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Basis Risk and Inflation
Replication

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Basis Risk and Inflation Replication

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Abstract

We study inflation replication in European markets and find that investors can improve their inflation hedge by acquiring foreign inflation-linked derivatives on the international market. Although European inflation-linked bonds holdings have a substantial impact on the inflation hedging ability, their weight in the hedging portfolio is declining over the investment horizon. We show that UK and US inflation-linked bonds can be attractive as well by exploiting long run dynamics of inflation and currency movements. While under stable conditions the replication ability of these portfolios can be improved, uncertainty about long run dynamics may still influence its hedging performance. We confirm with a Bayesian methodology taking into account the uncertainty associated with long run dynamics that during the Financial crisis local nominal bond holdings increased while foreign inflation-linked bonds decreased. While we observe the flight to local securities for inflation hedging investors, European inflation-linked bond holdings remain steady, showing the importance of these bonds in the replication strategy of the investor.

Keywords: Inflation hedging, Basis risk, Cointegration, inflation derivatives

JEL Classifications: E44, F21, and G15

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1 Introduction

International investors acquire foreign inflation derivatives such as inflation-linked bonds in major markets to profit from high liquidity. At the US TIPS auctions about 40% of the total demand consists of foreign investors, suggesting that US inflation-linked bonds are popular assets for foreign portfolios (Fleckenstein, Longstaff, & Lustig, 2013). However, do these foreign inflation-linked assets protect against the local inflation risk of investors? The theory of Purchasing Power Parity (PPP) predicts that investors can acquire any foreign inflation-linked instrument without constituting additional risk. The explanation is that the exchange rate will compensate the investor for the difference between the foreign inflation rate and his inflation exposure. Empirical studies, however, typically reject the PPP between countries, so that foreign investors will be exposed to basis risk regarding inflation (Roll, 1979). We examine this basis risk and explain by means of inflation replication the demand of foreign investors to acquire foreign inflation derivatives on the international markets.

In this paper we investigate the risk associated with foreign inflation derivatives for investors who are not able to acquire inflation-linked derivatives on the local market. Liquidity and high trading costs might also cause such limitations. A vast literature investigates the alternatives for such an investor, focusing on the hedging ability of various nominal asset classes (see e.g. Bodie (1976), Fama and Schwert (1977) for nominal bonds and equity, and for commodities, e.g. Campbell et al. (2003) and Hoevenaars et al. (2008)). They find that these nominal assets are unable to insure against inflation risk, which suggests that only real assets offer a long-run hedge against inflation risk. Consequently, the literature mostly focuses on including local inflation-linked securities in the asset mix (for a discussion see e.g., Ang, 2012). Despite its insights, the literature largely ignores the ability of investors to acquire foreign inflation derivatives on the international market. While inflation derivatives are the only asset class that could immunize the investor from inflation risk, assets generating equivalent payoffs similar to the inflation shocks experienced by an investor are not traded in the financial market. Consequently, even local inflation derivatives based on a national aggregated inflation measure might constitute a mismatch with the actual inflation experienced by an investor and would require a specific inflation replication strategy. Especially for pension funds with long term liabilities the differences between cost of living adjustments and the consumer price level inflations can attribute to substantial basis risk over the horizon (Boskin, Dulberger, Gordon, Griliches, & Jorgenson, 1998). Therefore, we analyze how investors can replicate his actual inflation with foreign inflation-linked derivatives by exploiting long run dynamics of inflation measures.

To study inflation hedging with foreign inflation derivatives, we construct portfolios that replicate the investor's inflation exposure with both local and foreign assets. To incorporate the horizon effect of the investments and the inflation risk, we estimate both the term structure of asset returns and inflation. Due to the dependence of the correlation structure on the investment horizon, the weights of the investor's inflation tracking portfolios may shift. Two important factors may alter the asset allocation as well, namely long run dependency between the inflation measures and currency risk. To investigate whether investors can utilize this long run dependency over various investment horizons, we analyze two types of investors. The VECM-type of investor exploits long run dependency between his inflation exposure and foreign inflation measures, while the VAR-type of investors ignores this information. To study

these factors separately, we incorporate currency hedge strategies to study the effect of exchange rate movements separately. In our setting, the international market consists of EU, UK and US inflation derivatives, and includes equity and nominal bonds of Japan, UK, US and local markets. We take the perspective of a Dutch, French and German investor to analyze the impact on the hedging strategies for European investors from both large and small economies.

We first consider the question of whether investors can improve their inflation hedges by acquiring foreign inflation derivatives. In our sample period from 1999 to 2011, we show that on average investing in inflation derivatives from European, UK, US and Japanese markets is beneficial for investors exposed to either Dutch, French or German inflation. While Japanese inflation-linked securities would constitute a large mismatch with the investor's inflation risk, the exchange rate compensates for this effect. Due to the fact that the exchange rates are quite volatile over time, the European inflation-linked bond is an important asset for European investors. Not surprisingly, we show that European bond holdings are quite substantial, while the remaining weight of the portfolio is allocated to nominal bonds. However, we find that over the investment horizon the demand for European inflation-linked bonds reduces for all three investors. The attractiveness of the European inflation-linked bond diminishes, while the US inflation-linked bond becomes more prominent. When currency risk is hedged, the Japanese carry trade has an important weight in our portfolios together with European inflation-linked bonds. Excluding European inflation-linked bonds from the asset choice, the investor can still substantially improve the hedging portfolio by acquiring UK and US inflation-linked bonds. Over the investment horizon, we document that local nominal bond holdings together with UK inflation-linked bonds decrease, while the US inflation-link bond exposure increases. Thus, investors benefit from investing in foreign inflation-linked bonds, but currency risk and the investment horizon can substantially affect the portfolio weights. To verify whether investors can exploit long run dynamics, we establish a cointegration relation between the investor's inflation exposure and foreign inflation measures. This cointegration relation captures long run dynamics enabling investors to adjust their strategy and incorporate long run dependency of the inflation measures. Investors incorporating such strategies, VECM-type investors, cannot necessarily benefit from incorporating long run risk in our sample. We find that Dutch and German VECM investor can improve the hedging error respectively 2% and 5% at a 5 years investment horizon while hedging currency risk. Since the exchange rates can substantially influence the returns of the portfolio, we only find that the German VECM-type investor can exploit long run dynamics if exposed to currency risk. These results are mostly driven by our short sample period in which the German cointegration is most strong. Excluding European inflation-linked bonds from the asset mix allows us to use an extended sample period. In this period, the VECM-type investors outperforms the VAR-type investor in all three cases. If currency risk is hedged, the German VECM-type investors can improve his tracking error about 7% at a 5 years horizon while the Dutch and French investor can only improve 1.5% and 0.3%. This suggests that a stable cointegration relation is crucial for inflation hedging strategies relying on long run dynamics.

Since long run dynamics of inflation exposures with European inflation are hard to capture with data currently available, we employ a Bayesian methodology to incorporate parameter uncertainty. This methodology allows us to explicitly take into account the uncertainty related to the cointegration relation and the asset returns. Our Bayesian results suggest that parameter uncertainty substantially impacts the portfolio allocations. Again, we find a decline of

European bond holdings over the investment horizon. In the Dutch and German cases this decline is more substantial, whereas in the French case the decline is less steep, if we compare the weights to the previous results without parameter uncertainty. For example, the German VECM-type investor holds 42% European inflation-linked bonds at a 1 month horizon whereas at a 5 years horizon the weight drops to 30% of these bonds. Although the portfolio weights over the horizon differ among specifications, European inflation-linked bonds bear substantial weight in the portfolios. Similarly, we find that all investors increase nominal bond holdings to about 25% if exposed to currency risk. For the French VAR-type investor, parameter uncertainty increases the nominal bond holdings from 20% at a 1 months horizon to about 27% at a 5 years horizon. In the approach without parameter uncertainty, the French VAR-type investor decreases his bond exposure from 14% to 8%. Consequently, parameter uncertainty can alter the portfolio weights for local holdings as well.

According to the PPP, the interaction between inflation measures and exchange rates may influence the attractiveness of foreign inflation-linked bonds. Since exchange rates are more volatile than inflation rates in our sample, currency hedges with forward contract do alter the allocation of the hedging portfolios. In our model, the currency hedging investor assigns large weights to Japanese nominal bonds, exploiting the Japanese carry trade. Since nominal returns on Japanese nominal bonds are less volatile, these bonds hedged with forward currency contracts may offer an alternative hedging strategy to the investor in our sample. The attractiveness of the US inflation-linked bond diminishes due to the parameter uncertainty in case of unhedged currency risk. All three Bayesian investors decrease the weight of US inflation-linked bonds over the investment horizons, whereas the portfolio allocations without a Bayesian framework are upward sloping. Surprisingly, US inflation-linked bonds remain to have a more substantial role in our inflation hedging portfolios compared to UK inflation-linked bonds. Only for long investment horizons, the German investors attach a similar importance to UK inflation-linked bonds. The attractiveness of the US and UK inflation-linked bonds to hedge inflation Dutch, French or German inflation exposure is strongly influenced by currency risk over the horizon. Consequently, replicating inflation with foreign inflation-linked bonds requires investors to take into account such basis risk.

To evaluate how investors responded to the aftermath of the financial crisis in 2008, we investigate time varying inflation replication portfolios. Our model reveals that during the crisis the demand for local nominal bonds substantially increased for all three investors on the short investment horizon. While these portfolio weights increase about 51% at 1 month investment horizon, at a 5 years horizon these holdings change on average about 2.7%. At the same time, these investors increase their UK inflation-linked portfolio weights, while decreasing the allocation to US inflation-linked bonds. Surprisingly, all investors maintain similar portfolio weights for European inflation-linked bonds at a 5 years horizon. After the crisis, the dynamics reverse and all Bayesian inflation hedging investors decrease their nominal bond holdings. Consequently, our model confirms that the Bayesian inflation hedging investor switches their holdings to local nominal bonds. This flight home effect during the financial crisis was also documented in the debt market, where investors shift their demand to local assets (see e.g. Giannetti and Laeven (2012)). We add to this insight that a long run inflation hedging perspective may offer an explanation of why local nominal bonds were attractive during the financial crisis.

Our work extends the literature on inflation hedging in three ways. First, we build on the

literature of the PPP for long run dynamics between inflation measures (see e.g., Roll, 1979) and apply this insight to inflation hedging portfolios. Unlike Bekaert and Wang (2010), we propose a method to include long run inflation dependency in the asset allocation portfolio to allow the investor to exploit long run dynamics. This paper demonstrates how uncertainty involved with long run dynamics of inflation affects European inflation hedging investors. Under stable conditions of the long run dynamics, inflation hedging investors are likely to exploit these dynamics in their portfolios on longer investment horizons. Secondly, we confirm the importance of investment horizon as suggested by Schotman and Schweitzer (2000) and extend this insight to the asset class of foreign inflation-linked derivatives. In particular, we analyze the importance of European inflation-linked bonds for the European market. Thirdly, we extend the literature on home bias by offering an explanation in terms of inflation hedging to the question why the investor resorts to local assets during the financial crisis. Existing literature (see e.g. Popov and Udell (2010) and Cetorelli and Goldberg (2012)) mainly focus on the banking sector to capture the flight home effect in the debt market, we on the other hand offer an explanation of how inflation hedging can drive the home bias effect in the governmental debt market by foreign investors.

The remainder of this paper is organized as follows. Section 2 motivates our analysis of foreign inflation-linked securities and explains how the PPP affects inflation hedging in the international market. In Section 3 we define the portfolio choice problem of the investor and explain how investors can exploit the cointegration relation between inflation measures in our VECM model. Consequently, we are able to describe its effect on the long run term structure of asset returns. The empirical results are reported and discussed in Section 4. Our concluding remarks follow in Section 5.

2 Basis risk and foreign inflation-linked securities

A central theme motivating the use of foreign inflation-linked derivatives is that the foreign inflation measures relate to the inflation exposure of the investor. The Purchasing Power Parity (PPP) states that as a result of the interaction of inflation rates and exchange rates the difference between price levels denominated in a common currency cannot differ between countries. The underlying idea of this hypothesis is that the law of one price should hold among countries for tradable goods. Under the PPP hypothesis the investor can hedge his inflation exposure by acquiring similar securities based on foreign inflation, since the spot exchange rate will compensate the mismatch between the inflation rates. Therefore, investments in foreign inflation-linked derivatives will not constitute basis risk given the investor is exposed to aggregated inflation if the PPP holds.

Although short term violations of PPP can occur due to the slow adjustment rate of commodity prices, early studies observe empirical deviations from the PPP hypothesis (See e.g. (Roll, 1979), and (Huang, 1987)). On the other hand, McNown and Wallace (1989) find evidence that supports the PPP hypothesis for high inflation countries in a framework that incorporates a long run perspective. Recent empirical studies suggest that the PPP with respect to the US dollar seems to hold for various countries over a longer horizon (See e.g. (Taylor, 2002) and (Wallace & Shelley, 2006)). However, deviations from the PPP might be persistent due to Balassa Samuelson effects (Samuelson, 1994). For example, differences in productivity

between countries can lead to dissimilar price levels of nontradable goods. These deviations constitute a risk for the inflation hedging investor in the long run if mean reversion does not occur.

In our analysis we assume that the investor is exposed to inflation measured by the national consumer price index. In order to quantify basis risk for our sample period when using foreign inflation derivatives, we determine the mismatch between the foreign inflation measure that are traded on financial markets and the inflation to which the investor is exposed to. Only in a few financial markets inflation-linked securities based on a national consumer price index are traded. Examples of large markets are Japan, UK, and US. Several countries in Europe have introduced an inflation-linked bond that immunizes investors from European inflation. Consequently, Eurozone investors will be exposed to additional risk of a mismatch between their exposed inflation and the inflation that underlies their hedging derivatives. On the other hand investors will not be at risk for changes in the exchange rate. To quantify the basis risk in our sample, we use three European inflation exposures, namely Dutch, French and German consumer price index inflation, representing the perspective of a Dutch, French and German investor respectively. Among markets that offer inflation-linked bonds, we have chosen the relatively largest markets based on outstanding notional amounts in order to account for liquidity effects. These markets are: Europe, Japan, UK, and US¹. While Japan, UK, and US issue inflation-linked bonds based on their national CPI inflation, European inflation-linked bonds are issued based on HICP Euro Area inflation measure.

Table 1 reports the basis risk for our sample period for all three inflation exposures. We approximate basis risk in this table as the difference between two inflation measures denominated in the Euro currency. This approach allows us analyze the risk of foreign inflation-linked derivatives ignoring differences in real returns of both economies. On average the yearly mismatch is negative implying that investors would benefit from replication using foreign inflation-linked derivatives. Even though Japanese inflation is quite low and results in an average positive mismatch, the exchange rate dynamics increases the attractiveness of Japanese inflation derivatives². As a results, the hedging ability of securities based on these inflation measures are influenced by currency dynamics. Since currency exchange spot rates are quite volatile, it introduces a large basis risk for the investor. This is, for example, reflected in the large standard errors of Japanese mismatch. Since our result on basis risk is mostly driven by currency movements, Japanese inflation-linked bonds might be less relevant for hedging inflation compared to European, UK and US inflation derivatives. Hence, we refrain from incorporating those securities in our framework. However, we do allow investors to benefit from the currency trade by adding nominal Japanese bonds to the asset choice.

Table 1 indicates that in terms of average mismatch, the UK inflation derivatives would yield the highest compensation. However, the volatility of this mismatch indicates that investing in UK inflation constitutes more basis risk than in the Japanese inflation derivatives. Surprisingly, the US mismatch has a lower volatility compared to the UK as well. This suggest that UK inflation-linked securities might not be optimal choice for an inflation hedging investor. Thus, currency dynamics are an important determinant in the asset allocation.

¹The report Barclays Capital (2005) suggests that the European, Japanese, UK, and US markets are in terms of notional amounts the largest inflation derivatives markets.

²The appreciation of the Yen over the whole sample period is about 23.5%, so that an investor holding Japanese currency would profit substantially from a long position.

The volatility of the mismatch between the EU and the Netherlands is substantially larger than in the cases of France and Germany. The impact of inflation in both France and Germany on the HICP Eurozone inflation is larger than for Dutch inflation³. Consequently, the hedging capacity of European inflation-linked securities in terms of basis risk are more favourable for investors from Germany and France. The US inflation-linked securities are for all three investors promising considering the low volatility. Since the mismatch is positively skewed, larger positive yearly mismatches are more likely. Thus, investing in US inflation-linked securities constitutes more basis risk compared to European inflation derivatives due to exchange rate dynamics. Generally, European inflation-linked derivatives consist of less risk and hence will have an important role in the asset allocations for an investor hedging inflation.

Another component of inflation hedging is the correlation of the asset with the inflation measure. For example, if correlation between the inflation exposure of an investor and the hedging asset is sufficient, the investor can exploit the comovement by leveraging his position. However, the risk of changes in exchange rates can strongly influence the hedging ability of a foreign derivative. For example, an appreciating currency during the investment period can influence the attractiveness of assets denominated in other currencies. Therefore, we explicitly take currency risk into account in our model of the asset returns. To determine the effect of exchange rates on the asset allocation, we compare the asset allocation in which the investors are exposed to currency risk to an allocation in which currency risk is hedged with forward contracts.

3 Hedging Inflation Framework

In this section we derive the hedging portfolio framework and introduce a cointegration analysis between the investor's inflation exposure and foreign inflation measures in order to incorporate long run coherency.

3.1 Portfolio Choice

We consider an investor who wants to hedge his inflation exposure with a buy and hold strategy over different horizons. The optimal asset allocation consists of a minimum variance portfolio that replicates the inflation to which the investor is exposed to. At time t the investor hedges his expected inflation exposure with specific traded assets for a certain time horizon s . Formally, the investor's problem can be denoted as

$$\begin{aligned}
& \min_{\omega_t} \omega_t' \text{Var}_t[R_{t+1 \rightarrow t+s}^p] \omega_t \\
& \text{s.t. } \omega_t' \left(\mathbf{E}_t[R_{t+1 \rightarrow t+s}^p] + \frac{1}{2} \text{Var}_t[R_{t+1 \rightarrow t+s}^p] \right) = \mathbf{E}_t[\pi_{t+1 \rightarrow t+s}] + \frac{1}{2} \text{Var}_t[\pi_{t+1 \rightarrow t+s}] \\
& \omega_t' \mathbf{1} = 1,
\end{aligned} \tag{1}$$

³The average weight between 1996 and 2011 used to determine the HICP Euroarea inflation measure is 20.6% for France and for Germany 29.8% whereas the Dutch weight is only 5.1%. The HICP Euroarea inflation measure consists of the weighted average of the individual HICP inflation measures. The HICP measure differs from the national consumer price indices. The country's weight in the HICP Euroarea is determined by the relative household consumption expenditure in comparison with the total expenditure of the Euro area.

where ω_t is a time-dependent vector with portfolio weights, $R_{t+1 \rightarrow t+s}^p$ are the returns of the traded assets determined over horizon s at time t , and $\pi_{t+1 \rightarrow t+s}$ denotes the investor's expected inflation exposure over horizon s at time t . The restriction in the optimization problem requires that the minimum variance portfolio is mimicking the arithmetic mean of inflation. Consequently, the solution of the optimization is a minimum variance portfolio of traded assets replicating the investor's inflation exposure. Since the investor cannot invest in securities that generate payoffs equivalent to his inflation exposure, he replicates his exposure using a portfolio from equity, nominal and real bonds traded on the financial markets. Although we ignore short selling constraints, our model can be easily adapted. For tractability we will assume that the monthly gross returns and inflation are lognormally distributed. We distinguish between the conditional and unconditional allocation problem. The conditional problem is stated as above, while the unconditional can be restated by dropping the time dependency of the expectation and variance. The log expected gross return, $E_t[R_{t+1 \rightarrow t+s}^p] + \frac{1}{2} \text{Var}_t[R_{t+1 \rightarrow t+s}^p]$, denotes the arithmetic mean return. In order to investigate the effect of the holding periods, we scale both means and variances by horizon s and subsequently report these in our empirical section.

For the equity market allocation the investor can choose from the Nikkei, FTSE, and the Dow Jones, and his local market. The local markets consist of the AEX for the Dutch investor, the CAC for the French investor and the DAX for the German investor. International equity indices tend to show reversal in returns relatively to other equity markets. Richards (1997) and Balvers, Wu, and Gilliland (2000) find most evidence of this reversal on a horizon of three years. This implies that there are long run dynamics between these markets. Therefore, it is important to include multiple markets available for the investor. The nominal bond market choice consists of 10 years government bonds from Japan, UK, US and the local market of the investor. The inflation-linked bonds are from the UK and US with a maturity of 5 years. The European inflation-linked bond return is approximated by using the German nominal 5 year maturity bonds and the inflation swap rates for the same maturity. European inflation swaps rates are based on the HICP inflation rates and do not dependent on the issuing country. Due to the limitations of the available data for inflation-linked bonds, our data is sampled on a monthly frequency. Our sample periods range from January 1999 to December 2011 without European inflation-linked security and from May 2005 to December 2011 with European inflation-linked security.

In Table 2 we present the sample statistics of the inflation measures and the returns of the assets. We find that the dynamics of the returns are substantially influenced by hedging currency risk. With the use of forward contracts the investor can hedge this risk and reduce variability in the asset returns denominated his local currency. In our sample period, hedging exchange rates improves on average the returns for the US and Japan. This implies that the investor can benefit from the difference in the nominal interest rates between the two countries. However, hedging the UK pound is only beneficial for the investor to reduce variability in his returns. In particular, investors can reduce the standard deviation of the monthly returns of the UK equity market by 11.5% by hedging this risk. In Japan and the US, the effect on the variability of the asset returns is smaller. Consequently, in our empirical section we analyse two scenarios either with currency hedged asset returns and asset returns that are exposed to currency risk.

The analytic solution of our optimization problem in Equation (1) is equivalent to an op-

timization of an inflation tracking portfolio (See e.g. Bekaert and Wang (2010)). The latter portfolio minimizes the hedge error that consists of the exposed inflation and the assets returns. Our specification allows for horizon analysis and the incorporation of a cointegration relation between the inflation to which the investor is exposed to and national aggregated inflation measures. If the inflation exposure to which the investor is exposed to is tied together in the long run with the foreign inflation measures included in the model, then the VECM-type of investor will incorporate this effect in his strategic asset allocation.

3.2 Asset returns and inflation

We describe the long run dynamics between the inflation exposure of the investor and the foreign inflation measures via the following cointegration relation

$$I_t^H = \alpha_0 + \alpha_1 t + \gamma_1 I_t^{EU} + \gamma_2 I_t^{JP} + \gamma_3 I_t^{UK} + \gamma_4 I_t^{US} + \epsilon_{\pi,t}, \quad (2)$$

where I_t^H denotes the logarithmic price level H to which the investor is exposed to, i.e. either Dutch, French or German inflation. The price levels of the foreign inflation measures are given on the right side of the equation. The cointegrated residual is stationary under this specification, such that $\epsilon_{\pi,t} \sim I(0)$. This equation implies that exposed monthly inflation $\pi_t^H = \Delta I_t^H$ is equivalent to $\alpha_1 + \gamma_1 \pi_t^{EU} + \gamma_2 \pi_t^{JP} + \gamma_3 \pi_t^{UK} + \gamma_4 \pi_t^{US} + \Delta \epsilon_{\pi,t}$. We include a time trend in our specification in order to capture a deterministic time trend between the price levels. Due to our specification the dynamics of the investor's exposure to monthly inflation is influenced in the long run by foreign inflation. Hence, the price levels share a common stochastic trend. We impose no restrictions on the parameters γ_i , so that price levels may have different exposures to underlying long run risks.

We motivate our cointegration specification based on the empirical literature related to the PPP (See e.g. Juselius and MacDonald (2004) and Chen, Choi, , and Devereux (2008)). The interest in the PPP literature has focused on price levels shifts in certain baskets of goods and service across countries in order to examine whether inflation shares a common stochastic trend (see e.g. Taylor and Taylor (2004)). Following this approach, Chen et al. (2008) find mixed evidence in eleven developed countries on the long run comovement of these price levels since 1950. Since we select only four major developed economies, we are able to avoid the number of possible cointegrational relations.

Next, we describe the asset returns for the various investment horizons by modeling the single period returns together with the inflation state variables. We estimate the following VECM

$$\begin{bmatrix} R_{t+1} \\ NB_{t+1} \\ RB_{t+1} \\ \pi_{t+1} \\ \epsilon_{\pi,t+1} \end{bmatrix} = \begin{bmatrix} a_R \\ a_{NB} \\ a_{RB} \\ a_\pi \\ a_\epsilon \end{bmatrix} + \begin{bmatrix} * & 0 & 0 & * & * \\ 0 & * & 0 & * & * \\ 0 & 0 & * & * & * \\ 0 & 0 & 0 & * & * \\ 0 & 0 & 0 & * & * \end{bmatrix} \begin{bmatrix} R_t \\ NB_t \\ RB_t \\ \pi_t \\ \epsilon_{\pi,t} \end{bmatrix} + \begin{bmatrix} u_{R,t+1} \\ u_{NB,t+1} \\ u_{RB,t+1} \\ u_{\pi,t+1} \\ u_{\epsilon,t+1} \end{bmatrix}, \quad (3)$$

where a denotes the vector of constants, R_t the equity return, NB_t nominal bond return, RB_t the real bond return, and π_t the foreign inflation and the inflation the investor is exposed to. The variable $\epsilon_{\pi,t}$ is the residual of the cointegration relation as described in Equation (2). We

project the returns on their lags and associated national inflation measure. Following Bansal and Kiku (2011), we ignore interactions between the bond markets and the equity markets. By introducing matrix $X_t = [R_{t+1} \quad NB_{t+1} \quad RB_{t+1} \quad \pi_{t+1} \quad \epsilon_{\pi,t+1}]'$, we can rewrite our VECM in matrix notation as follows

$$X_{t+1} = a + BX_t + u_{t+1}. \quad (4)$$

The equity returns R_t and nominal bond return NB_t consist of the stock markets from Japan, UK, US and the local equity market of the investor, which is either the Dutch, French or German market. The real bond returns are taken from the EU, UK, and US. The variable π_t denotes the foreign inflation measures of the EU, Japan, UK, the US, and the inflation of France, Germany, or the Netherlands. The variable X_t is consequently a (17×1) -matrix and u is a vector of error terms that follow a normal distribution with zero mean and variance-covariance matrix Σ_u .

Our approach differs from the hedging inflation literature by including the error-correction specification of the inflation measures in the asset returns. Typically, the standard framework is to estimate asset returns and inflation with a VAR model, see e.g. Campbell and Shiller (1988), Campbell et al. (2003), Kandel and Stambaugh (1996), Hodrick (1992), and Schotman and Schweitzer (2000). In our specification multi-period returns of the investor's local market will depend on the dynamics of the long-horizon local inflation measure. The interaction between the cointegration residual and the equity and bond markets can capture the effect of a disequilibrium between the inflation measures on the asset markets. Thus, the cointegration relation can influence the dynamics of the asset returns. Consequently, including the error correction in variable in the return dynamics may alter the inflation hedging portfolio allocation. To compare the implications of the VECM model with the standard VAR model, we estimate both models. The VAR specification can be obtained by excluding the error-correction variable $\epsilon_{\pi,t}$ from Equation (3).

3.3 Expected returns and risks

The hedging portfolio allocation in Equation (1) depends on expectation and the variance of the multi-period distribution. First, we derive the solution to the unconditional problem and then the conditional returns and risk structure. In this derivation, we follow the arguments of Bansal and Kiku (2011).

The unconditional expectation of the returns over multiple horizons is equal to the mean of the returns $\bar{R} = \frac{1}{T} \sum_{t=1}^T R_t$, so that

$$E[R_{t+1 \rightarrow t+s}^p] = \frac{1}{s} \sum_{k=1}^s \bar{R} = \bar{R}. \quad (5)$$

The unconditional variance of the returns at various horizons can be derived by expressing the VECM model as an infinite-order moving average. According to Wold's theorem we can decompose the state variables X_t as function of the coefficient B and the residuals u_t . As a result, we can write the unconditional variance of X_t as

$$\Omega_0 = \sum_{k=0}^{\infty} B^k \Sigma_u B'^k. \quad (6)$$

Incorporating the time-horizon s we get the following expression

$$\Omega_s = \Omega_0 + \frac{1}{s} \sum_{k=1}^{s-k} (s-k) \left(B^k \Omega_0 + \Omega_0 B'^k \right), \quad (7)$$

where the matrix $B^k \Omega_0$ denotes the k -order autocovariance of X_t . Note that the covariance is scaled by the horizon s , so that measurement is per unit in time. The unconditional variance matrix can be partitioned in returns and inflation as follows,

$$\Omega_s = \begin{bmatrix} \Omega_{Rp,s} & * \\ * & \Omega_{\pi,s} \end{bmatrix}, \quad (8)$$

with $\text{Var}[R_{t+1 \rightarrow t+s}^p] = \Omega_{Rp,s}$ and $\text{Var}[\pi_{t+1 \rightarrow t+s}^H] = \Omega_{\pi,s}$. In the unconditional case, the expectation is not dependent on the horizon, while the unconditional variance-covariance matrix is dependent. As a result, return dynamics may be altered across horizons.

The conditional problem can be solved by using the structure of the VECM in Equation (3). The mean of the assets returns and inflation variables can be computed by

$$\text{E}[R_{t+1 \rightarrow t+s}^p] = \frac{1}{s} \sum_{k=1}^s \left(C_k A + B^k X_t \right), \quad (9)$$

where $C_k = C_{k-1} + B^{k-1}$ for $k = 1, \dots, s$, and $C_k = 0$. Using the fact that summing s consecutive observations of state variables X_t subtracted with its mean is a function of the innovations u_t , i.e.

$$\sum_{k=1}^s X_{t+k} - \text{E}_t \left[\sum_{k=1}^s X_{t+k} \right] = \sum_{k=1}^s C_k u_{t+1+s-k}, \quad (10)$$

we can derive the conditional variance-covariance matrix. We can exploit the fact that the errors are identically distributed and serially uncorrelated, so that

$$\Sigma_s = \frac{1}{s} C_s \Sigma_u C_s' + \left(1 - \frac{1}{s} \Sigma_{s-1} \right), \quad (11)$$

with $\Sigma_0 = 0$. The conditional covariance is scaled by the associated horizon and is partitioned as follows

$$\Sigma_s = \begin{bmatrix} \Sigma_{Rp,s} & * \\ * & \Sigma_{\pi,s} \end{bmatrix}, \quad (12)$$

with $\text{Var}_t[R_{t+1 \rightarrow t+s}^p] = \Sigma_{Rp,s}$ and $\text{Var}_t[\pi_{t+1 \rightarrow t+s}^H] = \Sigma_{\pi,s}$. In the conditional setting both the horizon and the time dimension is incorporated. Consequently, we can analyze the impact of time varying economic conditions, so that investors can take the current levels of inflation into account when determining their hedging portfolio.

4 Empirical results

In this section we present our estimation results on the portfolio choice over various horizons implied by our VECM. We compare our results with a traditional VAR model for the estimation of the asset returns and inflation. First, we discuss the cointegration relation between the inflation measures. Subsequently, we describe the estimates for our model. Finally, we report the Bayesian portfolio strategies for various horizons to investigate the effect of parameter uncertainty.

4.1 Cointegration evidence

We estimate the cointegration relation as defined in Equation (2) by ordinary least squares (OLS) regression. For both Dutch and German inflation, the sample autocorrelation of the residuals determined by the cointegration relation decline rapidly within three lags and slightly increase in the subsequent lags, whereas for the residuals of the French cointegration equation exhibits a gradual decline in autocorrelation. We employ an augmented Dickey-Fuller test, which rejects the null hypothesis of a unit root at a 5% level for Dutch price levels and at a 1% level for the French and German price levels. Subsequently, we use a Johansen cointegration test to determine the number of cointegration relations in our sample. We find one cointegration relation in all three cases. This evidence supports our model specification for the long run dynamics of inflation exposure of the investor.

The estimates of the cointegration relation for the Dutch, French and German case indicate that the long run dynamics of the inflation measures are not similar. Although all three cases have a relatively high loading on the European price level series compared to other inflation series, the estimates differ substantially among the three presented cases. We report the estimates of the cointegration determined by OLS. These estimates are similar to cointegration coefficients implied by the Johansen VECM model. We find the following estimated equations for the cointegration relation

$$\begin{aligned}
 I_t^{NL} &= 121.29 - 0.05t + 1.63 I_t^{EU} - 0.19 I_t^{JP} - 0.19 I_t^{UK} - 0.46 I_t^{US} + \epsilon_{\pi,t}, \\
 &\quad (53.57) \quad (0.02) \quad (0.15) \quad (0.08) \quad (0.10) \quad (0.07) \\
 I_t^{FR} &= 0.89 - 0.00t + 0.80 I_t^{EU} + 0.02 I_t^{JP} + 0.03 I_t^{UK} - 0.06 I_t^{US} + \epsilon_{\pi,t}, \quad (13) \\
 &\quad (0.07) \quad (0.00) \quad (0.07) \quad (0.03) \quad (0.05) \quad (0.03) \\
 I_t^{GER} &= 174.75 + 0.05t + 0.34 I_t^{EU} + 0.28 I_t^{JP} + 0.06 I_t^{UK} + 0.12 I_t^{US} + \epsilon_{\pi,t}. \\
 &\quad (20.84) \quad (0.01) \quad (0.08) \quad (0.06) \quad (0.05) \quad (0.03)
 \end{aligned}$$

These estimates are based on the sample period from January 1999 to December 2011 as discussed in Table 2. The implications of our cointegration relation is that the inflation exposure of an investor has a stochastic trend with inflation measures of other economies. Although French and German economy have a large impact on the determination of European inflation, their long run dependency differs substantially. We find coefficients of about 0.80 and 0.34 for the French and German case respectively. This observation suggest that economies with a large impact on Eurozone inflation, do not necessarily have similar and substantial long run dependency. In both the Dutch and German case, the foreign inflation measure have a substantial impact as well. For Dutch inflation, we observe that US inflation is an important component in the cointegration relation whereas for German inflation the Japanese inflation receives substantial weight. This suggests that the investor might exploit long run coherency of other foreign

inflation-linked securities besides European inflation-linked securities to hedge his inflation exposure.

Since coefficients of the cointegration relation might be unstable across sample periods and sampling frequencies, we test its sensitivity by reestimating these relations on two sample periods from 1996 to 2011 and from 2005 to 2011. We find similar estimates for the French and German cointegration equation. Surprisingly, we find an unstable cointegration relation for the Dutch case. The impact of European and US price levels on Dutch price levels in the cointegration equation is less stable across different samples. In the extended sample period the impact of European price level on the Dutch price levels decreases from 1.63 (SE of 0.15) as reported in Equation (13) to 0.28 (SE of 0.40). In the subsample of 2005 to 2011, the decrease is substantially smaller with an estimate of 0.84 (SE of 0.20). These variations are of concern for an investor on how to incorporate cointegration evidence in their investment decision. In order to address this issue, we incorporate a Bayesian approach to allow for parameter uncertainty in the asset allocation. By allowing parameter uncertainty, we do not rely on the OLS estimates of the cointegration relation in modeling the asset returns. Consequently, this approach will be only dependent on the observed data.

Our estimation of the cointegration relation suggests that the error correction may influence the hedging allocation. Therefore, we analyze the inflation exposures across various horizons and their associated variation. We follow Bekaert and Wang (2010) in the selection of investment horizons and report from 1 months up to 5 years. The inflation measures under different regimes are presented in Table 4. To analyze the implications of the different specifications on the inflation measures between the VECM and the VAR specification of our model, we report the inflation term structure in terms of expectation and volatility. The moments of European, Japanese, UK, and US inflation measures depend on the chosen investor's inflation exposure. Therefore, these results can differ due to the included cointegration relations in the VECM model. In Table 4 we report the moments using the Dutch cointegration relation as previously defined in Equation (13). Changing the cointegration relation to the French or German specification mostly affects the volatilities of the inflation measures, but does not alter our conclusions on the economic significance of the cointegration relation.

The arithmetic means of the inflation measures in Table 4 remain quite stable over the various horizons for the VECM and the VAR specification. Note that the arithmetic mean in the unconditional case is defined as the expected mean plus half of the scaled variance associated with the specific horizon as defined in Equation (1). Since the variance component in the arithmetic means depends on the specification used to model the dynamics of the returns, it can differ among the two specifications. The VECM specification mostly affects the volatilities of the inflation measures to which the investor is exposed to, namely Dutch, French and German inflation. Thus, predictability of the asset returns by incorporating the cointegration relation is economically quite small. One of the factors driving this result is that we report in monthly expectations. Consequently, the Dutch and French inflation variability increases less sharply and the German variability decreases more steeply in the VECM specification. In the German case, the volatility decreases from 0.33% for an one month horizon to 0.17% for a 5 years horizon in the VECM specification, but in the VAR model this remains 0.23%. Although these changes on a monthly basis might be small, it can substantially affect portfolio consequences evaluated at a larger horizon. In addition, the correlation structure is altered due to the VECM specification. As a result, this can influence the ability of the VECM-type investor to exploit

long run dynamics in his asset allocation.

Turning to implications of the cointegration on the asset returns, we find that the cointegration relation also influences the term structure of traded asset returns. In Table 3 we present the returns and volatility of the asset returns for both the VECM and VAR specification for a Dutch investor. Although the VECM specification alters the expected returns and the volatility, its economical effect on the monthly returns is not clearly evident in all three asset classes. As for nominal bonds, the returns increase over the horizons in both specifications. The return on a nominal Dutch bond is 0.11% at a 1 month horizon, which increases to 0.12% at a 5 years horizon in the VECM specification. In the VAR specification the term structure remains flat, resulting in 0.11% return at a 5 years horizon. A similar pattern can be observed for the volatility structure. In the VECM specification the volatilities of the nominal bonds increase with respect to the VAR specification as well. Consequently, nominal bonds will be more risky for a VECM-type of investor, yet yield higher returns.

The equity returns tend to increase only slightly in the VECM specification compared to the VAR. For example, the average monthly Dutch equity returns in the VECM specification is about -0.17% at a 1 month horizon whereas at a 5 year horizon the return increases to -0.14%. The VAR specification yields similar results. The differences between the two specifications for the foreign equity markets are hard to capture on a monthly basis. For the inflation-linked bonds, the cointegration does not largely impact the returns. However, the returns in Table 3 are influenced by currency risk. If the investor hedges currency risk with forward contracts, then the terms structure of returns will be affected. As previously discussed, this will mostly have an impact on the volatility structure of the asset returns as described in Table 2. The cointegration relation will have less effect on the return dynamics of the assets, so that the returns of two specifications will be similar. On the other hand, volatilities over the horizons remain different between the two specifications. The term structure of asset returns is dependent on whether the Dutch, French or German cointegration is relation used. For the French and German cases, we observe similar effects for the nominal bond returns and volatilities as in the Dutch case. Therefore, the cointegration relation will also affect the asset allocation in these two cases.

To summarize our findings thus far, both currency hedging and the VECM specification lead to different expected returns and associated risks. Especially, the returns of the nominal bonds tend to increase more sharply in the VECM specification and become more volatile due to the influence of the cointegration relation. Consequently, the difference in volatility influences the demand of an investor for these assets, since the inflation exposure of the investor is less volatile in a VECM specification. Additionally, the correlations across horizons are influenced by the cointegration relation. Therefore, the investors will be able to exploit long run dynamics to hedge their actual experienced inflation.

4.2 Classical hedging allocation

By means of the return profiles of the assets and the inflation measures, we can determine the optimal hedging allocation for the investors with different investment horizon. We report our benchmark case of an investor hedging currency risk and having access to European inflation-linked bonds. This benchmark case is evaluated for three investors, namely for Dutch, French and German investors. Throughout our analysis, we ignore short selling constraints since these

restrictions do not alter our conclusions on basis risk and inflation-linked bonds. First, we focus on hedging with European inflation-linked bonds and the associated strategic hedging allocation. Second, we analyze the incorporation of foreign inflation-linked bonds traded in other currencies. To conclude our analysis, we investigate the effect of parameter uncertainty on the portfolio choice. In particular, we analyze the local nominal bond and inflation-linked bond holdings during the financial crisis in a conditional framework for a Bayesian investor.

4.2.1 Unconditional strategy with European inflation-linked bonds

In Table 5 we report the portfolio allocation for a Dutch investor with access to European inflation-linked bonds and currency risk hedged by forward contracts. We find that in the optimal solution the investor allocates considerable wealth to European inflation-linked bonds. Nominal bonds have an important role in hedging inflation as well, whereas equity markets are less attractive in the inflation replicating strategy. Similarly, we find that if the investor hedges currency risk, UK and US inflation-linked bonds have only a small proportion of wealth allocated to them. For both the short and long investment horizon, the European inflation-linked bond allocation is quite substantial. However, the weight of the bond decreases over the horizon. For example, the Dutch VECM-type investor reduces his allocation from 45% at one month horizon to about 31% at a 5 years horizon. The Dutch VAR-type investor only lowers his proportion of European inflation-linked bonds to 33% at a 5 years horizon. This indicates that both type of investors hedging Dutch inflation with a longer horizon should incorporate a lower fraction of European inflation-linked bonds in their portfolios.

Another important component in the hedging allocation is the large weight for the Japanese nominal bond. This result can be explained by the Japanese carry trade during the sample period. Profiting from the interest rate differences used in the currency hedging strategy, the investor can benefit from including nominal Japanese bonds. Interestingly, both types of investors allocate about 10% of their wealth in nominal Dutch bonds at short maturity and increase their demand to 15% at a 5 years horizon. This suggests that there is a trade off between nominal bonds and European inflation-linked bonds over the holding investment horizon. Thus, long horizon investors shift part of their wealth from European inflation-linked bonds into nominal Dutch bonds. Our results indicate that the currency hedge may alter our conclusions, therefore we also explore the optimal allocation for an investor exposed to currency risk. In case the investor is exposed to currency risk, the impact between the VAR and VECM specification is more substantial. In Table 6 we present the optimal allocation strategy for a Dutch investor exposed to currency risk. Again, the European inflation-linked bond has a substantial role in hedging inflation in the VECM specification. The weight of the bond reduces from 0.46% at a 1 month horizon to 0.38% at a 5 year horizon. However, in the VAR specification the weight for European inflation-linked bonds reduces to 0.24 %. So, the currency hedge causes an important shift in the allocation over the horizon. Moreover, both type of investors increase their nominal Dutch bond holdings, because the Japanese nominal bond returns are substantially lower when exposed to currency risk. As a result, the demand of both type of Dutch investors for nominal Japanese bonds is reduced to zero at all horizons. Since the Dutch VECM-type investor incorporates the cointegration relation to exploit long run dynamics, he increases his proportion of European inflation-linked bonds. The VAR-type investors instead increases his nominal Dutch bond holdings. Surprisingly, both type of Dutch investors

hold a substantial amount of US inflation-linked bonds compared to the Dutch investors who hedge currency risk. Part of this result is driven by the depreciation of the dollar in our sample. Since the US inflation-linked bond holdings are larger than the European bond holdings, other foreign inflation-linked bonds can have important role when the investor is faced with currency risk.

We repeat our analysis for French and German investors hedging their actual inflation exposures. We verify to which extent our previous conclusion concerning the asset allocation alter when investors are exposed to other European inflation measures. In Tables 7 and 8 we report the French case with and without currency exposure. From Table 7 we can conclude that the French case is similar to the Dutch case. European inflation-linked bonds have a large weight in the portfolio of the investor together with the Japanese nominal bond. However, in case of currency risk, as reported in Table 8, the French investor has a much larger demand for European inflation-linked bonds than the Dutch investor. His demand in the VECM specification is about 58% at a 5 year horizon. Instead of increasing his demand for local nominal bonds as in the Dutch scenario, the French investor has a large exposure to equity. In addition, his demand for US real bonds is substantially lower, but increasing over the horizon. Thus, the French investor has, similar to the Dutch investor, a trade off between European and US inflation-linked bonds over the investment horizon.

The German case is similar to the previous cases, except that there is a large difference between the VECM-type and VAR-type investor in case currency is hedged. In Tables 9 and 10 we report the German case. At an investment horizon of 1 month both specifications allocate about 47% to European inflation-linked bonds, but at a 5 year horizon the VECM-type investor reduces to a weight of 43%. In contrast with the VECM-type investor, the VAR-type investor only allocates 33% at a 5 year horizon. Thus, a German VECM-type investor would allocate substantially more wealth to these bonds on a longer horizon to exploit the long run dependency. Both type of German investors exposed to currency risk will substantially reduce their European inflation-linked bonds and increase their allocations to US inflation-linked bonds at longer horizons as in the Dutch and French case. This indicates that US inflation-linked bonds have an important role in replicating his inflation exposure, although the VECM investor will incorporate less bonds at long run horizons. Similar to the Dutch investor, the German investor holds a large proportion of local nominal bonds. For example, if currency risk is not hedged, the Dutch and German proportion allocated to local nominal bond is on average about 25%, whereas French local nominal bond holding is 10%. Therefore, local nominal bond holdings can vary between the investors of different European countries.

In terms of performance, only the German VECM-type investors improves his replication strategy regardless of the currency hedge. At 5 years horizon, the German VECM-type investor hedging currency risk reduces his hedging error by 3 % compared to the VAR-type investor. Exposed to currency risk, the improvement is only 2.5% compared to the VAR-type of investor. This suggests that currency risk reduces the opportunity to exploit long run coherency. The Dutch VECM-type of investor is only able to improve his hedging error by 2% if currency risk is hedged. The French VECM-type of investor does not seem to improve his portfolio using long run dynamics, as the VAR-type of investor improves his hedging error by ignoring long run dynamics by 7% if currency risk is hedged. These results are mostly driven by the short sample period. Consequently, the estimated long run dynamics are less stable over such sample periods. Since the German cointegration relation remains quite stable across subsample

periods, the German investor can improve his hedging portfolio. This shows that investors cannot necessarily exploit long run dynamics in their replicating portfolios with European inflation-linked bonds in the asset choice.

To summarize, we find that European inflation-linked bonds have an important role in the inflation hedging strategies for Dutch, French and German investors. The VECM-type investor cannot in all cases benefit from incorporating long run dynamics of basis risk. In addition, there is a demand for foreign inflation-linked bonds even though the investor is exposed to currency risk and can invest in European inflation-linked bonds. An important component in the allocations is whether currency risk is hedged. The improvement of the replication portfolio by incorporating the long run dynamics can especially be observed on longer investment horizons. Subsequently, we turn to the question whether only foreign inflation-linked bonds not denominated in Euros can improve the replicating portfolio of the investor. Excluding European inflation-linked bonds from the asset choice, allows us to use an extended sample period. In this way we can capture the long run coherency more accurately.

4.2.2 UK and US inflation-linked bonds only

To investigate the impact of UK and US inflation-linked bonds, we exclude European inflation-linked bonds from the asset choice of the investor. In Table 11 we only present the bond allocations of the nominal and the UK and US inflation-linked bonds in case the investor is exposed to currency risk. Although holdings in equity and foreign nominal bonds remain a part of the total portfolio, we focus on whether investors can exploit long run dynamics in our extended sample period. Our previous results indicate that local nominal bond holdings are influenced in case of an investment opportunity in European inflation-linked bonds. Table 11 shows that investors exposed to currency risk substantially allocate their wealth to foreign inflation-bonds, although the investors remain to hold large proportions of nominal bonds in their portfolios.

The VECM-type investor holds across various horizons more wealth in his local nominal bonds than the VAR-type investor. For all three investors, nominal bond holdings decrease over the investment horizon, although the holdings of VECM-type investors decrease less sharply. For example, the German VECM-type investor has about 58% of German nominal bonds in his portfolio at a 1 month horizon and reduces this weight to 56% at a 5 year horizon, whereas the VAR-type investor holds only 49% at a 5 year horizon. A similar effect can be seen in the Dutch and French case, although the effect is substantially smaller compared to the German investor. All three investors increase their holdings of UK inflation-linked bonds over the investment horizon, regardless of the long run dynamics. This shows that for long investment horizons UK inflation-linked bonds increase their attractiveness while nominal local bond holdings are reduced. Compared to our previous results for our reduced sample period, the dynamics of the UK inflation-linked bonds over the investment horizon are reversed. Although parameter uncertainty is of concern for the implementation of the hedging portfolio, UK and US inflation-linked bond holdings are substantial regardless of the sample period.

Turning to the question whether the VECM-type investors can exploit long run dynamics in the extended sample period, we find improvements for the inflation replicating portfolio in all three cases. The hedging portfolios improve on average by about 0.5% in case the investor is exposed to currency risk. Therefore, exploiting long run coherency remains difficult.

Although we do not report the portfolio weights in case currency risk is hedged, we find more substantial improvements. In particular, the German VECM-type investor can substantially improve by 7%, while the Dutch and French VECM-type investor can improve their hedging portfolio by 1.5% and 0.3%, respectively. These results indicate that a longer sample period improves the ability of the investor to exploit the long run dynamics. Although the economic significance of the improvement for the French VECM-type investor is small, compared to performance in the reduced sample period the improvement is quite substantial. Generally, exploiting long run coherency is more likely if currency risk is hedged. Since hedging currency risk reduces the asset volatility, the VECM-type of investor can benefit unconditionally from implementing long run coherency. Therefore, implementing the cointegration relation in the inflation hedging position of the investor can be beneficial, although the economic significance of the improvement could be less certain.

Next we verify whether investors can benefit from adding UK and US inflation-linked bonds to their asset choice. To measure the improvement, we compare both the performance of the portfolio with and without these inflation-linked bonds. We find that for all three investors regardless whether currency risk is hedged that the performance of the portfolios improve substantially by including UK and US inflation-linked bonds. Especially when exposed to currency risk, the impact of adding foreign inflation-linked bonds has much economic significance. The Dutch investors can improve their portfolio by about 45%, whereas French and German investors improve about 30% and 35%, respectively. If currency risk is hedged, the improvements reduce to about 13% for the Dutch and French investor and about 10% for the German investor. These results suggest that foreign inflation-linked bonds can be beneficial for all three investors. Next, we will focus on how parameter uncertainty affects the portfolio choice of investors.

4.3 Hedging allocations with parameter uncertainty

We investigate the effect of parameter uncertainty for both the VECM-type investor and the VAR-type investor. We present the case that the investor is exposed to currency risk and can acquire European inflation-linked bonds. Given the uncertainty about long run dynamics and our small sample period, we employ a Bayesian approach. This ensures that the hedging allocations only rely on the actual data. First, we focus on the asset allocation under parameter uncertainty in an unconditional setting and compare this to our previous findings. Subsequently, we assess the conditional setting in a Bayesian approach and observe a flight home effect in the allocations of the investors during the financial crisis. For details on the Bayesian methodology, we refer to Appendix A.

4.3.1 Unconditional setting

Table 12 confirms our previous results on the importance of the European inflation-linked bonds. Both types of Dutch investors allocate a substantial weight to European inflation-linked bonds, which is again declining over the investment horizon. Similarly, we observe this decline in the French and German cases, which are reported in Table 13 and 14. Both the Dutch and German investor reduce their European inflation-linked bond holdings less sharply compared to previous results without parameter uncertainty. For example, at a 5 years maturity the German

Bayesian investor holds about 30% European inflation-linked bonds, which is about 5% more. The French Bayesian investor, however, holds less European inflation-linked bonds for longer investment horizon. Therefore, parameter uncertainty influences the European inflation-linked bond holdings, yet does not alter our previous conclusions.

Parameter uncertainty has an impact on the nominal bond holdings of the investors as well. All investors increase their nominal bonds weights to a level of about 25%. Especially in the French case parameter uncertainty reverses the dynamics over the investment horizon for the local nominal bond holdings. The French Bayesian VAR-type investor has French nominal bond holdings that increase from 20% at a 1 month horizon up to 27% at a 5 years horizon. However, the French VAR-type investor, ignoring parameter uncertainty, reduces his bond weights from 14% to 8% over the same horizon. Parameter uncertainty also diminishes the attractiveness of the US inflation-linked bonds. While investors ignoring parameter uncertainty increase their US inflation-linked bond holding over the investment horizon, all three Bayesian investors decrease their weights. As a result, parameter uncertainty reduces the attractiveness of foreign inflation-linked bonds while local nominal bond holdings become more important.

Regarding the VECM-type and VAR-type investors, we find less differences in the German case than in the Dutch and French case. This observation is in line with our previous result regarding uncertainty of the Dutch and French cases. However, incorporating parameter uncertainty into the hedging strategy does not substantially alter the differences between the two specifications. Next, we analyze parameter uncertainty in a conditional setting.

4.3.2 Conditional setting

We implement a conditional setting within our framework to allow for time varying economic conditions in a Bayesian context. A conditional type of investor hedges his inflation exposure incorporating market timing, i.e. the conditional investors take into account the current level of their inflation exposure, the foreign inflation measures and the asset returns. To analyze the impact of the conditional setting, we present the optimal allocation of the inflation-linked bond holdings for the Dutch VECM-type and VAR-type investor exposed to currency risk in Figure 1 with a 1 year investment horizon.

Figure 1 suggests that the impact of time varying economic conditions on bond holdings for hedging inflation across our sample period is not quite substantial, except for the period of the financial crisis. Our results on the French and German case, reported in figures 2 and 3 respectively, yield a similar conclusion. The conditional framework reveals similarly to the unconditional setting that investors hold a substantial fraction of inflation-linked bonds. The level of inflation-linked bond holdings is lower in the conditional setting. For example, in the Dutch and French case the portfolio weights of European inflation-linked bonds are about 10% lower than in the VAR specification. However, these results do not alter our previous conclusions.

Turning to the flight home bias, our results show that only in the financial crisis the conditional type of investors substantially alters his portfolio. To explore the impact of the financial crisis on the portfolios, we present in Tables 15, 16, and 17 respectively the Dutch, French, and German average portfolio weights for three periods. During the period of the financial crisis in 2008, the portfolio weights for nominal bonds of all three investors increase substantially

on the short investment horizon. For example, the Dutch investor raises his holdings by 47% from a weight of 8.6% to 12.6%. The French and German investor increase their holdings respectively by about 60% and 46%. A similar result can be observed for investors with a longer investment scope. Since the term structure of asset returns for long maturity is less sensitive for monthly fluctuations, the magnitude for the 5 year investment scope is smaller, about 2.7% on average. Meanwhile, the investors reduce their holdings of US inflation-linked bonds and increase their demand for UK inflation-linked bonds. Surprisingly, the European inflation-linked bond has the most stable allocation throughout all three periods regardless of investment horizon.

Our empirical evidence suggests a flight home effect occurs for the inflation hedging investors caused by the financial crisis. Evidence from the debt market shows that investors are more prone to select local assets rather than foreign assets during the financial crisis (see e.g. Giannetti and Laeven (2012)). Similarly, in our model the conditional Bayesian investor increases his demand for local nominal bonds to hedge his inflation risk. Since the allocations of the hedging portfolios are determined by market rates, the flight home effect occurs only due to changes in the international market. Therefore, the inflation hedging perspective may offer an explanation why investors resort to local assets during liquidity shocks.

After the financial crisis, our model reveals that the portfolio allocations return to precrisis levels for longer investment horizons. On average, all three conditional investors decrease their local nominal bond holdings by about 2.8% for a 5 years investment horizon, so that they hold a similar amount of bonds as before the financial crisis. For shorter investment horizons, the portfolio alters slightly after the financial crisis compared to allocations prior to the crisis. For example, both the Dutch and French conditional investor hold about 10% less local nominal bonds at a 1 month investment horizon compared to precrisis levels, whereas the German investor increases his weight by 18%. The European bond holdings slightly increase for all three investors, ranging from 2% for the Dutch and French investor to 0.2% for the German investor. Therefore, only the European inflation-linked bond holdings remain similar to precrisis levels after the financial crisis for all investment horizons.

Overall, our Bayesian analysis confirms our previous results that inflation-linked bonds have a substantial weight in inflation hedging portfolios. Over the investment horizon, we document a declining weight for the European inflation-linked bonds. Incorporating parameter uncertainty does not alter this trend, although the decline is less sharp. As a result, local nominal bond holdings are more attractive for longer investment horizons. Furthermore, our Bayesian conditional framework shows that European inflation-linked bonds holdings remain quite stable throughout the financial crisis for all investment horizons. During the financial crisis, the local nominal bond holdings of the investors increase substantially, suggesting a flight home effect for the inflation hedging investors.

5 Conclusion

This paper presents a framework of how investors can replicate their actual inflation exposure by acquiring foreign inflation derivatives on the international market. We focus on two primary questions. First, we verify whether inflation hedging investors can benefit from entering the international market and second, we investigate if investors can exploit long run dynamics

between their actual inflation risk and foreign inflation measures.

With regard to the first question, we find that European investors can substantially improve the hedging capacity of their portfolios by incorporating foreign inflation-linked derivatives. In particular, European inflation-linked bonds have a substantial weight in the portfolio allocations. However, these weights decline over the investment horizon, suggesting that other foreign inflation-linked derivatives can be attractive. Second, we show how inflation hedging investors can incorporate long run dynamics of inflation measures to improve their hedging portfolios. Under stable conditions of the long run inflation dynamics, the investors are able to exploit their allocations in the international market.

These results point to the importance of the international market for inflation-linked derivatives. Especially for the pension sector, inflation derivatives can be used to hedge inflation-linked liabilities. Early studies suggested that pension schemes could benefit from incorporating local inflation-linked bonds (Bodie, 1988). We extend this view by showing that investors can benefit from foreign inflation-linked bonds in case either the actual inflation experienced by the investor substantially differs from the national aggregated inflation measure or the local market does not offer inflation-linked derivatives. Inflation replication with foreign inflation-linked bonds allows pension funds to profit from high liquidity in major markets to hedge their inflation denominated liabilities.

References

- Ang, A. (2012). Real assets. *Working paper*.
- Balvers, R., Wu, Y., & Gilliland, E. (2000). Mean reversion across national stock markets and parametric contrarian investment strategies. *Journal of Finance*, 55(2), 745-772.
- Bansal, R., & Kiku, D. (2011). Cointegration and long-run asset allocation. *Journal of Business & Economic Statistics*, 29(1), 161-173.
- Barclays Capital. (2005). Inflation derivatives a users guide.
- Bauwens, L., & Lubrano, M. (1996). *Identification restrictions and posterior densities in cointegrated gaussian var systems*. In Fomby, T. (ed.), *Advances in Econometrics*, Vol. 11, Part B, pp.3-28. London: JAI Press Inc.
- Bekaert, G., & Wang, X. (2010). Inflation risk and the inflation risk premium. *Economic Policy*, 25, 755-806.
- Bodie, Z. (1976). Common stocks as a hedge against inflation. *Journal of Finance*, 31, 459-470.
- Bodie, Z. (1988). Inflation, index-linked bonds, and asset allocation. *Working paper*.
- Boskin, M. J., Dulberger, E. R., Gordon, R. J., Griliches, Z., & Jorgenson, D. W. (1998). Consumer prices, the consumer price index, and the cost of living. *Journal of Economic Perspectives*, 12(1), 3-26.
- Campbell, J. Y., Chan, Y. L., & Viceira, L. M. (2003). A multivariate model of strategic asset allocation. *Journal of Financial Economics*, 67, 4180.
- Campbell, J. Y., & Shiller, R. (1988). Stock prices, earnings, and expected dividends. *Journal of Finance*, 43, 661-676.
- Cetorelli, N., & Goldberg, L. S. (2012). Banking globalization and monetary transmission. *Journal of Finance*, 67(5), 1811-1843.
- Chen, L., Choi, S., & Devereux, J. (2008). Have absolute price levels converged for developed economies? the evidence since 1870. *Review of Economics and Statistics*, 90(1), 29-36.
- Fama, E., & Schwert, G. (1977). Asset returns and inflation. *Journal of Financial Economics*, 5, 115-146.
- Fleckenstein, M., Longstaff, F. A., & Lustig, H. (2013). The tips - treasury bond puzzle. *The Journal of Finance*, Forthcoming.
- Giannetti, M., & Laeven, L. (2012). The flight home effect: Evidence from the syndicated loan market during financial crises. *Journal of Financial Economics*, 104(1), 23 - 43.
- Hodrick, R. (1992). Dividend yields and expected stock returns: alternative procedures for inference and measurement. *Review of Financial Studies*, 5, 357-286.
- Hoevernaars, R., Molenaar, R., Schotman, P., & Steenkamp, T. (2008). Strategic asset allocation with liabilities: Beyond stocks and bonds. *Journal of Economic Dynamics and Control*, 32(9), 2939-2970.
- Huang, R. (1987). Expectations of exchange rates and differential inflation rates:

- Further evidence on purchasing power parity in efficient markets. *Journal of Finance*, 42(3), 69-79.
- Juselius, K., & MacDonald, R. (2004). International parity relationships between the usa and japan. *Japan and the World Economy*, 16, 1734.
- Kandel, S., & Stambaugh, R. (1996). On the predictability of stock returns: An asset-allocation perspective. *Journal of Finance*, 51, 385-424.
- McNown, R., & Wallace, M. (1989). National price levels, purchasing power parity, and cointegration: a test of four high inflation economies. *Journal of International Money and Finance*, 8, 533-545.
- Popov, A., & Udell, G. (2010). Cross-border banking and the international transmission of financial distress during the crisis of 2007-2008. *ECB Working Paper*.
- Richards, A. J. (1997). Winner-loser reversals in national stock market indices: Can they be explained? *Journal of Finance*, 52(5), 2129-2244.
- Roll, R. (1979). Violations of purchasing power parity and their implications for efficient international commodity markets. in Marshall Sarnat and G.P. Szego, eds, *International Finance and Trade, Vol. 1, Cambridge, MA: Ballinger Publishing Co., 1*.
- Samuelson, P. A. (1994). Facets of balassa-samuelson thirty years later. *Review of International Economics*, 2(3), 201-226.
- Schotman, P., & Schweitzer, M. (2000). Horizon sensitivity of the inflation hedge of stocks. *Journal of Empirical Finance*, 7, 301-315.
- Taylor, A. (2002). A century of purchasing-power parity. *Review of Economics and Statistics*, 84, 139-150.
- Taylor, A., & Taylor, M. (2004). The purchasing power parity debate. *Journal of Economic Perspectives*, 18(3), 135-158.
- Wallace, F., & Shelley, G. (2006). An alternative test of purchasing power parity. *Economics Letters*, 92(2), 177-183.

A Bayesian approach

In a Bayesian approach, the posterior density of the model is required. To obtain this distribution for the VAR model, we follow Bauwens and Lubrano (1996) by rewriting the model into a system of seemingly unrelated regressions. Formally, define this system of equations as

$$y_i = X_i\beta_i + \epsilon_i, \quad (\text{A.1})$$

for each $i = 1, \dots, n$ with n denoting the total number of state variables in the system. If the individual time series included in the model have dimension T , then y_i is a vector with $((T-1) \times 1)$ observations, X_i is a matrix with dimensions $((T-1) \times k_i)$ with k_i independent variables, β_i consists of a coefficient vector with k_i elements, and ϵ_i is the vector with the associated errors for each observation $(T-1)$. We rewrite this model in two forms in order to draw parameters from the posterior density. By stacking all the observations for each equation i , we can express Equation (A.1) as

$$y = x\beta + \epsilon, \quad (\text{A.2})$$

where $y = (y_1, \dots, y_n)$ is a vector with dimensions $((T-1)n \times 1)$, $\beta = (\beta_1, \dots, \beta_n)$ with a vector of k_n elements, $x = \text{diag}(x_1, \dots, x_n)$ with dimensions $((T-1)n \times k_n)$, and $\epsilon = (\epsilon_1, \dots, \epsilon_n)$. In the second approach, we write a VAR specification

$$Y = XB + E, \quad (\text{A.3})$$

with $Y = (y_1 \dots y_n)$ is a matrix with dimensions $((T-1) \times n)$, $X = (X_1 \dots X_n)$ has dimensions $((T-1) \times k_n)$, $B = \text{diag}(\beta_1, \dots, \beta_n)$ is a matrix with dimensions $(k_n \times n)$ and $E = (E_1 \dots E_n)$ is a matrix with dimensions $((T-1) \times n)$. Next, we derive the posterior density functions for the VAR and VECM framework.

A.1 VAR framework

In deriving the posterior density function for the VAR model, we assume a uninformative prior. This implies that the investor does not have any prior believe on the parameters of the model. Hence, the prior function is of the form

$$f(\beta, \Sigma) \propto |\Sigma|^{-(n+1)/2}, \quad (\text{A.4})$$

where Σ denotes the variance-covariance matrix of the error in the VAR model. For this uninformative prior, the marginal posterior density of the parameters can be written as

$$\begin{aligned} \beta|\Sigma &\sim \text{N}(\hat{\beta}, [x'(\Sigma^{-1} \otimes I_{T-1})x]^{-1}) \\ \Sigma|\beta &\sim \text{IW}(Q, T-1), \end{aligned} \quad (\text{A.5})$$

with

$$\begin{aligned} \hat{\beta} &= [x'(\Sigma^{-1} \otimes I_{T-1})x]^{-1}x'(\Sigma^{-1} \otimes I_{T-1})y \\ Q &= (Y - XB)'(Y - XB). \end{aligned}$$

Since the marginal posterior densities of the two parameters β and Σ are not available, we rely on the Block-Gibbs sampling algorithm (See e.g. Bauwens and Lubrano (1996)). Conditional

on a previous simulation of the variance-covariance matrix Σ_{j-1} , we can draw β_j from the conditional density function. Again, with the sampled β_j the variance-covariance matrix Σ_j can be drawn from the inverse Wishart distribution. This sequential sampling method is initialized with the ordinary least squares estimates of the model. To remove potential influence of the starting values, we remove the first 500 draws from the sequence of parameters. Additionally, we remove draws if any eigenvalues of matrix with the autoregressive coefficients of the included variables are larger than 0.98 in order to ensure stationarity as in Bansal and Kiku (2011).

Our final sequence consists of 20000 draws from the posterior density. Using these parameters, we calculate the associated means and variance-covariance matrices of the various horizons. For each of these moments, we determine the optimal allocation strategy. We report the average of portfolio holdings for various horizons and a 95% confidence bounds of these allocations. This procedure results in the optimal portfolio allocations that only rely on the observed data.

A.2 VECM framework

In deriving the posterior density functions for the VECM framework, we assume again that investors holds a uninformative believe on the VECM parameters and the cointegration relation. Assuming a uniform distribution for the coefficient cointegration vector γ , we denote this flat prior as $f_0(\gamma)$. Let Z denote the matrix with the price levels indices and the deterministic components of the cointegration relation such that its product with the coefficient cointegration vector, $Z\gamma'$, yields a vector with cointegration errors. We can formally define the prior distribution for the VECM framework as

$$f(\beta, \Sigma, \gamma) \propto f_0(\gamma) |\Sigma|^{-(n+1)/2}. \quad (\text{A.6})$$

Following Bauwens and Lubrano (1996), we can write the conditional densities as

$$\begin{aligned} \beta | \Sigma, \gamma &\sim \text{N}(\hat{\beta}, [x'(\Sigma^{-1} \otimes I_{T-1})x]^{-1}) \\ \Sigma | \beta, \gamma &\sim \text{IW}(Q, T-1), \\ f_0(\gamma) &\propto f_0(\gamma) \frac{|\gamma' W_0 \gamma|^{l_0}}{|\gamma' W_1 \gamma|^{l_1}}, \end{aligned} \quad (\text{A.7})$$

with

$$\begin{aligned} M_x &= I - X(X'X)^{-1}X' \\ W_0 &= Z'M_X Z \\ W_1 &= Z'M_X (I_{T-1}(Y(Y'M_X Y)^{-1}Y'))M_X Z \\ l_0 &= (T - n - 2)/2 \\ l_1 &= (T - 2)/2, \end{aligned}$$

and $\hat{\beta}$ and Q are defined as in the VAR specification. Since an analytical solution for the marginal posterior density is not available, we need to rely on simulation techniques. We apply the Griddy-Gibbs sampling technique to determine the marginal posterior density for each element of the coefficient cointegration vector γ . We obtain the marginal distribution density of each coefficient of the cointegration relation by evaluating the marginal function over a grid of points. For each grid point, we draw from the marginal function conditional on the remaining parameters and obtain the unconditional value. Next, we normalize the marginal density

functions for each coefficients such that we can determine the cumulative density function. By drawing uniformly from inverted CDF, we can obtain simulations for γ^j . For each γ^j , we can apply the Block-Gibbs sampling technique to obtain the remaining parameters β and Σ as discussed in the previous section. We obtain a sequence of 20000 draws for each of the parameters and determine the associated mean and variance-covariance matrices for all horizons. Next, we calculate for each draw the optimal strategy allocation. This allows us to obtain an allocation that does not rely on the VECM parameters, but only depends on the observed data.

B Figures and Tables

Figure 1: Optimal conditional Bayesian allocation strategy for the Dutch investor

This figure presents the portfolio weights for EU, UK and US inflation-linked bonds for an investment horizon of 1 year. In this conditional framework the Dutch investor is exposed to currency risk. This allocation is the mean of all simulated strategies derived in our Bayesian framework.

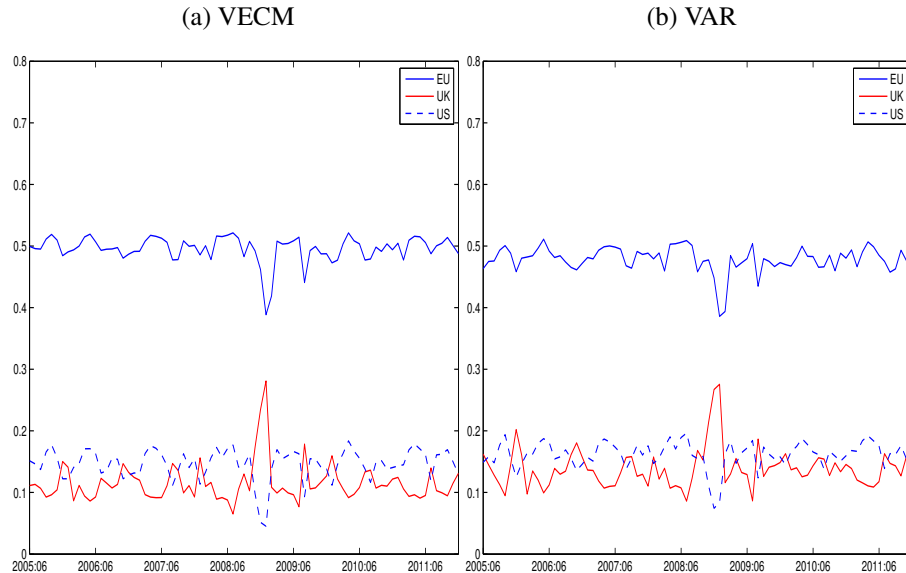


Figure 2: Optimal conditional Bayesian allocation strategy for the French investor

This figure presents the portfolio weights for EU, UK and US inflation-linked bonds for an investment horizon of 1 year. In this conditional framework the French investor is exposed to currency risk. This allocation is the mean of all simulated strategies derived in our Bayesian framework.

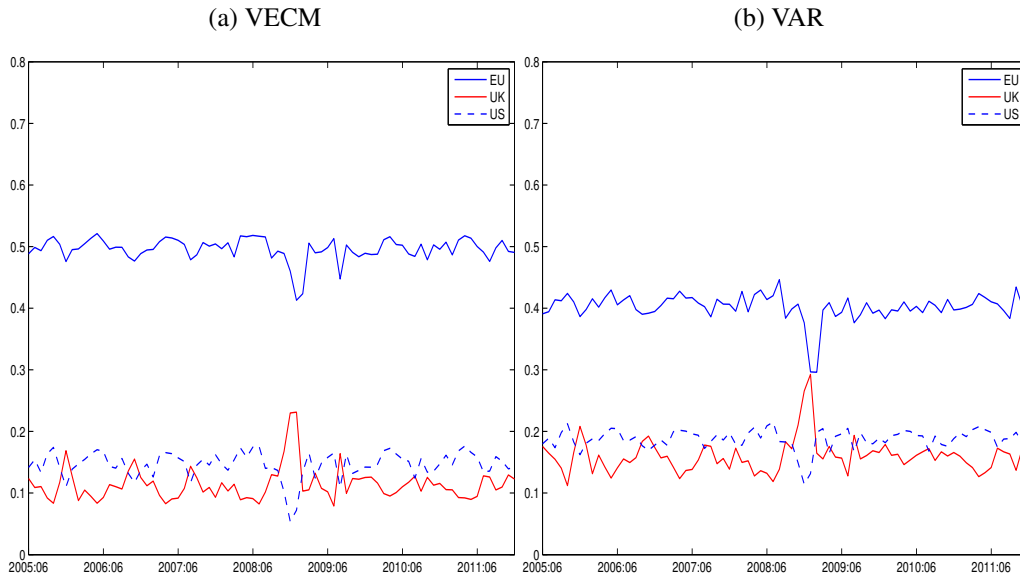


Figure 3: Optimal conditional Bayesian allocation strategy for the German investor

This figure presents the portfolio weights for EU, UK and US inflation-linked bonds for an investment horizon of 1 year. In this conditional framework the German investor is exposed to currency risk. This allocation is the mean of all simulated strategies derived in our Bayesian framework.

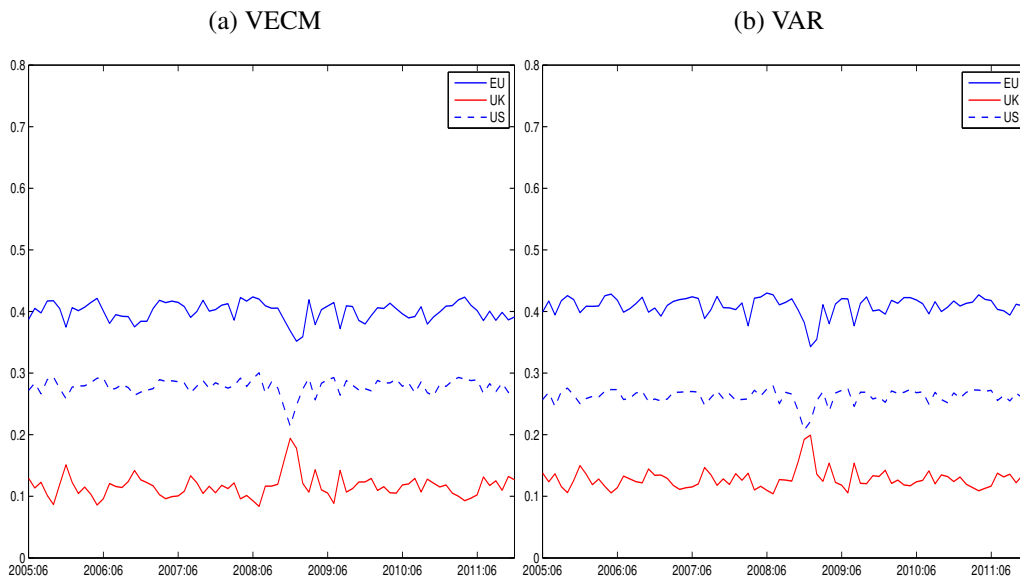


Table 1: Basis risk

This table presents the dynamics of basis risk for a Dutch, French and German investor. For foreign inflation measures, we use HICP Euro area, RPI of the UK, the All urban CPI of the US and Japanese CPI excluding fresh foods inflation measures. The inflation exposures of the investors are all the national CPI inflation measures. Basis risk is defined by subtracting the investor's exposed inflation with the foreign inflation measure denoted in Euros. A positive difference indicates the annual costs of the investor, whereas a negative sign implies the investor benefits from using securities linked to this inflation measure. Furthermore, this table contains the summary statistics of the mismatches. The inflation rates are determined by yearly inflation rates from January to December. The sample period is from 1999 to 2011.

	Mean	St. dev	Skew	Kurt
<u>Dutch inflation Exposure</u>				
EU	-0.67%	0.7%	0.35	2.09
UK	-2.66%	13.3%	-1.14	2.90
US	-0.46%	7.9%	1.32	4.90
JP	-1.19%	11.2%	-0.15	1.43
<u>French inflation Exposure</u>				
EU	-0.62%	0.3%	0.47	2.11
UK	-2.60%	13.5%	-1.15	2.90
US	-0.40%	8.0%	1.19	4.51
JP	-1.14%	11.7%	-0.15	1.40
<u>German inflation Exposure</u>				
EU	-0.66%	0.2%	-0.57	2.13
UK	-2.64%	13.4%	-1.15	2.91
US	-0.45%	7.9%	1.25	4.80
JP	-1.18%	11.5%	-0.17	1.41

Table 2: Data summary

This table reports the descriptive statistics in percentages for the asset categories, namely the equity market, the nominal and real bond markets. Returns are determined by the difference of logarithmic price levels and are denominated in Euros. The currency hedged returns correspond to returns adjusted with an one month currency forward contract. The European inflation-linked bond returns are constructed with use of German nominal bonds and European inflation swap rates. All data are sampled at monthly frequency and denominated in Euros. The sample period covers January 1999 to December 2011 for all assets, except the European inflation-linked bond which covers May 2005 to December 2011.

	Equity markets				Nominal bond markets			
	With currency risk		Currency risk hedged		With currency risk		Currency risk hedged	
	Mean	Std	Mean	Std	Mean	Std	Mean	Std
US	0.09	4.94	0.15	4.90	0.08	3.86	0.14	2.88
UK	-0.16	5.15	-0.16	4.56	0.01	2.58	0.01	2.29
JP	-0.16	6.02	-0.10	6.09	0.20	3.71	0.26	1.33
NL	-0.38	6.56			0.11	2.08		
FR	0.12	6.92			0.05	2.01		
GER	-0.15	5.90			0.09	2.10		
	Real bond markets							
	With currency risk		Currency risk hedged					
	Mean	Std	Mean	Std				
US	0.26	2.99	0.33	1.64				
UK	0.23	2.01	0.23	1.43				
EU	0.22	1.31						
	Inflation measures				Inflation exposure			
	Mean	Std			Mean	Std		
EU	0.18	0.33			NL	0.17	0.46	
JP	-0.03	0.47			FR	0.15	0.27	
UK	0.25	0.39			GER	0.14	0.33	
US	0.20	0.41						

Table 3: Term structure of asset returns with currency risk

This table reports the expected asset returns and their associated risk across horizons for the investor exposed to currency risk. For both the VECM and the VAR model, the expected return and the volatility are presented. Since the arithmetic means and volatilities of the assets in the VECM model can differ due to the included cointegration relation, the reported moments are constructed using the Dutch cointegration relation. In the parenthesis the Bootstrap standard errors are reported.

	Expected return (%)				Volatility (%)			
	1	12	24	60	1	12	24	60
VECM								
Equity US	0.207 (0.424)	0.229 (0.424)	0.230 (0.425)	0.230 (0.425)	4.93 (0.31)	5.35 (0.55)	5.38 (0.57)	5.39 (0.58)
Equity UK	-0.030 (0.431)	-0.013 (0.431)	-0.012 (0.431)	-0.012 (0.431)	5.15 (0.37)	5.47 (0.59)	5.49 (0.61)	5.50 (0.63)
Equity JP	0.026 (0.529)	0.063 (0.530)	0.066 (0.530)	0.067 (0.530)	6.02 (0.37)	6.61 (0.70)	6.65 (0.73)	6.67 (0.75)
Equity NL	-0.168 (0.543)	-0.144 (0.541)	-0.143 (0.541)	-0.142 (0.541)	6.57 (0.49)	6.92 (0.78)	6.94 (0.81)	6.95 (0.83)
NBond US	0.151 (0.364)	0.173 (0.364)	0.177 (0.364)	0.179 (0.364)	3.88 (0.22)	4.43 (0.48)	4.50 (0.52)	4.54 (0.54)
NBond UK	0.039 (0.203)	0.039 (0.203)	0.039 (0.203)	0.039 (0.203)	2.57 (0.15)	2.56 (0.25)	2.57 (0.27)	2.57 (0.28)
NBond JP	0.274 (0.308)	0.277 (0.309)	0.277 (0.309)	0.278 (0.309)	3.72 (0.28)	3.81 (0.41)	3.82 (0.43)	3.82 (0.44)
NBond NL	0.110 (0.194)	0.116 (0.194)	0.117 (0.194)	0.117 (0.194)	2.10 (0.13)	2.37 (0.26)	2.41 (0.28)	2.43 (0.30)
RBond US	0.309 (0.231)	0.304 (0.231)	0.304 (0.231)	0.304 (0.231)	2.99 (0.20)	2.82 (0.27)	2.81 (0.27)	2.81 (0.28)
RBond UK	0.251 (0.172)	0.255 (0.172)	0.255 (0.172)	0.255 (0.172)	2.01 (0.23)	2.17 (0.29)	2.18 (0.29)	2.19 (0.30)
VAR								
Equity US	0.207 (0.424)	0.229 (0.425)	0.230 (0.425)	0.230 (0.425)	4.94 (0.31)	5.35 (0.54)	5.37 (0.56)	5.39 (0.57)
Equity UK	-0.030 (0.427)	-0.015 (0.426)	-0.014 (0.426)	-0.013 (0.426)	5.16 (0.37)	5.45 (0.58)	5.46 (0.60)	5.47 (0.61)
Equity JP	0.026 (0.523)	0.060 (0.525)	0.062 (0.525)	0.063 (0.525)	6.02 (0.37)	6.56 (0.67)	6.59 (0.69)	6.60 (0.71)
Equity NL	-0.167 (0.534)	-0.145 (0.534)	-0.144 (0.534)	-0.144 (0.534)	6.58 (0.51)	6.91 (0.76)	6.92 (0.78)	6.93 (0.79)
NBond US	0.150 (0.341)	0.165 (0.342)	0.167 (0.342)	0.168 (0.343)	3.87 (0.22)	4.24 (0.43)	4.27 (0.45)	4.29 (0.46)
NBond UK	0.039 (0.195)	0.037 (0.195)	0.037 (0.195)	0.037 (0.195)	2.57 (0.15)	2.49 (0.23)	2.48 (0.24)	2.48 (0.24)
NBond JP	0.274 (0.309)	0.277 (0.310)	0.277 (0.310)	0.277 (0.310)	3.72 (0.30)	3.80 (0.43)	3.80 (0.44)	3.80 (0.45)
NBond NL	0.110 (0.178)	0.113 (0.178)	0.113 (0.178)	0.113 (0.178)	2.10 (0.13)	2.23 (0.22)	2.23 (0.23)	2.24 (0.23)
RBond US	0.309 (0.231)	0.304 (0.231)	0.304 (0.231)	0.304 (0.231)	2.99 (0.20)	2.82 (0.26)	2.81 (0.27)	2.81 (0.28)
RBond UK	0.251 (0.170)	0.255 (0.170)	0.255 (0.170)	0.255 (0.170)	2.01 (0.23)	2.17 (0.29)	2.18 (0.29)	2.18 (0.30)

Table 4: Horizon of Inflation expectations

This table reports the profile of the inflation measures across horizons. For both the VECM and the VAR model, the expected return and the volatility are presented. Since the arithmetic means and volatilities of the EU, Japan, UK, and US in the VECM model can differ due to the included cointegration relation, the reported moments are constructed using the Dutch cointegration relation. The French and German inflation moments in this table are determined by their equivalent cointegration relation. In the parenthesis the Bootstrap standard errors are reported which are determined by a residual Bootstrap.

	Expected Inflation (%)				Volatility (%)			
	1	12	24	60	1	12	24	60
VECM								
EU	0.179 (0.030)	0.179 (0.030)	0.179 (0.030)	0.179 (0.030)	0.33 (0.13)	0.36 (0.17)	0.36 (0.18)	0.36 (0.18)
JP	-0.029 (0.056)	-0.028 (0.056)	-0.028 (0.056)	-0.028 (0.056)	0.47 (0.17)	0.65 (0.32)	0.66 (0.34)	0.67 (0.35)
UK	0.247 (0.038)	0.248 (0.038)	0.248 (0.038)	0.248 (0.038)	0.40 (0.15)	0.47 (0.23)	0.48 (0.23)	0.48 (0.24)
US	0.206 (0.061)	0.207 (0.061)	0.207 (0.061)	0.207 (0.061)	0.41 (0.17)	0.69 (0.37)	0.72 (0.39)	0.73 (0.41)
NL	0.171 (0.049)	0.172 (0.049)	0.172 (0.049)	0.172 (0.049)	0.47 (0.17)	0.62 (0.37)	0.62 (0.39)	0.62 (0.40)
FR	0.147 (0.022)	0.147 (0.022)	0.147 (0.022)	0.147 (0.022)	0.27 (0.09)	0.28 (0.13)	0.28 (0.13)	0.27 (0.13)
GER	0.136 (0.013)	0.136 (0.013)	0.136 (0.013)	0.136 (0.013)	0.33 (0.11)	0.19 (0.08)	0.18 (0.07)	0.17 (0.07)
VAR								
EU	0.179 (0.030)	0.179 (0.030)	0.179 (0.030)	0.179 (0.030)	0.33 (0.13)	0.37 (0.18)	0.37 (0.18)	0.37 (0.18)
JP	-0.029 (0.056)	-0.028 (0.056)	-0.028 (0.056)	-0.028 (0.056)	0.47 (0.17)	0.65 (0.32)	0.66 (0.34)	0.67 (0.34)
UK	0.247 (0.038)	0.248 (0.038)	0.248 (0.038)	0.248 (0.038)	0.40 (0.15)	0.47 (0.22)	0.47 (0.23)	0.48 (0.23)
US	0.206 (0.058)	0.207 (0.058)	0.207 (0.058)	0.207 (0.058)	0.41 (0.17)	0.65 (0.35)	0.67 (0.37)	0.68 (0.38)
NL	0.171 (0.055)	0.172 (0.055)	0.172 (0.055)	0.172 (0.055)	0.46 (0.15)	0.64 (0.31)	0.65 (0.32)	0.65 (0.33)
FR	0.147 (0.023)	0.147 (0.023)	0.147 (0.023)	0.147 (0.023)	0.27 (0.09)	0.29 (0.12)	0.29 (0.13)	0.29 (0.13)
GER	0.136 (0.023)	0.136 (0.023)	0.136 (0.023)	0.136 (0.023)	0.33 (0.12)	0.23 (0.09)	0.23 (0.09)	0.23 (0.09)

Table 5: Optimal allocation strategy for Dutch investor with currency hedge

This table reports the Dutch optimal allocation of the hedging portfolio in percentages across different horizons. The portfolio weights have been given for both the VECM and the VAR model. In this allocation the investors is not exposed to currency risk as exchange rate risk is hedged by forward contracts. The number in parentheses are the lower and upper bounds of the corresponding 95% Bootstrap confidence intervals.

	Investment horizon (months)			
	1	12	24	60
VECM				
Equity US	-0.06 (-0.09,0.07)	-0.09 (-0.13,0.09)	-0.10 (-0.13,0.09)	-0.10 (-0.14,0.09)
Equity UK	-0.02 (-0.10,0.12)	0.06 (-0.10,0.18)	0.06 (-0.10,0.18)	0.06 (-0.10,0.19)
Equity JP	0.06 (-0.02,0.08)	0.07 (-0.02,0.09)	0.07 (-0.02,0.09)	0.07 (-0.02,0.09)
Equity NL	0.05 (-0.09,0.07)	0.02 (-0.09,0.08)	0.02 (-0.09,0.08)	0.02 (-0.09,0.08)
NomB US	-0.07 (-0.18,0.07)	-0.05 (-0.16,0.15)	-0.05 (-0.17,0.16)	-0.05 (-0.17,0.16)
NomB UK	-0.18 (-0.30,0.01)	-0.20 (-0.33,0.05)	-0.21 (-0.33,0.05)	-0.21 (-0.34,0.05)
NomB JP	0.85 (0.50,0.94)	0.94 (0.40,1.02)	0.94 (0.39,1.02)	0.95 (0.37,1.02)
NomB NL	0.10 (-0.17,0.22)	0.14 (-0.16,0.29)	0.15 (-0.17,0.29)	0.15 (-0.17,0.29)
RealB US	-0.10 (-0.22,0.10)	-0.08 (-0.24,0.19)	-0.08 (-0.24,0.20)	-0.08 (-0.24,0.21)
RealB UK	-0.09 (-0.11,0.31)	-0.12 (-0.14,0.34)	-0.12 (-0.14,0.35)	-0.12 (-0.14,0.36)
RealB EU	0.45 (0.17,0.58)	0.32 (0.00,0.55)	0.31 (-0.01,0.56)	0.31 (-0.03,0.56)
VAR				
Equity US	-0.07 (-0.13,0.07)	-0.11 (-0.16,0.07)	-0.11 (-0.16,0.07)	-0.11 (-0.17,0.07)
Equity UK	-0.01 (-0.10,0.13)	0.05 (-0.09,0.20)	0.05 (-0.09,0.21)	0.06 (-0.09,0.21)
Equity JP	0.06 (-0.02,0.08)	0.06 (-0.02,0.08)	0.07 (-0.02,0.08)	0.07 (-0.02,0.08)
Equity NL	0.05 (-0.09,0.08)	0.03 (-0.09,0.08)	0.02 (-0.09,0.08)	0.02 (-0.10,0.08)
NomB US	-0.08 (-0.23,0.05)	-0.06 (-0.19,0.11)	-0.06 (-0.20,0.12)	-0.06 (-0.20,0.13)
NomB UK	-0.20 (-0.33,0.02)	-0.23 (-0.38,0.04)	-0.23 (-0.38,0.04)	-0.23 (-0.38,0.04)
NomB JP	0.84 (0.51,0.97)	0.96 (0.45,1.08)	0.96 (0.44,1.08)	0.96 (0.44,1.08)
NomB NL	0.12 (-0.16,0.24)	0.14 (-0.19,0.29)	0.14 (-0.20,0.29)	0.14 (-0.20,0.29)
RealB US	-0.09 (-0.22,0.14)	-0.06 (-0.21,0.24)	-0.05 (-0.21,0.25)	-0.05 (-0.20,0.25)
RealB UK	-0.08 (-0.10,0.29)	-0.12 (-0.13,0.32)	-0.12 (-0.13,0.32)	-0.12 (-0.13,0.32)
RealB EU	0.46 (0.17,0.61)	0.34 (0.01,0.59)	0.33 (-0.01,0.59)	0.33 (-0.01,0.60)

Table 6: Optimal allocation strategy for Dutch investor exposed currency risk

This table reports the Dutch optimal allocation of the hedging portfolio in percentages across different horizons. The portfolio weights have been given for both the VECM and the VAR model. In this allocation the investors is not exposed to currency risk as exchange rate risk is hedged by forward contracts. The number in parentheses are the lower and upper bounds of the corresponding 95% Bootstrap confidence intervals.

	Investment horizon (months)			
	1	12	24	60
VECM				
Equity US	0.02 (-0.02,0.19)	-0.01 (-0.07,0.18)	-0.01 (-0.08,0.18)	0.00 (-0.09,0.19)
Equity UK	-0.03 (-0.15,0.13)	0.03 (-0.11,0.19)	0.03 (-0.11,0.19)	0.03 (-0.12,0.20)
Equity JP	0.00 (-0.10,0.04)	-0.01 (-0.12,0.05)	-0.01 (-0.12,0.05)	-0.01 (-0.12,0.05)
Equity NL	0.12 (-0.10,0.13)	0.05 (-0.09,0.11)	0.05 (-0.09,0.11)	0.04 (-0.09,0.11)
NomB US	-0.12 (-0.22,0.07)	-0.19 (-0.22,0.09)	-0.21 (-0.22,0.10)	-0.22 (-0.22,0.10)
NomB UK	0.25 (-0.21,0.35)	0.31 (-0.26,0.39)	0.32 (-0.26,0.39)	0.33 (-0.27,0.39)
NomB JP	-0.05 (-0.05,0.19)	-0.04 (-0.05,0.18)	-0.04 (-0.06,0.18)	-0.03 (-0.06,0.18)
NomB NL	0.26 (-0.16,0.38)	0.23 (-0.23,0.44)	0.22 (-0.25,0.44)	0.21 (-0.25,0.44)
RealB US	0.18 (-0.03,0.28)	0.38 (0.00,0.49)	0.40 (0.00,0.51)	0.42 (-0.01,0.52)
RealB UK	-0.09 (-0.10,0.34)	-0.14 (-0.16,0.35)	-0.14 (-0.16,0.36)	-0.15 (-0.16,0.35)
RealB EU	0.46 (0.37,0.82)	0.38 (0.27,0.83)	0.38 (0.26,0.84)	0.38 (0.25,0.84)
VAR				
Equity US	0.02 (-0.04,0.19)	-0.02 (-0.09,0.19)	-0.02 (-0.09,0.19)	-0.02 (-0.09,0.19)
Equity UK	-0.02 (-0.14,0.17)	0.11 (-0.10,0.23)	0.12 (-0.10,0.23)	0.12 (-0.10,0.23)
Equity JP	-0.02 (-0.12,0.04)	-0.01 (-0.13,0.04)	-0.01 (-0.14,0.05)	-0.01 (-0.14,0.05)
Equity NL	0.12 (-0.11,0.13)	0.04 (-0.10,0.11)	0.03 (-0.10,0.11)	0.03 (-0.10,0.11)
NomB US	-0.11 (-0.23,0.08)	-0.11 (-0.24,0.09)	-0.12 (-0.24,0.10)	-0.12 (-0.24,0.10)
NomB UK	0.23 (-0.24,0.37)	0.23 (-0.26,0.41)	0.23 (-0.26,0.42)	0.23 (-0.26,0.42)
NomB JP	-0.05 (-0.08,0.17)	-0.08 (-0.09,0.16)	-0.08 (-0.09,0.16)	-0.08 (-0.09,0.16)
NomB NL	0.30 (-0.14,0.35)	0.34 (-0.19,0.40)	0.35 (-0.19,0.39)	0.35 (-0.19,0.41)
RealB US	0.19 (-0.02,0.30)	0.40 (0.03,0.56)	0.41 (0.02,0.58)	0.42 (0.02,0.60)
RealB UK	-0.08 (-0.12,0.33)	-0.16 (-0.18,0.31)	-0.16 (-0.18,0.31)	-0.16 (-0.19,0.31)
RealB EU	0.43 (0.33,0.81)	0.26 (0.21,0.82)	0.25 (0.20,0.82)	0.24 (0.19,0.83)

Table 7: Optimal allocation strategy for French investor with currency hedge

This table reports the French optimal allocation of the hedging portfolio in percentages across different horizons. The portfolio weights have been given for both the VECM and the VAR model. In this allocation the investors is not exposed to currency risk as exchange rate risk is hedged by forward contracts. The number in parentheses are the lower and upper bounds of the corresponding 95% Bootstrap confidence intervals.

	Investment horizon (months)			
	1	12	24	60
VECM				
Equity US	-0.02 (-0.08,0.07)	-0.06 (-0.13,0.08)	-0.07 (-0.14,0.08)	-0.07 (-0.14,0.08)
Equity UK	0.07 (-0.09,0.14)	0.12 (-0.07,0.18)	0.13 (-0.07,0.19)	0.13 (-0.07,0.20)
Equity JP	0.06 (-0.01,0.08)	0.06 (-0.01,0.09)	0.06 (-0.01,0.10)	0.06 (-0.01,0.10)
Equity FR	-0.09 (-0.12,0.05)	-0.09 (-0.13,0.04)	-0.09 (-0.14,0.04)	-0.09 (-0.14,0.04)
NomB US	-0.08 (-0.16,0.07)	0.00 (-0.12,0.13)	0.00 (-0.12,0.14)	0.01 (-0.11,0.14)
NomB UK	-0.13 (-0.30,0.04)	-0.14 (-0.34,0.07)	-0.14 (-0.35,0.08)	-0.14 (-0.36,0.08)
NomB JP	0.89 (0.56,0.99)	0.95 (0.50,1.08)	0.95 (0.48,1.08)	0.95 (0.47,1.08)
NomB FR	-0.07 (-0.26,0.18)	-0.13 (-0.30,0.17)	-0.13 (-0.31,0.17)	-0.13 (-0.31,0.18)
RealB US	-0.11 (-0.22,0.08)	-0.08 (-0.22,0.17)	-0.07 (-0.22,0.19)	-0.07 (-0.22,0.19)
RealB UK	0.03 (-0.04,0.27)	0.01 (-0.08,0.31)	0.01 (-0.08,0.31)	0.01 (-0.09,0.32)
RealB EU	0.44 (0.17,0.63)	0.34 (0.03,0.60)	0.33 (0.01,0.60)	0.33 (0.01,0.60)
VAR				
Equity US	-0.02 (-0.08,0.08)	-0.04 (-0.11,0.08)	-0.05 (-0.11,0.08)	-0.05 (-0.12,0.08)
Equity UK	0.08 (-0.09,0.14)	0.11 (-0.07,0.18)	0.11 (-0.06,0.18)	0.12 (-0.06,0.19)
Equity JP	0.06 (-0.01,0.08)	0.06 (-0.01,0.09)	0.06 (-0.01,0.09)	0.06 (-0.01,0.09)
Equity FR	-0.09 (-0.13,0.04)	-0.09 (-0.13,0.04)	-0.09 (-0.13,0.04)	-0.09 (-0.14,0.04)
NomB US	-0.08 (-0.17,0.06)	-0.01 (-0.12,0.13)	0.00 (-0.12,0.14)	0.00 (-0.12,0.14)
NomB UK	-0.14 (-0.30,0.03)	-0.14 (-0.34,0.06)	-0.14 (-0.35,0.06)	-0.14 (-0.35,0.06)
NomB JP	0.89 (0.55,0.98)	0.98 (0.51,1.07)	0.98 (0.50,1.07)	0.98 (0.50,1.07)
NomB FR	-0.05 (-0.25,0.18)	-0.15 (-0.30,0.15)	-0.15 (-0.31,0.15)	-0.16 (-0.31,0.15)
RealB US	-0.11 (-0.21,0.08)	-0.10 (-0.21,0.17)	-0.10 (-0.21,0.18)	-0.10 (-0.21,0.18)
RealB UK	0.04 (-0.04,0.28)	0.02 (-0.06,0.30)	0.02 (-0.06,0.30)	0.02 (-0.06,0.30)
RealB EU	0.42 (0.15,0.61)	0.35 (0.04,0.60)	0.35 (0.03,0.60)	0.35 (0.03,0.61)

Table 8: Optimal allocation strategy for French investor exposed to currency risk

This table reports the French optimal allocation of the hedging portfolio in percentages across different horizons. The portfolio weights have been given for both the VECM and the VAR model. In this allocation the investors is not exposed to currency risk as exchange rate risk is hedged by forward contracts. The number in parentheses are the lower and upper bounds of the corresponding 95% Bootstrap confidence intervals.

	Investment horizon (months)			
	1	12	24	60
VECM				
Equity US	0.11 (-0.05,0.20)	0.08 (-0.09,0.19)	0.08 (-0.09,0.20)	0.08 (-0.10,0.20)
Equity UK	0.15 (-0.12,0.17)	0.20 (-0.09,0.20)	0.20 (-0.09,0.21)	0.20 (-0.09,0.21)
Equity JP	0.02 (-0.10,0.06)	0.01 (-0.12,0.05)	0.01 (-0.12,0.05)	0.01 (-0.12,0.05)
Equity FR	-0.16 (-0.19,0.11)	-0.16 (-0.18,0.11)	-0.16 (-0.17,0.12)	-0.16 (-0.17,0.12)
NomB US	-0.12 (-0.20,0.08)	-0.07 (-0.21,0.08)	-0.06 (-0.21,0.09)	-0.06 (-0.22,0.09)
NomB UK	0.05 (-0.21,0.15)	0.03 (-0.27,0.19)	0.03 (-0.27,0.19)	0.03 (-0.28,0.19)
NomB JP	0.04 (-0.05,0.17)	0.02 (-0.07,0.16)	0.03 (-0.07,0.17)	0.03 (-0.07,0.17)
NomB FR	0.11 (-0.19,0.31)	0.07 (-0.18,0.36)	0.06 (-0.18,0.37)	0.06 (-0.19,0.38)
RealB US	0.14 (-0.01,0.29)	0.23 (0.03,0.53)	0.23 (0.03,0.56)	0.23 (0.02,0.58)
RealB UK	0.04 (0.00,0.34)	0.01 (-0.05,0.32)	0.01 (-0.06,0.32)	0.01 (-0.06,0.32)
RealB EU	0.62 (0.31,0.83)	0.59 (0.19,0.80)	0.58 (0.18,0.80)	0.58 (0.17,0.80)
VAR				
Equity US	0.12 (-0.04,0.20)	0.07 (-0.08,0.19)	0.07 (-0.09,0.19)	0.07 (-0.09,0.19)
Equity UK	0.15 (-0.12,0.17)	0.20 (-0.08,0.21)	0.21 (-0.08,0.21)	0.21 (-0.08,0.22)
Equity JP	0.01 (-0.10,0.05)	0.01 (-0.11,0.05)	0.01 (-0.12,0.05)	0.01 (-0.12,0.05)
Equity FR	-0.16 (-0.19,0.10)	-0.15 (-0.18,0.10)	-0.15 (-0.17,0.10)	-0.15 (-0.17,0.11)
NomB US	-0.13 (-0.21,0.07)	-0.08 (-0.20,0.08)	-0.07 (-0.20,0.09)	-0.07 (-0.21,0.09)
NomB UK	0.04 (-0.21,0.16)	0.04 (-0.26,0.18)	0.04 (-0.26,0.18)	0.04 (-0.26,0.18)
NomB JP	0.04 (-0.05,0.17)	0.03 (-0.07,0.16)	0.03 (-0.07,0.16)	0.03 (-0.07,0.16)
NomB FR	0.14 (-0.18,0.35)	0.08 (-0.17,0.38)	0.08 (-0.17,0.38)	0.08 (-0.18,0.38)
RealB US	0.14 (0.00,0.29)	0.26 (0.04,0.50)	0.27 (0.04,0.53)	0.27 (0.03,0.54)
RealB UK	0.04 (0.00,0.33)	0.01 (-0.05,0.32)	0.01 (-0.06,0.32)	0.00 (-0.06,0.32)
RealB EU	0.61 (0.31,0.83)	0.53 (0.19,0.81)	0.52 (0.18,0.81)	0.52 (0.18,0.82)

Table 9: Optimal allocation strategy for German investor with currency hedge

This table reports the German optimal allocation of the hedging portfolio in percentages across different horizons. The portfolio weights have been given for both the VECM and the VAR model. In this allocation the investors is not exposed to currency risk as exchange rate risk is hedged by forward contracts. The number in parentheses are the lower and upper bounds of the corresponding 95% Bootstrap confidence intervals.

	Investment horizon (months)			
	1	12	24	60
VECM				
Equity US	-0.04 (-0.10,0.06)	-0.06 (-0.13,0.07)	-0.06 (-0.13,0.07)	-0.06 (-0.14,0.07)
Equity UK	-0.08 (-0.17,0.07)	-0.07 (-0.18,0.11)	-0.07 (-0.19,0.12)	-0.07 (-0.19,0.12)
Equity JP	0.04 (-0.01,0.07)	0.04 (-0.02,0.08)	0.05 (-0.02,0.08)	0.05 (-0.02,0.08)
Equity GER	0.09 (-0.03,0.15)	0.09 (-0.05,0.16)	0.10 (-0.05,0.16)	0.10 (-0.05,0.16)
NomB US	-0.06 (-0.16,0.07)	0.00 (-0.12,0.14)	0.00 (-0.12,0.15)	0.01 (-0.12,0.16)
NomB UK	-0.18 (-0.29,-0.01)	-0.21 (-0.35,0.00)	-0.22 (-0.36,0.00)	-0.22 (-0.36,0.00)
NomB JP	0.75 (0.50,0.91)	0.84 (0.46,1.00)	0.84 (0.46,1.01)	0.84 (0.46,1.01)
NomB GER	0.05 (-0.15,0.17)	0.04 (-0.21,0.20)	0.04 (-0.23,0.19)	0.04 (-0.23,0.19)
RealB US	-0.10 (-0.24,0.07)	-0.11 (-0.27,0.14)	-0.11 (-0.27,0.14)	-0.11 (-0.27,0.15)
RealB UK	0.04 (-0.05,0.28)	0.01 (-0.07,0.30)	0.01 (-0.07,0.31)	0.01 (-0.07,0.31)
RealB EU	0.47 (0.25,0.61)	0.42 (0.11,0.65)	0.42 (0.11,0.65)	0.43 (0.10,0.66)
VAR				
Equity US	-0.05 (-0.10,0.06)	-0.08 (-0.14,0.06)	-0.08 (-0.14,0.06)	-0.08 (-0.15,0.06)
Equity UK	-0.07 (-0.17,0.07)	-0.03 (-0.15,0.13)	-0.03 (-0.15,0.14)	-0.03 (-0.15,0.14)
Equity JP	0.04 (-0.01,0.07)	0.04 (-0.01,0.08)	0.04 (-0.01,0.08)	0.04 (-0.01,0.08)
Equity GER	0.09 (-0.03,0.15)	0.08 (-0.06,0.14)	0.08 (-0.06,0.14)	0.08 (-0.06,0.14)
NomB US	-0.07 (-0.17,0.05)	-0.03 (-0.15,0.11)	-0.03 (-0.15,0.12)	-0.03 (-0.15,0.13)
NomB UK	-0.17 (-0.28,-0.01)	-0.20 (-0.34,0.01)	-0.20 (-0.35,0.01)	-0.21 (-0.35,0.01)
NomB JP	0.75 (0.48,0.89)	0.84 (0.44,0.99)	0.84 (0.43,0.99)	0.84 (0.43,1.00)
NomB GER	0.05 (-0.15,0.18)	0.08 (-0.17,0.23)	0.08 (-0.18,0.23)	0.08 (-0.18,0.23)
RealB US	-0.07 (-0.20,0.09)	-0.03 (-0.17,0.20)	-0.03 (-0.18,0.21)	-0.02 (-0.17,0.22)
RealB UK	0.04 (-0.05,0.27)	0.00 (-0.07,0.29)	-0.01 (-0.07,0.30)	-0.01 (-0.08,0.30)
RealB EU	0.46 (0.22,0.59)	0.34 (0.00,0.58)	0.34 (0.03,0.59)	0.33 (0.03,0.59)

Table 10: Optimal allocation strategy for German investor exposed to currency risk

This table reports the German optimal allocation of the hedging portfolio in percentages across different horizons. The portfolio weights have been given for both the VECM and the VAR model. In this allocation the investors is not exposed to currency risk as exchange rate risk is hedged by forward contracts. The number in parentheses are the lower and upper bounds of the corresponding 95% Bootstrap confidence intervals.

	Investment horizon (months)			
	1	12	24	60
VECM				
Equity US	0.03 (-0.04,0.16)	-0.01 (-0.08,0.16)	-0.02 (-0.09,0.16)	-0.02 (-0.09,0.15)
Equity UK	-0.10 (-0.22,0.07)	0.00 (-0.20,0.14)	0.00 (-0.20,0.14)	0.01 (-0.21,0.15)
Equity JP	-0.03 (-0.10,0.04)	-0.03 (-0.11,0.04)	-0.03 (-0.11,0.04)	-0.03 (-0.11,0.04)
Equity GER	0.18 (0.02,0.20)	0.14 (0.00,0.20)	0.14 (-0.01,0.20)	0.14 (-0.01,0.20)
NomB US	-0.08 (-0.16,0.08)	-0.06 (-0.15,0.10)	-0.06 (-0.16,0.11)	-0.06 (-0.16,0.11)
NomB UK	0.08 (-0.16,0.14)	0.12 (-0.17,0.19)	0.12 (-0.18,0.19)	0.12 (-0.18,0.19)
NomB JP	0.03 (-0.04,0.16)	0.01 (-0.05,0.15)	0.01 (-0.05,0.16)	0.01 (-0.04,0.16)
NomB GER	0.23 (-0.09,0.26)	0.26 (-0.16,0.31)	0.26 (-0.17,0.31)	0.26 (-0.18,0.32)
RealB US	0.16 (-0.01,0.27)	0.30 (-0.01,0.44)	0.31 (-0.02,0.46)	0.32 (-0.03,0.47)
RealB UK	0.10 (0.04,0.33)	0.01 (-0.03,0.33)	0.01 (-0.04,0.33)	0.00 (-0.04,0.33)
RealB EU	0.41 (0.33,0.74)	0.27 (0.21,0.78)	0.26 (0.20,0.80)	0.25 (0.19,0.81)
VAR				
Equity US	0.02 (-0.06,0.15)	-0.01 (-0.09,0.14)	-0.01 (-0.10,0.14)	-0.02 (-0.10,0.14)
Equity UK	-0.11 (-0.24,0.07)	-0.05 (-0.21,0.12)	-0.04 (-0.22,0.12)	-0.04 (-0.22,0.13)
Equity JP	-0.03 (-0.10,0.04)	-0.04 (-0.11,0.03)	-0.04 (-0.12,0.03)	-0.04 (-0.12,0.03)
Equity GER	0.19 (0.02,0.22)	0.17 (0.02,0.21)	0.17 (0.02,0.22)	0.17 (0.02,0.22)
NomB US	-0.09 (-0.18,0.07)	-0.09 (-0.20,0.07)	-0.09 (-0.20,0.08)	-0.09 (-0.21,0.08)
NomB UK	0.09 (-0.16,0.15)	0.11 (-0.18,0.20)	0.11 (-0.19,0.20)	0.12 (-0.19,0.21)
NomB JP	0.03 (-0.05,0.17)	0.01 (-0.07,0.17)	0.01 (-0.07,0.17)	0.01 (-0.07,0.17)
NomB GER	0.21 (-0.12,0.28)	0.25 (-0.15,0.31)	0.25 (-0.16,0.32)	0.25 (-0.16,0.32)
RealB US	0.17 (0.00,0.27)	0.35 (0.05,0.50)	0.37 (0.06,0.52)	0.38 (0.06,0.54)
RealB UK	0.10 (0.03,0.34)	0.02 (-0.04,0.33)	0.02 (-0.04,0.32)	0.02 (-0.05,0.32)
RealB EU	0.42 (0.32,0.75)	0.27 (0.16,0.75)	0.26 (0.16,0.75)	0.26 (0.16,0.76)

Table 11: Optimal foreign bond allocation with currency risk

This table reports the optimal bond allocation of the hedging portfolio in percentages across different horizons for all three investors, namely the Dutch, French and German. The asset choice of the investor excludes European inflation-linked bonds. The portfolio weights have been given for both the VECM and the VAR model. In this allocation the investors are exposed to currency risk since exchange rates are not hedged by forward contracts. The number in parentheses are the lower and upper bounds of the corresponding 95% Bootstrap confidence intervals.

	Investment horizon (months)			
	1	12	24	60
VECM				
NomB NL	0.57 (0.38,0.73)	0.52 (0.31,0.72)	0.52 (0.30,0.72)	0.51 (0.30,0.73)
RealB UK	0.16 (0.05,0.38)	0.17 (0.04,0.41)	0.17 (0.03,0.41)	0.16 (0.02,0.42)
RealB US	0.30 (0.14,0.52)	0.26 (0.07,0.52)	0.26 (0.07,0.53)	0.26 (0.06,0.53)
NomB FR	0.63 (0.38,0.73)	0.52 (0.31,0.72)	0.51 (0.30,0.72)	0.51 (0.30,0.73)
RealB UK	0.18 (0.05,0.38)	0.22 (0.04,0.41)	0.22 (0.03,0.41)	0.22 (0.02,0.42)
RealB US	0.18 (0.14,0.52)	0.15 (0.07,0.52)	0.15 (0.07,0.53)	0.15 (0.06,0.53)
NomB GER	0.58 (0.34,0.68)	0.56 (0.28,0.69)	0.56 (0.28,0.70)	0.56 (0.28,0.70)
RealB UK	0.14 (0.03,0.33)	0.20 (0.06,0.40)	0.21 (0.06,0.40)	0.21 (0.06,0.40)
RealB US	0.22 (0.17,0.53)	0.15 (0.09,0.53)	0.15 (0.08,0.53)	0.15 (0.08,0.53)
VAR				
NomB NL	0.56 (0.38,0.72)	0.50 (0.30,0.69)	0.50 (0.29,0.69)	0.50 (0.29,0.69)
RealB UK	0.16 (0.04,0.37)	0.20 (0.07,0.42)	0.20 (0.07,0.42)	0.20 (0.07,0.43)
RealB US	0.30 (0.14,0.53)	0.25 (0.09,0.53)	0.25 (0.09,0.53)	0.25 (0.09,0.53)
NomB FR	0.63 (0.39,0.77)	0.51 (0.28,0.71)	0.51 (0.28,0.71)	0.50 (0.27,0.71)
RealB UK	0.19 (0.04,0.38)	0.22 (0.09,0.43)	0.22 (0.09,0.44)	0.22 (0.09,0.44)
RealB US	0.18 (0.13,0.52)	0.15 (0.09,0.52)	0.15 (0.08,0.52)	0.14 (0.08,0.52)
NomB GER	0.58 (0.33,0.68)	0.50 (0.24,0.66)	0.50 (0.23,0.66)	0.49 (0.23,0.66)
RealB UK	0.14 (0.02,0.32)	0.16 (0.04,0.38)	0.16 (0.05,0.38)	0.16 (0.05,0.39)
RealB US	0.22 (0.16,0.54)	0.18 (0.11,0.54)	0.17 (0.11,0.54)	0.17 (0.11,0.54)

Table 12: Dutch Bayesian optimal allocation exposed to currency risk

This table reports the Dutch optimal bond allocation of the hedging portfolio in percentages across different horizons. The portfolio weights have been given for both the VECM and the VAR model. In this allocation the investors are exposed to currency risk since exchange rates are not hedged by forward contracts. The number in parentheses are the lower and upper bounds of the corresponding 95% confidence intervals.

	Investment horizon (months)			
	1	12	24	60
VECM				
Equity US	0.11 (-0.04,0.26)	0.16 (-0.03,0.32)	0.16 (-0.04,0.32)	0.16 (-0.04,0.32)
Equity UK	-0.10 (-0.32,0.13)	-0.07 (-0.33,0.23)	-0.06 (-0.33,0.24)	-0.05 (-0.32,0.24)
Equity JP	-0.01 (-0.09,0.08)	-0.03 (-0.13,0.06)	-0.04 (-0.13,0.06)	-0.04 (-0.13,0.06)
Equity NL	0.06 (-0.09,0.21)	0.06 (-0.14,0.26)	0.05 (-0.14,0.26)	0.05 (-0.14,0.26)
NomB US	-0.34 (-0.54,-0.12)	-0.24 (-0.51,0.07)	-0.22 (-0.50,0.10)	-0.20 (-0.49,0.12)
NomB UK	0.26 (0.03,0.44)	0.15 (-0.18,0.44)	0.12 (-0.20,0.43)	0.11 (-0.22,0.42)
NomB JP	-0.02 (-0.13,0.09)	0.04 (-0.12,0.20)	0.04 (-0.12,0.21)	0.05 (-0.12,0.21)
NomB NL	0.37 (0.12,0.61)	0.32 (-0.03,0.68)	0.30 (-0.06,0.67)	0.29 (-0.08,0.66)
RealB US	0.29 (0.09,0.49)	0.21 (-0.08,0.48)	0.19 (-0.11,0.48)	0.18 (-0.13,0.48)
RealB UK	-0.12 (-0.30,0.09)	0.01 (-0.27,0.30)	0.03 (-0.26,0.33)	0.05 (-0.26,0.34)
RealB EU	0.48 (0.26,0.71)	0.40 (0.10,0.70)	0.40 (0.09,0.72)	0.41 (0.09,0.74)
VAR				
Equity US	0.10 (-0.03,0.23)	0.15 (0.01,0.28)	0.15 (0.01,0.28)	0.15 (0.01,0.29)
Equity UK	-0.11 (-0.31,0.09)	-0.14 (-0.35,0.07)	-0.14 (-0.35,0.07)	-0.15 (-0.35,0.08)
Equity JP	-0.01 (-0.08,0.07)	-0.04 (-0.12,0.04)	-0.04 (-0.12,0.04)	-0.04 (-0.12,0.04)
Equity NL	0.09 (-0.03,0.21)	0.15 (0.01,0.28)	0.15 (0.01,0.29)	0.15 (0.01,0.29)
NomB US	-0.34 (-0.52,-0.15)	-0.29 (-0.51,-0.06)	-0.29 (-0.51,-0.05)	-0.29 (-0.51,-0.05)
NomB UK	0.30 (0.16,0.44)	0.27 (0.08,0.46)	0.27 (0.07,0.46)	0.27 (0.07,0.46)
NomB JP	-0.02 (-0.11,0.07)	0.03 (-0.07,0.13)	0.03 (-0.07,0.14)	0.04 (-0.07,0.14)
NomB NL	0.37 (0.15,0.59)	0.42 (0.15,0.69)	0.42 (0.14,0.70)	0.42 (0.14,0.70)
RealB US	0.29 (0.12,0.47)	0.23 (0.02,0.45)	0.23 (0.01,0.46)	0.22 (0.00,0.46)
RealB UK	-0.14 (-0.29,0.01)	-0.07 (-0.25,0.11)	-0.06 (-0.24,0.12)	-0.06 (-0.24,0.12)
RealB EU	0.46 (0.27,0.66)	0.30 (0.08,0.52)	0.29 (0.07,0.52)	0.29 (0.06,0.52)

Table 13: French Bayesian optimal allocation exposed to currency risk

This table reports the French optimal bond allocation of the hedging portfolio in percentages across different horizons. The portfolio weights have been given for both the VECM and the VAR model. In this allocation the investors are exposed to currency risk since exchange rates are not hedged by forward contracts. The number in parentheses are the lower and upper bounds of the corresponding 95% confidence intervals.

	Investment horizon (months)			
	1	12	24	60
VECM				
Equity US	0.14 (0.02,0.25)	0.17 (0.01,0.31)	0.17 (0.01,0.31)	0.17 (0.00,0.31)
Equity UK	0.12 (-0.05,0.27)	0.10 (-0.13,0.33)	0.09 (-0.15,0.33)	0.08 (-0.16,0.33)
Equity JP	0.01 (-0.06,0.07)	-0.01 (-0.09,0.08)	-0.02 (-0.10,0.08)	-0.02 (-0.10,0.08)
Equity NL	-0.16 (-0.22,-0.09)	-0.12 (-0.24,0.02)	-0.11 (-0.24,0.05)	-0.10 (-0.24,0.07)
NomB US	-0.22 (-0.39,-0.05)	-0.19 (-0.41,0.07)	-0.18 (-0.42,0.09)	-0.17 (-0.41,0.10)
NomB UK	0.01 (-0.16,0.18)	-0.01 (-0.25,0.24)	-0.01 (-0.26,0.24)	-0.01 (-0.27,0.25)
NomB JP	0.05 (-0.04,0.14)	0.07 (-0.07,0.21)	0.07 (-0.08,0.21)	0.08 (-0.08,0.22)
NomB FR	0.19 (-0.02,0.39)	0.19 (-0.09,0.48)	0.19 (-0.11,0.49)	0.18 (-0.12,0.49)
RealB US	0.21 (0.04,0.38)	0.19 (-0.05,0.44)	0.19 (-0.07,0.44)	0.18 (-0.09,0.45)
RealB UK	0.03 (-0.13,0.19)	0.09 (-0.17,0.33)	0.09 (-0.17,0.34)	0.10 (-0.17,0.36)
RealB EU	0.64 (0.44,0.83)	0.52 (0.24,0.79)	0.51 (0.23,0.80)	0.51 (0.22,0.80)
VAR				
Equity US	0.14 (0.03,0.24)	0.20 (0.10,0.31)	0.20 (0.10,0.31)	0.21 (0.10,0.32)
Equity UK	0.07 (-0.06,0.20)	0.13 (-0.01,0.27)	0.14 (0.00,0.28)	0.14 (0.00,0.28)
Equity JP	0.03 (-0.02,0.09)	0.00 (-0.06,0.07)	0.00 (-0.06,0.06)	0.00 (-0.06,0.06)
Equity FR	-0.14 (-0.19,-0.09)	-0.19 (-0.25,-0.13)	-0.19 (-0.25,-0.13)	-0.19 (-0.25,-0.13)
NomB US	-0.28 (-0.44,-0.13)	-0.28 (-0.46,-0.10)	-0.28 (-0.46,-0.09)	-0.28 (-0.46,-0.09)
NomB UK	0.10 (-0.04,0.24)	0.00 (-0.15,0.17)	0.00 (-0.16,0.17)	-0.01 (-0.17,0.17)
NomB JP	0.07 (-0.01,0.15)	0.12 (0.03,0.22)	0.12 (0.03,0.22)	0.13 (0.03,0.22)
NomB FR	0.20 (-0.03,0.43)	0.27 (0.01,0.54)	0.27 (0.01,0.54)	0.27 (0.00,0.54)
RealB US	0.19 (0.04,0.35)	0.18 (0.00,0.37)	0.18 (-0.01,0.38)	0.18 (-0.02,0.38)
RealB UK	0.00 (-0.14,0.14)	0.09 (-0.07,0.26)	0.10 (-0.06,0.27)	0.10 (-0.06,0.27)
RealB EU	0.61 (0.40,0.82)	0.46 (0.22,0.70)	0.46 (0.21,0.70)	0.46 (0.21,0.70)

Table 14: German Bayesian optimal allocation exposed to currency risk

This table reports the German optimal bond allocation of the hedging portfolio in percentages across different horizons. The portfolio weights have been given for both the VECM and the VAR model. In this allocation the investors are exposed to currency risk since exchange rates are not hedged by forward contracts. The number in parentheses are the lower and upper bounds of the corresponding 95% confidence intervals.

	Investment horizon (months)			
	1	12	24	60
VECM				
Equity US	0.10 (0.00,0.20)	0.14 (0.01,0.26)	0.14 (0.01,0.27)	0.14 (0.00,0.28)
Equity UK	-0.26 (-0.42,-0.10)	-0.27 (-0.47,-0.06)	-0.27 (-0.48,-0.03)	-0.26 (-0.48,-0.01)
Equity JP	-0.02 (-0.08,0.04)	-0.04 (-0.10,0.03)	-0.04 (-0.10,0.03)	-0.04 (-0.10,0.03)
Equity GER	0.22 (0.11,0.34)	0.24 (0.06,0.41)	0.24 (0.04,0.42)	0.23 (0.03,0.41)
NomB US	-0.27 (-0.42,-0.11)	-0.23 (-0.43,-0.01)	-0.22 (-0.43,0.02)	-0.22 (-0.44,0.03)
NomB UK	0.17 (0.05,0.30)	0.11 (-0.09,0.29)	0.10 (-0.13,0.29)	0.09 (-0.15,0.29)
NomB JP	0.07 (-0.01,0.15)	0.09 (-0.04,0.20)	0.09 (-0.05,0.21)	0.09 (-0.05,0.21)
NomB GER	0.24 (0.05,0.43)	0.26 (-0.03,0.57)	0.26 (-0.06,0.59)	0.25 (-0.07,0.60)
RealB US	0.22 (0.07,0.37)	0.19 (-0.03,0.40)	0.18 (-0.05,0.40)	0.18 (-0.07,0.41)
RealB UK	0.11 (-0.03,0.25)	0.22 (0.01,0.44)	0.23 (0.01,0.46)	0.24 (0.01,0.48)
RealB EU	0.42 (0.24,0.58)	0.29 (0.05,0.53)	0.29 (0.04,0.55)	0.30 (0.03,0.57)
VAR				
Equity US	0.09 (0.00,0.18)	0.13 (0.04,0.22)	0.13 (0.04,0.23)	0.13 (0.04,0.23)
Equity UK	-0.25 (-0.39,-0.11)	-0.27 (-0.41,-0.13)	-0.27 (-0.41,-0.13)	-0.27 (-0.42,-0.13)
Equity JP	-0.03 (-0.08,0.02)	-0.05 (-0.10,0.00)	-0.05 (-0.10,0.00)	-0.05 (-0.10,0.00)
Equity GER	0.22 (0.13,0.32)	0.24 (0.13,0.35)	0.24 (0.13,0.35)	0.24 (0.13,0.36)
NomB US	-0.25 (-0.39,-0.12)	-0.23 (-0.37,-0.09)	-0.23 (-0.37,-0.08)	-0.23 (-0.37,-0.08)
NomB UK	0.17 (0.06,0.27)	0.13 (0.00,0.25)	0.12 (0.00,0.25)	0.12 (-0.01,0.25)
NomB JP	0.07 (0.00,0.13)	0.11 (0.03,0.18)	0.11 (0.03,0.18)	0.11 (0.03,0.18)
NomB GER	0.23 (0.07,0.38)	0.25 (0.06,0.44)	0.25 (0.06,0.44)	0.25 (0.06,0.45)
RealB US	0.22 (0.10,0.35)	0.20 (0.06,0.35)	0.20 (0.05,0.35)	0.20 (0.05,0.35)
RealB UK	0.10 (-0.02,0.22)	0.20 (0.05,0.34)	0.20 (0.05,0.35)	0.20 (0.06,0.36)
RealB EU	0.43 (0.30,0.57)	0.30 (0.15,0.45)	0.29 (0.14,0.45)	0.29 (0.14,0.44)

Table 15: Conditional Dutch Bayesian optimal allocation with currency risk

This table reports the average of the Dutch optimal bond allocation of the replicating portfolio across different horizons. We split the sample in three periods: Prior to the Financial crisis is classified from June 2005 to August 2008, during is classified from September 2008 to December 2009, and post crisis from January 2010 to December 2011. The portfolio weights have derived for a conditional VECM-type of investor in a Bayesian context. In this allocation the investor is exposed to currency risk as exchange rate risk is not hedged by forward contracts.

	Investment horizon (months)			
	1	12	24	60
Prior the financial crisis				
NomB NL	8.6 %	13.7 %	13.9 %	13.9 %
RealB UK	12.4 %	10.9 %	10.9 %	10.9 %
RealB US	14.7 %	14.9 %	14.9 %	15.1 %
RealB EU	63.4 %	50.1 %	49.7 %	49.7 %
During the financial crisis				
NomB NL	12.6 %	15.8 %	14.9 %	14.2 %
RealB UK	13.4 %	13.4 %	12.1 %	11.2 %
RealB US	14.2 %	13.3 %	14.0 %	14.8 %
RealB EU	60.3 %	48.1 %	48.8 %	49.4 %
Post the financial crisis				
NomB NL	9.4 %	13.6 %	13.8 %	13.8 %
RealB UK	11.8 %	11.2 %	11.0 %	10.9 %
RealB US	15.1 %	15.1 %	15.0 %	15.1 %
RealB EU	62.2 %	49.8 %	49.6 %	49.7 %

Table 16: Conditional French Bayesian optimal allocation with currency risk

This table reports the average of the French optimal bond allocation of the replicating portfolio across different horizons. We split the sample in three periods: Prior to the Financial crisis is classified from June 2005 to August 2008, during is classified from September 2008 to December 2009, and post crisis from January 2010 to December 2011. The portfolio weights have derived for a conditional VECM-type of investor in a Bayesian context. In this allocation the investor is exposed to currency risk as exchange rate risk is not hedged by forward contracts.

	Investment horizon (months)			
	1	12	24	60
Prior the financial crisis				
NomB FR	9.4 %	13.7 %	13.9 %	13.9 %
RealB UK	12.3 %	10.8 %	10.8 %	10.8 %
RealB US	14.2 %	15.0 %	14.9 %	15.1 %
RealB EU	62.9 %	50.1 %	49.8 %	49.7 %
During the financial crisis				
NomB FR	13.7 %	16.2 %	15.1 %	14.3 %
RealB UK	14.6 %	13.4 %	12.1 %	11.3 %
RealB US	13.3 %	13.0 %	13.9 %	14.7 %
RealB EU	58.7 %	47.9 %	48.8 %	49.4 %
Post the financial crisis				
NomB FR	10.4 %	13.7 %	13.9 %	13.8 %
RealB UK	10.5 %	11.0 %	10.9 %	10.9 %
RealB US	15.8 %	15.1 %	15.0 %	15.1 %
RealB EU	61.5 %	49.8 %	49.7 %	49.7 %

Table 17: Conditional German Bayesian optimal allocation with currency risk

This table reports the average of the German optimal bond allocation of the replicating portfolio across different horizons. We split the sample in three periods: Prior to the Financial crisis is classified from June 2005 to August 2008, during is classified from September 2008 to December 2009, and post crisis from January 2010 to December 2011. The portfolio weights have derived for a conditional VECM-type of investor in a Bayesian context. In this allocation the investor is exposed to currency risk as exchange rate risk is not hedged by forward contracts.

	Investment horizon (months)			
	1	12	24	60
Prior the financial crisis				
NomB GER	3.4 %	9.0 %	10.4 %	11.3 %
RealB UK	10.2 %	11.2 %	11.4 %	11.5 %
RealB US	19.0 %	28.0 %	28.3 %	28.5 %
RealB EU	59.7 %	40.4 %	39.2 %	38.7 %
During the financial crisis				
NomB GER	5.4 %	10.2 %	11.1 %	11.6 %
RealB UK	11.2 %	12.8 %	12.4 %	11.9 %
RealB US	18.5 %	27.1 %	27.7 %	28.2 %
RealB EU	58.3 %	39.1 %	38.4 %	38.4 %
Post the financial crisis				
NomB GER	2.8 %	9.2 %	10.5 %	11.3 %
RealB UK	10.5 %	11.5 %	11.6 %	11.6 %
RealB US	18.7 %	28.0 %	28.3 %	28.5 %
RealB EU	59.6 %	40.0 %	39.0 %	38.6 %