Bond market evidence of time variation in exposures to global risk factors and the role of US monetary policy*

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Abstract

This paper empirically shows that US monetary policy influences present and future exposures of developed markets' government bond returns to measures of global, systematic risk and thus affects the time variation of these returns. This finding highlights spillovers from US monetary policy not only to US dollar denominated foreign assets but also to foreign assets denominated in other currencies than the US dollar. From an asset pricing perspective, the evidence highlights that exchange rate risk and time variation in sensitivities to global bond

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and exchange rate risk are important to describe time variation in developed markets' government bond returns.

KEYWORDS: Bond return, global CAPM, monetary policy, risk factors, spillover, time variation

JEL: E52, G10, G15

1 Introduction

This paper assesses time variation in excess returns on government bond indexes, denominated in local currency, of six developed markets: Switzerland, Japan, Germany, Australia, Canada and the UK. This assessment is based on a global asset pricing model for bond returns and is aimed at answering two questions: Are exchange rate risks and time variation in exposures to global risk factors important to understand the time variation in excess returns on the government bonds of the countries under study? And if so, what drives the time variation in the sensitivities to global risk factors? Answers to these questions are relevant for asset managers and policymakers as government bonds do not only serve as benchmark assets in financial markets but are also at the centre of most regulatory initiatives in the aftermath of the global financial crisis (IMF, 2012).

The main motivation for this paper's focus on developed economies' bond markets stems from Gourinchas and Jeanne (2012). They contribute to the discussions about shortages of safe assets (e.g. IMF, 2012) by arguing that only public assets such as central bank liabilities (central bank money) and government bonds have the potential to fulfill the basic criteria of safe assets[1]. It is hence vital to understand what forces influence prices and returns on supposedly safe assets such as government bonds.

The main motivation for this paper's focus on a global asset pricing framework as basic workhorse of the empirical analysis stems from Longstaff et

[1]According to the IMF (2012), these basic criteria are low credit or market risk, high (market) liquidity, limited inflation risk, low exchange rate risk and limited idiosyncratic risk. In addition, safe assets should not be dependent on characteristics such as the issuer of a bond.

al. (2011). They analyze credit default swap (CDS) spreads to show that sovereign risk of G10 countries is to a large extent globally determined. In addition, Miranda-Aggripino and Rey (2015) argue that a single, global risk factor can account for a substantial part of cross-sectional dispersion in returns on a wide variety of different asset classes. Given its focus on returns on government (sovereign) bonds, a global asset pricing model is hence a natural benchmark for the purpose of this study.

Against this background, the contribution of this paper is threefold. First, it contributes to the asset pricing literature, mainly focused on equity markets, on the importance of exchange rate risks and time variation in the exposure to risk factors to explain asset returns. This paper shows that explicitly taking exposures to exchange rate risk into account improves our understanding of time variation in the six countries' government bond excess returns under study. This evidence is related to the findings by Dumas and Solnik (1995), De Santis and Gerard (1998) and Harvey et al. (2002) that exchange rate risk is priced in the cross-section of stock market returns. It is also related to Hofmann et al. (2016) highlighting a link between emerging markets' sovereign bond returns and the corresponding US dollar exchange rate changes. Employing a recently proposed econometric technique to assess the time series path of parameters, e.g. regression coefficients, by Müller and Petalas (2010), I find that time variation in the exposures to global bond market and exchange rate risk adds additional descriptive power for the government bond excess returns under study. This evidence thus follows Harvey (1991) in allowing for time-varying exposures to risk factors but without using conditional variables and the associated difficulty to pick the most relevant ones. It also confirms findings by Brusa et al. (2014) who find significant time variation in the exposures of international equity returns to global stock market and currency risk factors.

Second, this paper assesses the drivers of time-varying exposures to global risk. The motivation for this assessment is given by Rey (2013) who finds common movements in prices of risky assets, capital flows and banks' leverage ('global financial cycle'). This global financial cycle is contemporaneously correlated with VIX, the CBOE option implied volatility index of the S&P 500 stock index and a measure of (global) risk aversion and uncertainty (e.g. Bekaert et al., 2013). Furthermore, Rey (2013) and Miranda-Agrippino and Rey (2015) argue that US monetary policy is a key driver of the global financial cycle and the global component of asset prices. This paper hence assesses if VIX, the summary measure of the global financial cycle, and US shadow policy rates (Lombardi and Zhu, 2013; Wu and Xia, 2015), a summary measure of the US monetary policy stance, are contemporaneously linked to the time variation in government bond returns' global risk factor exposures. In addition, I assess in-sample predictive power of VIX or US shadow policy rates for quantities of global risk (exposures to global risk factors). This analysis follows Viceira (2012) who shows that predictors of US bond excess returns are also successful predictors of sensitivities to systematic bond market risk. I find that in both cases, contemporaneous and (in-sample) forecasting relations, the US monetary policy stance is a driver of time variation in the exposures to global risk factors. This finding is far weaker for the VIX. This evidence hence suggests that US monetary policy influences present and future exposures of global, systematic risk that developed markets' government bonds load up. Hence, the assessment of the importance of time-varying exposure to global risk in order to describe time variation in bond excess returns contributes to the extensive literature dealing with the question if global, regional or country-specific risks drive asset returns and how their relative importance changes over time (e.g. Bekaert and Harvey, 1995, 2000; Bekaert et al., 2007; Bekaert et al., 2011; Ferson and Harvey, 1993; Dahlquist and Hasseltoft, 2013).

It is the third contribution of this paper to provide an analysis of the importance of time-varying quantities of global risk for international bond returns.[2] I find that a simple, global unconditional CAPM can explain between 40% to 70% of time variation in government bond excess returns if time variation in risk factor exposures and exchange rate risk is taken into account. US monetary policy is a key driver of this time variation in risk factor exposures which highlights the impact of US monetary policy spillovers on both US dollar and local currency denominated government bonds.

The remainder of the paper is organized as follows. Section 2 describes the conceptual background and the empirical framework. Section 3 presents the data and descriptive statistics of the government bond returns under study. Section 4 gives the empirical results. Finally, section 5 concludes.

[2] This paper thus complements studies such as Barr and Priestley (2004) who assess bond market integration and the predictability of bond returns in a similar set of countries as this paper. Ilmanen (1995) finds that the predictability of international bond returns is related to global risk factors. Dahlquist and Hasseltoft (2013) show that a single global bond market risk factor predicts local currency bond returns of the major economies about as well as or better than its local counterpart. In addition, the global bond risk factor seems to be tightly linked to US bond risk premia. Borri and Verdelhan (2011) highlight that differences in exposures to US market risk explain cross-sectional differences in excess returns on portfolios comprised of US dollar denominated sovereign debt of emerging markets while Driessen et al. (2003) find that a single world interest rate level factor accounts for almost half of the variation in bond returns of developed markets.

2 Conceptual background and empirical framework

The basic workhorse of this paper is the empirical version of a global, unconditional CAPM (Solnik, 1974; Stehle, 1977). In this framework, the only determinant of expected asset returns is the sensitivity to the return on the global benchmark ('market') portfolio. The dependent asset returns and the return on the global market portfolio are expressed in the same currency. Translated into the empirical context of this paper, the global CAPM can be represented by the regression in equation (1)

$$r_t^{i,lc} - r_t^{f,i} = a^i + \beta^i (r_t^{global,lc} - r_t^{f,i}) + \varepsilon_t^i \tag{1}$$

in which the dependent variable is the return on the government bond index of country i ($r_t^{i,lc}$) in excess of the respective country's risk-free rate ($r_t^{f,i}$). It is regressed on the excess return on the global bond market denominated in the same, here local, currency ($r_t^{global,lc} - r_t^{f,i}$). This paper focuses on government bond indexes of six developed countries (Switzerland, Japan, Germany, Australia, Canada and the UK) which predominantly issue local currency denominated bonds in contrast to many emerging markets (see e.g. Borri and Verdelhan, 2011). Therefore, I express all variables in equation (1) in local currency terms.

Typically the CAPM market portfolio is approximated by a broad stock market index. However, since the focus of this study lies on government bond excess returns, I use a broad global government bond index as measure of global, systematic risk on bond markets. This choice reflects that Barr and Priestley (2004) find that incorporating information from stock market data does not influence their assessment of international bond market integration using a similar sample of countries as in this study. In addition, Ilmanen (1995) shows that the evidence of bond return predictability by a global factor can be explained in a simple version of the CAPM if a bond market index is used as proxy of the market portfolio. A global stock portfolio fails in this respect.

The simple, global bond market CAPM of equation (1) assumes that foreign exchange rate risk is perfectly hedged (dependent and explanatory variables are expressed in the same currency) and does not affect the risk-return considerations of the global investor. However, based on evidence from globally active US mutual funds, Hau and Rey (2006) argue that exchange rate risk is only imperfectly hedged. In addition, Dumas and Solnik (1995) show that exchange rate risk (sensitivity to exchange rate returns) is an important determinant of equity returns.

Against this background, I reformulate equation (1) in order to separate the impact of exchange rate returns on the global bond market return. Notice that $r_t^{global,lc} = \frac{1}{N}\sum_{k=1}^{N} r_t^{k,lc}$ with N the number of countries considered in the formation of the index. If we assume a common currency, e.g. the US dollar (\$), as numeraire we can rewrite $r_t^{k,lc} = r_t^{k,\$} + \Delta s_t^{k,\$}$, so that the global bond stock market return in local currency from the perspective of country i ($i \neq k$) obeys $r_t^{global,lc} = \frac{1}{N}\sum_{k=1}^{N} r_t^{k,\$} + \frac{1}{N}\sum_{k=1}^{N} \Delta s_t^{k,\$}$. For notational convenience, let us define $r_t^{global,\$} = \frac{1}{N}\sum_{k=1}^{N} r_t^{k,\$}$ and $\Delta s_t^{i} = \frac{1}{N}\sum_{k=1}^{N} \Delta s_t^{k,\$}$. The global CAPM can thus be rewritten to explicitly allow for exposure to exchange rate returns.

Empirically this exchange rate term is later obtained by subtracting $r_t^{global,\$}$ from $r_t^{global,lc}$.

$$r_t^{i,lc} - r_t^{f,i} = a^i + \gamma^i(r_t^{global,\$} - r_t^{f,i}) + \delta^i(\Delta s_t^i) + \varepsilon_t^i \tag{2}$$

In words, equation (2) relates the excess return on the government bond index of country i denominated in the local currency on the left-hand side of equation (2) to the excess return of the US dollar denominated global government bond index and the average return on the dollar exchange rate against the local currency of country i. I run the regressions in equation (2) to see if this model version ('Model 2') outperforms the simple, global CAPM ('Model 1') which would be a sign that exchange rate risk is not only important to understand cross-sectional variation in international equity returns but also time variation in international bond returns.

Recently, Brusa et al. (2014) find considerable time variation in the exposure of a broad set of international equity porfolios to global measures of systematic risk on stock and foreign exchange markets. In addition, there is evidence that the degree of international integration of stock or bond markets varies over time (Barr and Priestley, 2004; Bekaert and Harvey, 1995, 2000; Bekaert et al., 2007; Bekaert et al., 2011; Dahlquist and Hasseltoft, 2013). Against this backdrop, I study varients of the global CAPM, equations (1) and (2), that additionally allow for time variation in the sensitivity to the global bond market risk factor and the respective average exchange rate return in equation (2). The empirical part hence assesses the CAPM versions described in equations (3) and (4), i.e. 'Model 3' obeys

$$r_t^{i,lc} - r_t^{f,i} = a^i + \beta_t^i(r_t^{global,lc} - r_t^{f,i}) + \varepsilon_t^i \quad (3)$$

and 'Model 4' is represented by

$$r_t^{i,lc} - r_t^{f,i} = a^i + \gamma_t^i(r_t^{global,\$} - r_t^{f,i}) + \delta_t^i(\Delta s_t^i) + \varepsilon_t^i \quad (4)$$

In order to obtain time series of the regression coefficients γ_t and δ_t , I use the method proposed by Müller and Petalas (2010) to approximate parameter paths. Müller and Petalas (2010) give a step-by-step guide in order to implement their algorithm that provides an asymptotically accurate description of parameter paths by translating a general parametric model for a parameter into a pseudo linear Gaussian model. This algorithm uses information from the full sample period to approximate the path of a parameter, e.g. a regression coefficient, independent from the precise nature of the underlying process of time variation. This latter feature of the Müller and Petalas (2010) method makes it particularly attractive in the context of this paper since it does not require to choose a particular set of instrumental variables (as e.g. in Harvey, 1991 or Dumas and Solnik, 1995) or to take a stand on the appropriate time window to run rolling window regressions (as e.g. in Brusa et al., 2014) in order to assess the nature of time variation in the global risk factor exposures.

Allowing for time variation in exposures to risk factors and at the same time using a flexible method to approximate the time variation in exposure to global risk factors takes recent evidence of non-linearities in the relation between asset returns and returns on risk factors into account. For example, Lettau et al. (2014) find that downside risk, i.e. sensitivity to the US stock market return when it is low (negative), is priced in returns on diversified portfolios of different asset classes. By contrast, upside risk, i.e. sensitivity to the US stock market return when it is high (positive) is not priced in the cross-section of asset portfolio returns. Papers dealing with currency returns also underscore the importance of taking non-linear dynamics of exchange rate return exposures to systematic currency risk factors into account (e.g. Christiansen et al., 2011). Grisse and Nitschka (2015) build on this insight and use the Müller and Petalas (2010) algorithm[3] to assess time variation in the safe haven characteristic of Swiss franc returns in variants of recently proposed asset pricing models for currency returns (Lustig et al., 2011; Verdelhan, 2015). They find strong evidence of time variation in exposures to global currency risk factors.

3 Data and descriptive statistics

The sample covers the period from February 1993 to June 2015. The data frequency is monthly. The dependent variables in this study are returns on benchmark ten-year government bond indexes of Switzerland (CH), Japan (JPN), Germany (GER), Australia (AUS), Canada (CND) and the United Kingdom (UK). The indexes are compiled and provided by Datastream and take coupon payments into account (total return indexes). They are denominated in local currency. To obtain excess returns, I subtract a one-month

[3]Other studies that use this algorithm include Goldberg and Klein (2011) and Goldberg and Grisse (2013).

local money market rate from the respective ten-year government bond return. The data on one-month money market rates is from the BIS Monetary and Economics database.

Panel A of table (1) presents the mean excess returns on the bond indexes under study along with their sample t-statistic, i.e. the mean excess returns divided by the standard error of the excess returns over the sample period. According to the t-statistics all government bond excess returns were at least two standard errors away from zero over the sample period. The average excess returns vary between three and four percent per annum. Hence, the cross-sectional variation is small compared with so called emerging markets (Borri and Verdelhan, 2011). Panel B of table (1) gives the pairwise correlations of the dependent variables. Though on average positive, the correlation coefficients between the excess returns on the six different economies' bond indexes display less than perfect common movement. The correlation coefficients vary between 0.3 and 0.8. Taken together, these observations explain why the focus of this paper is on the time variation in these developed economies' bond returns. There is not much cross-sectional dispersion to explain, but there seem to be differences in the time series dynamics.

[about here table 1]

The explanatory variables for each country's bond excess return follow from the use of a global (bond market) CAPM. I use the Citigroup world bond market index (total return index; incorporating bonds of all maturities) denominated in the respective local currency in excess of the local short-term money market rate as proxy of the world bond market return as in equation (1). This paper uses the respective world index denominated in US dollar to obtain the version of the global CAPM presented in equation (2), i.e. the global government bond return in US dollar in excess of the local currency short rate and the average dollar exchange rate return. The average dollar exchange rate return is obtained by subtracting the global bond return in US dollar from the global bond return in local currency. A positive exchange rate return corresponds to an appreciation of the US dollar against the foreign currency. The source of these data is Datastream. Table 2 gives details about the global bond index returns. Panel A of table 2 provides a decomposition of the mean excess returns on the global bond indexes in local currencies into their US dollar denominated bond return and the dollar exchange rate return components. The general pattern is clear. With the exception of Switzerland, the exchange rate return contributes little to the mean excess returns of the local currency denominated global bond index returns. The US dollar global bond returns vary only across countries because I subtract the respective local money market rate.

However, as the variance decomposition in panel B of table 2 shows, the exchange rate returns contribute strongly to the variability of the global bond returns. Panel B of table 2 presents the results from the following decomposition

$$\begin{aligned} var(r_t^{global,lc} - r_t^{f,i}) &= var(r_t^{global,\$} - r_t^{f,i}) + var(\Delta s_t^i) \\ &\quad +2cov((r_t^{global,\$} - r_t^{f,i}), \Delta s_t^i) \end{aligned} \tag{5}$$

and division by $var(r_t^{global,lc} - r_t^{f,i})$ so that the sum of the three components adds to one. In all cases, exchange rate variability is the main driver of the global return volatility. Moreover, the covariances between the exchange rate returns and the US dollar global bond return components are negative indicating that positive global bond market returns expressed in US dollar are associated with depreciating US dollar exchange rates over the sample period.

[about here table 2]

In addition, I use the CBOE option-implied volatility index of the S&P 500 (VIX) to assess if time variation in the sensitivities of the government bond returns to the risk factors described above are related to VIX levels. Here I interpret the VIX as a proxy of the 'global financial cycle' documented in Rey (2013). The source of the monthly VIX series is the CBOE website. Finally, based on insights by Rey (2013) and Miranda-Agrippino and Rey (2015), I assess if the monetary policy stance of the US helps to explain the time variation in exposures to the global bond market risk factors. As a proxy of the US monetary policy stance I use the US shadow policy rate of Wu and Xia (2015). Before the introduction of bond purchasing programs, i.e. quantitative easing (QE), by the FED, the federal funds rate provided an adequate description of the US monetary policy stance (Bernanke and Blinder, 1992). The concept of shadow rates aims at translating the effect of QE into a policy rate equivalent (Lombardi and Zhu, 2013; Wu and Xia, 2015). The shadow rate by Wu and Xia (2015) can be obtained from the website of the FED Atlanta.

4 Empirical results

This section presents the main empirical results. It starts with graphical and regression-based evidence to show that allowing for time variation in the sensitivity of the bond excess returns under study to the global risk factors significantly improves the fit of the global CAPM. Section 4.2 highlights that US monetary policy, as approximated by the US shadow policy rate, is not only contemporaneously linked to time-varying global risk factor exposures but also predicts (in the sense of Granger causality) these exposures. This evidence is far weaker for VIX.

4.1 Model performances

In this paper, four variants of a global bond market CAPM are confronted with six different government bond excess returns denominated in the respective local currency. The distinction between a global CAPM formulation expressing dependent and explanatory variables in the same currency and a global CAPM that expresses the bond return in US dollar (as a numeraire) and average US dollar exchange rate returns is one dimension along which the model variants can be distinguished. The second dimension concerns the question if the sensitivities to the global CAPM risk factors are constant or varying over time.

The following six graphs (one for each of the developed markets under study) give a visual impression of the descriptive power of the global bond market CAPM variants. The upper panels depict the actual bond excess return and the two excess returns implied by the two CAPM variants with constant sensitivities to risk factors, i.e. $\hat{r}_t^{i,1} = a^i + \beta^i(r_t^{global,lc} - r_t^{f,i})$ for the model variant that assumes the same currency denomination of the dependent and the explanatory variables (green line) and $\hat{r}_t^{i,2} = a^i + \gamma^i(r_t^{global,\$} - r_t^{f,i}) + \delta^i(\Delta s_t^i)$ for the model variant that distinguishes between bond market and exchange rate returns (red line).

The lower panels of figures (1) to (6) give the corresponding implied returns (along with the actual return) when the model additionally allows for time variation in the sensitivity to the risk factors, i.e. $\hat{r}_t^{i,3} = a^i + \beta_t^i(r_t^{global,lc} - r_t^{f,i})$ and $\hat{r}_t^{i,4} = a^i + \gamma_t^i(r_t^{global,\$} - r_t^{f,i}) + \delta_t^i(\Delta s_t^i)$ respectively. The colour code from the upper panel applies to the lower panels as well.

For all of the bond excess returns under study, the model variants with constant sensitivities to risk factors (models 1 and 2) describe relatively little of the time variation in bond excess returns. The actual bond excess returns are more volatile than the corresponding excess returns implied by the global CAPM versions with constant sensitivities to the global bond market risk factors. This result is most pronounced for Switzerland and Japan but more generally true. In addition, the extreme returns during crisis periods, such as the global financial crisis around 2008, constitute a challenge for the global CAPM variants with constant sensitivities.

The picture is different for the global CAPM allowing for time variation in the sensitivity to the risk factors. To produce the graphs, I use the time series of regression coefficients calculated with the Müller and Petalas (2010) algorithm described in section 2. Allowing for time variation in the sensitivities to the risk factors seems to be important. It is particularly helpful to describe the government bond excess returns of the six economies during crisis periods, such as the Asian/Russian crisis 1997/1998, the global financial crisis from 2007 to 2009 and the sovereign debt crisis in the euro area from 2010 to 2012.

[about here figure 1]

[about here figure 2]

[about here figure 3]

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[about here figure 5]

[about here figure 6]

To complement the graphical analysis, I run regressions of the actual government bond excess returns on the fitted values from the four model variants. Table 3 gives an overview of the adjusted R^2 from these regressions in order to roughly quantify by how much the descriptive power of the global CAPM improves when distinguishing between bond and foreign exchange returns and by how much time variation in the sensitivities to these returns improves the model fit. These regressions take the following form:

$$r_t^{i,lc} - r_t^{f,i} = \mu + \zeta^i \hat{r}_t^{i,X} + e_t^i \qquad (6)$$

with $X = 1, 2, 3$ or 4, i.e. the returns implied by the four global CAPM variants introduced above.

[about here table 3]

As table 3 shows, the R^2 statistics from the regressions (6) are highest for the CAPM variant that separates the global bond return into its bond and exchange rate return components and additionally allows for time variation in the sensitivities to the two return components. The R^2 statistics then range between 40% and 70% compared with 4% to 30% in the case of the global bond market CAPM with constant risk factor sensitivities. These results hence corroborate the impression left by the graphical representation of the actual bond excess returns and their counterparts implied by the four global CAPM variants. Allowing for time variation in the exposures of local bond excess returns to the bond market and exchange rate component of global benchmark portfolio return is vital to describe the time variation in the local government bond excess returns.

Why does the distinction between global bond and exchange rate returns help to describe time variation in the individual countries' bond excess returns? If we express the countries' bond excess returns and the global bond market return in the same currency, then we assume that exchange rate risks are perfectly hedged and, from a global investor's perspective, play no role in determining the risk-return trade-off of the investment in the local bond market. However, evidence from globally active US mutual funds suggests that foreign exchange risk is only incompletely hedged (Hau and Rey, 2006).

Furthermore, the better performance of model 2 compared with model 1, is in line with cross-sectional evidence showing that exchange rate risk, in the form of exposure to exchange rate returns, is priced in equity returns (Dumas and Solnik, 1995; De Santis and Gerard, 1998; Harvey et al., 2002; Brusa et al., 2014). The evidence presented in the figures (1) to (6) and panel A of table 3 suggest that explicitly accounting for foreign exchange rate risk better describes time variation in government bond excess returns than a global bond market CAPM that assumes perfect insurance against foreign exchange rate risk as well.

Why does allowing for time variation in the sensitivities (the quantities) of global, systematic bond market and foreign exchange rate risk improve the descriptive power of the global CAPM even further? This evidence reflects that conditional versions of global or international capital asset pricing models that allow for foreign exchange rate risk outperform their unconditional counterparts (Harvey, 1991; Dumas and Solnik, 1995). By conditioning on instrumental variables these models capture time variation in sensitivities to risk factors. Brusa et al. (2014) also stress that time-variation to global stock and currency risk factors is important to understand the cross-sectional dispersion in international equity returns. The evidence presented in this paper shows that time variation in exposure to global risk factors is also important in describing the variation of government bond excess returns over time.

Moreover, the time-varying sensitivities of the bond excess returns under study do not depend on the choice of instrumental variables or the use of rolling window regressions. The algorithm of Müller and Petalas (2010) does not impose any functional form on parameter paths and is thus a flexible way to assess time variation in the exposures to the global risk factors. Of course, two qualifications have to be mentioned. First, this paper is only focused on simple measures of global, systematic risk on bond markets. I ignore regional or country-specific risk factors which would surely further improve the explanatory power for the government bond returns. For example, Barr and Priestley (2004) examine the predictability of bond excess returns (also in developed markets) and find that local risk is a non-negligible driver of expected bond returns. Similarly, a vast number of studies highlight the importance of regional and country-specific risks as determinants of risk premia on equity markets (Bekaert and Harvey, 1995, 2000; Bekaert et al., 2007; Bekaert et al., 2011; Dahlquist and Hasseltoft, 2013). Second, the Müller and Petalas (2010) algorithm uses the information from the full sample to evaluate potential time variation in the relation between the government bond excess returns and the measures of global systematic risk. This information is not ex ante available for investors.

4.2 What drives time variation in the quantity of global bond market risk?

How do the sensitivities to the global risk factors vary over time? And what are the drivers of their time variation? Figure (7) provides the graphical answer to the first question. The upper panel of figure (7) gives the time series of exposures to the average exchange rate return (δ_t^i) while the lower panel presents the exposures to the global bond market return expressed in US dollars (γ_t^i) . There is some variation in these exposures over time, most notably in the recent years dominated by the global financial crisis and the euro area crisis. Furthermore, there are pronounced cross-sectional differences in the time series patterns. For example, the sensitivities of the Japanese government bond excess returns increased quite strongly around 1998 which coincides with the Asian crisis. All of the other countries' global bond market exposures fell or moved little in this period. Another example is Switzerland. At the end of the sample period, there are massive declines in the sensitivities of Swiss government bond returns to the global bond market risk factors. The global risk factor exposures fell around January 2015 when the Swiss National Bank (SNB) removed the minimum exchange rate against the euro and at the same time lowered the rate on its sight deposit accounts (above an exemption threshold) from -0.25% to -0.75%.

[about here figure 7]

These two examples highlight that regional (Asian crisis) and country-specific (SNB monetary policy decision) shocks drive variation in exposures to global bond market risk factors. This leads to the question if other, global developments, might explain the time variation in the sensitivities of local bond returns to global risk factors as well. One potential, global source of time variation is the presence of a global financial cycle, i.e. common movement in asset prices, capital flows and banks' leverage, documented by Rey (2013). VAR analysis in Rey (2013) shows that monetary policy in a key country, such as the US, is the main driver of this global financial cycle. Against this background, the remainder of this section assesses if variables correlated with the global financial cycle and/or summary measures of US monetary policy are drivers of the time variation in the local government bonds' sensitivities to the global bond market risk factors. This assessment serves as complement to Miranda-Aggripino and Rey (2015) who show that one global factor, related to the global financial cycle, can explain a considerable amount of cross-sectional differences in returns on different asset classes. Furthermore, Driessen et al. (2003) show that one factor, interpretable as world interest rate level factor, explains almost 50% of the variation in bond returns of the major economies.

Here, I assess the contemporaneous relation as well as the lead-lag relation of time variation in the quantities of global risk (δ_t^i or γ_t^i), a variable correlated with the global financial cycle, VIX, and a summary measure of US monetary policy. We know since Bernanke and Blinder (1992) that the federal funds rate is a summary measure of the US monetary policy stance. However, since QE gained more and more importance as policy tool since the global financial crisis, a measure of the monetary policy stance has to take the effects of quantitative monetary policy measures into account. One way of achieving this end is the calculation of so called shadow policy rates (Lombardi and Zhu, 2013; Wu and Xia, 2015). Shadow rates translate QE into an equivalent policy rate value. Since the end of 2009, the shadow rates of Wu and Xia (2015) and Lombardi and Zhu (2013) are in negative territory stressing the expansionary nature of QE. By contrast, the actual FED funds rate stays close to zero and in positive territory for the same period. Against this background, I use the Wu and Xia (2015) shadow policy rate ($shadow$)

as summary measure of US monetary policy.[4]

The contemporaneous relation between global risk exposures and the measures of the global financial cycle as well as the US monetary policy stance is reflected in the contemporaneous pairwise correlation coefficients presented in table 4. The table displays the correlation coefficients along with p-values (in parenthesis) from bootstrapping the correlation coefficients 1000 times. A couple of observations stand out. First, there is no significant contemporaneous correlation between VIX and *shadow*. This observation suggests that the significant correlation coefficients of the exposures to the global risk factors with these variables reflect different contemporaneous risks. VIX is a summary measure of risk aversion and uncertainty (see e.g. Bekaert et al., 2013). The shadow policy rate is a summary measure of US monetary policy. Contemporaneously, there is no significant link between the two variables over the sample period. Second, the signs of the correlations with VIX and *shadow* differ across countries. For Switzerland and Japan, the government bond excess returns' exposures to the global bond return and average exchange rate return are high when the shadow rate is high and VIX is low. For the other countries the opposite holds true.

The contemporaneous negative link between global bond risk factor exposures and VIX is in line with the view that Switzerland and Japan are so called safe havens, i.e. assets of these economies provide insurance against global risk on average and particularly so in times of stress (Grisse and

[4] The shadow rate of Lombardi and Zhu (2013) is not available for the recent years of the sample period. However, the results for a restricted sample period are not sensitive to the choice of a particular shadow rate. These results are not reported but available upon request.

Nitschka, 2015). If VIX is high, i.e. risk aversion and/or uncertainty are high, these bonds provide insurance because they are less exposed to global, non-diversifiable risk than other assets of different countries.

The contemporaneous positive correlation of Swiss and Japanese global risk exposures with the US monetary policy stance is more difficult to explain. Applying the stock/bond excess return decomposition of Campbell and Ammer (1993), Nitschka (2014) shows that excess returns on Swiss government bonds are predominatly driven by inflation news. Since bonds are nominal assets, surprisingly high inflation lowers bond prices and hence leads to low expected returns. Bonds tend to become more risky in times of high inflation. If we assume that a high shadow rate coincides with a time of high (global) inflation[5], then bonds that are predominantly driven by inflation news become more risky and hence the exposure to global bond market risks as a proxy of the bond's riskiness should be high. This reasoning seems to apply to Switzerland and Japan.

The negative correlations for the other countries' bond returns with the US shadow policy rate might reflect that these bond excess returns are more sensitive to news about expected risk premia that vary over the business cycle. If high shadow rates do not only coincide with a time of high inflation but also an economic boom, then currently expected asset returns are low which is reflected in relatively low exposures to measures of systematic risk. This reasoning is based on the observation that expected returns on stock markets are countercyclical. They are relatively high in recessions and relatively low in expansions (e.g. Lustig and Verdelhan, 2012).

[5]A high shadow policy rate is a sign of restrictive monetary policy.

[about here table 4]

Moreover, Agrippino-Miranda and Rey (2015) show that US monetary policy influences the future path of global asset prices. They find that the global component of asset prices declines in response to a contractionary US monetary policy shock, e.g. a policy rate hike. Against this background, I assess if time variation in the global bond risk factor exposures is not only contemporaneously related to VIX and *shadow* but if the exposures are also predictable by these variables. This assessment is motivated by Viceira (2012) who shows that known predictors of US bond excess returns also forecast time variation in the quantity of systematic bond market risk, i.e. the exposures to risk factors. As the time series of global risk factor sensitvities under study has been obtained from the application of an algorithm that uses information from the full sample period, I focus on the assessment of in-sample predictability.

Since most of the time variation in δ_t^i and γ_t^i is slowly moving as shown in figure (7), there is strong positive autocorrelation in the exposures. To account for this fact, I use a vector autoregressive framework (VAR) in order to assess if past values of VIX and *shadow* forecast (Granger cause) the exposures δ_t^i and γ_t^i despite their strong, positive autocorrelations. The VARs take the following form

$$z_t^i = \mu + \Gamma(L) z_{t-l}^i + \varepsilon_t^i \tag{7}$$

with the z_t^i including either δ_t^i or γ_t^i as first variable and as second and third variable VIX_t and $shadow_t$.

The VAR results for a lag length of three months (suggested by standard information criteria) are presented in table 5. This table gives the sign of the sum of the VAR coefficients (positive or negative) along with the p-value of the Granger causality test if past values of *shadow* or VIX forecast the risk factor exposures.[6] The R^2 statistics (not reported in the tables) reach values around 0.95 because of the strong autocorrelation in the risk factor exposures. The null hypothesis of the Granger causality test is that past values of the respective variable do not forecast (in-sample) the global risk factor exposures in the presence of past values of the other variables.

The key finding of the Granger causality test results presented in table 5 is the predictive power of the shadow rate for quantities of global, systematic bond market risk. This finding is less pronounced for the exchange rate return component of the global bond market return under study than for the bond market return expressed in US dollar. However, the main results are qualitatively similar. Interestingly, VIX hardly forecasts the global risk factor exposures. The stance of US monetary policy seems to be more important in this respect. The signs of the VAR coefficients are the same as the contemporaneous correlation coefficients. High past values of the shadow rate, a signal of contractionary monetary policy in the US, are associated with lower sensitivities to global risk for most of the countries under study. This finding is in line with the Bayesian VAR results on the link between US monetary policy shocks and global asset prices documented in Miranda-Agrippino and Rey (2015). US monetary policy seems to influence how much global risk

[6]The other two equations in the VAR system show that the shadow rate as well as VIX are only predictable by their own lags.

developed markets' government bonds load up and hence their returns and prices. The results are weakest for Switzerland and Japan where we basically find no predictive power of VIX_t and $shadow_t$ for future global risk exposures. A possible explanation for this finding has already been given in the description of the time series of risk factor sensitivities depicted in figure (7). These two countries were prone to rather regional or country-specific shocks that obviously had an impact on the sensitvities of these countries' government bond returns to global risk factors.

Taken together, the Granger causality tests show that the US monetary policy stance predicts (in-sample) future quantities of global risk that government bonds of most of the countries under study load up. This finding highlights that US monetary policy is not only important for US dollar denominated assets. It is also an important driver of returns on assets such as government bonds of so called developed markets as well. These assets are typically denominated in local currency and hence should be subject to influences of the respective currency area's own monetary policy stance. The VIX, as proxy of the global financial cycle, exhibits virtually no predictive power in this context.

[about here table 5]

5 Conclusions

Motivated by recent discussions about safe assets and their role in the global financial system, this paper has aimed at describing time variation in excess returns on local currency denominated government bond indexes of six developed markets. This paper has assessed how much of the time variation in the government bond returns under study can be described in a simple, global CAPM for bond returns. This assessment revealed that between 40% to 70% of the time variation was related to global bond market and exchange rate risk. Time-varying exposures to global systematic risk are important to understand the variation of government bond excess returns over time.

Based on these insights, this paper has shown that time variation in the sensitivities to global risk factors is linked to the monetary policy stance of the global financial system's central country: the US. A summary measure of the US monetary policy stance is not only contemporaneously related to risk factor exposures. It also predicts how much global risk the government bond excess returns load up. Apart from the direct influence of monetary policy on the term structure of interest rates (and hence bond prices), measures of the monetary policy stance also signal future exposure to systematic risk.

The main results of this paper show that the monetary policy stance of one, single but central economy is a driver of the time variation in global risk factor exposures and hence returns on international government bonds. This finding would be natural for assets denominated in US dollars. However, this paper highlights that this reasoning applies even to local currency denominated bonds of developed economies. It thus underscores that spillovers from US monetary policy can have wide reaching effects.

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Tables

Table 1: Descriptive statistics of local currency denominated government bond excess returns
This table presents mean returns (in excess of a short-term local debt rate) and associated t-statistics (mean return divided by sample standard error) of excess returns on total return government bond indexes of Switzerland (CH), Japan (JPN), Germany (GER), Australia (AUS), Canada (CND) and the United Kingdom (UK) in panel A. Panel B gives the pairwise correlations of the bond excess returns. The sample period runs from February 1993 to June 2015.

Panel A: Mean excess returns (in % p.a.) and sample t-statistics						
	CH	JPN	GER	AUS	CND	UK
mean	4.08	3.47	4.02	3.05	4.22	3.27
t-statistic	4.19	3.49	3.46	2.03	3.27	2.47
Panel B: pairwise correlations						
	CH	JPN	GER	AUS	CND	UK
CH	1	0.28	0.72	0.56	0.52	0.60
JPN		1	0.30	0.34	0.34	0.24
GER			1	0.65	0.67	0.81
AUS				1	0.78	0.66
CND					1	0.72
UK						1

Table 2: Return and variance decompositions of local currency denominated global bond market returns

This table presents a decomposition of the returns on local currency denominated versions of a global bond market index in excess of the respective countries' short-term money market rate into the US dollar denominated bond market return and the corresponding exchange rate return. Panel A gives the results from the decomposition of mean returns. Panel B gives the results from the decomposition of the respective variances. The three parts of the variance decomposition should sum up to one but may not due to rounding.

Panel A: Decomposition of mean returns (in % p.a.)						
	CH	JPN	GER	AUS	CND	UK
$r_t^{global,lc} - r_t^{f,i}$	1.93	4.76	2.92	0.14	2.21	1.19
$r_t^{global,\$} - r_t^{f,i}$	3.92	4.72	2.52	0.28	2.09	1.33
Δs_t^i	-1.98	0.04	0.40	-0.14	0.12	-0.15
Panel B: Variance decomposition						
$\frac{var(r_t^{global,\$} - r_t^{f,i})}{var(r_t^{global,lc} - r_t^{f,i})}$	0.68	0.62	0.87	0.34	0.51	0.65
$\frac{var(\Delta s_t^i)}{var(r_t^{global,lc} - r_t^{f,i})}$	1.94	1.72	2.10	1.19	0.83	1.10
$\frac{2cov((r_t^{global,\$} - r_t^{f,i}), \Delta s_t^i)}{var(r_t^{global,lc} - r_t^{f,i})}$	-1.62	-1.34	-1.98	-0.52	-0.34	-0.76

Table 3: Model fit (R^2)

This table presents the R^2statistic from regressions of actual government bond excess returns on the values implied by the four model variants. Model 1 is the global CAPM without any exchange rate risk and constant sensitivities as presented in equation (1). Model 2 is the global CAPM with exchange rate risk but constant sensitivities (equation 2)). Model 3 is the global CAPM variant that assumes no exchange rate risk but time variation in the sensitivity to the global bond market return (equation (3)). Model 4 distinguishes between global bond market and foreign exchange rate returns and additionally allows for time variation in the respecitve sensitivities as highlighted in equation (4). Country acronyms are as explained in the notes to table 1. The sample period runs from February 1993 to June 2015.

Panel A: Models with constant risk factor exposures						
	CH	JPN	GER	AUS	CND	UK
Model 1	0.08	0.04	0.32	0.13	0.16	0.30
Model 2	0.20	0.15	0.53	0.25	0.25	0.35
Panel B: Models with time-varying exposures						
Model 3	0.35	0.35	0.49	0.34	0.34	0.43
Model 4	0.51	0.41	0.68	0.54	0.50	0.54

Table 4: Pairwise contemporaneous correlations between time series of risk factor exposures, VIX and the US shadow policy rate

This table presents pairwise contemporaneous correlation coefficients (and in parenthesis p-values for the null of no correlation from boostrapping the correlation coefficients) between exposures to the global bond market return denominated in US dollars and the VIX as well as the shadow US policy rate in panel A. Panel B of this table displays the corresponding information for the exposures to the exchange rate return. The sample period runs from Feburary 1993 to June 2015.

Panel A: Exposure to global bond return in US$ (γ_t^i)								
	shadow	VIX	CH	JPN	GER	AUS	CND	UK
shadow	1	−0.05	0.15	0.45	−0.25	−0.48	−0.59	−0.39
		(0.39)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
VIX		1	−0.19	−0.27	−0.07	0.45	0.30	−0.39
			(0.00)	(0.00)	(0.25)	(0.00)	(0.00)	(0.00)
CH			1	−0.15	0.04	−0.09	−0.02	0.21
				(0.02)	(0.52)	(0.16)	(0.75)	(0.00)
JPN				1	0.08	−0.57	−0.48	−0.02
					(0.17)	(0.00)	(0.00)	(0.77)
GER					1	0.11	0.23	0.53
						(0.07)	(0.00)	(0.00)
AUS						1	0.85	0.12
							(0.00)	(0.03)
CND							1	0.41
								(0.00)
UK								1

Panel B: Exposure to exchange rate return (δ_t^i)								
	shadow	VIX	CH	JPN	GER	AUS	CND	UK
shadow	1	−0.05	0.17	0.39	−0.21	−0.50	−0.69	−0.30
		(0.39)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
VIX		1	−0.12	−0.04	−0.25	0.31	0.19	−0.44
			(0.04)	(0.47)	(0.00)	(0.00)	(0.00)	(0.00)
CH			1	−0.09	−0.30	−0.26	−0.50	−0.45
				(0.16)	(0.00)	(0.00)	(0.00)	(0.00)
JPN				1	0.09	−0.42	−0.37	−0.04
					(0.15)	(0.00)	(0.00)	(0.52)
GER					1	0.29	0.21	0.35
						(0.00)	(0.00)	(0.00)
AUS						1	0.81	0.03
							(0.00)	(0.68)
CND							1	−0.40
								(0.00)
UK								1

Table 5: Granger causality tests (sign of sum of VAR coefficients and p-values): Time-varying risk factor exposures and drivers of the global financial cycle

This table gives the signs of the sum of VAR coefficients (" + " and " − ") for the lagged values of the respective variable in the VAR as well as p-values (in parenthesis) of Granger causality tests from a VAR that includes either the time series of exposures to the global bond market return (γ_t^i) or to the average exchange rate return (δ_t^i) along with the shadow US policy rate (*shadow*) and the VIX. The p-values indicate if past values of the respective three variables Granger cause the exposures γ_t^i or δ_t^i. The null hypothesis of the Granger causality test is that past values of the respective variable do not forecast (in-sample) the global risk factor exposures in the presence of past values of the other variables. The lag length in the VAR is three months as suggested by standard information criteria (AIC, SIC). The sample period runs from February 1993 to June 2015.

Panel A: Exposure to global bond return in US\$ (γ_t^i)			
	γ_{t-l}^i	$shadow_{t-l}$	VIX_{t-l}
CH	+ (0.00)	+ (0.09)	+ (0.87)
JPN	+ (0.00)	+ (0.26)	− (0.78)
GER	+ (0.00)	− (0.09)	− (0.22)
AUS	+ (0.00)	− (0.02)	− (0.35)
CND	+ (0.00)	− (0.00)	− (0.80)
UK	+ (0.00)	− (0.02)	− (0.02)
Panel B: Exposure to exchange rate return (δ_t^i)			
	δ_{t-l}^i	$shadow_{t-l}$	VIX_{t-l}
CH	+ (0.00)	+ (0.47)	+ (0.24)
JPN	+ (0.00)	+ (0.69)	+ (0.78)
GER	+ (0.00)	− (0.08)	− (0.47)
AUS	+ (0.00)	− (0.07)	+ (0.06)
CND	+ (0.00)	− (0.02)	+ (0.42)
UK	+ (0.00)	− (0.02)	− (0.13)

Figures

Figure 1: Actual vs. model implied bond excess returns: CH

Figure 2: Actual vs. model implied bond excess returns: JPN

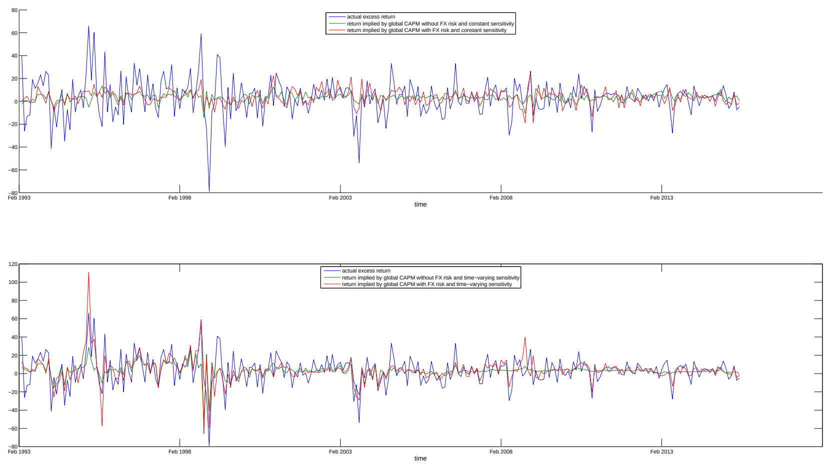

Figure 3: Actual vs. model implied bond excess returns: GER

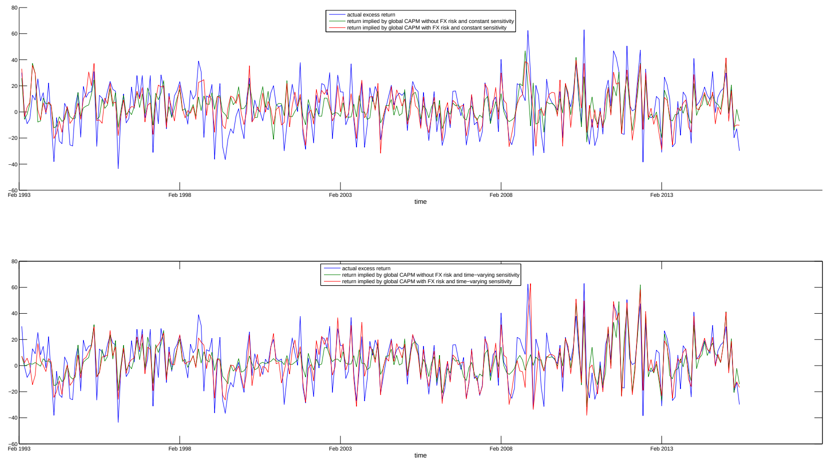

Figure 4: Actual vs. model implied bond excess returns: AUS

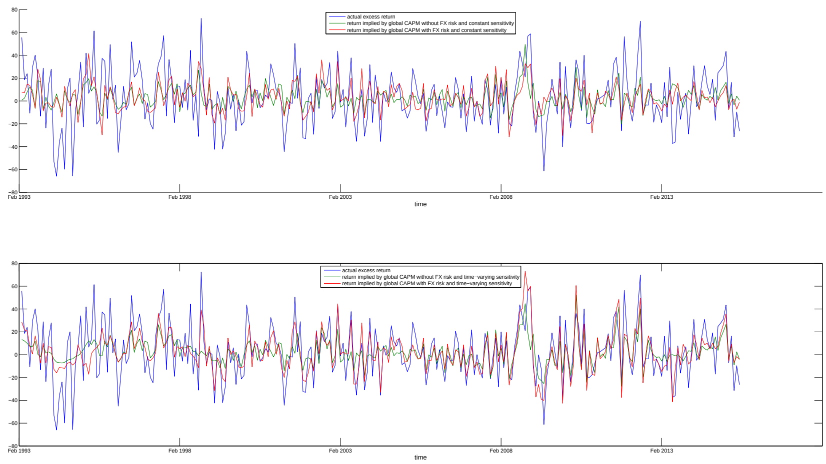

Figure 5: Actual vs. model implied bond excess returns: CND

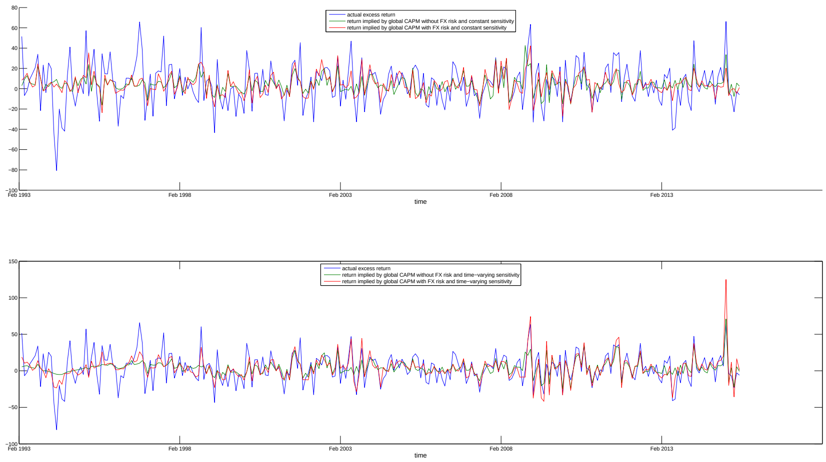

Figure 6: Actual vs. model implied bond excess returns: UK

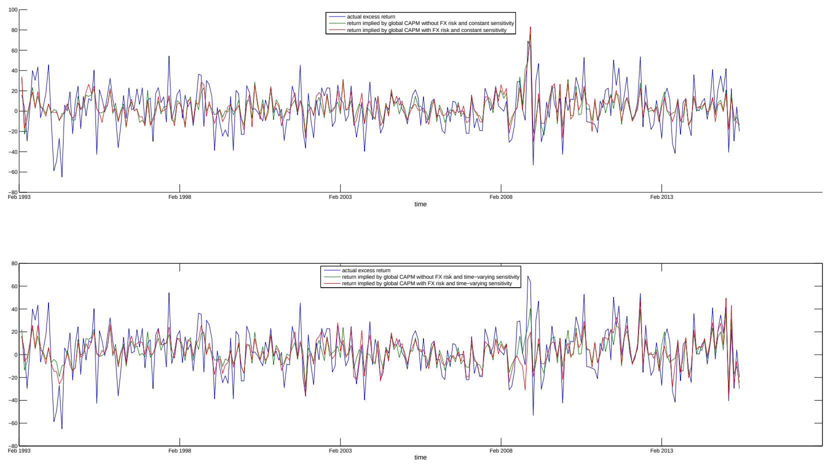

Figure 7: Time series of exposures to global bond return and average foreign exchange rate return