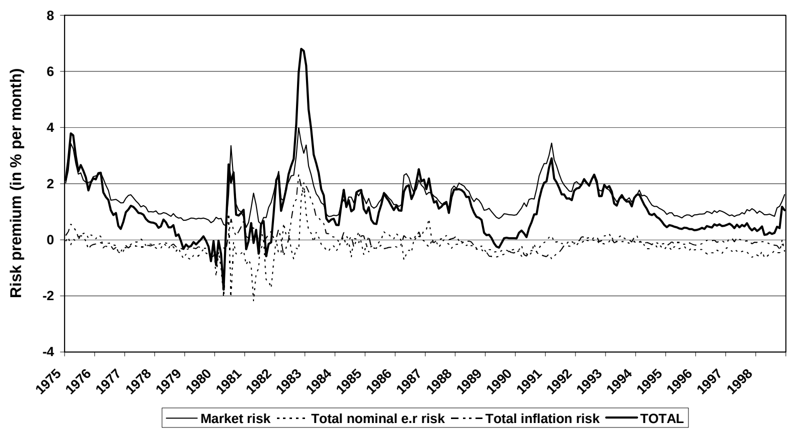


Figure 3
Estimated risk premia decomposition: MSCI Equity indices

MSCI France: Aggregate Risk Premia



MSCI Japan: Aggregate Risk Premia



MSCI U.K.: Aggregate Risk Premia

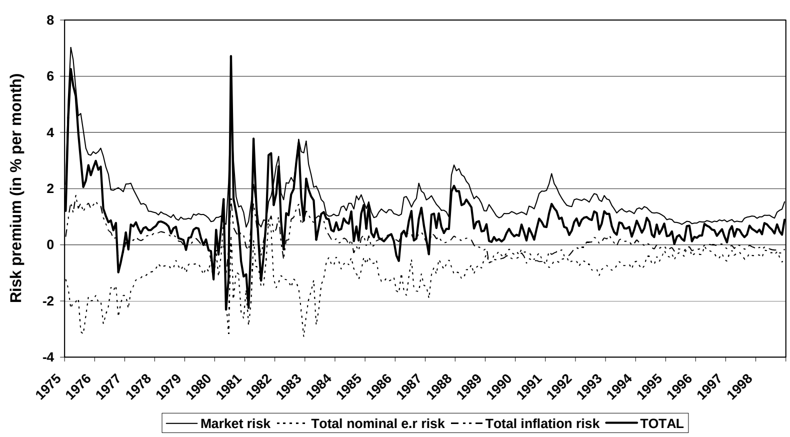
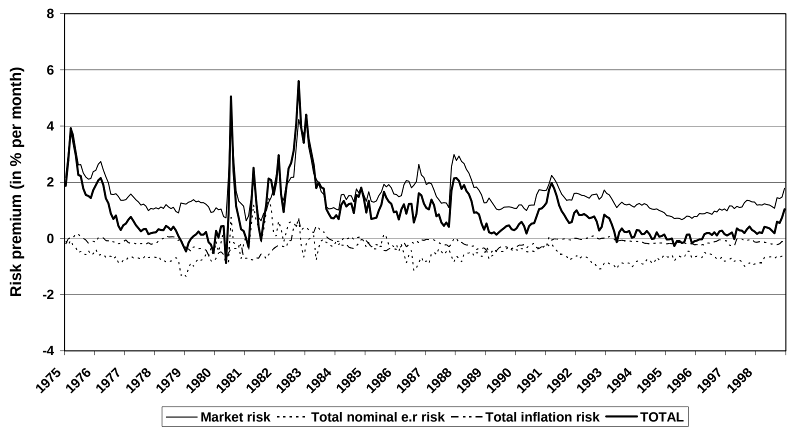


Figure 3 - *continued*
Estimated risk premia decomposition: MSCI Equity indices

MSCI U.S.: Aggregate Risk Premia



MSCI World: Aggregate Risk Premia

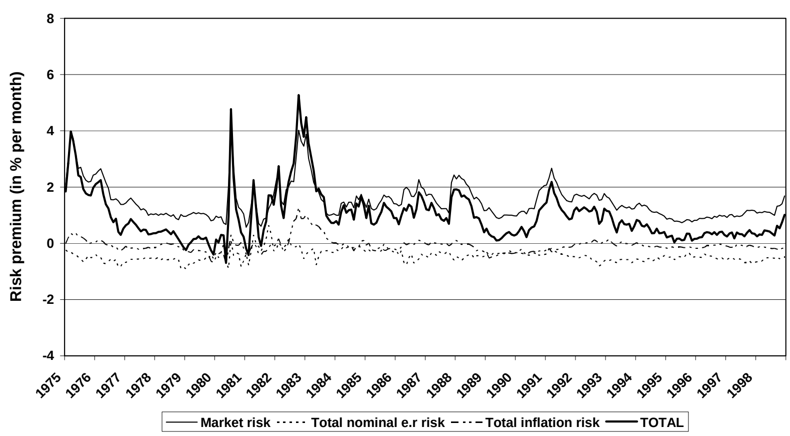


Figure 4
The price of inflation risk over the full sample period 1975-2003