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Empirical Studies on Sovereign Fixed Income Markets

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Empirische studies over soevereine vastrentende markten

Thesis

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Preface

Sovereign fixed income markets already started to draw my attention at the age of 10 when my father Wim Duyvesteyn bought his first 30-year Dutch government bond. I was looking on a daily basis at the Dutch teletekst pages for bond prices and yields trying to monitor the investment return of my dad. When I noticed that my own savings rate was declining, my mother Jeanette van Leeuwen explained to me that the level of the interest rate and the year-on-year inflation are related. Already at an early age my parents took my interest in financial markets seriously. I was able to structurally follow the important developments in the macro-economic news and key market indicators watching the Dutch “10-uur journaal” on daily basis. My interest for option markets and volatility were also aroused in this period when my father started to harvest the volatility risk premium using equity options. Together with my dad I experienced the risk of such an investment strategy live in 1998 during the Russian and LTCM defaults.

Another element in my youth was a constant flow of activities related to creativity and out-of-the-box thinking and acting. I think playing fantasy roleplaying games with my brothers Arnoud and Korneel and my sister Angeli stimulated me to become more creative and to be prepared for the unexpected. I had my first experience with computers and programming with my best primary school friend Paul van der Knaap writing code on the commodore 64 before being able to play a game. My first view of the beautiful city of Rotterdam was with my godfather Cor and godmother Els Kuijvenhoven in the Euromast tower.

At the Sint Stanislas College in Delft my interest for economics did not diminish. In addition I developed not only an interest for beta oriented subjects like mathematics and physics but also for languages like German and old Greek. I also enjoyed the subjects economics 1 and 2 sitting next to my friends Stijn Verslype and Vincent van der Valk respectively, not only because of the interesting material but also because of the interesting teachers Kees van Niekerk and Aad Duifhuis.

After high school my mother Jeanette van Leeuwen spent a lot of time with me to select a university and a follow-up study. I was in doubt between a more technical study in Delft and a more economic related study in Rotterdam. I found out that I could combine both in econometrics at the Erasmus University. While travelling to university I became friends with Martijn van der Voort, Robin Bul and Robert Al, all coming from the same region near The Hague. In the weekends we often met at the Plein in The Hague. We started to work together in the many project groups during the study and produced several good research reports.

Specifically two teachers during my study, Philip Hans Franses and Dick van Dijk, were able to transmit their enthusiasm for econometrics to me. Nico van der Sar got me highly interested in investing and the challenge to profit from inefficiencies in the markets. I even tried to harvest the value premium myself by buying relatively cheap stocks. Unfortunately it was difficult to attain a desirable diversification in my personal portfolio because of its relatively small size. Nico van der Sar also made me enthusiastic about reading and understanding academic articles and it was the first time that I heard the Portuguese language during his telephone calls with his Brazilian wife. I also had the honor to work on Nico's computer next to the famous professor Winfried Hallerbach that later was to become my colleague. Finally, it was Olaf Penninga who got me interested in Robeco while presenting the company at the university.

In 1999 I decided to apply for an internship at Robeco supervised by Philip Hans Franses from the university. My master thesis was based on a study called country allocation emerging equity markets supervised at Robeco by Jouke Hottinga and Ronald Wuijster. The model based on my research is still used at Robeco and known as the Carma model. After my internship and graduation I decided in 2000 to apply for a job at the research department of Peter Ferket. Working in a team on applied financial research appealed to me more than working alone on a PhD project. I also decided to broaden my financial knowledge with the CFA study material. If the first years I was able to learn a lot from experienced professionals like David Blitz, but I also had time left for other activities like the Robeco zomerconcerten and Rotterdam film festival with amongst others my colleague Daniel Haesen.

With the help of Jouke Hottinga and Olaf Penninga I learned a lot about the fixed income markets. One of my responsibilities was to monitor, evaluate and enhance the multi factor model Robeco was and is still using to predict interest rate changes. The model is used directly in the large investment fund Lux-o-rente managed by Maurice Meijers, Kommer van Trigt and later also by Olaf Penninga. One of my innovations has been the addition of a seasonal factor in July 2002. Chapter 4 of this dissertation provides a deeper understanding of the seasonal pattern in bond returns on which the factor is based. Super quant intern Ana-Maria Morarescu[1] provided excellent research assistance in this project.

In 2003 I travelled to Brazil with my friend Robin Bul and met my wife Jaqueline Vitor Duyvesteyn. After learning the Portuguese language and travelling a lot to Brazil and back my wife decided to move to the Netherlands in 2005 and we married in 2006. The strong connection with the country further stimulated my interest for emerging market countries and also for travelling.

In 2007 the super quant intern Robert Berry[2], a PhD from Princeton university, joined Robeco. Under the supervision of Gerben de Zwart and myself Robert investigated the volatility risk premium in the swaption market. This internship initiated my decision to start writing papers with the ultimate goal to bind these together in a PhD dissertation. This was a new ambition after passing the final CFA exam and learning the Portuguese language. The valuable insights from the internship of Martin Scholtus[3] in 2008 also helped me to better understand the swaption market technicals and to improve the quality of the paper. I want to thank Gerben for his continuous effort to cooperate on the paper and to finally bring it to its current status. I am also grateful to the family of Gerben for the hospitality in Rijnsburg during the numerous weekends that we have devoted to the study. The paper co-authored with Gerben de Zwart led to a publication in the Journal of Banking and Finance in 2015 and to Chapter 6 of this dissertation.

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[1] http://www.robeco.com/en/careers/super-quant/super-quants-generation-2014.jsp
[2] http://www.robeco.com/en/careers/super-quant/super-quants-generation-2007.jsp
[3] http://www.robeco.com/en/careers/super-quant/super-quants-generation-2008.jsp

When Gerben de Zwart left Robeco I continued doing research and writing papers in cooperation with my new colleague Martin Martens. Martin had a lot more experience with writing academic articles because of his former career at the Erasmus university. In 2010 with the help of super quant intern Erwin Hazeveld[4] Martin and I applied the famous Merton model on countries. This research project ultimately led to Chapter 5 of my dissertation.

In 2011 I investigated whether the interest rate prediction multi-factor model of Robeco could also be applied on emerging markets. The results confirmed the evidence for developed markets and led to a new paper with Martin Martens that was published in the Journal of Fixed Income in 2014. Chapter 2 of my dissertation is based on this publication. At Robeco the research also led to the launch of a new product end of 2012 called emerging Lux-o-rente, managed by Maurice Meijers and as of recently by Paul Murray-John, Paul van der Worp and myself. The cover photo of this dissertation is related to the so called quant duration product line of Robeco that also uses a wave photo in the marketing material[5]. The wave also relates to the dynamic nature of the sovereign fixed income market and the various curves that can be identified.

With my colleague Rikkert Scholten I developed a country sustainability ranking at Robeco in cooperation with RobecoSAM. In 2015 this ranking became the basis of a new government bond index of S&P[6]. Patrick Verwijmeren, Martin Martens and I analysed the predictive power of one of the components of the ranking, political risk, in 2013. The results were promising and we wrote a paper on it which is serving as Chapter 3 of my dissertation.

In 2015 I was able to base my dissertation on the five aforementioned empirical studies on sovereign fixed income markets. I am very grateful for the time spent by my promotor Patrick Verwijmeren, co-promotor Martin Martens and inner doctoral committee members Mathijs van Dijk, Dick van Dijk and Onno Steenbeek to provide me with useful feedback to further improve the quality of my dissertation.

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[4] http://www.robeco.com/en/careers/super-quant/super-quants-generation-2010.jsp
[5] http://www.robeco.com/en/professionals/strategies-products/quant-fixed-income/index.jsp
[6] http://www.sustainability-indices.com/index-family-overview/esg-indices/index.jsp

Dear family, friends and colleagues, you have helped and stimulated me in various ways to bring my dissertation to completion. I want to thank all of you and I will never forget your support. I want to thank a few persons in name since it is not possible to mention all of you. First of all I want to thank my wife Jaqueline Vitor Duyvesteyn for the love, support, understanding and help to keep up the discipline to work on my papers. Without you I would have never been able to finish the dissertation. Second, I want to thank my parents Wim Duyvesteyn and Jeanette Duyvesteyn - van Leeuwen for the love and support I always could count on. Third, I want to thank Martin Martens and Gerben de Zwart for the continuous energy and drive to finish the five papers. Fourth, I want to thank Eliane Haseth for keeping track of all the necessary paperwork and deadlines accompanying the publication of a PhD dissertation. Finally I want to thank Patrick Verwijmeren for taking the responsibility of being my co-promotor and the many stimulating meetings at the university with useful feedback.

After finishing and defending my PhD dissertation my newest challenge is taking care of my son Arthur and my daughter Valentina, both just born on July 3rd 2015. I want to thank my mother-in-law Marlene Vitor Ribeiro for helping Jaqueline and me in taking care of the children in the first months. That way Marlene has helped me to be able to allocate enough time and energy to finish the final work on this dissertation. I also want to thank my fresh brother in law Andreas for bringing Marlene to us from Germany and for his unlimited care and positivism. Finally I want to thank my brothers in law Leandro and Jackson to help me improve my Portuguese language skill and to check the Portuguese abstract (resumo) of my dissertation.

1. Introduction

The sovereign fixed income market is very large and therefore empirical research to better understand it is important. Doeswijk, Lam and Swinkels (2014) show that the relative size of the market varied between 20% and 40% from 1959 to 2012 within a multi-asset market portfolio. The size of the market stood at USD 33 trillion or 36% at the end of 2012. This dissertation contains five contributions to the academic literature on the sovereign fixed income market. The common feature of these empirical studies is the price efficiency of the market. The five studies cover a wide range of fixed income markets including developed and emerging bond markets, nominal bonds and inflation-linked bonds, and cash instruments and derivatives.

The large sovereign fixed income market is important for many institutional and individual market participants. Governments finance their fiscal budget in this market, central banks need the market to implement a monetary policy, pension funds and insurance companies have to calculate the present value of their liabilities and asset managers and investors want to achieve positive returns using the fixed income market. New developments in this market and new research findings call for new research. The new local currency government bond market of emerging countries has grown to a large size about USD 1.5 trillion in 2015. Important question is whether default risk or interest rate risk is the most important driver of this new market? If interest rate risk is more important the bond returns may be predicted with the same factors that can predict developed market bond returns. Comparing the new local currency bond market to the older U.S. dollar denominated bond market, can we also apply the adapted Merton model on emerging markets and use its output to predict returns?
New research shows that the level of political risk is an important risk factor for the sovereign fixed income market. Do bond returns also react to the changes in political risk? We also observe a new and pronounced seasonal pattern in bond returns that has not been covered by the academic literature yet, can we explain this pattern?

The swaption derivative market is not well understood yet by certain large investors.[7] Nevertheless, the swaption market has become the largest non-cleared interest rate derivative market with a notional size of USD 30 trillion.[8] Although swaption market models are different from equity option models, can we also find evidence of the volatility and jump risk premiums in swaption markets? And how do these premiums interact?

This dissertation can be linked to two strands of the academic literature. Chapters 2-5 are related to predicting the bond risk premium (BRP) and Chapter 6 is related to the volatility risk premium (VRP) in bond markets.

In the first of these strands of literature, the BRP is explained by the term, default, and liquidity premiums. Fama and French (1993) show that the default premium and the term premium are both priced for stocks, government bonds and corporate bonds. In addition, Longstaff (2004) and Montfort and Renne (2013) show that a liquidity factor is also priced in developed government bond markets. For liquid governments bonds with no or low default risk the BRP is similar to the term premium.

The expectations hypothesis for bond markets proposed by Lutz (1940) assumes a term premium of zero. The rationale behind the hypothesis is that government bonds with different maturities all have the same return as a short term cash investment. However, government bonds show an annual excess return of 0.9% over cash based on an updated international dataset from Dimson, Marsch and Staunton (2002) for the period 1900-2013. This result is not consistent with the expectations hypothesis. MacAuley (1938) was already familiar with this empirical finding[9]. Alternative hypotheses to the expectations hypothesis are the liquidity hypothesis by Hicks (1946), the segmentation hypothesis by Culbertson (1957) and the preferred habitat hypothesis by Modigliani and Sutch (1966). The liquidity hypothesis assumes relatively higher forward rates to compensate for the higher risk of longer holding periods. The segmentation hypothesis assumes that individual investors tend to focus only on government bonds with particular maturities. The preferred habitat hypothesis is similar to

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[7] http://fd.nl/economie-politiek/799364/bestuurders-pensioenfondsen-blunderen-met-complexe-derivaten
[8] ISDA, Apr 2014, Size and Uses of the Non-Cleared Derivatives Market
[9] Macaulay (1938, p. 33): "The forecasting of short term interest rates by long term interest rates is, in general, so bad that the student may well begin to wonder whether, in fact, there really is any attempt to forecast."

the segmentation hypothesis but improves by combining it with other theories. All three alternative hypotheses allow for a positive term premium and a positive BRP.

Fama (1984a, 1984b) has shown that the size of the BRP varies over time. The obvious research question is whether the size of the BRP can be predicted. Dyl and Joehnk (1981) published the first paper on using the term spread to predict bond excess returns. Fama and Bliss (1987) show that a forward rate can also be used to predict bond excess returns and Fama (2006) confirms the 1987 finding and explains the predictive power with a mean reversion of interest rates to a longer term trend. Cochrane and Piazzesi (2005) further extend this idea by combining the predictive power of multiple forward rates. Ilmanen (1995; 1997) includes equity momentum, term spread and bond momentum as predictors of government bond excess returns. Ludvigson and Ng (2009) find that the joint information in a large database of macro-economic data can predict bond returns. Finally, Kamstra, Kramer and Levi (2015) document a seasonal pattern in U.S. Treasury returns that coincides with the number of reported cases of Seasonal Affective Disorder (SAD). The disorder is related to the amount of day light varying over the year in the northern hemisphere. Bond returns are better in the fall when investors get depressed and sell equities for bonds and worse in spring when equity and bond positions are reversed.

Chapter 2 in this dissertation, "Emerging government bond market timing", contributes to the literature by investigating the predictability of the BRP for emerging government bond markets. In recent years many emerging market countries have issued government bonds in their own local currency. Contrary to the older emerging government bonds issued in U.S. dollars this new market behaves itself more like developed market government bonds with a larger exposure to the term and liquidity premiums than to the default risk premium. Ilmanen (1997) shows that developed markets can be predicted with the bond momentum, equity momentum and term spread factors. Chapter 2 confirms that these three factors can also predict the emerging local currency bond markets. Hence, also in this respect these emerging bond markets behave in a similar way to the developed markets. The same three factors cannot predict emerging government bonds issued in U.S. dollars, however. The study also confirms that the three factors could be used to predict developed markets in the 15 years following the Ilmanen (1997) study. This shows that the emerging government bond market does not fully incorporate the information that triggered recent bond and equity returns, and that the steepness of the curve contains information about future bond returns.

Chapter 3, “Political risk and expected government bond returns”, focuses on the default risk premium within the older emerging government bond market issued in U.S. dollars and the newer EMU bond market issued in euros. In the recent euro crisis country spreads between European countries with the same currency (i.e. the euro) and a single central bank reappeared. These spreads almost disappeared when the euro was introduced in 1999, but returned in 2009 and almost led to the demise of the euro. Political risk is an important driver of sovereign default risk. A recent study by Bekaert et al. (2014) shows that the level of political risk can explain a third of the spread between emerging market dollar bonds and U.S. Treasuries. Chapter 3 of this dissertation shows that changes in political risk can predict government bond returns. Countries with decreasing political risk achieve higher future risk-adjusted returns than countries with increasing political risk. The result is consistent for both the developed EMU bond market and the emerging dollar debt market. Hence, the bond market does not efficiently incorporate changes in political risk.

In Chapter 4, “Inflation and seasonality in bond returns”, a new seasonal pattern in international developed government bond returns is documented. Bond returns are 3.8 percentage points higher in the second half of the calendar year than in the first half of the calendar year. We contribute to the literature by explaining this new seasonal pattern in international government bond returns with an opposite seasonal pattern in the not seasonally adjusted U.S. inflation rate. The seasonal pattern in inflation is mainly driven by the underlying fuel components. More demand for heating oil and gasoline in the first half of the year is a likely determinant for the seasonal pattern in inflation. The fuel components can also explain why the seasonal pattern of U.S. bond returns was not significant between 1952 and 1979. In the same period, U.S. inflation did not demonstrate a significant seasonal pattern either. The absence of a free-floating oil price in that period probably explains the absence of the seasonal pattern in the two fuel components.

Chapter 5, “Forecasting sovereign default risk with Merton’s model”, focuses on predicting the default risk premium using the famous Merton model (1974). This model estimates the default risk of a company based on its corporate bonds and debt, equity, and equity volatility as inputs. Gray, Merton and Bodie (2007) have adapted the model to use it for government bonds. This new model estimates the sovereign default risk of a country using both the emerging market government bonds denominated in the local currency and U.S. dollars and the currency volatility as inputs. The local currency debt acts like the equity of a country and the U.S. dollar debt acts like the real debt. Gapen et al. (2008) show the model spread level is highly correlated with the market spread level. Chapter 5 contributes to the literature by showing that *changes* in the model spread are correlated with *changes* in CDS market spreads and can even predict these spread changes after correcting for structural risk premiums over time. Hence, information from the emerging government bond market can be used to predict sovereign CDS market returns, which indicates that the CDS market is not fully price-efficient.

The second strand of literature is on the bond market related volatility risk premium. Similar to the demand of a positive BRP, investors require a negative VRP. Buyers of volatility related instruments like options have a limited downside when the option premium decreases to zero and an unlimited upside when volatility increases. Volatility tends to behave asymmetrical with small declines and large and sudden increases. Therefore, sellers of volatility demand a risk premium. Duarte, Longstaff and Yu (2007) find evidence of a volatility risk premium in the fixed income market. Cremers, Halling, and Weinbaum (2014) find that the VRP in the equity market can be attributed to two types of risk: volatility risk and jump risk. Volatility risk is related to the market price of equity volatility, also called vega; jump risk is related to large changes in the price of the equity, also called gamma.

Chapter 6 of this dissertation, “Riding the swaption curve”, complements the literature on the VRP. The volatility risk and jump risk premiums in fixed income markets are consistent with the results of Cremers, Halling and Weinbaum (2014) for the equity volatility market. Contrary to equity volatility, the model to hedge fixed income volatility related instruments like swaptions is not evident. We contribute to the literature showing that the results are robust for the Black (1976), Vasicek (1977) and SABR (Rebonato et al. 2009) models all assuming a different behavior of interest rates. We also compare our work with riding strategies on the yield curve instead of the swaption volatility curve, like the study of Dyl and

Joehnk (1981). Yield curve riding strategies buy longer-dated bonds and sell these before maturity. Riding the swaption curve and riding the yield curve have in common that their respective forward curves are not realized over time.

2. Emerging government bond market timing

Based on Duyvesteyn and Martens (2014), published in the Journal of Fixed Income. We are grateful for the useful comments from Olaf Penninga, Kommer van Trigt and seminar participants at Robeco.

2.1 Introduction

Emerging Market (EM) countries can issue debt in U.S. Dollars or in their local currency. EM dollar debt will be affected by the U.S. yield curve and the country specific credit spread. For a U.S. investor EM local currency debt returns will depend on the local yield curve dynamics and the exchange rate. In this study we show that well-known predictors for developed government bond excess returns – bond momentum, equity momentum and term spread – can also predict the excess returns of government bond debt of emerging countries issued in local currency[10]. The results for the bond markets of emerging countries Brazil, Mexico, South-Africa, Poland, Malaysia and South-Korea are interesting for a number of reasons. First, EM local currency debt is a rapidly growing asset class, with the amount outstanding more than 1.5 trillion U.S. Dollars[11]. Second, many emerging countries currently have debt-to-GDP ratios that are lower and thus better than most developed countries. Third, the average correlation between the total returns in dollars of the local currency debt of the six EM and U.S. treasuries is just one percent offering diversification benefits of adding EM to a portfolio of U.S. treasuries. In contrast, the same correlation between EM Dollar debt and U.S. treasuries is 50 percent. With current yields much higher for local currency emerging bonds than for developed bonds, emerging local currency bonds are attractive to invest in. Finally, we show that active duration management can add value. The fact that equity momentum and term spread can predict EM bond returns suggests that these markets

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[10] Following Ilmanen (1995), all excess returns are in local currency terms. It is a proxy for the bond's currency-hedged returns for a foreign investor. This way the focus is on returns driven by yield pick-up and yield changes, not on the more volatile currency returns.

[11] Source: September 2012 local markets guide of JP Morgan. The U.S. $1.5 trillion relates to index-eligible local markets (GBI-EM Broad market capitalization). Total EM local currency debt accounts for over 80% or U.S. $7.9 trillion of the outstanding U.S. $9.6 trillion EM debt stock for sovereign and corporate and local currency instruments.

have matured because the underlying interest rates respond similarly to growth and inflation dynamics as they do in developed markets.

Dyl and Joehnk (1981) have published the first paper on using the term spread to predict bond excess returns. Ilmanen (1995; 1997) includes equity momentum and term spread as predictors of government bond excess returns. Ilmanen (1997), Yamada (1999), Luu and Yu (2012) and Moskowitz et al. (2012) provide evidence that bond momentum can predict the developed bond market returns of Australia, Canada, Germany, Japan, the U.K. and the U.S.. In this study we show that bond momentum, equity momentum and term spread can also predict the excess returns of government bond debt of emerging countries issued in local currency. As far as we know we are the first to investigate the predictive power of such factors for emerging debt. We also provide an update of the predictive power of equity momentum and term spread for developed bond markets.

The term spread or yield curve steepness is first used by Dyl and Joehnk (1981) as a predictor for bond excess returns. Subsequently, Fama and Bliss (1987), Campbell and Shiller (1991), and Ilmanen (1995; 1997) also use it to predict developed bond returns. Ilmanen uses the term spread as an overall proxy for the bond risk premium. The larger the term spread, the more attractive government bonds are. He also argues that the term spread is sometimes influenced by the market’s (unobservable) rate expectations, and hence it will be a noisy proxy for the bond risk premium. Therefore, it is better to combine the term spread with other predictor factors to get a more robust prediction for the future bond returns. In this study we combine the term spread with two other predictors of future bond returns: bond momentum and equity momentum.

Ilmanen (1995; 1997) shows that past equity returns also predict government bond returns. His explanation is that investors are more risk-averse (fearful) when their current wealth is low relative to their past wealth. Conversely, greater wealth near business cycle peaks makes investors less risk-averse (greedy). Recent stock market performance is seen as a proxy for the (unobservable) aggregate level of risk aversion. If recent stock market performance has been poor, current wealth is low(er), and investors are more risk-averse. They therefore prefer (government) bonds and drive up the prices of these bonds. Similarly positive stock returns are followed by negative bond returns.

Evidence that bond momentum can predict government bond returns is provided by Ilmanen (1997) for the U.S., Yamada (1999) for Japan, and Luu and Yu (2012) and Moskowitz et al. (2012) for Australia, Canada, Germany, Japan, the U.K. and the U.S.. An often cited explanation for the success of momentum strategies is that market participants under react to new information. Related to the under reaction are conservativeness and anchoring biases of investors. Momentum expects positive (negative) bond returns to be followed by more positive (negative) bond returns.

By testing the predictive ability of term spread, equity momentum and bond momentum for EM debt we also provide insight to what extent EM interest rates behave in a similar way to interest rates from developed markets. A prime example is equity momentum. Ilmanen (1995; 1997) uses a negative sign for equity momentum as a predictor for developed bond returns, due to the aforementioned relation between the stock market performance, current wealth, and the level of risk-averseness of investors. Keim and Stambaugh (1986), and Hong et al. (2012), however, use a positive sign for equity momentum as a predictor for U.S. credit market returns. Hence if we find that equity momentum with a negative sign can predict EM interest rates, we can conclude that EM interest rates behave in a similar way as interest rates from developed markets. The credit risk of EM countries has at best a minor impact on interest rate dynamics.

Miyajima et al. (2012) find that EM local currency government yields have behaved more like safe haven yields since 2008: Domestic factors like the monetary and fiscal policy have tended to dictate the dynamics of the yields and EM yields have dropped, rather than increased, in response to worsening global risk sentiment. We confirm this conclusion by showing that the returns of EM local currency debt related to yield pick-up and yield changes (not exchange rates) have a substantial average correlation of 31% with U.S. treasury returns, compared to just 6% with U.S. High Yield (HY) credits.

2.2 Methodology

We predict government bond excess returns with three factors: bond momentum, equity momentum and term spread[12].

The bond momentum and equity momentum factors are initially based on 1-month total returns (including coupons and dividends) in excess of the cash return based on 3-month LIBOR rates. Later on we also analyze 3-month bond and equity momentum to reduce transaction costs. For each country and each factor we compute each month whether the factor is positive or negative. For each factor and each country we then take either a long or a short position that will earn or pay the excess bond return for the coming month. Given a positive bond momentum or a positive term spread we take a long position; given a positive equity momentum we take a short position. We take short positions after negative excess bond returns or a negative term spread, and a long position after negative equity returns.

We use investment strategies to evaluate the predictive power of factors since we are interested in the economic significance of the predictive power of these factors. The alternative to strategies is to use predictive regressions (further split in in-sample and out-of-sample regressions), providing statistical evidence. See Thornton and Valente (2012) for an excellent discussion on the differences between these two methods. They show that the Cochrane and Piazzesi's (2005) forward rates factor, found to be successful in in-sample predictive regressions for excess bond returns does not have economic value in an investment strategy.

We aggregate the individual country strategy returns to get a portfolio view on the predictive power of bond momentum, equity momentum and term spread. We look at multi-factor

[12] The factors are all based on data from financial markets. Ilmanen (1997) mentions that financial market variables are better predictors of government bond returns than macro-economic fundamentals. He argues that market-based variables are forward-looking while macro-economic data describe past events. Ludvigson and Ng (2009) indicate that whereas existing theories imply that there should be a relation between rational variation in bond risk premia and macro-economic fundamentals, there is little empirical evidence of a link between the macro-economy and bond risk premia. Ludvigson and Ng provide evidence of such a link by using dynamic factors based on more than 100 macro-economic time-series.

strategy returns per country, combining the returns from the bond momentum, equity momentum and term spread strategies. Finally we put it altogether in a portfolio of countries and strategies. We do so separately for developed and emerging markets. All combinations are equal weighted assuming no superior predictive power for an individual country or factor.

2.3 Data

We focus on the same six developed markets as in Luu and Yu (2012) and Moskowitz et al. (2012): Australia, Canada, Germany, Japan, the U.K. and the U.S.. These are the most liquid developed bond markets. For EM we focus on Brazil, Mexico, South-Africa, Poland, Malaysia and South-Korea. Besides covering 6 time-zones and 4 continents, the swap markets needed for active duration management are well developed for all six countries[13]. The first five countries also have the maximum (capped) weight of 10 percent each in the JP Morgan GBI-EM diversified index which is often used by investors to track the local currency government debt market for EM. According to the World Bank classification South-Korea is considered to be a developed market, which led the major index providers JP Morgan and FTSE to include the country in their developed markets index universe for respectively bonds and equities. However, due to accessibility issues and in particular a lack of full currency convertibility two other major index providers Barclays and MSCI still consider South-Korea as emerging market for respectively bonds and equities. South-Korea currently has the most liquid bond futures market after Germany, the U.S., Japan and the U.K. according to Bloomberg volume data. Hence for all countries active duration management taking both long and short positions is feasible in practice.

For both developed and emerging markets we use monthly data starting in January 2001. Only data for South-Africa is available from 1999. In January 2001 data for Poland and South-Korea become available, marking the starting date of the analysis. By looking at the same period for developed and emerging it is easier to compare results. For developed we

[13] The 2010 triennial report of the Bank for International Settlements (BIS) shows that Brazil, Mexico, South-Africa, Poland, Malaysia and South-Korea all have a turnover in excess of one billion USD a day in OTC interest rate derivatives. See www.bis.org/publ/rpfxf10t.htm. Note that EM local currency debt bond returns expressed in dollars depend on both EM yield dynamics and exchange rate returns. By using swaps (or futures for South-Korea) we purely focus on exploiting the predictability in the yield dynamics.

will report some key results in Appendix 2.A with data starting in 1973. For each country the equity market return is measured by its MSCI total return index and the bond market return is measured by its JP Morgan total return index. Both indices are expressed in the local currency. 3-month LIBOR rates to calculate excess returns are obtained from Bloomberg. Data on U.S. HY credits are obtained from Barclays, including the returns in excess of maturity-matched U.S. treasuries.

The term spread is defined as the 10-year government bond yield minus the 3-month LIBOR rate for developed markets, whereas for emerging markets we use the index yield instead of the 10-year yield[14]. If the bond yield exceeds the LIBOR rate the strategy goes long in the bond market. If the bond yield is below the LIBOR rate the strategy takes a short position. Bond and equity momentum are defined as the total return of the local government bond and equity market indices in the preceding month in excess of the return on the 3-month LIBOR cash investment. These excess returns are comparable to the returns of futures contracts on equity and bond indices. Following Ilmanen (1995) all excess returns are in local currency terms. It is a proxy for the bond's currency-hedged returns for a foreign investor. This way the focus is on returns driven by yield pick-up and yield changes, not on the more volatile currency returns.

The investment strategies have a monthly rebalancing frequency and take either long or short positions in each government bond index in excess of the LIBOR rate. The sample characteristics of the buy-and-hold (always long) are provided in Table 2-1. Developed and emerging bond markets posted on average annual excess returns over LIBOR of respectively 2.5 and 2.6 percent per annum from January 2001 to December 2012, reflecting both coupons and capital gains due to predominantly declining interest rates.

[14] For Brazil, Malaysia and Mexico we need to use the bond index yield instead of the 10-year bond yield due to limited data availability and quality. For consistency we also use the bond index yield for the other 3 EM markets. Results using the 10-year bond yield for Malaysia, South Africa and South Korea are similar to using the bond index yields. When there is no LIBOR available a particular country we use the 3-month T-bill rate of that country.

Table 2-1: Developed and emerging markets buy-and-hold characteristics

Country	Excess return p.a.	Volatility p.a.	Sharpe ratio	First month
Panel A: Developed bond markets				
Australia	1.1%	4.0%	0.27	Jan 2001
Canada	3.4%	4.0%	0.86	Jan 2001
Germany	3.0%	4.1%	0.74	Jan 2001
Japan	1.6%	2.0%	0.79	Jan 2001
United Kingdom	2.5%	5.4%	0.46	Jan 2001
United States	3.3%	5.1%	0.65	Jan 2001
Portfolio developed	2.5%	3.5%	0.71	Jan 2001
Panel B: Emerging bond markets				
Brazil	2.0%	4.9%	0.41	May 2003
Poland	2.7%	3.9%	0.70	Jan 2001
Malaysia	0.9%	3.3%	0.26	Jan 2002
Mexico	3.4%	5.6%	0.61	Jan 2002
South Africa	2.8%	6.8%	0.41	Jan 2001
South Korea	2.5%	3.9%	0.65	Jan 2001
Portfolio emerging	2.6%	3.3%	0.78	Jan 2001

Note: Sample statistics for the excess bond returns over local LIBOR rates. The ‘Portfolio developed’ and ‘Portfolio emerging’ are equal weighting the excess returns of the 6 developed and 6 emerging countries, respectively. The first month depends on the data availability of a total return bond index and a 3-month LIBOR rate. For Brazil we start in May 2003 despite there being index returns from January 2002 to December 2002, because no index eligible government bonds were outstanding from January 2003 to April 2003. The final month is December 2012.

Table 2-2 shows the correlations between the various markets. Canadian and U.S. excess bond returns have the highest correlation at 86 percent whereas Brazilian and Japanese excess bond returns have the lowest correlation at just 4 percent. The average correlation across developed markets is 63 percent and across emerging markets it is 35 percent. Between developed and emerging markets the average correlation is just 26 percent, illustrating the diversification benefits of adding emerging local currency debt to a portfolio already containing developed government bonds. The average correlation across developed markets since June 1973 (not reported here) is on average 35 percent. Compared to the 63 percent correlation from 2001 onwards this shows that correlations across developed markets have increased over time.

Table 2-2: Developed and emerging markets buy-and-hold excess return correlations

	Australia	Canada	Germany	Japan	United Kingdom	United States	Brazil	Poland	Malaysia	Mexico	South Africa	South Korea
Australia	100%											
Canada	69%	100%										
Germany	69%	73%	100%									
Japan	36%	44%	36%	100%								
U.K.	67%	80%	79%	41%	100%							
U.S.	71%	86%	75%	38%	76%	100%						
Brazil	15%	27%	13%	4%	28%	26%	100%					
Poland	27%	29%	33%	6%	33%	32%	40%	100%				
Malaysia	30%	25%	31%	18%	24%	30%	32%	40%	100%			
Mexico	20%	34%	18%	15%	23%	31%	48%	36%	27%	100%		
South Africa	23%	26%	27%	21%	31%	28%	44%	38%	34%	40%	100%	
South Korea	39%	35%	35%	21%	36%	37%	27%	21%	30%	36%	33%	100%

Note: Correlations between monthly bond returns in excess of local LIBOR rates. The starting month is January 2001, except for Brazil, Malaysia and Mexico which start n May 2003, January 2002 and January 2002, respectively. The final month is December 2012.

2.4 Predicting excess bond returns

Table 2-3 shows for each of the 12 countries the predictive ability of 1-month bond momentum, 1-month equity momentum, and the term spread. Of all information ratios (IRs), 33 are positive and only 3 are negative. Summarizing the results for developed countries in the equally weighted (EW) portfolio, bond momentum has an IR of 0.34, equity momentum an IR of 0.68, and the term spread has an IR of 0.56. Hence all three factors are successful in predicting developed government bond excess returns from 2001 to 2012. Table 2-9 in Appendix 2.A shows that this is also the case for the much longer 1973-2012 period, with IRs of 0.78 for bond momentum, 0.34 for equity momentum, and 0.59 for term spread. Hence equity momentum and term spread have continued to work after Ilmanen's (1995) publication. Luu and Yu (2012) and Moskowitz et al. (2012) already showed this for bond momentum.

Table 2-3: Performance of bond momentum, equity momentum and term spread

	Bond momentum			**Equity momentum**			**Term spread**		
Country	Excess return	Vol	IR	Excess return	Vol	IR	Excess return	Vol	IR
Panel A: Developed bond markets									
Australia	0.4%	4.0%	0.11	2.8%	3.9%	0.71	-0.7%	4.0%	-0.17
Canada	2.0%	4.1%	0.48	1.8%	4.1%	0.45	2.6%	4.1%	0.65
Germany	1.6%	4.1%	0.39	1.5%	4.1%	0.36	1.8%	4.1%	0.43
Japan	0.3%	2.1%	0.17	0.8%	2.0%	0.38	1.6%	2.0%	0.79
United Kingdom	0.4%	5.5%	0.07	4.0%	5.3%	0.75	1.6%	5.4%	0.29
United States	1.0%	5.2%	0.19	1.7%	5.2%	0.32	2.5%	5.1%	0.49
Portfolio developed	**1.0%**	**2.8%**	**0.34**	**2.1%**	**3.1%**	**0.68**	**1.6%**	**2.8%**	**0.56**
Panel B: Emerging bond markets									
Brazil	2.0%	4.9%	0.41	1.5%	4.9%	0.30	1.8%	5.0%	0.36
Poland	1.3%	4.0%	0.32	1.3%	4.0%	0.33	-2.4%	3.9%	-0.60
Malaysia	1.3%	3.2%	0.40	0.7%	3.3%	0.22	1.3%	3.2%	0.41
Mexico	-1.4%	5.7%	-0.25	1.6%	5.7%	0.28	2.5%	5.7%	0.44
South Africa	1.2%	6.8%	0.18	2.8%	6.8%	0.41	2.9%	6.8%	0.42
South Korea	0.9%	3.9%	0.22	2.3%	3.9%	0.59	3.0%	3.8%	0.78
Portfolio emerging	**1.3%**	**2.4%**	**0.52**	**1.7%**	**2.6%**	**0.64**	**1.4%**	**2.4%**	**0.56**

Note: Annualized gross performance of active duration management for excess government bond returns based on 1-month bond excess return momentum, 1-month equity excess return momentum, and term spread. Term spread is defined as the 10-year government bond yield minus the 3-month LIBOR rate for developed markets and as the JP Morgan bond index yield minus the 3-month LIBOR rate for emerging markets. Bond momentum and equity momentum are defined as the total return of the local government bond and equity market indices in the preceding month in excess of the return on a 3-month LIBOR cash investment. The signs of bond momentum and term spread are positive, and the sign of equity is negative. The sample period is January 2001 to December 2012, with the exceptions that Brazil starts in May 2003 and Malaysia and Mexico start in January 2002.

For emerging countries the EW portfolio results show bond momentum has an IR of 0.52, equity momentum an IR of 0.64, and term spread has an IR of 0.56. Hence the factors found to successfully predict developed bond market excess returns, also can predict EM local currency bond excess returns. The results for the portfolios also show the risk reduction due to diversification when combining the results for six countries.

Ilmanen (1995) suggests that term spread is an overall proxy for the bond risk premium, but that it is also a noisy proxy. Therefore, it is better to combine the term spread with other predictor factors to get a more robust prediction for future bond returns. Table 2-4 shows the results when averaging the returns for the three single-factor strategies of each country. The multi-factor strategy has a positive IR for each of the 12 bond markets, ranging from 0.04 (Poland) to 0.87 (South-Korea). The portfolio results are even stronger. For developed markets the EW combination of the results for the 6 developed countries provides an IR of 0.79 (1.03 from 1973 to 2012, see Table 2-10 in Appendix 2.A), whereas for EM the IR is 1.07. These IRs are substantially higher than when only using term spread, achieved by reducing volatility. For developed markets and EM an investor can earn on average an extra return of respectively 1.5 and 1.4 percent per annum by following this multi-factor active duration strategy. The cumulative excess returns of the multi-factor strategy and that of each of the three single-factor strategies are shown in Figure 2-1 for developed markets and in Figure 2-2 for emerging markets. These graphs show that the strategies earn gradually over time, and hence are robust over time.

Table 2-4: Multi-factor strategy for developed and emerging market

	Multi-factor strategy				
Country	Excess return p.a.	Volatility	Information ratio	Sharpe ratio buy & hold	Sharpe ratio buy & hold + multi-factor strategy
Panel A: Developed bond markets					
Australia	0.8%	2.4%	0.36	0.27	0.40
Canada	2.2%	2.9%	0.73	0.86	0.89
Germany	1.6%	2.7%	0.61	0.74	0.82
Japan	0.9%	1.4%	0.66	0.79	0.82
United Kingdom	2.0%	3.3%	0.61	0.46	0.64
United States	1.7%	3.3%	0.53	0.65	0.68
Portfolio developed	**1.5%**	**2.0%**	**0.79**	**0.71**	**0.83**
Panel B: Emerging bond markets					
Brazil	1.8%	3.4%	0.52	0.41	0.55
Poland	0.1%	1.8%	0.04	0.70	0.59
Malaysia	1.3%	2.2%	0.57	0.26	0.46
Mexico	0.8%	3.1%	0.24	0.61	0.63
South Africa	2.3%	3.2%	0.72	0.41	0.65
South Korea	2.1%	2.4%	0.87	0.65	0.80
Portfolio emerging	**1.4%**	**1.3%**	**1.07**	**0.78**	**0.99**

Note: Performance statistics for the multi-factor strategy which is an equal weighted portfolio of the 1-month bond momentum, 1-month equity momentum, and term spread strategies. The portfolios developed and emerging are equal weighting the results of the 6 developed and 6 emerging countries, respectively. The final month of the sample period is December 2012. For the starting month for each country see Table 2-1.

Figure 2-1: Cumulative excess return factors and multi-factor strategy dev. markets

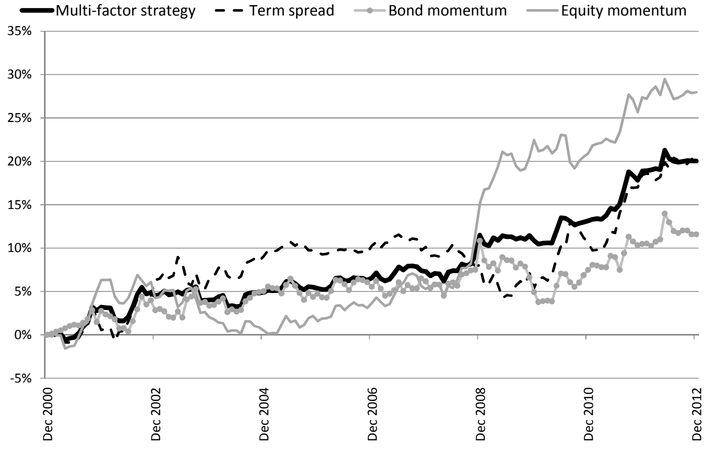
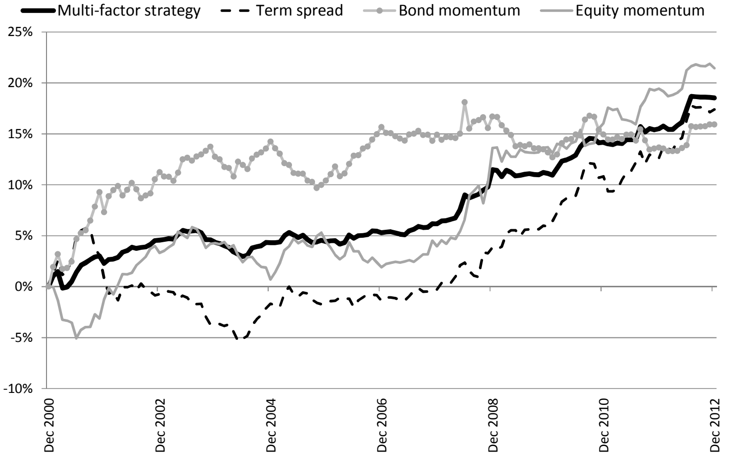


Figure 2-2: Cumulative excess return factors and multi-factor strategy emerging markets



Note: Cumulative gross performance of 1-month bond momentum, 1-month equity momentum, term spread, and the multi-factor strategy that equally weights the returns on the three single-factor strategies. Term spread is defined as the 10-year government bond yield minus the 3-month LIBOR rate for developed markets and as the JP Morgan bond index yield minus the 3-month LIBOR rate for emerging markets. Bond momentum and equity momentum are defined as the total return of the local government bond and equity market indices in the preceding month in excess of the return on a 3-month LIBOR cash investment. The signs of bond momentum and term spread are positive, and the sign of equity is negative. The sample period is January 2001 to December 2012.

The final two columns in Table 2-4 also show that combining the buy and hold portfolio with the multi-factor investment strategy as an overlay adds value. Besides the already mentioned 1.5 and 1.4 percent additional annual returns, the Sharpe ratios rise from 0.71 to 0.83 for developed bond markets (1973-2012: from 0.33 to 0.70), and from 0.78 to 0.99 for emerging bond markets. The buy-and-hold portfolio we have defined here is currency hedged. For investors who do not hedge the currency risk though, the Sharpe ratios rise from 0.74 to 0.89 for developed markets and from 0.77 to 0.87 for emerging markets.

2.5 Taking into account transaction costs

So far we ignored transaction costs and used a 1-month setting for both bond and equity momentum. Of course, such a fast setting will result in frequent trades. We analyze the impact of transaction costs on the results and add the slower 3-month setting resulting in lower turnover and lower costs. We asked brokers for transaction cost estimates for developed and emerging markets. Based on this information we use conservative estimates of transaction costs: For developed markets we use a one basis point bid-ask spread on the yield, which translates approximately to seven basis points at the bond index level assuming an index duration of seven years. For emerging bond markets we use a five basis point spread on the yield, leading to 22.5 basis points costs for the bond index assuming an index duration of 4.5 years. Hence, a switch from long to short or short to long costs 22.5 basis points.

The results in Table 2-5 show that term spread has the lowest turnover with 0.7 trades per market per year for developed markets. As a result the net IR of 0.54 is similar to the gross IR of 0.56 we reported in Table 2-3. One-month bond and equity momentum, however, have more than 10 trades per country per year. For developed bond markets the net IR for bond momentum at 0.06 is therefore substantially lower than the gross IR at 0.34. For emerging markets the net IR of bond momentum is negative due to the higher transaction costs for emerging markets: the gross IR of 0.52 becomes a net IR of -0.48. Also the net IR for 1-month equity momentum is negative at -0.38.

Table 2-5: Investment strategy and transaction costs

	Term spread	Bond 1-month	Bond 3-month	Equity 1- month	Equity 3-month	Strategy 1-month	Strategy 3-month
Panel A: Developed bond markets							
Gross excess return	1.6%	1.0%	1.2%	2.1%	1.8%	1.5%	1.5%
Gross IR	0.56	0.34	0.40	0.68	0.57	0.79	0.70
Turnover	0.7	11.1	5.6	10.2	5.2	6.2	3.5
Transaction costs	0.1%	0.8%	0.4%	0.7%	0.4%	0.4%	0.2%
Net excess return	1.5%	0.2%	0.8%	1.4%	1.4%	1.1%	1.3%
Net IR	0.54	0.06	0.27	0.45	0.45	0.57	0.58
Panel B: Emerging bond markets							
Gross excess return	1.4%	1.3%	1.6%	1.7%	2.7%	1.4%	1.9%
Gross IR	0.56	0.52	0.57	0.64	0.99	1.07	1.27
Turnover	1.4	10.7	5.2	11.7	5.5	5.3	3.3
Transaction costs	0.3%	2.4%	1.2%	2.6%	1.2%	1.2%	0.7%
Net excess return	1.0%	-1.1%	0.5%	-1.0%	1.5%	0.2%	1.2%
Net IR	0.43	-0.48	0.17	-0.38	0.54	0.18	0.78

Note: Performance and turnover statistics taking into account transaction costs. “Model 1-month” is equally weighting the returns from the term spread, 1-month bond and 1-month equity momentum strategies. “Model 3-month” replaces the 1-month momentum strategies by the 3-month momentum strategies. Turnover is expressed as the number of trades per country per year. Transaction costs for switching from a long (short) to a short (long) are assumed to be 7 basis points for developed markets and 22.5 basis points for emerging markets.

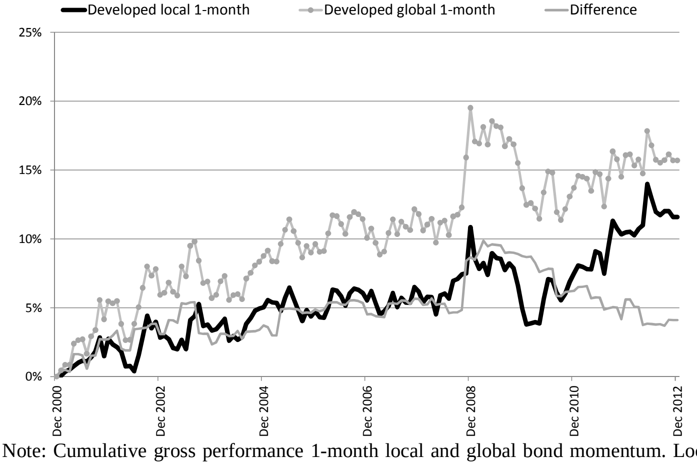
Turnover is about halved by switching from 1-month to 3-month momentum. For developed markets this increases the net IR for bond momentum. For emerging markets using the 3-month setting is a substantial improvement moving the net IRs into positive territory at 0.17 (bond momentum) and 0.54 (equity momentum). Whereas for developed markets the multi-factor strategy IR is similar when basing the multi-factor strategy on 1-month or 3-month bond and equity momentum, for emerging markets we clearly see an improvement. The net IR improves from 0.18 to 0.78, and transaction costs drop from 1.2 percent to 0.7 percent per annum.

2.6 Global or local bond momentum

Correlations between (developed) bond markets have risen over time. Ilmanen (1995) has already investigated the predictive power of global factors. A global factor has the same signal for each country. The motivation is that if bond markets move closely together the implicit country allocation from for example local bond momentum may not be helping performance. In fact Ilmanen and Sayood (2002) find that cross-sectional momentum does not work: If one country has an above average bond return, more often than not the other countries will catch up, rather than the higher return country continuing to have a higher return. Global bond momentum also avoids the potential noise of measuring the return momentum of a single country.

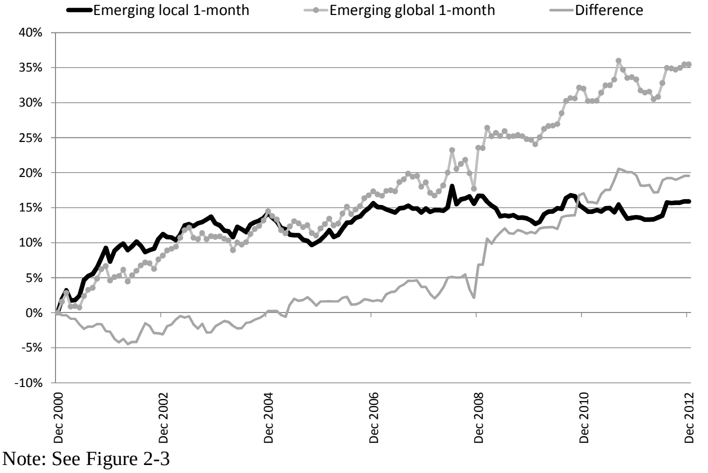
To test the impact of a higher correlation between bond markets over time, we compare 1-month local bond momentum with 1-month global bond momentum. For the latter we simply take the average 1-month excess return of all the six bond markets in the developed or emerging universe. Figure 2-3 shows that for developed global bond momentum has performed better. This result means that between countries there is more likely mean-reversion than momentum, confirming the conclusion of Ilmanen and Sayood (2002). Figure 2-4 shows a similar result for emerging markets. Hence also for EM between countries there is more likely mean-reversion between the bond returns from the different countries than momentum.

Figure 2-3: Global and local bond momentum in developed bond markets



Note: Cumulative gross performance 1-month local and global bond momentum. Local momentum takes each month for each country a long or a short position depending on whether the excess bond return in the previous month was positive or negative, respectively. Global bond momentum uses the previous month's average excess bond return of the six individual bond markets and takes a long or short position in all six markets depending on whether this average excess bond return is positive or negative, respectively.

Figure 2-4: Global and local bond momentum in emerging bond markets



Note: See Figure 2-3

2.7 EM local currency debt vis-à-vis EM USD debt

We show that well-known predictors for developed government bond markets also work for excess returns of EM local currency debt. This suggests that interest rates in emerging markets have similar drivers as those in developed markets. In this section we look in more detail at the contemporaneous return correlations between EM local currency debt on the one hand and U.S. treasuries and U.S. HY on the other hand. We also include EM hard currency (dollar) debt in this comparison. All six emerging markets that we analyze also have USD debt outstanding. We decompose the EM dollar debt total returns into U.S. treasuries returns and EM credit returns. We decompose the local currency debt total returns into local rates returns and exchange rate returns. Note that so far we have predicted the rates part of EM local currency returns and those of developed markets. Table 2-6 shows the correlations between the various components of EM local currency returns and EM dollar returns on the one hand, and U.S. treasuries returns and U.S. high yield credit returns (in excess of U.S. treasuries) on the other hand.

Table 2-6: Correlations EM government bond and credit returns

		Brazil	Poland	Malaysia	Mexico	South Africa	South Korea	Average
Panel A: correlation with U.S. treasuries								
Dollar debt	U.S. treas	100%	100%	100%	100%	100%	100%	100%
	Excess	-20%	-29%	-4%	-38%	-22%	-1%	-19%
	Total	7%	54%	66%	48%	41%	85%	50%
LC debt	Rates	26%	32%	30%	31%	28%	37%	31%
	FX	-18%	-7%	-5%	-20%	-7%	-2%	-10%
	Total	-13%	1%	11%	-2%	3%	8%	1%
Panel B: correlation with U.S. high yield excess return over treasuries								
Dollar debt	U.S. treas	-49%	-49%	-49%	-49%	-49%	-49%	-49%
	Excess	40%	60%	59%	80%	69%	16%	54%
	Total	38%	14%	12%	34%	33%	-32%	17%
LC debt	Rates	23%	6%	-15%	21%	5%	-5%	6%
	FX	52%	42%	47%	51%	45%	55%	49%
	Total	50%	36%	27%	48%	37%	42%	40%

Note: Total EM dollar debt returns ('Dollar debt') are decomposed in a part attributable to U.S. Ttreasury returns ('U.S. treas') and the return in excess of duration matched U.S. treasuries ('Excess'). EM local currency (LC) debt returns expressed in dollars are decomposed in a part attributable to local interest rates ('Rates') and exchange rate (FX) returns. This table shows the correlations of these return components with U.S. treasury returns (Panel A) and U.S. high yield excess returns over duration-matched treasures (Panel B).

Panel A of Table 2-6 focuses on the correlations with U.S. treasuries returns. For EM dollar debt by construction the U.S. treasuries component is 100% correlated with U.S. treasuries returns. The credit part is as expected negatively correlated with U.S. treasuries returns[15]. The total return correlation is 50%. For EM local currency debt the interest part of the returns has a correlation of 31% with U.S. treasuries returns[16], whereas the currency component has a negative correlation of -10%. The total return correlation is just 1%. Hence, from a diversification perspective a U.S. investor already owning U.S. treasuries is better off adding EM local currency debt to the portfolio than adding EM dollar debt.

Panel B focuses on the correlations with U.S. high yield credit returns in excess of duration-matched U.S. treasuries. As expected, the credit part ('Excess') of EM dollar debt has a correlation of 54% with the excess returns on U.S. high yield. Interestingly, the currency component of the EM local currency returns also has a high correlation of 49% with U.S. high yield. Hence both EM credit and currency returns have credit-like return characteristics.

[15] Gueye and Sy (2013) also find a negative relationship between U.S. interest rates and EM bond spreads.

[16] Miyajima et al. (2012) find that at least a quarter of the decline in EM bond yields can be attributed to lower U.S. Treasury yields.

Whereas total returns on EM dollar debt are more highly correlated with U.S. treasuries, the total returns on EM local currency debt are more highly correlated with U.S. high yield. This underscores the importance of separating the interest rate and currency part of EM local currency debt for the analyses in all previous sections.

These conclusions have consequences for the sign of equity momentum as predictor of bond returns. For the interest rate part of local currency debt we need to use the negative sign that is also used in Ilmanen (1995; 1997) for developed government bond returns. For excess returns of EM USD debt (the credit part of the dollar debt returns) we need to use a positive sign as is also used in Hong et al. (2012) for U.S. credits.

Table 2-7 shows the results of using equity momentum with a negative sign. For the interest rates component of EM local currency debt we see the IR of 0.64 already presented in Table 2-3. In contrast the currency part cannot be predicted by equity momentum. For EM USD debt we find as expected a negative IR (-0.32) for the excess returns because we should have used a positive sign for equity momentum given that dollar debt excess returns are highly correlated with U.S. high yield credits. Table 2-7 also shows the importance of separating the U.S. rates and credit components in dollar debt by looking at credit returns in excess of duration-matched U.S. Treasury returns. Not doing so gives a near-zero IR of -0.05.

Table 2-7: Equity momentum applied to EM debt returns

	Brazil	Poland	Malaysia	Mexico	South Africa	South Korea	Portfolio
LC debt Rates	0.30	0.33	0.22	0.28	0.41	0.59	0.64
LC debt FX	-0.49	0.06	-0.28	0.16	0.24	0.13	0.10
Dollar debt total	-0.08	0.08	-0.06	0.02	-0.09	-0.09	-0.05
Dollar debt excess	-0.10	-0.43	-0.28	-0.37	-0.13	-0.36	-0.32

Note: This table shows the IRs from predicting the various return components of EM local currency debt and EM dollar debt by 1-month equity momentum. Total EM dollar debt returns (‘Dollar debt’) are decomposed in a part attributable to U.S. treasury returns (‘U.S. treas’) and the return in excess of duration matched U.S. treasuries (‘Excess’). EM local currency (LC) debt returns expressed in dollars are decomposed in a part attributable to local interest rates (‘Rates’) and exchange rate (FX) returns.

2.8 Conclusion

We show that EM local currency debt excess returns can be predicted with bond momentum, equity momentum and term spread. Also after taking into account transaction costs it is possible to apply an active duration strategy on EM interest rate swaps. For the period 2001 to 2012 such an overlay strategy has a net IR of 0.78 and adds 1.2 percent per annum to the return on a buy-and-hold index. Hence well-known predictors of government bond returns of developed markets can also predict the yield dynamics of EM local currency debt.

The fact that predictors for developed bond markets can also predict EM local currency debt returns suggests that the rates component in EM local currency debt behaves like developed government bond yields. Indeed, we find that the correlation between EM local currency debt excess returns and U.S. treasury returns is 31 percent, whereas it is just 6 percent between EM local currency debt excess returns and U.S. High Yield returns in excess of maturity-matched U.S. treasuries.

Appendix 2.A: Longer history for developed government bond markets

The results for developed markets cover the 2001-2012 period to match the sample period for emerging debt. In this appendix we show several results for developed markets for the much longer 1973-2012 period. We extend the history before 1985 with data from Datastream (from Jan 1980 – Dec 1985) and a broker (from May 1973 - Dec 1979). For excess return calculations when LIBOR rates are not available we use 3-month Eurocurrency rates from Reuters and broker data.

Table 2-8: Developed markets buy-and-hold characteristics

Country	Excess return p.a.	Volatility	Sharpe ratio	First month
Australia	0.6%	5.8%	0.11	May 1974
Canada	1.9%	7.4%	0.26	May 1974
Germany	2.4%	4.6%	0.52	Jun 1973
Japan	2.2%	5.6%	0.40	Jun 1973
United Kingdom	1.2%	8.9%	0.13	Jun 1973
United States	1.3%	6.8%	0.18	Jun 1973
Portfolio developed	**1.5%**	**4.5%**	**0.33**	***Jun 1973***

Note: Sample statistics for the excess returns over local LIBOR rates. The 'Portfolio developed' is equal weighting the results of the 6 developed and 6 emerging countries, respectively. The first month depends on the data availability of a total return bond index and a 3-month rate. Corresponding table in the text: Table 2-1, panel A.

Table 2-9: Performance of bond momentum, equity momentum and term spread

	Bond momentum			**Equity momentum**			**Term spread**		
Country	Excess return	Vol	IR	Excess return	Vol	IR	Excess return	Vol	IR
Australia	2.0%	5.8%	0.34	1.3%	5.8%	0.22	0.9%	5.8%	0.15
Canada	3.4%	7.4%	0.47	2.6%	7.4%	0.35	1.8%	7.4%	0.24
Germany	4.0%	4.5%	0.88	0.5%	4.7%	0.10	2.9%	4.6%	0.62
Japan	2.5%	5.5%	0.44	1.4%	5.6%	0.25	2.7%	5.5%	0.49
United Kingdom	2.0%	8.9%	0.23	-0.6%	8.9%	-0.06	1.0%	8.9%	0.12
United States	2.6%	6.8%	0.38	2.5%	6.8%	0.37	3.2%	6.8%	0.47
Portfolio developed	**2.8%**	**3.6%**	**0.78**	**1.2%**	**3.6%**	**0.34**	**2.1%**	**3.6%**	**0.59**

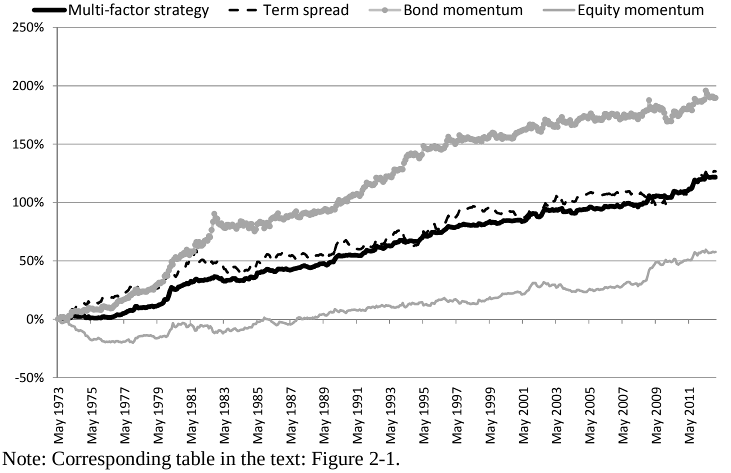
Note: Annualized gross performance of active duration management based on 1-month bond excess return momentum, 1-month equity excess return momentum, and term spread. Term spread is defined as the 10-year government bond yield minus the 3-month LIBOR rate. Bond momentum and equity momentum are defined as the total return of the local government bond and equity market indices in the preceding month in excess of the return on 3-month LIBOR cash investment. The signs of bond momentum and term spread are positive, and the sign of equity is negative. The final month of the sample period is December 2012. For the starting month for each country see Table 2-8. Corresponding table in the text: Table 2-3.

Table 2-10: Multi-factor strategy for developed markets

Country	Excess return p.a.	Volatility	Information ratio	Sharpe ratio buy & hold	Sharpe ratio buy & hold + strategy
Australia	1.4%	3.1%	0.44	0.11	0.32
Canada	2.6%	3.9%	0.67	0.26	0.54
Germany	2.4%	2.6%	0.93	0.52	0.88
Japan	2.2%	3.4%	0.65	0.41	0.57
United Kingdom	0.8%	4.7%	0.18	0.13	0.21
United States	2.8%	3.8%	0.73	0.18	0.52
Portfolio developed	**2.0%**	**2.0%**	**1.03**	**0.33**	**0.70**

Note: Performance statistics for the multi-factor strategy which is an equal weighted portfolio of the 1-month bond momentum, 1-month equity momentum, and term spread investment strategies. The portfolio is an equal weighting the results of the 6 developed countries. Corresponding table in the text: Table 2-4, Panel A.

Figure 2-5. Cumulative excess return investment strategy and factors developed markets



Note: Corresponding table in the text: Figure 2-1.

Table 2-11: Investment strategy and transaction costs

	Term spread	Bond 1-month	Bond 3-month	Equity 1- month	Equity 3-month	Strategy 1-month	Strategy 3-month
Gross excess return	2.1%	2.8%	1.9%	1.2%	1.5%	2.0%	1.8%
Gross IR	0.59	0.80	0.51	0.33	0.39	1.03	0.87
Turnover	1.2	10.3	5.3	11.4	6.0	5.3	3.4
Transaction costs	0.1%	0.7%	0.4%	0.8%	0.4%	0.4%	0.2%
Net excess return	2.0%	2.1%	1.6%	0.4%	1.0%	1.7%	1.6%
Net IR	0.57	0.59	0.41	0.11	0.28	0.84	0.76

Note: Performance and turnover statistics taking into account transaction costs. "Strategy 1-month" is equally weighting the returns from the term spread, 1-month bond and 1-month equity momentum strategies. "Strategy 3-month" replaces the 1-month momentum strategies by the 3-month momentum strategies. Turnover is expressed as the number of trades per country per year. Transaction costs for switching from a long (short) to a short (long) are assumed to be 7 basis points for developed markets. Corresponding table in the text: Table 2-5, panel A.

3. Political risk and expected government bond returns

Based on Duyvesteyn, Martens and Verwijmeren (2015). We are grateful for the useful comments from Roland Beck (discussant), Paul Beekhuizen, Geert Bekaert, John Coppock, Helene Samyschew (discussant) and participants at the 2015 European Sovereign Debt Crisis conference in Monaco organized by the Luxembourg School of Finance and the 2015 18th annual conference of the Swiss Society for Financial Market Research in Zurich.

3.1 Introduction

The importance of political risk in developed government bond markets has recently been highlighted. Examples are the euro crisis and the October 2013 debate between the Republicans and Democrats on the U.S. debt-ceiling. These recent political developments have had a large influence on bond prices. During the U.S. debt ceiling debate, U.S. bond markets were clearly pricing in an increased possibility of a U.S. default.[17] This sharp rise of short-term bond yields was reversed as soon as a resolution was found on 16 October, 2013. During the euro crisis, stock markets and European bond yields fluctuated heavily depending on estimates of whether Greece would leave the Eurozone and whether Italy and Spain needed a bailout by the other European countries. Changes in the Greek, Italian, and Spanish governments were needed to regain the trust from both investors and other European countries. As such, political risk seems to be very important for bond prices, even in developed markets.

In this paper we analyze the relationship between political risk and bond prices. Our main contribution is to show that *changes* in political risk ratings *predict* the bond risk premium. Bonds from countries whose political risk ratings have improved outperform those from countries whose political risk ratings have deteriorated. By using political risk rating changes one can avoid the largest losses in bad times when credit spreads increase and keep up with the market index in good times. In bad times these political risk changes are particularly important to be able to distinguish between more stable and riskier countries.

[17] Nippani and Smith (2014) provide a detailed analysis on this event and the reaction of the financial market.

We use political risk ratings from the Political Risk Services (PRS) group. PRS collects political information and converts this into risk points based on a subjective analysis of the available information.[18] The resulting political risk ratings are commercially but not publicly available. The ratings cover political risk in a broad sense, including government stability, socioeconomic conditions, investment profiles, internal and external conflicts, corruption, and law and order. The ratings are updated every month.

At the end of each month we select the four countries with the highest improvements in political risk ratings ('Best 4') and the four countries with the highest deteriorations ('Worst 4). We evaluate the portfolio returns in the subsequent month. We find that selecting the Best 4 leads to higher bond risk premiums, measured by realized bond returns, especially compared to the Worst 4. The return of this investment strategy based on political risk changes is called the change in political risk premium.

We investigate whether the political risk premium is subsumed by other well-known factors driving the bond markets. We control for the term premium and the default premium, which are found to be priced-in risk factors for corporate bond returns in Gebhardt, Hvidkjaer and Swaminathan (2005a). In addition we analyse factors related to momentum, liquidity, macro-economic developments and the credit rating. Longstaff (2004) and Renne and Montfoort (2013) find priced liquidity measures based on comparing the less liquid bonds from respectively U.S. and German government related agencies to liquid government bonds. The political risk premium cannot be explained by the risk factors. The unexplained alpha of a regression that takes into account the default, term and liquidity premium is 0.8% per annum for bonds issued by the euro countries in euros and 7.6% for emerging market bonds denominated in U.S. dollars.

The bond market does not seem to react to changes in political risk in a timely matter. A logical explanation is that political risk ratings are not public information, and that it is not straightforward to quantify political risk. Changes in political risk ratings also contain valuable information for credit agencies. Countries with improving or deteriorating political risk ratings on average also get a subsequent improvement or deterioration respectively in credit ratings.

[18] The PRS group was established in 1979, placing it among the first commercial providers of political and country risk forecasts. Several academic studies have made use of their data (see for example Bekaert, Harvey, Lundblad, and Siegel, 2014).

Our findings are an important contribution to the literature on the price discovery in government bond markets. The U.S. bond market reacts quickly to important macroeconomic announcements (Balduzzi, Elton and Green, 2001) and order flows (Brandt and Kavajecz, 2004). Nowak, Jobst and Tamirisa (2011) confirm that economic announcements are also important for the price discovery in emerging government bond markets and observe a slower absorption of information compared to developed government bond markets. We show for both the Eurozone and emerging countries that bond prices also react to changes in political risk ratings, but both bond markets are not fully efficient in terms of the speed with which they adjust to these changes in political risk.

We also contribute to the literature on predicting financial market returns using changes in political risk. Erb, Harvey and Viskanta (1996) investigate the predictive power of various risk measures, including those from PRS. They find predictive power of political risk changes for currency returns, but not for bond returns. Perhaps the results for bond returns were not significant because of the short sample (1985-1995 for developed markets and 1990-1995 for emerging markets) that was analyzed, with a limited number of bad times. Our paper does find significant predictive power for bond returns by using the much longer 1993–2014 time period that includes multiple good and bad times. As mentioned earlier our Best 4 portfolio outperforms the Worst 4 portfolio primarily in bad times. We also focus on bond returns with the same currency, eliminating any noise that currencies may have on the analysis. We are able to find strong evidence that changes in political risk are important for the price discovery in both developed and emerging government bond markets.

Related to our study is a strand of literature with the focus on the *level* of political risk and the relation with financial markets. We empirically confirm such a link by showing that poor political risk ratings are associated with poor credit ratings and high bond yields. Hence, unsurprisingly, countries which score poorly on political risk need to pay investors a higher bond risk premium. Erb, Harvey and Viskanta (1999) find a strong relation between emerging market bond spreads and the composite risk rating of PRS, of which 50% is based on political risk. Similar findings are reported by Butler, Fauver and Mortal (2009), who link state corruption to higher municipal bond yields, and Qi, Roth and Wald (2010), who show that greater political rights are associated with lower corporate bond yield spreads. A more recent study by Bekaert, Harvey, Lundblad and Siegel (2014) finds that political risk accounts for one third of the sovereign credit spread in emerging market government bonds issued in U.S. dollars, a very significant result underscoring the importance of political risk for bond yields.[19]

The remainder of this study is organized as follows. Section 3.2 describes the data, including political risk ratings, bond data and credit ratings. Section 3.3 presents the methodology. The main results are discussed in Section 3.4. Section 3.5 investigates the importance of the components that make up the total political risk ratings. Section 3.6 concludes.

3.2 Data

In this section we first describe the political risk ratings. We then present the bond data and provide sample statistics on political risk ratings, spread levels and credit ratings.

3.2.1 Political risk ratings

The political risk ratings used in this study are produced by the Political Risk Services (PRS) group in the International Country Risk Guide[20]. The political risk rating consists of 12 components, which are shown in Table 3-1. PRS collects political information and converts this into risk points for each individual risk component on the basis of a consistent evaluation process. The political risk ratings are made on the basis of a subjective analysis of the available information. The ratings are distributed monthly on a commercial basis to subscribers. We have a database of the real-time total ratings and the 12 components from December 1993 to April 2014.

To assess political risk, PRS makes the following classification: if the points awarded are less than 50% of the total, that component can be considered as very high risk. The 50%-60% range indicates high risk, 60%-70% moderate risk, 70%-80% low risk and 80%-100% very low risk. The same categorization applies to the total score.

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[19] There is more empirical work on the importance of political risk for equity markets. See for example Erb, Harvey and Viskanta (1996a), Bittlingmayer (1998), Santa-Clara and Valkanov (2003), Belo, Gala and Li (2013), Mei and Guo (2004), Boutchkova, Doshi, Durnev and Molchanov (2012) and Pastor and Veronesi (2012; 2013).

[20] An alternative data source would be the newspaper coverage of policy-related economic uncertainty, see Baker, Bloom and Davis (2013) and www.policyuncertainty.com. These data, however, only cover five countries of the 35 countries we analyze.

Table 3-1: Components of Political Risk Ratings

Component	Max points	Short description what each component assesses
A Government Stability	12	Ability to carry out declared program and stay in office
B Socioeconomic Conditions	12	Socioeconomic pressures that could constrain government action or fuel social dissatisfaction
C Investment Profile	12	Factors affecting the legislative risk of investments
D Internal Conflict	12	Political violence and its actual or potential impact on governance
E External Conflict	12	Risk to the incumbent government from foreign action
F Corruption	6	Corruption within the political system.
G Military in Politics	6	Involvement is a diminution of democratic accountability
H Religious Tensions	6	Single religious group may seek to replace civil law by religious law
I Law and Order	6	Strength and impartiality of the legal system and popular observance of the law
J Ethnic Tensions	6	Tension attributable to racial, nationality or language divisions
K Democratic Accountability	6	How responsive a government is to its people
L Bureaucracy Quality	4	Ability to minimize revisions of policy when governments change
Total	100	0-49.9: Very high risk; 50-59.9: High risk; 60-69.9: Moderate risk; 70 to 79.9 Low risk; >79.9: Very low risk

Source: https://www.prsgroup.com/ICRG_Methodology.aspx. This link provides a more detailed description of each component.

3.2.2 Bond data

This study uses the European Monetary Union (EMU) bond index and the Emerging Market Bond Index (EMBI+) of JP Morgan. The JP Morgan EMU government bond index is a popular market capitalization weighted index that consists of bonds issued by 11 countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal and Spain. All bonds are issued in euros or before 1999 in legacy currencies like the German mark and the French franc. The EMU index started in January 1999 with nine countries, and contains all fixed rate bonds with a maturity larger than one year. Austria and Greece were added in April 2001. Greece was removed in April 2012 because the country did not have any remaining outstanding bonds with a fixed coupon and therefore none of Greece’s outstanding bonds were index eligible. There is no rating restriction. The very small EMU countries in terms of outstanding debt like Malta have not been added to the index. Panel A of Table 3-2 provides an overview.

The EMBI+ index is J.P. Morgan’s most liquid U.S. dollar emerging market debt index. Only issues with a current amount outstanding of USD 500 million or more and a remaining life of greater than 2½ years are eligible for inclusion in the index. The index started in January 1994. Panel B of Table 3-2 shows all 24 countries that were part of the index at some point in time. Note that by using historical constituents we avoid a survivorship bias.

Table 3-2: Composition JP Morgan indexes

Country	**Member of index**	**Country**	**Member of index**
Panel A EMU government bond index			
Austria	4/2001 – current	Ireland	1/1999 - current
Belgium	1/1999 - current	Italy	1/1999 - current
Finland	1/1999 - current	The Netherlands	1/1999 - current
France	1/1999 - current	Portugal	1/1999 – current
Germany	1/1999 - current	Spain	1/1999 - current
Greece	4/2001 – 3/2012		
Panel B EMBI+ government bond index			
Argentina	1/1994 – current	Nigeria	1/1994 – 9/2006
Brazil	1/1994 – current	Panama	1/1994 – current
Bulgaria	1/1994 – 11/2013	Peru	1/1994 – current
Columbia	5/1999 – current	Philippines	1/1994 – 8/1998; 4/1999 – current
Croatia	3/2011 – current	Poland	1/1994 – 3/2007
Ecuador	1/1994 – current	Qatar	11/2000 – 7/2002
Egypt	5/2002 – 3/2008	Russia	1/1994 – current
Hungary	4/2011 – current	South Africa	12/1994 – 1/1997; 4/2002 – current
Indonesia	10/2006 – current	South Korea	4/1998 – 6/2002
Malaysia	1/2002 – 11/2004	Turkey	7/1999 – current
Mexico	1/1994 – current	Ukraine	7/2001 – current
Morocco	1/1994 – 10/2006	Venezuela	1/1994 – current

Note: The JP Morgan EMU government bond index is a market cap-weighted index for fixed rate government bonds with a maturity larger than 1 year. There are no rating requirements for inclusion in the index. The JP Morgan EMBI+ (Emerging Market Bond Index) is a market cap-weighted index for fixed rate government bonds with a maturity larger than 2.5 years. This is the smallest emerging market bond index for USD-denominated debt in terms of number of countries due to three selection criteria: a country must be at least investment grade; the amount outstanding should be at least $500 million; and bond trading must be sufficiently liquid. The end date ‘current’ is April 2014.

3.2.3 Spread and credit rating data

Table 3-3 shows the average spread levels, political risk rating levels, and credit ratings over the sample period for each country. A clear pattern arises: on average, countries with a poor credit rating have higher spreads and lower political risk ratings.[21] The worst eight EMBI+ countries (sorted by spread) have an average spread of 9.32%, a B+ rating and a political risk score of 61. In contrast, the best five EMU countries (sorted by spread) have an average spread of 0.12%, an AAA rating and a political risk score of 86.

Table 3-3: Average spread, political risk rating and credit rating

Panel A: EMU countries

High spread change				**Medium spread change**				**Low spread change**			
Country	Spread	Polrisk	Rating	Country	Spread	Polrisk	Rating	Country	Spread	Polrisk	Rating
Greece	363	75	A-					Austria	22	87	AAA
Portugal	174	82	A+					France	15	77	AAA
Ireland	124	86	AA					Finland	13	92	AAA
Italy	84	77	AA-					NL	10	88	AAA
Spain	79	77	AA					Germany	-1	85	AAA
Belgium	34	82	AA+								
Average	**143**	**80**	**AA-**					**Average**	**12**	**86**	**AAA**
Panel B: EMBI+ countries											
Argentina	1590	69	B-	Morocco	472	70	BB	Panama	305	73	BB+
Nigeria	1314	47	BB-	Hungary	397	74	BB+	Qatar	287	77	BBB+
Ecuador	1215	57	CCC+	Croatia	396	72	BBB-	Indonesia	277	59	BB
Venezuela	922	55	B+	Turkey	402	60	BB-	S. Korea	242	76	BBB
Russia	718	62	BB+	Colombia	358	56	BB+	Poland	211	79	BBB+
Ukraine	611	64	B	Peru	348	63	BB+	S. Africa	184	68	BBB
Brazil	573	66	BB	Philippines	346	64	BB	Egypt	157	63	BB+
Bulgaria	515	71	BB	Mexico	338	70	BBB-	Malaysia	110	73	BBB+
Average	**932**	**61**	**B+**	**Average**	**382**	**66**	**BB+**	**Average**	**222**	**71**	**BBB-**

Note: The 11 EMU countries are divided in two groups on basis of the average bond spread compared to Germany. The left panel contains the 6 countries with the highest spread and the right panel contains the 5 countries with the lowest spread. The 24 EMBI+ countries are divided in three groups on basis of the average bond spread compared to the U.S.. The left panel contains the 8 countries with the highest spread and the right panel contains the 8 countries with the lowest spread. Political risk is higher when the (political risk) rating is lower. Political risk rating (Polrisk) and average credit rating (S&P, Moody's and Fitch) are averages over time. The average credit rating is rounded and translated to the notation style of S&P. For EMU countries the average spread (in basis points) is from Barclays Capital and based on the option adjusted spread calculated by comparing each country's yield curve to the German zero curve (fixed at the beginning of the month causing small spreads for Germany at month-end after large interest rate changes). For EMBI+ countries the average spread (in basis points) is from JP Morgan and based on the strip spread (the value of collateralized flows (if any) are 'stripped' from the bond) calculated by comparing each country's yield curve to the U.S. Treasury curve. Averages are based on the period January 1999 – April 2014 for EMU countries and based on the period January 1994 – April 2014 for EMBI+ countries. The exact data period for each country is shown in Table 3-2.

[21] Appendix 3.A shows the average political risk ratings also including the average scores on the twelve components that make up the total political risk rating.

Figure 3-1A shows the average spread over time for the EMU universe. It can be seen that the recent crisis period stands out. Figure 3-1B shows the average spread over time for the EMBI+ universe for which, contrary to the EMU universe, multiple good and bad times have occurred over time.

Figure 3-1A: EMU spread

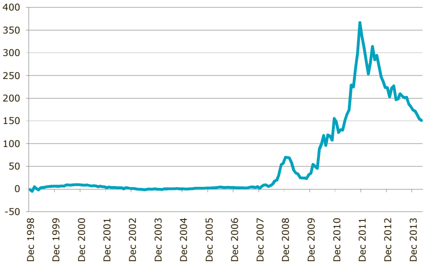
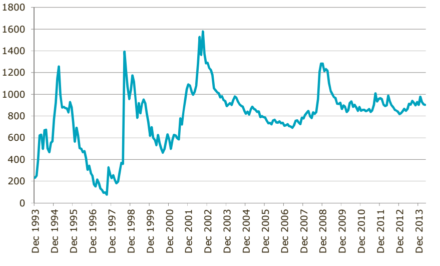


Figure 3-1B: EMBI+ spread



Note: The graphs show the equally weighted spread development through time. The spread is based on the changes of all countries in the index in each month. The spread level of country entries in and exits from the index does not influence the spread.

The default and term spread factors for the EMU and EMBI+ universes are shown in Figure 3-2A and Figure 3-2B, respectively. The default premium is defined as the return of the market index over U.S. Treasuries for EMBI+ and over German bunds for EMU. The term premium is defined as the return of U.S. Treasuries over cash for EMBI+ and the return of German bunds over cash for EMU. The sum of the default premium and term premium is equal to the EMBI+ or EMU return in excess of cash. For both EMU and EMBI+ the term premium is positive due to generally declining yields in Germany and U.S. over time and the average bond index yields being higher than cash. For EMU the default premium starts to play a role end of 2007, with negative returns followed in 2012 by positive returns when the more risky European bond markets started to recover from the crisis. The default premium for EMU is zero over the entire period. Contrary to EMU we do see a positive default premium for EMBI+.

Figure 3-2A: EMU term and default risk

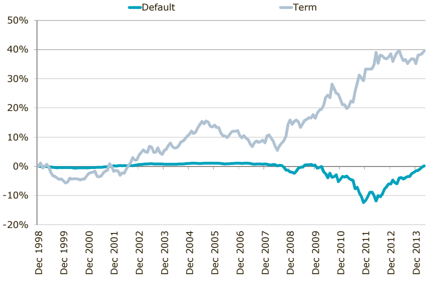
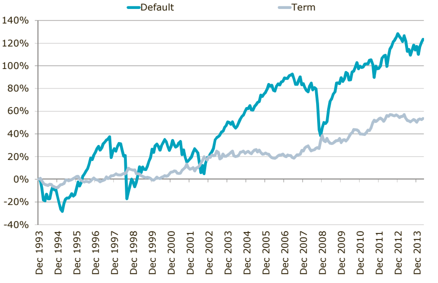


Figure 3-2B: EMBI+ term and default risk



Note: The graphs show the cumulative term and default risk premiums through time for EMU and EMBI+. The default premium is the return of the market index over U.S. Treasuries for EMBI+ and over German bunds for EMU. The term premium is the return of U.S. Treasuries over cash for EMBI+ and the return of German bunds over cash for EMU. The sum of the default and term premium is equal to the market return over cash.

Table 3-4 shows the average changes in spreads, political risk ratings and credit ratings. Again looking at two EMU groups and three EMBI+ groups there is a clear correlation between spread changes on the one hand, and credit rating changes and political risk rating changes on the other hand. The EMU group with the largest spread increases has an average annual spread increase of 9.1%, a drop in political risk ratings of 11.1 points and a rating drop of 7.3 notches (a 1-notch upgrade is for example from BB to BB+). The EMBI+ group with the largest spread increases has an average spread increase of 0.81%, a drop in political risk ratings of 4.8 points and a rating drop of 0.7 notches. At the other end of the spectrum, the EMBI+ group with the largest spread decreases has an average spread decrease of 6.0%, a rise in political risk ratings of 0.3 points and an average rating improvement of 3.0 notches.

Table 3-4: Changes in average spread, political risk rating and credit rating

Panel A: EMU countries

High spread change				**Medium spread change**				**Low spread change**			
Country	Spread	Polrisk	Rating	Country	Spread	Polrisk	Rating	Country	Spread	Polrisk	Rating
Greece	4960	-10.0	-14.3					Belgium	39	-1.5	-0.7
Portugal	132	-18.5	-9.5					NL	17	-11.0	-0.3
Spain	121	-6.0	-6.0					Finland	6	-3.5	0.7
Italy	117	-9.5	-5.0					Germany	5	-0.5	0.0
Ireland	88	-9.0	-7.3					Austria	-2	0.5	-0.3
France	42	-13.5	-1.3								
Average	**910**	**-11.1**	**-7.3**					**Average**	**13**	**-3.2**	**-0.1**

Panel B: EMBI+ countries

High spread change				Medium spread change				Low spread change			
Country	Spread	Polrisk	Rating	Country	Spread	Polrisk	Rating	Country	Spread	Polrisk	Rating
Argentina	432	-15.0	-4.5	Mexico	-111	-6.5	3.8	Turkey	-253	2.5	4.0
Venezuela	376	-21.5	-4.5	Malaysia	-118	4.5	1.7	Peru	-275	2.5	3.7
Indonesia	29	-3.5	3.0	S-Africa	-134	-4.0	0.3	Morocco	-280	1.5	1.0
Nigeria	4	-3.0	0.0	Egypt	-154	-4.5	-0.3	Poland	-470	-4.0	4.3
Croatia	-11	-5.0	-1.3	Ecuador	-165	-4.0	-1.7	Colombia	-519	8.5	0.7
Hungary	-25	-2.5	-1.3	Philippines	-168	-0.5	3.0	Ukraine	-643	-2.0	-2.3
Panama	-46	11.0	2.0	Russia	-200	-12.0	3.0	Brazil	-909	1.5	5.7
Qatar	-110	1.0	1.3	S-Korea	-251	-2.0	3.3	Bulgaria	-1419	-8.5	6.7
Average	81	-4.8	-0.7	Average	-163	-3.6	1.7	Average	-596	0.3	3.0

Note: The 11 EMU countries are divided in two groups on basis of the average bond change in spread compared to Germany. The left panel contains the 6 countries with the largest spread change and the right panel contains the 5 countries with the smallest spread change. The 24 EMBI+ countries are divided in three groups on basis of the full period change in bond spread compared to the U.S.. The left panel contains the 8 countries with the largest spread change and the right panel contains the 8 countries with the smallest spread change. The political risk is higher when the (political risk) rating change is negative. Political risk rating change (Polrisk) and average credit rating change (S&P, Moody's and Fitch) are based on the full research period. The average credit rating change is translated in a number based on notches, e.g. a downgrade from BBB+ to BBB is translated to -1. Changes are based on the period January 1999 – April 2014 for EMU countries and based on the period January 1994 – April 2014 for EMBI+ countries. The exact data period for each country is shown in Table 3-2.

These results show that political risk is relevant for bond yields. Both for levels and for changes there is a clear relationship with ratings and spreads. Countries with good (improving) political risk ratings are also countries with good (improving) credit ratings and low (decreasing) spreads. In the remainder of this study we will investigate whether the most recent political risk ratings are fully incorporated in bond prices, or whether bond prices only partially incorporate current political risk. A recent study by Bekaert, Harvey, Lundblad and Siegel (2014) shows the importance of the political risk level for the bond market. Therefore we focus our research on the changes in political risk.

3.3 Methodology

3.3.1 Forming portfolios

To investigate the importance of political risk for bond prices, and to examine whether changes in political risk predict bond prices, we construct portfolios based on 1-year changes in political risk ratings[22]. At the end of each month[23] we rank the countries that are at that moment in the index and for which political risk ratings are available. The four countries with the largest improvement of the political risk rating represent the Best 4 portfolio, and the four countries with the largest deterioration of the political risk rating represent the Worst 4.[24] The weights for the countries within each of these two portfolios are based on their respective market capitalization scaled to add up to 100%. When countries have the same political risk rating change they both enter the portfolio, leading to more countries in the portfolio. The change in political risk premium is defined as the return of the Best minus Worst portfolios in the subsequent month[25]. The portfolios are constructed for both the EMU and EMBI+ universes of countries.

3.3.2 Risk-adjusted performance

We need to make sure that the relation between changes in political risk ratings and bond prices we document in the next section is really something new. It could be that we are capturing indirectly a known premium when constructing two portfolios based on changes in political risk ratings.

First, we want to control for the default and term premium defined in Section 3.2.3. Gebhardt, Hvidkjaer and Swaminathan (2005a) found these premiums to be priced risk factors for corporate bond returns and have since become the standard asset pricing model for bonds.

Second, it could be that on average the government bonds in the long and short portfolios based on changes on political risk differ in terms of liquidity risk. Longstaff (2004) and Renne and Montfoort (2013) find priced liquidity measures based on comparing the less

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[22] The 1-year look-back period is a compromise between up-to-date information and avoiding too many zero changes as PRS often leaves many components unchanged in the monthly updates. With the 1-year look-back period the frequency of zero changes is 11% for both EMU and EMBI+. Using e.g. 3-month changes the frequency of zero changes rises to 32%.

[23] The political risk data are available about a week before the end of the month, hence using monthly data we actually delay the information.

[24] Using portfolios is a commonly used technique for examining the cross-sectional importance of a fundamental variable isolating the cross-sectional variation from the time-series variation. The alternative would be to use predictive regressions. For an excellent debate on predictive regressions vis-à-vis using portfolios see Thornton and Valente (2012). They show that the Cochrane and Piazzesi (2005) forward rates factor, found to be successful in in-sample predictive regressions for excess bond returns, actually has no economic value in a true real-time exercise.

liquid bonds from respectively U.S. and German government related agencies to liquid government bonds of these countries.

Third, the changes in the subjective assessments by experts at the PRS group could be influenced by changes in market bond yields. In that case we are perhaps selecting portfolios based on past bond returns, i.e. momentum. We measure momentum as the return differences between Best 4 and Worst 4 portfolios based on 1-year bond returns.

Finally, we control for the changes in financial and economic risk ratings from the PRS group and changes in credit ratings to make sure the political risk rating changes are primarily driven by true political risk changes and not financial and economic risk changes in disguise, or adjustments by credit agencies. To do so we construct the returns of Best 4 minus Worst 4 portfolios based on 1-year changes in financial risk ratings and economic risk ratings, and 1-year changes in average credit ratings based on ratings from S&P, Moody's and Fitch.

To control for all the aforementioned effects we run restricted versions of the following multiple regression:

$$\Delta POL_t = \alpha + \beta_1 DEF_t + \beta_2 TERM_t + \beta_3 LIQ_t + \beta_4 \Delta CRED_t + \beta_5 \Delta FIN_t + \beta_6 \Delta ECO_t + \beta_7 MOM_t + \varepsilon_t \qquad (3\text{-}1)$$

where ΔPOL_t is the change in political risk premium, α the unexplained return, DEF_t the default premium, and $TERM_t$ the term premium. LIQ_t is a liquidity measure based on the market cap weighted excess returns of KfW compared to Germany for EMU and the market cap weighted excess return of RefCorp compared to U.S. treasuries for the emerging markets[26]. $\Delta CRED_t$, ΔFIN_t, ΔECO_t, and MOM_t represent the returns of the Best 4 minus Worst 4 portfolios based on the change in credit ratings, financial risk ratings, economic risk ratings, and past 12-month bond returns, respectively. We also consider restricted versions of equation (3-1) to analyze the relevance of each individual control factor. We use Newey-West standard errors to correct for heteroscedasticity and auto-correlation.

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[26] RefCorp is short for the Resolution Trust Corporation which is a U.S. government corporation established to rescue savings and loan institutions that failed during the savings and loan crisis. REFCORP provided liquidity to these organizations by issuing bonds. KfW is short for Kreditanstalt fur Wiederaufbau ("Reconstruction Credit Institute") is owned by the Federal Republic of Germany and the States of Germany. RefCorp and KfW bonds have the same standing as Government bonds in case of a credit event. Hence price differences are only due to liquidity differences.

3.4 Political risk premium

3.4.1 Portfolios based on 1-year changes in political risk ratings

Our main contribution lies in examining the predictive power of changes in political risk ratings. We construct portfolios based on 1-year changes in political risk ratings (ΔPOL)[27]. Note that a portfolio based on 1-year changes of political risk can be quite different from a portfolio based on the level of political risk. First, a portfolio based on the level of political risk has a much lower turnover through time. Second, the average monthly rank correlations between the rankings based on the level and 1-year change of political risk are only 23% and 13% respectively for the EMU and EMBI+ universes.

The characteristics of the Best 4 improving countries and the Worst 4 deteriorating countries are presented in Table 3-5. Strikingly, we observe for both the EMU and EMBI+ universes that the Best 4 portfolios outperform the Worst 4 portfolios and the index. For EMU, the annualized return is 5.6% for the portfolio of the countries that have shown the largest improvement in political risk ratings, at a risk of 4.1% and Sharpe ratio of 0.77. This is 1.1% per annum higher than the returns on the portfolio of countries that have shown the largest deterioration in political risk ratings, and 0.8% per annum higher than the index.

For the EMBI+ universe a similar picture emerges. The Best 4 market cap-weighted portfolio has higher returns compared to both the index and the 'Worst 4' portfolio. Compared to the index the return is 4.1% per annum higher, and the Sharpe ratio is 0.82 compared to 0.52 for the index[28]. Thus, changes in political risk ratings predict the differences between the bond risk premiums of the various countries[29]. Political risk ratings

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[27] We have also analyzed results based on the political risk level. Both the return and risk are higher for the Worst 4 portfolio and lower for the Best 4 portfolio. The Sharpe ratios of both portfolios do not deviate much from the index. The result indicates that political risk is an important risk factor and that knowledge of the political risk level is incorporated in the bond market, confirming the results of Bekaert, Harvey, Lundblad and Siegel (2014). Contrary to our results for the changes in political risk, forecasting future bond market returns with the political risk level is not possible.

[28] Changing to more concentrated portfolios selecting the Best 3 gives a Sharpe ratio of 0.86 for EMU and the same Sharpe ratio of 0.82 for EMBI+. Also the Best 4 equal-weighted (as opposed to market-cap weighted) portfolios have a strong performance with a Sharpe ratio of 0.81 for EMU and 0.70 for EMBI+.

[29] In practice the portfolios we use to determine the changes in political risk premium would incur transaction costs. The typical transaction costs are a one basis point bid-ask spread on the yield for developed markets and a five basis point spread on the yield for emerging bond markets. Given the turnover and index duration of the bond indices these transaction costs would amount to about 10 basis points annual costs for the EMU universe and about 50 basis points annual costs for the EMBI+ universe for the Best minus Worst portfolios. Net returns are still positive and significant for the EMBI+ universe.

also predict credit ratings. For example, for EMBI+ the Best 4 portfolio sees on average an improvement in the credit rating during the investment month. These results suggest that changes in political risk are not directly incorporated in government bond prices or credit ratings.

Table 3-5: Ranking portfolios on 1-year changes in political risk ratings

	EMU			EMBI+		
	Index	**Worst 4**	**Best 4**	**Index**	**Worst 4**	**Best 4**
Return p.a.	4.8%	4.5%	5.6%	10.5%	9.0%	14.6%
Stdev p.a.	3.8%	4.4%	4.1%	13.9%	19.4%	13.7%
Sharpe ratio	0.60	0.47	0.77	0.52	0.29	0.82
Rating		AA+	AA+		BB	BB
Rating change		-0.37	-0.02		-0.31	0.52

Note: Each month the countries are sorted on basis of the one year change of political risk. The four countries with the largest increase (or smallest decrease) in political risk ratings are grouped in the Best 4 portfolio and the four countries with the largest decrease (or smallest increase) in political risk scores are grouped in the Worst 4 portfolio. The portfolios are aggregated on basis of the market cap of the relevant countries. The Sharpe ratio is calculated as the total return in excess of the 3-month Euribor rate for the EMU and the return in excess of the 3-month U.S. Libor rate for the EMBI+. The rating is based on the average rating of S&P, Moody’s and Fitch over the whole sample and in the notation of S&P. The rating change is measured in notches and annualized, e.g. a downgrade from AA+ to AA in one year is translated to -1. The sample period is from January 1999 to April 2014 for EMU and from January 1994 to April 2014 for EMBI+.

A potential explanation for these findings is that the importance of political risk has been underestimated. Only recently have Bekaert et al. (2014) shown that political risk can explain one third of the credit spread. In addition, political risk is difficult to measure[30] and the political risk ratings that we employ are not public information.

The predictive power of changes in political risk is best illustrated with an example. Obvious events to investigate are large historical defaults like Russia in 1998 and Argentina in 2001. The negative bond returns before and during the Russian default were correctly predicted by the change in political risk, but also by the change of the economic risk, credit rating changes and momentum. Financial risk was the only indicator that selected Russia in the best portfolio because of a stronger current account to GDP before the default. The political risk change also predicted the negative returns in Argentina before and during the default. Economic risk and credit rating changes were also successful in this event, whereas

[30] A reviewer pointed out that perhaps the problem of ‘difficult to measure’ is aggravated for smaller countries and that the predictive ability of changes in political risk stems from these smaller countries. However excluding at each point in time countries with a market cap above 10% actually makes the results somewhat weaker. For EMU the Worst 4 portfolio has a Sharpe ratio of 0.25 compared to 0.61 for the Best 4 portfolio. For EMBI+ the Worst 4 portfolio has a Sharpe ratio of 0.39 compared to 0.68 for the Best 4 portfolio.

financial risk changes and momentum were not successful. Both defaults were not followed by quick recoveries.

Therefore, we have investigated a third case in more detail. Just after the default of Argentina in 2001 the financial markets of its larger neighbor Brazil were also plagued by turmoil in 2002. The turmoil was primarily caused by the presidential elections in October 2002. After leading the country for eight years president Cardoso was succeeded by newcomer Lula da Silva. Financial markets became nervous when Lula da Silva, a former president of a steel workers' union, was leading the polls in 2002, and political risk ratings worsened. The yield of Brazilian government bonds more than doubled from 11.7% on 15 March 2002 to 25.5% on 30 July 2002. The yield remained high until the elections in October.

After the elections the markets were reassured by a sound policy from the new president, and political risk ratings improved, leading Brazil to be selected in the 'Best 4' portfolio. Bond yields declined from 23.9% on 15 October 2002 back to 11.7% on 17 April 2003.The Brazilian bond market return was 75%, which was substantially higher than the emerging U.S. dollar government bond market that had a return of 29%. The other indicators we have investigated were less successful in this case. The change in financial risk and economic risk selected Brazil in the 'Worst 4' portfolio after the elections when the bond market recovered. The change in the credit rating and momentum selected Brazil in the 'Worst 4' portfolio before the elections, but kept the country in the 'Worst 4' portfolio during the recovery. Political risk is the only indicator that successfully predicted the recovery of the Brazilian bond market and avoided investing during the crisis. We will further investigate the nature of political risk in good and bad times in Section 3.4.3.

3.4.2 Changes in political risk ratings and price discovery

We further investigate the price discovery of government bonds related to changes in political risk in Table 3-6. We first define a Best minus Worst portfolio based on 1-year changes in political risk (ΔPOL). As a second step we delay the political risk data by one and two months and recalculate the changes in political risk premium. Both for the EMU and

EMBI+ universes, ΔPOL has positive returns and a high Sharpe ratio of 0.41 for EMU[31] and 0.43 for EMBI+. The result for EMBI+ is statistically different from zero. Both for the EMU and EMBI+ universes the political risk premium more than halves after delaying the information by two months. We conclude that bond markets need a few months to incorporate most of the information in the changes of political risk.

Table 3-6: Price discovery change in political risk premium

	ΔPOL_t	ΔPOL_{t-1}	ΔPOL_{t-2}
Panel A.: EMU			
Return p.a.	1.1%	1.0%	0.4%
Stdev p.a.	2.7%	2.7%	2.9%
Sharpe ratio	0.41	0.36	0.14
Panel B: EMBI+			
Return p.a.	5.6%	2.6%	1.7%
Stdev p.a.	13.1%	11.4%	13.1%
Sharpe ratio	0.43*	0.23	0.13

Note: Based on 1-year changes in political ratings at the end of each month we form Best 4 and Worst 4 portfolios and compute the return difference in the subsequent month to create the change in political risk premium ΔPOL_t. To study the price discovery we delay the information from the change in political risk by 1 to 2 months, denoted by ΔPOL_{t-1} to ΔPOL_{t-2}. The 1%, 5% and 10% significance levels are denoted by ***, ** and *, respectively. The sample period is from January 1999 to April 2014 for EMU and from January 1994 to April 2014 for EMBI+.

3.4.3 Changes in political risk ratings and crisis periods

To better understand the strong performance of the Best 4 portfolios based on past 1-year changes in political risk ratings we further investigate the performance in crisis and recovery periods. To identify 'good' and 'bad' times we use the changes in the market cap-weighted spread based on the constituents of the EMU and EMBI+ index. A month is allocated to 'good' times if the spread decreased and to 'bad' times if the spread increased. Note that portfolios based on the best *levels* of political risk ratings would have relatively good returns in bad times and relatively poor returns in good times. The question here is: What about the performance of the portfolios based on the past 1-year changes in political risk ratings?

[31] The size of the changes in political risk premium for the EMU universe is robust for the shorter sample period from January 2008 – April 2014.

Table 3-7: Excess return portfolios on political risk changes in good times and bad times

	EMU			EMBI+		
	Index	**Worst 4**	**Best 4**	**Index**	**Worst 4**	**Best 4**
Full sample	2.3%	2.1%	3.2%	7.2%	5.7%	11.3%
Good times	3.9%	4.5%	4.2%	31.6%	33.9%	32.7%
Bad times	0.4%	-0.8%	2.0%	-25.6%	-32.3%	-17.5%

Note: The table shows the excess returns of portfolios formed monthly on changes in the ex-ante available political risk ratings. The full sample results are split in periods of good times and bad times based on one month changes of the aggregate market cap weighted credit spread. For EMBI+ 140 months are selected as good and 104 months as bad. For EMU 99 months are selected as good and 85 months as bad. The sample period is from January 1994 – April 2014 for EMBI+ and from January 1999 – April 2014 for EMU.

The results in Table 3-7 show that the outperformance of the Best 4 based on 1-year changes in political risk ratings is mostly achieved in bad times. The Best 4 portfolio performs similar to the index and the Worst 4 portfolio in good times. In bad times the Best 4 portfolios for both EMU and EMBI+ do much better than the index and the Worst 4 portfolios. Hence the key finding in Table 3-5 that 1-year changes in political risk ratings result in superior bond portfolios is driven by keeping up in good times and doing much better in bad times.

For EMU, for example, in good times the index has an annualized return of 3.9% and the Worst 4 and Best 4 portfolios have annualized returns of 4.5% and 4.2% respectively. There is a clear difference, however, in bad times where the Worst 4 portfolio returns –0.8%, the index 0.4% and the Best 4 portfolio 2.0%. This difference is statistically different at a significance level of 1%, showing that the changes in political risk are mainly important in bad times. We see a similar picture for EMBI+. In good times there is little difference between the index, Worst 4 and Best 4 portfolios. But in bad times the index loses 25.6% per annum and the Worst 4 portfolio as much as 32.3%. The Best 4 portfolio manages to limit the loss to 17.5% per annum in periods of rising spreads. Similar to the results for the EMU universe the difference between the returns of the Best and Worst portfolios in bad times is statistically significant at a significance level of 1%. The results show that the changes in political risk are able to predict differences between bond market returns in bad times. In such periods both developed and emerging bond markets need time to discover the new price that incorporates the changed political landscape.

3.4.4 Changes in political risk ratings: really something new?

The results so far show that changes in political risk ratings are a strong predictor of future differences between bond market returns. We now investigate whether changes in political risk ratings represent a new important bond factor or whether it represents an existing bond factor in disguise. To investigate this we construct a number of Best and Worst portfolios based on other characteristics. Table 3-8 contains the characteristics of the Best minus Worst portfolios based on 1-year changes in political risk (ΔPOL), credit risk ($\Delta CRED$), financial risk (ΔFIN), economic risk (ΔECO), and 12-month momentum (*MOM*). In addition it shows the performance of the default, term and liquidity premium.

As already observed from Table 3-6 both for the EMU and EMBI+ universes, ΔPOL has positive returns and a high Sharpe ratio of 0.41 for EMU and 0.43 for EMBI+. Of the other Best minus Worst portfolios, none has such high Sharpe ratios in both the EMU and EMBI+ universe. The EMU universe momentum (*MOM*) does have a Sharpe ratio of 0.44 but it has a zero Sharpe ratio for EMBI+. For the EMBI+ universe the Best minus Worst portfolios based on changes in economic risk (ΔECO) has a Sharpe ratio of 0.55 but for EMU the Sharpe ratio is just 0.10. The Best minus Worst portfolios based on changes in financial risk (ΔFIN) for EMU has a small negative return but for EMBI+ even a large negative return and a Sharpe ratio of -0.41. As explained in Section 3.4.1 selecting bond markets based on financial risk put Russia in the Best 4 portfolio during its default in 1998 due to a strong current account and Brazil in the Worst 4 portfolio during its 2003 recovery.

Of the well-known risk factors for bonds the default premium (*DEF*) is zero for EMU and 5.0% for EMBI+. And the bond risk premium (*TERM*) for both universes yields about 2.3% per annum, reflecting partially the declining yields over the sample period. The liquidity premium is slightly positive for EMU (Germany) and zero for EMBI+ (U.S.).

Hence the main candidates to explain the strong performance of the Best minus Worst portfolios based on changes in political risk ratings are the bond risk premium (*TERM*) for both universes; momentum (*MOM*) for the EMU universe; and the default premium (*DEF*) and changes in economic risk (ΔECO) for the EMBI+ universe.

Table 3-8: Characteristics change in political risk premium and alternative return premiums

	ΔPOL	*DEF*	*TERM*	$\Delta CRED$	ΔFIN	ΔECO	MOM	*LIQ*
Panel A.: EMU								
Return p.a.	1.1%	0.0%	2.3%	0.6%	-0.2%	0.2%	1.9%	0.3%
Stdev p.a.	2.7%	2.3%	3.9%	4.4%	2.9%	2.4%	4.3%	0.7%
Sharpe ratio	0.41	0.02	0.57**	0.14	-0.08	0.10	0.44*	0.38
Correlation								
ΔPOL	100%							
DEF	-47%	100%						
TERM	18%	-33%	100%					
$\Delta CRED$	43%	-85%	29%	100%				
ΔFIN	14%	-38%	9%	43%	100%			
ΔECO	22%	-49%	25%	41%	29%	100%		
MOM	30%	-48%	18%	65%	17%	32%	100%	
LIQ	7%	28%	-28%	-19%	16%	-23%	-10%	100%
Panel B: EMBI+								
Return p.a.	5.6%	5.0%	2.2%	-1.2%	-6.2%	7.7%	-0.1%	-0.1%
Stdev p.a.	13.1%	13.9%	4.6%	14.1%	15.0%	13.9%	16.7%	1.6%
Sharpe ratio	0.43*	0.36	0.48**	-0.08	-0.41*	0.55**	0.00	-0.05
Correlation								
ΔPOL	100%							
DEF	-44%	100%						
TERM	8%	-17%	100%					
$\Delta CRED$	46%	-33%	18%	100%				
ΔFIN	-41%	42%	-12%	-17%	100%			
ΔECO	34%	-22%	-1%	45%	5%	100%		
MOM	37%	-43%	10%	58%	-29%	33%	100%	
LIQ	16%	-7%	-1%	9%	-3%	-3%	4%	100%

Note: DEF is the return of the market index over German bunds for EMU, and over U.S. treasuries for EMBI+. $TERM$ is the return of German bunds over cash for EMU, and of U.S. treasuries over cash for EMBI+. LIQ is based on the market cap weighted excess return of KfW compared to Germany for EMU and the market cap weighted excess return of RefCorp compared to U.S. treasuries for EMBI+. Based on 1-year changes in political ratings at the end of each month we form Best 4 and Worst 4 portfolios and compute the return difference in the subsequent month to create the change in political risk premium (ΔPOL). Similarly based on credit ratings (average rating S&P, Moody's and Fitch), financial risk ratings, economic risk ratings and 12-month bond returns we create the change in credit rating risk premium ($\Delta CRED$), the financial risk premium (ΔFIN), the economic risk premium (ΔECO) and 12-month momentum (MOM). The 1%, 5% and 10% significance levels are denoted by ***, ** and *, respectively. The sample period is from Jan 1999 to Apr 2014 for EMU and from Jan 1994 to Apr 2014 for EMBI+.

3.4.5 Loadings on risk factors

We first investigate the loading of the Best minus Worst portfolios based on changes in political risk ratings (ΔPOL) on the default premium, the term premium and liquidity premium which are generally seen as risk factors in the bond literature. The first 3 columns of Table 3-9 show the results.

Table 3-9: Regression change in political risk premium on alternative return premiums

	DEF	TERM	LIQ	3F	$\Delta CRED$	ΔFIN	ΔECO	MOM
Panel A: EMU								
α	1.1%	0.8%	1.0%	0.8%	1.0%	1.2%	1.1%	0.8%
p-value α	0.07	0.15	0.14	0.22	0.13	0.09	0.12	0.26
Coefficient	-0.56	0.13	0.29	-	0.26	0.13	0.25	0.19
p-value coefficient	0.00	0.15	0.49	-	0.02	0.44	0.20	0.05
3F coefficient	-0.59	0.06	1.10	-	-	-	-	-
3F p-value	0.10	0.20	0.02	-	-	-	-	-
R^2	22%	3%	1%	28%	18%	2%	5%	9%
Panel B: EMBI+								
α	7.7%	5.1%	5.7%	7.6%	6.1%	3.4%	3.1%	5.6%
p-value α	0.03	0.14	0.11	0.03	0.05	0.26	0.25	0.09
Coefficient	-0.41	0.23	1.32	-	0.42	-0.36	0.32	0.29
p-value coefficient	0.01	0.29	0.02	-	0.00	0.02	0.02	0.01
Multivariate coefficient	-0.17	-0.08	1.02	-	-	-	-	-
Multivariate p-value	0.03	0.58	0.03	-	-	-	-	-
R^2	19%	1%	3%	21%	21%	17%	11%	14%

Note: This table presents the results of restricted versions of the regression in equation (3-1),

$$\Delta POL_t = \alpha + \beta_1 DEF_t + \beta_2 TERM_t + \beta_3 LIQ_t + \beta_4 \Delta CRED_t + \beta_5 \Delta FIN_t + \beta_6 \Delta ECO_t + \beta_7 MOM_t + \varepsilon_t$$

Based on past 1-year changes in political ratings at the end of each month we form Best 4 and Worst 4 portfolios and compute the return difference in the subsequent month to create the change in political risk premium (ΔPOL). Similarly based on 1-year changes in credit ratings (average rating S&P, Moody's and Fitch), financial risk ratings and economic risk ratings we create the change in credit rating risk premium ($\Delta CRED$), the change in financial risk premium (ΔFIN), the change in economic risk premium (ΔECO) and previous 12-month bond returns (MOM). DEF is the return of the market index over German bunds for EMU, and over U.S. Treasuries for EMBI+. $TERM$ is the return of German bunds over cash for EMU, and of U.S. Treasuries over cash for EMBI+. LIQ is based on the market cap weighted excess return of KfW compared to Germany for EMU and the market cap weighted excess return of RefCorp compared to U.S. treasuries for EMBI+. "3F" is the multiple regression on *DEF*, *TERM* and *LIQ*. The constant (α) is expressed per annum. We use Newey-West standard errors to correct for heteroscedasticity and autocorrelation. The sample period is from Jan 1999 to Apr 2014 for EMU and from Jan 1994 to Apr 2014 for EMBI+.

For both EMU and EMBI+ we find that ΔPOL loads significantly and negatively on the default premium (*DEF*). Hence on average portfolios based on relatively positive changes in political risk ratings invest in the less risky countries. *DEF* explains around 20% of the monthly variation in the returns of ΔPOL. Because for EMU the default premium is zero and for EMBI+ strongly positive the alpha for EMU is equal to the Best minus Worst return at 1.1% and for EMBI+ even larger at 7.7% per annum. Hence controlling for the default premium makes the results for political risk changes even stronger.

The bond risk premium (*TERM*) and liquidity premium (*LIQ*) have limited explanatory power for ΔPOL explaining 3% or less of the variation on monthly returns. Only for EBMI+ ΔPOL loads significantly on the liquidity factor but due to the slightly negative return of the liquidity factor the alpha is 5.7%, 0.1% higher than the return spread for ΔPOL reported in Table 3-8.

The results for the multiple regression of ΔPOL on *DEF*, *TERM*, and *LIQ* are shown in the 4th column in Table 3-9 labeled '3F'. The explanatory power for EMU rises to 28% but alpha remains high at 0.8% per annum. In contrast to only using the significant default premium the alpha is no longer significant. Note that the effective sample is quite short for Europe (only since the end of 2007 did yields of European countries start to diverge), which makes it harder to find a statistically significant result. For EMBI+ the alpha is still highly significant at 7.6%. The 3 factors together explain 21% of the variation in monthly returns. Hence the risk factors cannot explain the strong performance of Best 4 minus Worst 4 based on changes in political risk.

3.4.6 Other factors explain ΔPOL?

The risk factors *DEF*, *TERM* and *LIQ* cannot really explain the alphas from ΔPOL. It could be, however, that forming portfolios based on changes in political risk ratings is a momentum strategy in disguise. We are also interested in the potential overlap between changes in political risk changes on the one hand, and changes in credit ratings, financial risk and economic risk on the other hand even though there is no literature documenting predictive ability of these three factors. The last 4 columns in Table 3-9 show the results.

First it is noteworthy that in both cases there is a significant positive loading on $\Delta CRED$ and momentum. Hence countries with relatively improving political risk ratings are also on average countries with relatively improving credit ratings and a better than average bond market performance. The alphas, however, are only marginally reduced, although for EMU sufficiently to make them insignificant.

Second for EMBI+ the loading on $\Delta FIN$and ΔECO is significant contrary to the results for EMU. The loading on ΔFIN is negative which is mainly caused by its wrong position in Russia during the 1998 default whilst ΔPOL rightly included it in the Worst 4 portfolio. The positive loading on ΔECO suggests that countries with relative improving political risk ratings are on average countries with relatively improving economic risk ratings. The magnitude of the premium for ΔECO at 7.7% (see Table 3-8 Panel B) is such that the ΔPOL alpha of 5.6% is reduced to 3.1%. This causes the ΔPOL alpha to become insignificant. The return of ΔECO is for 75% achieved in Russia while the return of ΔPOL is more evenly coming from multiple countries.

The results suggest that ΔPOL is a new important factor for the bond risk premium. There is some overlap with momentum and changes in credit ratings but ΔPOL has much stronger performance for both universes. Changes in economic risk ratings are also strong for EMBI+ and 46% correlated with ΔPOL which could be interesting for further research. For EMU, however, ΔECO has no predictive power.

3.5 The relevance of individual political risk components

Table 3-9 shows that yearly changes in political risk ratings are an important determinant of the bond risk premium. In this section we look at the importance of the individual political risk components shown in Table 3-1. Which components contribute most to the predictive ability of the total political risk rating?

The results in Table 3-10 for both EMU and EMBI+ show that most of the 12 components have a low and insignificant alpha based on the regression on the factors *DEF, TERM,* and *LIQ*. This is no surprise, given the small changes over time of these components (see Table 3-11 and

Table 3-12 in Appendix 3.A, row 'Changes'). The three components that stand out with higher returns are the components A, B, and to a lesser extent C denoting government stability, socioeconomic conditions and the investment profile, respectively. For EMU the risk-adjusted return difference between the most improving countries and most deteriorating countries for the socioeconomic conditions component is equal to 0.70%, compared to 0.77% based on the total political risk rating. For EMBI+ the risk-adjusted return for the government stability component is 7.3% compared to 7.6% for the total political risk rating.

Hence, the ability of governments to carry out their declared programs and to stay in office, socioeconomic conditions (such as unemployment and poverty) that could constrain government action or fuel social dissatisfaction, and the legislative risk of investments are important factors for both EMU and EMBI+ government bond investors. Huang, Wu, Yu and Zhang (2015) find that the relationship between international political crises and the level bond yields depends on the government stability and legal investor protection confirming the importance of these components for bond market risk.

Table 3-10: Alpha of the components of change in political risk premium

	EMU	EMBI+
Total political risk	0.77%	7.6%**
A. Government Stability	0.04%	7.3%***
B. Socioeconomic Conditions	0.70%	5.3%*
C. Investment Profile	0.38%	1.6%
D. Internal Conflict	0.15%	-0.4%
E. External Conflict	-0.02%	-2.9%
F. Corruption	0.00%	0.9%
G. Military in Politics	0.00%	0.6%
H. Religious Tensions	-0.05%	-0.5%
I. Law and Order	0.05%**	0.7%
J. Ethnic Tensions	0.00%	0.6%
K. Democratic Accountability	0.00%	2.7%*
L. Bureaucracy Quality	-0.01%	2.6%

Note: This table presents the alphas of the restricted regression in equation (3-1),

$\Delta POL_t = \alpha + \beta_1 DEF_t + \beta_2 TERM_t + \beta_3 LIQ_t + \varepsilon_t$

Based on 1-year changes in political ratings at the end of each month we form Best 4 and Worst 4 portfolios and compute the return difference in the subsequent month to create the change in political risk premium (ΔPOL). DEF is the return of the market index over German bunds for EMU, and over U.S. Treasuries for EMBI+. $TERM$ is the return of German bunds over cash for EMU, and of U.S. Treasuries over cash for EMBI+. LIQ is based on the market cap weighted excess return of KfW compared to Germany for EMU and the market cap weighted excess return of RefCorp compared to U.S. treasuries for EMBI+. The constant (α) is expressed per annum. The (total) political risk rating is based on the 12 components with the weights listed in Table 3-1. We apply the same methodology on the individual components to form Best 4 and Worst 4 portfolios and compute the alphas. The 1%, 5% and 10% significance levels are denoted by ***, ** and *, respectively. We use Newey-West standard errors to correct for heteroscedasticity and autocorrelation. The sample period is from Jan 1999 to Apr 2014 for EMU and from Jan 1994 to Apr 2014 for EMBI+.

For emerging U.S. dollar debt (EMBI+) we also find democratic accountability and to a lesser extent bureaucracy quality and investment profile to be important.

3.6 Conclusion

We find political risk to be an important determinant of the differences in global government bond risk premiums. First, the level of political risk is closely related to the creditworthiness of a country. Countries with high political risk are on average countries with poorer credit ratings and higher bond risk premiums.

Second, we find that changes over time in political risk are closely related to changes in the creditworthiness of a country. Countries for which political risk is improving are on average also the countries with improving credit ratings and relatively positive bond returns over the past year. Moreover, we find that the bonds from these countries going forward have higher returns than the bonds from countries with a relatively worse political risk. That is, whereas we find that political risk levels are properly incorporated in bond prices, changes in political risk levels contain information about future bond risk premiums. As such, bond prices do not immediately incorporate past changes in political risk. These same past changes in political risk also have some predictive ability for changes in ratings.

We therefore conclude that although bond market participants and rating agencies do take into account the political risk of a country, in terms of changes in political risk both bond prices and ratings are not fully efficient. These findings are robust when accounting for the term premium, default premium, and liquidity factors. Bond return momentum, financial risk, economic risk and liquidity risk also cannot explain these results. Our conclusion is that the change in political risk is a novel driver of future differences in global government bond risk premiums.

Appendix 3.A: PRS component scores per country

Table 3-11: Descriptive statistics political risk scores for EMU countries

	total and components												
	A	B	C	D	E	F	G	H	I	J	K	L	Total
Max	12	12	12	12	12	6	6	6	6	6	6	4	100
Changes	2.7	0.8	0.9	0.6	0.3	0.2	0.0	0.1	0.1	0.1	0.1	0.0	5.1
Austria	8	9	11	11	11	5	6	5	6	4	5	4	87
Belgium	8	8	10	11	12	4	6	5	5	3	6	4	82
Finland	9	9	11	11	12	6	6	6	6	6	6	4	92
France	8	8	11	10	10	4	5	5	5	3	6	3	77
Germany	9	8	11	11	11	5	6	6	5	4	6	4	85
Greece	8	7	10	9	10	2	5	5	4	5	6	3	75
Ireland	8	9	10	11	11	3	6	5	6	6	6	4	86
Italy	8	8	10	10	11	3	6	5	4	5	5	3	77
Netherlands	8	10	11	11	12	5	6	4	6	5	6	4	88
Portugal	8	8	10	10	10	4	6	6	5	6	6	3	82
Spain	8	7	11	9	10	4	5	5	5	4	6	3	77

Note: Average political risk scores and components from January 1999 to April 2014. "Changes" shows the average absolute change of a score per country.

Table 3-12: Descriptive statistics political risk scores for EMBI+ countries

	total and components												
	A	B	C	D	E	F	G	H	I	J	K	L	Total
Max	12	12	12	12	12	6	6	6	6	6	6	4	100
Changes	2.7	0.6	0.9	1.0	0.7	0.2	0.1	0.1	0.2	0.1	0.2	0.1	5.8
Argentina	8	5	6	10	10	2	4	6	3	6	5	3	69
Brazil	8	6	7	9	11	3	4	6	2	4	4	2	66
Bulgaria	8	4	10	11	10	3	5	5	4	5	5	2	71
Colombia	8	4	8	5	9	3	2	5	2	5	4	2	56
Croatia	7	5	9	11	11	2	5	5	5	5	6	3	72
Ecuador	7	4	5	8	10	3	2	5	3	4	4	2	57
Egypt	10	5	7	9	10	2	3	3	4	6	2	2	63
Hungary	7	7	8	11	10	3	6	6	4	4	6	3	73
Indonesia	7	6	8	8	10	3	3	1	3	2	5	2	59
Malaysia	11	8	9	11	11	3	5	4	3	4	3	3	73
Mexico	8	7	9	9	11	2	4	6	2	4	6	3	70
Morocco	10	5	8	10	10	3	4	4	6	5	3	2	70
Nigeria	8	2	5	8	10	1	1	2	2	2	3	1	47
Panama	8	6	9	10	10	2	5	5	3	5	5	2	71
Peru	7	5	8	7	10	3	4	6	3	3	4	2	62
Philippines	8	5	8	8	11	2	3	3	3	5	5	3	64
Poland	8	6	10	10	11	3	6	5	5	6	6	3	78
Qatar	11	8	10	11	10	2	4	4	6	6	2	2	77
Russia	9	5	7	8	9	2	4	5	4	3	3	1	61
S. Africa	8	5	10	9	11	3	5	5	3	4	5	2	68
S. Korea	9	7	8	10	9	3	5	6	4	6	6	3	76
Turkey	9	5	8	8	8	2	3	4	4	2	4	2	60
Ukraine	7	5	7	10	10	2	5	5	4	4	4	1	64
Venezuela	8	4	4	8	10	2	1	5	3	5	4	1	55

Note: Average political risk scores and components from January 1994 to April 2014. "Changes" shows the average absolute change of a score per country.

4. Inflation and seasonality in bond returns

Based on Duyvesteyn, Martens and Moraresc u (2015). We are grateful for the useful comments from Olaf Penninga, Laurens Swinkels, Patrick Verwijmeren, Casper Zomerdijk and seminar participants at Robeco.

4.1 Introduction

There is quite a large amount of literature on seasonal patterns in global equity returns and explanations for these patterns.[32] For government bonds, however, the evidence is limited and inconsistent. In addition, the patterns that have been examined for the bond market all originate from studies of seasonality in the stock market: The January effect, the Halloween effect and the effect caused by Seasonal Affective Disorder (SAD). Clayton, Delozier and Ehrhardt (1989) document that long-term U.S. Treasuries have lower returns in January than in the rest of the year.[33] Fridson (2000) finds that 10-year U.S. Treasury returns are higher from June to November and Athanassakos (2008) finds that Canadian bonds have higher returns from May to October. Kamstra, Kramer and Levi (2015) document a seasonal pattern in U.S. treasury returns that coincides with the number of reported cases of Seasonal Affective Disorder (SAD). They argue that the resulting increased risk aversion during the fall leads to higher bond returns and the returns on bonds are likely to be below average once the days become longer.

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[32] Wachtel (1942), Rozeff and Kinney (1976), Gultekin and Gultekin (1983), Keim (1983), Reinganum (1983), Berges, McConnell and Schlarbaum (1984), Van den Bergh and Wessels (1985), Kato and Schallheim (1985), Aggarwal and Rivoli (1989) and Ho (1990) all document "the January effect", with higher returns in the first month of the year. A recent study by Zhang and Jacobsen (2013) fails to find the January effect for their long U.K. data set. Bouman and Jacobsen (2002), Doeswijk (2008) and Andrade, Chhaochharia and Fuerst (2013) report on "the Halloween effect", with higher equity returns from November to April and lower stock returns from May to October. Swinkels and van Vliet (2012) show that the Halloween effect is stronger than the January effect. Ogden (2003) reports higher equity returns from October to March. Kamstra, Kramer and Levi (2003) find below-average stock returns in the fall and relatively higher returns in the winter. They argue that a depression related to the decreasing daylight (Seasonal Affective Disorder - SAD) during autumn which influences the mood translates into risk aversion during fall and as the days become longer, the risk appetite of the investors recovers.

[33] They point out several problems with the earlier studies on the January effect by Schneeweis and Woolridge (1979), Smirlock (1985), and Chang and Pinegar (1986) which all concluded there is no January effect in government bond returns. Smith (2002) finds mixed evidence for six developed countries depending on the method used.

In this study we conduct a broader investigation of the six most liquid government bond markets: Australia, Canada, Germany, Japan, the U.K. and the U.S. We document a new semi-annual seasonal pattern in bond returns from 1980-2014: On average, the excess bond returns for the six countries are 3.8 percentage points higher in the second half of the calendar year. The pattern is statistically significant not just for the equally weighted portfolio of six countries but also for each country individually. In contrast, we find no evidence of a January effect, only a weak and inconsistent (inverted) Halloween effect, and SAD is only significant for Canada, Germany and the U.S.

We then proceed to explain the existence of the semi-annual seasonal pattern in government bond returns. Our contribution provides the new finding that the non-seasonally adjusted U.S. consumer price index (CPI) causes the seasonality of international bond returns. U.S. inflation is on average 3.0 percentage points higher in the first half of the calendar year. When simultaneously regressing monthly bond returns on the semi-annual seasonal and monthly inflation the bond return seasonal is no longer significant. Interestingly for the U.S. CRSP bond data from 1952 to 1979, there is no seasonal pattern in the bond returns coinciding with the absence of a seasonal pattern in U.S. inflation.

Seasonality in U.S. inflation is caused by seasonality in fuel and gasoline prices, which affect the housing and transportation components of the CPI. The higher prices in the first half of the year coincide with a higher demand for heating oil in the winter and gasoline for the U.S summer driving season. The lack of seasonality in U.S. bond returns from 1952 to 1979 is then also understandable as oil prices were fixed in U.S. dollars until the early seventies, barring a few controlled adjustments. The results suggest that global bond markets do not properly anticipate seasonality in inflation.

The seasonal pattern in the national inflation can also explain the seasonal pattern in bond returns for several countries, but the results are weaker than for the U.S. inflation. Ehrmann and Fratzscher (2005) show that U.S. macro news is the dominant driver of both U.S. and European bond prices. Dahlquist and Hasseltoft (2013) report that global economies and international bond markets became more integrated in the last couple of decades. These findings support our finding that U.S. inflation and its seasonal pattern are important for international bond markets.

We add to the literature in at least three ways. First, we document a new seasonal pattern in international government bond returns. We find bond returns in the second half of the calendar year to be on average 3.8 percentage points higher than bond returns in the first half of the calendar year. Second, we add to the price discovery literature in bond markets by identifying a strong relationship between inflation and bond returns, which largely explains the seasonal pattern in bond returns. Third, we find that U.S. inflation has more explanatory power than domestic inflation for bond returns in Australia, Canada, Germany, Japan, and the U.K., which is consistent with the literature on the impact of macroeconomic news on the international bond markets[34].

4.2 Data

4.2.1 Bond data

We obtain monthly total price indices for the government bonds of Australia, Canada, Germany, Japan, the U.K. and the U.S. from Thomson Financial Datastream. For Germany, the U.K. and the U.S. the sample starts in January 1980. Japan starts in January 1982, Canada in January 1985 and Australia in March 1987. These six countries have the most liquid bond markets, where we see Germany as representative of Europe. We compute excess returns as the total return minus the cash return of a 1-month Eurocurrency deposit[35]. For the U.S. we also look at the CRSP Fixed-Term Indexes data. This allows us to go further back in time. For the U.S. CRSP excess returns we compute the equally weighted average total return of U.S. 1-, 2-, 5-, 7-, 10-, 20- and 30-year government bond returns in excess of the 30-day T-bill return. We use the data from January 1952, which is consistent with other studies[36] and the CRSP Fama-Bliss discount bond dataset.

As a preview on seasonality in bond returns we compute the average return per calendar month for the equally weighted portfolio of the six countries. Figure 4-1 reveals a striking

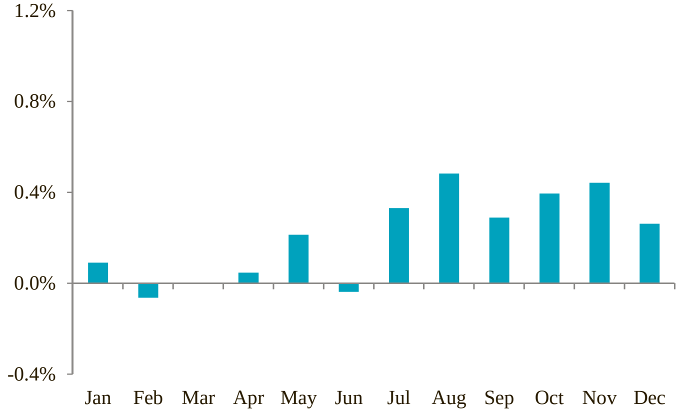
[34] Global economies and international bond markets became more integrated in the last couple of decades (Dahlquist and Hasseltoft, 2013). The literature confirms that U.S. macroeconomic news is important for global bond prices. Multiple studies on the link between international economic news and international bond markets include U.S. economic news and one or more other countries. See for example, Kim and Sheen (2000) [Australia], Gravelle and Moessner (2001) [Canada], Ehrmann and Fratzscher (2005) [Euro area], Craine and Martin (2008) [Australia], Andersen, Bollerslev, Diebold and Vega (2007) [Euro area], Andersson, Overby, and Sebestyén (2009) [Euro area, Germany, France, Italy, Spain, Belgium, and U.K.].

[35] For Australia we use a 90-day deposit rate before August 1988 because the 1-month Eurocurrency deposit rate is not available.

[36] For example in Kamstra, Kramer and Levi (2015)

and strong pattern: Returns are on average much larger in the second half of the calendar year than in the first half.

Figure 4-1: Average excess bond returns



Note: The sample period is 1980-2014. The equally weighted portfolio returns are based on the six countries in Table 4-1. In the early years when not all six countries have data the portfolio is based on those countries that are available. The figure shows the average excess bond return per calendar month.

Table 4-1 shows the starting dates and annualized average excess bond returns for the six individual countries and the equally weighted return of the six countries ('EW portfolio'). All excess returns per annum are large because bond yields have declined on average for this sample period. The final row shows the annualized return and standard deviation for the CRSP bond data for the period from January 1952 to December 1979. This will allow us to look at seasonal patterns in bond returns for this longer period. For the period January 1980 to December 2014 we find a 99% correlation between the U.S. bond returns of CRSP and Thomson Financial Datastream.

Table 4-1: Sample statistics for excess bond returns

			Excess bond returns		
Country	**Start month**	**End month**	**Total**	**H1**	**H2**
Australia	03/1987	12/2014	2.3%	0.6%	4.1%
Canada	01/1985	12/2014	3.2%	1.0%	5.4%
Germany	01/1980	12/2014	2.1%	0.3%	4.0%
Japan	01/1982	12/2014	2.4%	1.2%	3.6%
United Kingdom	01/1980	12/2014	2.3%	–0.5%	5.2%
United States	01/1980	12/2014	2.3%	0.4%	4.3%
EW portfolio return	01/1980	12/2014	2.3%	0.4%	4.2%
EW portfolio risk	01/1980	12/2014	4.0%	4.0%	3.9%
United States CRSP	01/1952	12/1979	–0.3%	–0.5%	–0.1%

Note: The excess bond return is the annualized return of all government bonds included in the Datastream government bond indices. The excess return is the total return minus the cash return of a 1-month Eurocurrency deposit from Reuters. For Australia we use a 90-day deposit rate before Aug 1988 because the 1-month deposit rate is not available. The final column shows the annualized standard deviation of the monthly returns.All data are from Datastream except for the U.S. CRSP data. 'EW portfolio' is based on equally weighting the six countries provided they exist. EW portfolio risk is the annualized risk of the EW portfolio. United States CRSP is based on the equally weighted average total return of U.S. 1-, 2-, 5-, 7-, 10-, 20- and 30-year government bonds in excess of the 30-day T-bill return.

Table 4-1 shows the average returns in the first (H1) and second half (H2) of the year for the individual countries and the portfolio. The average portfolio return is 0.4% per annum in the first half of the year and 4.2% per annum in the second half of the year. This strong seasonal pattern is also visible for each country individually. The smallest difference is for the U.S. CRSP data over the period 1952-1979.

A simple explanation of the difference could be a higher bond market risk in the second half of the year. However, the annualized bond market risk in the first half of the year (4.0%) is slightly higher than the bond market risk in the second half of the year (3.9%) and can therefore not explain this large return difference.

4.2.2 Macroeconomic data

To examine the seasonal effect we will make use of macro data. We gather non-seasonally adjusted data for GDP, industrial production, consumer price inflation (CPI), producer price inflation (PPI), consumer confidence, producer confidence, and the unemployment rate. We do not apply a publication lag and use the final data including potential data revisions. For example Chu, Pittman and Yu (2011) show that U.S inflation linked bond prices fully reflect the U.S. inflation data by the end of the corresponding month, before the official announcement of the inflation data which is normally about 2 weeks later. That motivates us to not delay the data by one month. We do analyse the impact of the publication lag on our key results in Section 4.5.3. The data source is Thomson Financial Datastream, which covers non-seasonally adjusted data for all the six countries of interest.

Table 4-2 shows the first month for which the macroeconomic data are available for each country. For GDP, industrial production, CPI and PPI we calculate the relative monthly or quarterly change and for the producer confidence, consumer confidence and unemployment rate we calculate the monthly absolute change. For GDP we only have quarterly data and for three Australian and one Canadian indicators as well. All data are not seasonally adjusted. Industrial production and GDP are measured in constant prices to avoid a potential overlap with the inflation indicators.

Table 4-2: Start month macroeconomic data

Country	**Consumer price inflation**	**Producer price inflation**	**Consumer confidence**	**Producer confidence**	**GDP**	**Industrial production**	**Unem-ployment**
Australia	03/1987*	03/1987*	03/1987	10/2007	04/1980*	03/1987*	03/1987
Canada	01/1985	01/1985	09/2001*	05/1999	04/1980*	02/1995	01/1985
Germany	01/1980	01/1980	02/1985	02/1991	04/1980*	01/1980	02/1991
Japan	01/1982	01/1982	01/1982	04/1996	04/1980*	01/1982	01/1982
U.K.	01/1980	01/1980	01/1980	-	04/1980*	01/1980	02/1983
U.S.	01/1980	01/1980	01/1980	08/1997	04/1980*	01/1980	01/1980
U.S. CRSP	01/1952	01/1952	02/1978	-	-	02/1957	01/1952

Note: All data are from Thomson Financial Datastream and are not seasonally adjusted. Inflation, GDP and industrial production are measured as the monthly (or quarterly) percentage change. Confidence and unemployment are measured as the monthly (or quarterly) absolute change. Consumer price inflation is based on the xxCONPRCF Datastream code where xx is the country code, except for the U.K. for which we use the RPI index (UKCHAW Datastream code) because of a longer data history. Producer price inflation is based on the xxPROPRCF Datastream code where xx is the country code. For the consumer confidence we use the ANZ Roy Morgan index for Australia, the Decima Research index for Canada, the DG ECFIN index for Germany, the Cabinet Office leading index for Japan, the GfK index for the U.K. and the University of Michigan index for the U.S. For the producer confidence we use the AIG index for Australia, the Ivey index for Canada, the IFO index for Germany, the Tankan index for Japan, and the ISM index for the U.S. A producer confidence index for the U.K. is available on Datastream but is not for free. GDP is based on the xxXGDPR.D Datastream code where xx is the country code. Industrial production is based on the xxI66..IG Datastream code where xx is the country code, except for Australia for which we use AUQ66..IG code. Unemployment is based on xxMLRT16R Datastream code where xx is the country code. *Australian consumer inflation, producer inflation and industrial production, Canadian consumer confidence and all GDP data are only available on a quarterly basis.

4.3 Methodology

Different methods are proposed in the literature to test for seasonality. We make use of the most popular method, which is the regression method.[37] More specifically we use the following regression:

$$Ex\_r_t = \alpha + \beta X_t + \gamma Y_t + \varepsilon_t \qquad (4\text{-}1)$$

where Ex_r_t is the excess bond return in month or quarter t, α is the intercept term, β is the coefficient of the seasonal variable X_t, γ is the coefficient of control variable Y_t, and ε_t is the error term. Most often X_t is a dummy variable that takes on the value of one for the months in which higher returns are expected, and zero for other months. This way the regression with $\gamma = 0$ is similar to a mean test on the difference in the mean of the months for which the dummy has been assigned a one and the mean of the other months. If the β in equation (4-1) is significantly higher or lower than zero we have evidence that bond returns are significantly higher or lower in the months for which the dummy variable is one. We will formally test for an H1 H2 seasonal pattern using equation (4-1) where

$$X_t = \begin{cases} 0 & if\ t \in \{Jan, Feb, Mar, Apr, May, Jun\}\ (H1) \\ 1 & if\ t \in \{Jul, Aug, Sep, Oct, Nov, Dec\}\ (H2) \end{cases} \qquad (4\text{-}2)$$

In addition we will test for alternative seasonal patterns documented in the literature. These are the January effect (X_t=1 only for the month January), the (inverted) Halloween effect

$$X_t = \begin{cases} 0 & if\ t \in \{Jan, Feb, Mar, Apr, Nov, Dec\} \\ 1 & if\ t \in \{May, Jun, Jul, Aug, Sep, Oct\} \end{cases} \qquad (4\text{-}3)$$

and the SAD factor where X_t takes on a different value for each month[38]. For variables that can potentially explain the seasonal pattern in bond returns we will use Y_t in equation (4-1). A variable explains (to a large extent) the seasonality in bond returns if without it β is significantly different from zero and with it β is no longer significantly different from zero. Equation (4-1) will be estimated using Ordinary Least Squares (OLS) and inference will be based on Newey-West standard errors[39].

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[37] See for example Bouman and Jacobsen (2002), Ogden (2003), Hong and Yu (2009), Kelly and Meschke (2010), Andrade, Chhaochharia and Fuerst (2013) and Zhang and Jacobsen (2013).

[38] We are grateful to Mark Kamstra for providing the data, see www.markkamstra.com/data.html.

[39] Jacobsen and Marquering (2008) apply different estimation techniques (OLS, GMM, Maximum Likelihood and panel regression) but draw the same conclusions from all methods.

4.4 Seasonal patterns in bond returns

Table 4-3 shows the results for the seasonality tests in equation (4-1) with $\gamma = 0$. The H1 H2 seasonal pattern in Figure 4-1 is highly significant with a t-statistic of 2.6, see Table 4-3 first column row '*EW portfolio*'. Hence the return difference of 3.8% between the first half of the year (H1) and the second half of the year (H2) for the equally weighted portfolio of the six countries is significant at the 1% significance level. For the individual countries the seasonal pattern is also significant at the 10% significance level. Only for the U.S. bond returns from 1951 to 1979, the 0.4% higher return in H2 is not significantly different from zero.

Table 4-3: Seasonal tests on excess bond returns

	Excess bond returns			
	H1 H2	**January**	**Halloween**	**SAD**
Australia	3.5%	-1.4%	0.5%	0.0036
	(1.7)	(-0.5)	(0.3)	(0.9)
Canada	4.3%	-0.6%	4.3%	0.0101
	(2.2)	(-0.2)	(2.3)	(2.6)
Germany	3.7%	-0.6%	0.7%	0.0047
	(2.6)	(-0.3)	(0.5)	(1.8)
Japan	2.3%	-2.7%	-0.8%	0.0013
	(1.8)	(-1.1)	(-0.5)	(0.5)
United Kingdom	5.7%	-2.3%	2.2%	0.0074
	(2.5)	(-0.6)	(0.9)	(1.5)
United States	3.9%	-1.4%	3.8%	0.0103
	(2.0)	(-0.5)	(2.1)	(3.1)
EW portfolio	**3.8%**	**-1.7%**	**1.6%**	**0.0061**
	(2.6)	**(-0.9)**	**(1.1)**	**(2.2)**
United States CRSP	0.4%	2.1%	-0.8%	0.0012
	(0.2)	(0.7)	(-0.5)	(0.4)

Note: This table shows the betas from equation (4-1) with $\gamma = 0$, where we regress excess bond returns on four different choices of the seasonal. For H1 H2 we use equation (4-2) for X_t in equation (4-1). For the January effect X_t takes on the value 1 for Januaries and 0 in other months. For the (inverted) Halloween effect X_t is defined in equation (4-3). Finally for the Seasonal Affective Disorder (SAD) X_t is set equal to the 12 monthly values from the Kamstra, Kramer and Levi (2015) paper. T-values based on Newey-West standard errors are presented inside parentheses. The detailed data description is shown in the note below Table 4-1.

The January effect is not strongly present in the data. None of betas is statistically significant, although the average return below zero has the expected sign. The Halloween effect is also not significant for the equally weighted portfolio of the six countries. Only for Canada and the U.S., the excess bond returns are significantly higher in the months May to October. The SAD factor is significant for the equally weighted portfolio, and also individually for Canada, Germany and U.S. The latter is consistent with the findings of

Kamstra, Kramer and Levi (2015). For Australia, Japan and the U.K., however, there is no significant SAD effect. The sign for Australia is even wrong, as the idea of SAD should apply in other months for Southern-Hemisphere countries.

In conclusion, the new H1 H2 seasonal is the most significant and robust seasonal effect for the six developed bond markets. We continue with investigating what is driving this strong seasonal pattern in bond returns.

4.5 Explaining the bond seasonal

4.5.1 Potential explanations

To understand the reasons behind the strong H1 H2 seasonal pattern in excess bond returns, we look at drivers of bond returns that can cause this seasonal pattern. Our primary candidate is inflation. Several studies find that (the change in expected) inflation (surprise) is an important determinant of government bond returns[40]. It is common to report and use seasonally adjusted inflation figures, except for inflation linked bond markets that we investigate in Section 4.6. If a seasonal pattern does exist in the inflation it would be only visible in non-seasonally adjusted data, therefore for this research question we use non-seasonally adjusted inflation data. Besides non-seasonally adjusted inflation, we also look at other macroeconomic non-seasonally adjusted variables to investigate whether the variation of economic activity can explain the seasonality in bond returns. We consider GDP growth, change in the unemployment rate and the industrial production, although Elton, Gruber and Blake (1995) find such growth related data to be less important for bond markets than inflation. Finally we include consumer and producer confidence, with the former being an indicator for investor sentiment and the latter being an indicator of for confidence in the economic activity. Doeswijk (2008) links the Halloween effect in equity markets to investor confidence and perhaps the same is possible for bond markets.

In the first place we test national macroeconomic data for national bond markets. Ehrmann and Fratzscher (2005) show that U.S. macro news is the dominant driver of both U.S. and European bond prices. Dahlquist and Hasseltoft (2013) report that global economies and international bond markets became more integrated in the last couple of decades. The

[40] See for example De Bondt and Bange (1992), Campbell and Ammer (1993), Elton, Gruber and Blake (1995), Ang and Piazzesi (2003), Brandt and Wang (2003), and Wright (2011).

global Cochrane and Piazzesi (CP; 2005) factor, dominated by the U.S. CP factor, predicts bond returns better than the national CP factors. Hence we will also use U.S. macroeconomic data to see whether these can explain seasonality in bond returns in the other markets. Ang, Bekaert, and Wei (2008) find that the inflation risk premium largely explains the variation in long-term nominal bond yields. Jotikasthira, Le, and Lundblad (2015) report that GDP weighted world inflation[41] and U.S. yields together explain over two-thirds of the covariance of international bond yields.

Kamstra, Kramer and Levi (2015) also consider other bond drivers to explain the seasonal pattern in U.S. treasury returns. For example, related to bond issuance, they consider debt-to-GDP but this indicator does not display a seasonal pattern. Auction dates and FOMC meetings also cannot explain the seasonal pattern in U.S. treasury returns. Related to investor sentiment, they investigate the Baker and Wurgler (2006; 2007) index but this index does not display a seasonal pattern. Hence, we focus on investigating whether national and U.S. macroeconomic data can explain the seasonal pattern in global bond returns.

4.5.2 Seasonal pattern in macroeconomic variables

To explain the seasonal pattern in bond returns by seasonality in macroeconomic data two conditions need to be met. First, the macroeconomic data should exhibit a similar (inverse) semiannual pattern as the bond returns. Second, the monthly bond returns and macroeconomic data should be strongly and positively (negatively) related. We first analyze the existence of a H1 H2 seasonal in the seven macroeconomic indicators. Table 4-4 shows the results for the six countries, the equal weighted portfolio and the U.S. CRSP data before 1980.

For the national macroeconomic data averaged over the six countries we see in column 7 of Table 4-4 that all macro indicators except for unemployment and real GDP growth display a significant H1 H2 seasonal pattern. For example consumer (producer) price inflation is on average 2.1% (2.2%) per annum higher in H1 than in H2. The sign of unemployment suggests it cannot explain the bond seasonal. A declining unemployment in H2 should on average trigger lower bond returns in H2, not higher bond returns. Consumer and producer confidence do not show a significant H1 H2 seasonal for respectively three and

[41] The equally weighted inflation of the six countries has a correlation of 74% with U.S. inflation.

two countries. Moreover, for Australia the sign of producer confidence is significant and positive, indicating lower bond returns in the second half of the year. The consumer and producer price inflation have the strongest seasonal with t-stats of respectively -5.0 and -3.8 for the portfolio. Consumer price inflation is the most likely candidate to explain the seasonal effect in bond returns given its highest t-stat. In the next Section we will therefore look in detail at the consumer price inflation. In Section 4.5.4 we will come back to the other macroeconomic data.

Table 4-4: H1 H2 seasonal test for macroeconomic data

	Australia	**Canada**	**Germany**	**Japan**	**U.K.**	**U.S.**	**EW portfolio**	**U.S. CRSP**
Consumer price	0.1%*	-2.7%	-0.7%	-1.1%	-2.6%	-3.0%	-2.1%	-0.3%
inflation	(0.1)	(-6.1)	(-1.7)	(-2.6)	(-4.0)	(-5.4)	(-5.0)	(-0.5)
Producer price	0.9%*	-2.4%	-1.8%	-1.1%	-2.5%	-3.2%	-2.2%	0.3%
inflation	(0.5)	(-2.5)	(-3.2)	(-1.6)	(-4.0)	(-3.6)	(-3.8)	(0.3)
Consumer	3.3	-10.9*	-10.3	-3.8	-16.5	-6.2	-7.1	-3.3
confidence	(0.6)	(-0.6)	(-3.3)	(-2.7)	(-4.7)	(-1.2)	(-3.5)	(-0.2)
Producer	10.3	-45.0	-4.8	-23.8	-	-2.1	-12.4	-
confidence	(3.0)	(-4.3)	(-1.6)	(-2.0)	-	(-0.9)	(-3.5)	-
GDP	0.3%*	-0.2%*	0.6%*	0.4%*	0.0%*	0.2%*	0.2%*	-
	(0.6)	(-0.5)	(1.2)	(0.7)	(-0.1)	(0.7)	(0.9)	-
Industrial	32.4%*	-18.4%	-17.3%	-5.3%	-5.4%	-8.5%	-9.6%	-16.6%
production	(5.9)	(-3.7)	(-2.9)	(-1.2)	(-1.3)	(-5.9)	(-3.2)	(-6.9)
Unemployment	0.8	0.2	0.1	-0.8	-0.5	-2.0	-0.4	-2.9
	(2.3)	(0.4)	(0.2)	(-3.6)	(-1.9)	(-6.0)	(-1.4)	(-6.2)

Note: This table shows the results for equation (4-1) where we regress monthly macroeconomic data on the H1 H2 seasonal in equation (4-2) and set $\gamma = 0$. The betas are annualized. T-values based on Newey-West standard errors are presented inside parentheses. The detailed data description is shown in the note below Table 4-2. *Australian consumer inflation, producer inflation and industrial production, Canadian consumer confidence and all GDP data are only available on a quarterly basis.

4.5.3 Does inflation explain the bond seasonal?

Given the results in Table 4-4, we analyze whether consumer price inflation can explain the bond seasonal. For this purpose we use the regression in equation (4-1) with the H1 H2 seasonal for X_t and monthly relative changes in CPI (inflation) for Y_t.[42] The results are reported in Table 4-5.

[42] We also look at the 2-step approach where we first regress excess bond returns on inflation and subsequently test whether the residuals of this regression still exhibit any H1 H2 seasonal. As expected this leads to the same conclusions.

The first two columns report the results for national inflation[43]. These results provide a mixed picture. For the U.S. there is a highly significant loading of -0.91 on inflation with a t-statistic of -3.4 and no longer a significant loading on H1 H2 for 1980-2014. The original H1 H2 return difference of 3.9% with a t-statistic of 2.0 (see Table 4-3 row 'United States' column 'H1 H2') drops to 1.1% with a t-statistic of 0.6 after including inflation. For Germany there is also a significant loading on local inflation but the H1 H2 seasonal is still significant. For the other countries monthly bond returns do not significantly load on inflation and hence the significant loadings (albeit on average smaller) on H1 H2 remain.

The final columns in Table 4-5, however, provide a different pattern. U.S. inflation[44] is a strong explanatory variable for all international bond returns. Most importantly none of the loadings on H1 H2 is significant after controlling for inflation. For the equally weighted portfolio the H1 H2 return difference drops to an insignificant 1.3% (t-statistic 0.9), compared to 2.8% when including national inflation and 3.8% (see Table 4-3) when not including inflation in the regression. Hence these results show that to a large extent seasonality in U.S. inflation is responsible for seasonality in international bond returns.[45,46,47]

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[43] We have no results for Australia as they report inflation only at a quarterly frequency.

[44] We have also analyzed U.S. inflation surprise data from Bloomberg (CPI CHNG Index). Although the actual seasonally adjusted inflation tends to be lower than expected by the panel of analysts in the second half of the year, the surprise data do not have a significant H1 H2 seasonal and surprise data do not have a significant impact on the bond market returns. Surprise data cannot help to explain the seasonal pattern in bond returns.

[45] On a monthly basis the bond return residual of the U.S. and Canada do exhibit a significant exposure to the SAD factor, consistent with the findings of Kamstra, Kramer and Levi (2015). On a quarterly basis the exposure to the SAD factor becomes insignificant. The link between quarterly inflation and quarterly bonds returns is stronger than the link on a monthly basis enabling inflation to explain the bond seasonal pattern even better on a quarterly basis.

[46] To come to our earlier point in Section 4.2.2 on delaying the macroeconomic data by one month: The delayed consumer price inflation cannot explain the bond seasonal. The 1-month delayed non-seasonally adjusted U.S. CPI has a significant but weaker H1 H2 seasonal (the difference between H1 and H2 drops from 3.0% to 1.6%) and its explanatory power for bond market returns is weaker with a t-stat of -1.9 versus -4.5 for the portfolio of all bond markets. This result echoes the findings by Chu, Pittman and Yu (2011) who show that U.S inflation linked bond prices fully reflect the U.S. inflation data by the end of the corresponding month, before the official announcement of the inflation data which is normally about 2 weeks later.

[47] Results are similar using first vintage data for the U.S. CPI from the FRED database of the Federal Reserve Bank of St Louis.

Table 4-5: Explaining the seasonal in bond returns with inflation

	National inflation		U.S. inflation	
	Inflation	**H1 H2**	**Inflation**	**H1 H2**
Australia			-0.47 (-1.6)	1.9% (0.9)
Canada	-0.11 (-0.4)	4.0% (1.9)	-0.69 (-3.0)	2.2% (1.1)
Germany	-0.35 (-2.6)	3.4% (2.5)	-0.90 (-4.8)	0.9% (0.7)
Japan	-0.14 (-1.0)	2.2% (1.7)	-0.45 (-2.2)	1.0% (0.7)
United Kingdom	-0.18 (-0.9)	5.2% (2.3)	-1.04 (-3.4)	2.5% (1.0)
United States	-0.91 (-3.4)	1.1% (0.6)	-0.91 (-3.4)	1.1% (0.6)
EW portfolio	**-0.51** **(-1.7)**	**2.8%** **(1.8)**	**-0.85** **(-4.5)**	**1.3%** **(0.9)**
United States CRSP	-0.14 (-0.8)	0.4% (0.2)	-0.14 (-0.8)	0.4% (0.2)

Note: This table shows the results for equation (4-1) where we regress monthly excess bond returns of the equally weighted portfolio of six countries on Xt, the H1 H2 seasonal in equation (4-2), and Yt, the inflation (percentage monthly change in CPI). The first two columns show the results for national inflation. The next two columns show the results where the U.S. inflation is used for all countries. T-values based on Newey-West standard errors are presented inside parentheses. The detailed description of the bond and macro data is shown in the notes below Table 4-1 and

Table 4-2.

4.5.4 What about other macroeconomic indicators?

We investigate whether other macroeconomic variables can also explain the bond seasonal. Again we first use national data and then U.S. data. We focus on the equally weighted bond portfolio of the six countries[48]. The results are presented in Table 4-6.

[48] Detailed results for the individual bond markets are available upon request.

Table 4-6: Explaining the seasonal in bond returns with macroeconomic data

	National data		**U.S. data**	
	Indicator	**H1 H2**	**Indicator**	**H1 H2**
Consumer price inflation	-0.51	2.8%	-0.85	1.3%
	(-1.7)	(1.8)	(-4.5)	(0.9)
Producer price inflation	-0.56	2.6%	-0.32	2.8%
	(-3.5)	(1.8)	(-3.4)	(2.0)
Consumer confidence	-0.000057	3.8%	-0.000065	3.8%
	(-0.3)	(2.5)	(-0.6)	(2.6)
Producer confidence	-0.000282	4.8%	-0.001163	3.6%
	(-1.2)	(3.2)	(-3.3)	(2.3)
GDP	-1.3	3.7%	-1.1	3.7%
	(-3.0)	(2.7)	(-4.7)	(2.8)
Industrial production	0.00088	3.8%	-0.02707	3.6%
	(0.1)	(2.6)	(-0.9)	(2.3)
Unemployment	0.00343	4.0%	0.00133	4.1%
	(1.8)	(2.7)	(1.1)	(2.7)

Note: This table shows the results for equation (4-1) where we regress monthly excess bond returns of the equally weighted portfolio of six countries on $X_{t,}$ the H1 H2 seasonal in equation (4-2), and Y_t, the monthly non-seasonally adjusted macroeconomic data. The first two columns show the results where the macro data is national. The next two columns show the results where the macro data is based on U.S. data. T-values based on Newey-West standard errors are presented inside parentheses. The detailed description of the bond and macro data is shown in the notes below Table 4-1 and
Table 4-2.

The first two rows of Table 4-6 show the same result for the consumer price inflation as the 'EW portfolio' rows in Table 4-5. For U.S. data the excess bond returns of the EW portfolio significantly load on consumer price inflation but not anymore on the H1 H2 seasonal. For the other macroeconomic indicators, we find that for the national macro data the producer price inflation is the most significant, with a t-statistic of -3.5. This also reduces the H1 H2 loading to 2.6% (from 3.8%) but it remains significant at the 10% significance level with a t-statistic of 1.8[49].

Other macroeconomic indicators are less successful in explaining the seasonal pattern. Both the national and U.S. version of consumer confidence and industrial production have very low explanatory power for monthly excess bond returns. U.S. producer confidence and GDP growth are significantly related to the average bond returns of the six countries. But the absence of a clear seasonal pattern in U.S. producer confidence (see Table 4-4) means it does not materially affect the loading on the H1 H2 seasonal. National unemployment does affect bond returns, but also in this case unemployment lacks a significant seasonal pattern (see

[49] The correlation between CPI and PPI is 64%. In a regression of the bond return on both components CPI remains significant, while PPI become insignificant and no additional H1 H2 return differential is explained. A multiple regression with all the macroeconomic factors does not further explain the H1 H2 return.

Table 4-4).[50] Hence we can conclude that none of the alternatives is able to explain the seasonal pattern in bond returns.

4.5.5 What is causing the seasonal in inflation?

Now that we established that seasonality in bond returns can be largely explained by seasonality in consumer price inflation, the logical follow-up question is: What is causing seasonality in inflation?

To understand why U.S. inflation exhibits a seasonal pattern, we analyze the eight main components of the U.S. CPI: Food and beverages, housing, apparel, transportation, medical care, recreation, education and communication, and other goods and services. Results and the data description are shown in Table 4-7. Five of the eight components show a significant seasonal H1 H2 pattern with the same sign as the total inflation. Education and other goods and services (like tobacco) show a significant opposite pattern with higher inflation in the second half of the year[51].

For the three components with the largest weight, food, housing, and transportation, we also include the three largest sub-components based on December 2014 weights. Fuels and utilities and motor fuel stand out with a very large and significant difference between H1 and H2. This result is consistent with Gorton and Rouwenhorst (2006) who note that heating oil prices are on average higher during the winter months, and gasoline prices increase in the second quarter caused by the yearly summer driving season[52]. A higher demand in the first half of the year for fuels seems a plausible explanation for the seasonal pattern in the price return of the two inflation components.

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[50] Delaying the macroeconomic data by one month to account for a publication lag does not materially change the results.

[51] For education this can be explained the typical yearly increase of tuition fees in August and September when the new educational year usually commences, see McGranahan and Paulson (2006).

[52] The Association for convenience and fuel retailing (NACS) has a detailed explanation on the impact of the summer driving season on gasoline prices related to a typical refinery maintenance period, a larger demand for oil and the mandatory switch to a summer-blend in April, more information can be found on the following website:
http://www.nacsonline.com/YourBusiness/FuelsReports/GasPrices_2013/Pages/Gas-Prices-Spring.aspx

Table 4-7: Sample statistics U.S. inflation components

Component	**Weight**	**Start month**	**End month**	**Jan-Jun (H1)**	**Jul-Dec (H2)**	**T-stat**
Total	100.0	31/1/1952	31/12/2014	4.4%	2.6%	-4.5
Food and beverages	15.3	28/2/1967	31/12/2014	4.7%	3.5%	-2.2
-Food at home	8.4	31/1/1952	31/12/2014	4.5%	2.1%	-3.6
-Away from home	5.8	28/2/1953	31/12/2014	4.0%	4.0%	-0.2
-Alcohol	1.0	31/1/1953	31/12/2014	3.5%	2.4%	-2.6
Housing	42.2	28/2/1967	31/12/2014	5.4%	3.1%	-4.3
-Shelter	32.7	31/1/1953	31/12/2014	4.5%	3.7%	-1.8
-Fuels and utilities	5.3	31/1/1953	31/12/2014	6.9%	0.8%	-6.0
-Furnishings and operations	4.2	28/2/1967	31/12/2014	3.0%	1.5%	-3.4
Apparel	3.3	31/1/1952	31/12/2014	1.0%	2.5%	1.5
Transportation	15.3	31/1/1952	31/12/2014	5.8%	1.0%	-3.6
-New and used motor vehicles	5.7	28/2/1993	31/12/2014	0.3%	0.6%	0.3
-Motor fuel	4.0	31/1/1952	31/12/2014	14.8%	-5.4%	-4.5
-Motor vehicle insurance	2.3	31/1/1952	31/12/2014	4.6%	6.0%	1.5
Medical care	7.7	31/1/1952	31/12/2014	5.8%	4.7%	-3.4
Recreation	5.8	28/2/1993	31/12/2014	2.2%	0.1%	-6.1
Education and communication	7.1	28/2/1993	31/12/2014	0.6%	3.8%	6.3
Other goods and services	3.4	28/2/1967	31/12/2014	4.6%	5.8%	2.5

Note: Sample statistics U.S. CPI-U and its eight components, of the three largest components the three largest sub components are also shown. The weight is the December 2014 CPI-U weight. The source of the data is the bureau of labor statistics of the U.S. department of labor (http://www.bls.gov/cpi/data.htm). The t-values are based on Newey-West standard errors for the β in the regression in equation (4-1) with
$\gamma = 0$ and X_t based on equation (4-2).

Can the strong seasonal in fuels and utilities and motor fuel, currently good for about 10% weight in the CPI, explain the seasonal pattern in international bond returns? To test this we first regress the total inflation return on these two components. The regression provides a fitted value based on these two components and a residual inflation that is uncorrelated with these two components. The fitted value can be interpreted as the sum of the two components weighted with the betas on the total inflation. Subsequently we regress the bond returns on the fitted value and we regress the bond returns on the residual inflation. If the fuel components are causing the H1 H2 seasonal in bond returns we expect that the fitted value can explain the H1 H2 seasonal, and that residual inflation cannot explain the H1 H2 seasonal in bond returns[53].

[53] We also tested for seasonality in the fitted values and residual inflation. As expected the fitted values display a strong seasonal pattern with a t-stat of -6.3, whereas residual inflation has an insignificant H1 H2 seasonal with a t-stat of -1.0.

Table 4-8: Explaining the seasonal in bond returns with inflation components

	Residual inflation		Two components inflation	
	Inflation	**H1 H2**	**Inflation**	**H1 H2**
Australia	-0.09	3.4%	-0.47	2.0%
	(-0.2)	(1.7)	(-1.8)	(1.0)
Canada	-0.21	4.3%	-0.66	2.5%
	(-0.6)	(2.1)	(-2.7)	(1.2)
Germany	-0.65	3.4%	-0.87	1.4%
	(-2.4)	(2.3)	(-4.0)	(1.2)
Japan	-0.42	2.2%	-0.32	1.5%
	(-1.5)	(1.4)	(-1.8)	(1.1)
United Kingdom	-0.48	5.5%	-1.20	2.5%
	(-1.3)	(2.2)	(-3.8)	(1.1)
United States	-0.64	3.7%	-0.90	1.5%
	(-1.6)	(1.7)	(-3.0)	(0.8)
EW portfolio	-0.62	3.6%	-0.82	1.7%
	(-2.1)	(2.2)	(-3.8)	(1.2)
United States CRSP	-0.42	0.0%	-0.27	0.6%
	(-1.7)	(0.0)	(-0.9)	(0.3)

Note: This table shows the results for equation (4-1) where we regress monthly excess bond returns on $X_{t,}$ the H1 H2 seasonal in equation (4-2), and Y_t. For the latter we first regress total U.S. inflation (non-seasonally adjusted CPI) on two of its components: Fuels and utilities, and Motor fuel. For Y_t we then either use the residuals of this regression, 'Residual inflation' or the fitted values of the regression, 'Fuel components'. T-values based on Newey-West standard errors are presented inside parentheses. The detailed description of the bond data and U.S. inflation components data is shown in the notes below Table 4-1 and Table 4-7.

The results in Table 4-8 show that the fuel components are indeed causing the H1 H2 seasonal. In the second column we see that for the equally weighted portfolio the original annualized return difference between H1 and H2 is slightly reduced from 3.8% to a still significant 3.6%. In the final column we see that the fitted values based on the two fuel components reduce the loading on H1 H2 to an insignificant 1.7%. The loadings on the residual inflation are insignificant except for Germany and the equally weighted portfolio. On the other hand the loadings on the fitted values based on the weighted sum of the fuel components are generally highly significant. Hence monthly bond returns are mostly influenced by these fuel components, which lends support that it is the (reverse) H1 H2 seasonal in fuel costs that drives the seasonality in bond returns.

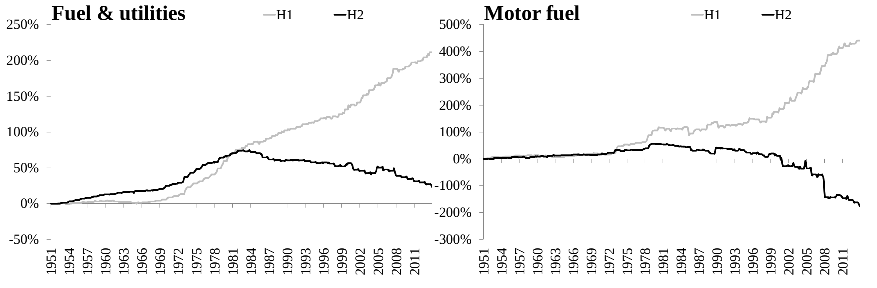
4.5.6 Why no seasonal from 1952 - 1979?

The last row of Table 4-3 shows that the U.S. bond market does not exhibit a significant seasonal return difference from 1952 – 1979. The last column of Table 4-4 shows that consumer inflation also does not show a significant seasonal difference for the same period.

Industrial production and unemployment do show a significant seasonal difference with a similar sign as in the period from 1980 – 2014, but a regression of the bond returns on these indicators does not lead to a significant seasonal in the residual bond returns from 1952 - 1979.

Figure 4-2 shows that the difference between the first and second half of the year started to deviate since the end of the seventies for both fuel components. The figure confirms that the H1 H2 seasonal effect is not significant in the period from 1952 – 1979. The figure also visually confirms the stable and significant difference between in the first half and the second half of the year since the end of the seventies. The price of oil was directly pegged to gold and the U.S. dollar before 1971. After the breakdown of the Bretton Woods system in 1971 and the two oil crises in 1973 and 1979, the oil price started to change on a monthly basis since 1979. The absence of a free floating oil price in the period from 1952 to 1979 is a probable explanation for the absence of the seasonal pattern in the two fuel components of the consumer price inflation.

Figure 4-2: cumulative H1 and H2 return fuel and utilities and motor fuel components



Note: The figure shows the cumulative price returns in the first half and the second half of the year for the fuels and utilities and the motor fuels components of the U.S. CPI.

4.6 Inflation-linked bonds

So far we have studied nominal bonds. We find that nominal bond returns have a significant seasonal pattern in returns that can be explained by inflation. In this Section we look at inflation-linked bonds (ILBs). Because the coupons and face value depend directly on *national* not-seasonally adjusted inflation, we expect to see no seasonal pattern in U.S. ILBs. We also expect to see less seasonality in the ILB returns of the other five countries. But because the seasonality in the bond returns is driven by U.S. inflation, which in turn is driven by fuel costs in U.S. Dollars, ILBs of the other five countries may also have a seasonal return pattern like nominal bonds.

Table 4-9: Sample statistics inflation linked bonds

Country	Start month	End month	Excess ILB return	Excess nom return
Australia	31/01/1997	31/12/2014	2.7%	2.6%
Canada	31/01/1997	31/12/2014	4.8%	5.1%
Germany	30/04/2006	31/12/2014	2.3%	3.1%
Japan	30/04/2004	31/12/2014	2.2%	1.8%
United Kingdom	30/06/1981	31/12/2014	0.9%	3.1%
United States	31/03/1997	31/12/2014	3.3%	3.6%
EW portfolio			0.6%	2.9%

Note: the excess bond return is the annualized return of all government bonds included in the Barclays government bond indices. The excess return is the total return minus the cash return of a 1-month Eurocurrency deposit from Reuters. Both inflation linked bond data and maturity-matched nominal bond data are from Barclays and cover the same data period for each country.

ILB data have less history. An overview is provided in Table 4-9. Given the shorter sample period we should first check whether the nominal bonds still exhibit a seasonal pattern over the shorter sample period, and that U.S. CPI largely explains this seasonal pattern. Subsequently we look at seasonality in ILB returns. If there is seasonality in the ILB returns, we can test whether it is also caused by U.S. inflation.

The results in Table 4-10 show in the right panel that despite the reduced sample size shown in Table 4-9 there are still clear signs of a significant H1 H2 seasonal for nominal bonds. These are the *italic* numbers in column 4 of Table 4-10. For the equally weighted portfolio the annualized return difference between H1 and H2 is equal to 5.7%, which is significant with a t-statistic of 2.0. In the final two columns we see that also for this subsample U.S. inflation has a significant impact on international bond returns and explains the seasonal pattern in these returns. For the equally weighted portfolio the return difference between H1 and H2 drops to 2.2% with a t-statistic of 0.7.

In the left panel of Table 4-10 the results for inflation linked bonds are presented. The first column (numbers in *italic*) shows that only the returns of U.K. ILBs have a significant H1 H2 seasonal pattern. The return difference is 4.7% per annum with a t-statistic of 2.0.

U.S. inflation does have a significant impact on U.K. bond returns with a t-statistic of -1.8. This reduces the H1 H2 difference to 2.1% with a t-statistic of 0.8.

Table 4-10: Seasonal tests on inflation linked bond returns

	Inflation linked bonds			Nominal bonds		
	H1 H2	Inflation	H1 H2	*H1 H2*	Inflation	H1 H2
Australia	*1.2%*	-0.2	0.4%	*4.4%*	-0.7	1.3%
	(0.5)	(-0.5)	(0.2)	*(1.5)*	(-2.2)	(0.4)
Canada	*-0.1%*	0.5	1.9%	*5.7%*	-1.2	0.8%
	(0.0)	(1.1)	(0.6)	*(1.8)*	(-3.0)	(0.2)
Germany	*3.0%*	-0.2	1.8%	*5.3%*	-0.8	0.6%
	(1.2)	(-0.5)	(0.7)	*(1.8)*	(-2.9)	(0.2)
Japan	*-0.9%*	0.7	2.7%	*3.2%*	-0.2	2.0%
	(-0.3)	(1.4)	(1.1)	*(1.9)*	(-1.3)	(0.9)
United Kingdom	*4.7%*	-0.9	2.1%	*8.0%*	-1.6	3.6%
	(2.0)	(-1.8)	(0.8)	*(2.7)*	(-3.7)	(1.1)
United States	*-1.0%*	0.4	0.5%	*5.7%*	-0.9	1.7%
	(-0.4)	(1.0)	(0.2)	*(2.0)*	(-1.8)	(0.5)
EW portfolio	*2.3%*	-0.6	0.5%	*5.7%*	-1.3	2.2%
	(1.2)	(-1.5)	(0.2)	*(2.0)*	(-3.2)	(0.7)

Note: This table shows the results for equation (4-1) where we regress monthly excess inflation-linked bond returns (left panel) or monthly excess nominal comparator bond returns (right panel) on X_t, the H1 H2 seasonal in equation (4-2), and Y_t, the monthly non-seasonally U.S. inflation. H1 H2 is a dummy that takes on the value of 1 for July to December and 0 otherwise. In the first and fourth columns the results are shown when X is based on the H1 H2 dummy alone, the second and third columns and the fifth and sixth columns show the results when X is based in the inflation return and the H1 H2 dummy. T-values based on Newey-West standard errors are presented inside parentheses. The detailed data description is shown in the note below Table 4-9.

Hence inflation-linked bonds have no seasonal pattern except for the U.K. This makes sense because both the denominator (discount rates) and nominator (inflation-adjusted coupons and face value) will move in the same direction in case inflation (unexpectedly) changes. Hence, there is a mitigating effect which is absent for nominal bonds where only the denominator will respond to unexpected inflation changes. The analysis on inflation linked bonds confirms the earlier conclusions that the seasonal effect in inflation is mainly responsible for the seasonal effect in nominal government bond returns.

4.7 Conclusion

We document a new seasonal pattern in international bond returns. On average nominal bond returns are 4.2% per annum in the second half of the year compared to 0.4% in the first half of the year. At the same time, non-seasonally adjusted inflation is on average 2.1% higher in the first half of the year. Hence, a logical explanation for the bond seasonal is that bond investors do not properly take into account seasonality in inflation, perhaps because current practice is to focus on seasonally adjusted economic figures. Therefore the bond price is on average too high at the start of the year and too low in the middle of the year. The bond price drops on average in the first half of the year when the inflation is higher and the price rises in the second half of the year when inflation is lower.

We do not always find a significant time-series relationship between a country's bond returns and local inflation. But we do find a strong relation between U.S. inflation and international bond returns. Regressing monthly bond returns on the H1 H2 seasonal and U.S. inflation shows that U.S. inflation can explain the seasonal pattern in international bond returns.

The seasonal pattern in U.S. inflation is primarily caused by a similar seasonal pattern in fuel prices. The fuel price increase in the first half of the year is likely caused by more demand for heating oil during the winter months and more demand for gasoline caused by the U.S. summer driving season.

5. Forecasting sovereign default risk with Merton’s model

Based on Duyvesteyn and Martens (2015), published in the Journal of Fixed Income. We thank Erwin Hazeveld for excellent research assistance. We are grateful for the useful comments from Bastiaan van Eerden, Dale Gray, Lars Norden (discussant), Evangelos Vagenas-Nanos (discussant), and seminar participants at the 16th (2013) Annual Conference of the Swiss Society for Financial Market Research in Zurich, the 34th (2014) International Symposium on Forecasting in Rotterdam, and the Erasmus University Rotterdam.

5.1 Introduction

In Merton's (1974) structural model, the equity of a firm is modeled as a call option on the market value of the assets with a strike price equal to the debt of the firm. As such, the model provides a theoretical relationship between equity and corporate bond prices. Gray et al. (2007) adapt Merton's model to apply it at the aggregate level to the sovereign balance sheet. The basic idea is that the local currency debt can be seen as the equity of a sovereign given the ability of a country to create new money. The foreign currency debt is similar to a corporation's debt because a country cannot easily create more foreign currency and practice shows that foreign currency debt is senior to local currency liabilities (Sims, 1999).

Several studies provide an empirical analysis of the sovereign structural model. Gray and Jones (2006), Gray et al. (2007), Keller et al. (2007) and Gapen et al. (2008) test the model on a combined 13 emerging countries. In general these studies find that the model outcomes make sense in that there is a large correlation between model-implied spreads (or the distance to defaults) and market spreads. Kalteier and Posch (2013) use market Credit Default Swap (CDS) data of 14 developed markets to calibrate the model parameters. They find that spreads of higher leveraged countries react more to global equity markets, whereas spreads of less leveraged countries react more to political stability.

In this study we focus on dynamics in spreads that are implied by the sovereign structural model. How long does it take before model implied spread changes and changes in other model outcomes are incorporated into the CDS market? This is different from what existing studies do. For example, Gapen et al. (2008) find a –83 percent correlation between distance-to-default and CDS spreads for 12 emerging countries. We, however, only find a correlation of –9 percent between 1-month *changes* in distance to defaults and 1-month *changes* in CDS spreads for 14 emerging countries. The correlation rises to –20 percent when comparing 3-month changes instead of 1-month changes. Hence, this is a clear indication that the CDS market is only slowly adapting to changes in the creditworthiness of a country picked up by the sovereign structural model. This is further underscored by our finding that past changes in the distance to default can predict future changes in CDS spreads. The predictive power is significant both statistically and economically.

One possible explanation for the found inefficiency in CDS markets is that the structural model outcomes are invisible to market participants. So what about the inputs? In the sovereign structural model we need to express the local currency liabilities of a sovereign in U.S. Dollars. Hence there is an important role in the model for both exchange rates and exchange rate volatility. Of course exchange rate returns are directly visible in the market so that should not cause predictive ability. Indeed we do find a strong contemporaneous correlation of about 50 percent between exchange rate returns and changes in CDS spreads, regardless of using the 1-month or 3-month sampling frequency. And indeed we do not find any predictability from exchange rate returns to changes in CDS spreads.

However, exchange rate volatility and the interaction with assets and debt in the sovereign structural model are not visible to market participants. In fact we find that model implied spread changes, changes in the probability of default and distance to default can all predict changes in CDS spreads. Even changes in exchange rate volatilities predict changes in CDS spreads. These results echo those of Bharath and Shumway (2008) for corporations. They show that the Merton distance to default measure can predict the actual default probability[54].

[54] For corporations Avramov et al. (2007) and Zhang et al. (2009) find a significant contemporaneous correlation between changes in equity volatility and changes in CDS spreads. But these studies do not investigate whether changes in equity volatility predict changes in CDS spreads. We also find a significant contemporaneous correlation between changes in exchange rate volatility and changes in CDS spreads. Carr and Wu (2007) find that CDS spreads of Mexico and Brazil co-vary with their respective currency option implied volatilities. They argue that the credit quality of a country is linked to the volatility of the currency because they are both positively linked to a country specific risk factor. The structural model provides such a link through the market value of the country's assets: A rise in exchange rate volatility will reduce the distance to default and hence increase the credit risk.

There is however also an important difference with the findings for corporations. Gebhardt et al. (2005b) find that equity returns predict corporate bond returns of the same firm. They attribute this finding to the debt market being less informational efficient than the equity market, among other factors due to stocks being more actively traded than corporate bonds. Hilscher et al. (2014) report that the equity market is also more efficient than the CDS market. The CDS market is more efficient than the corporate bond market according to Blanco, Brennan and Marsh (2005). The equity in the sovereign structural model is equivalent to the local currency debt expressed in dollars. Hence ‘equity returns’ depend on local currency debt returns and exchange rate returns. These returns, however, cannot predict emerging sovereign debt issued in dollars or changes in CDS spreads.

The remainder of this chapter is as follows. Section 5.2 describes the structural model for sovereign countries. Section 5.3 provides details on the data. The results are presented in Section 5.4. Finally, Section 5.5 concludes.

5.2 Sovereign structural model and testable implications

Gray et al. (2007) adapt Merton's (1974) model for corporations to make it applicable to sovereign countries. They start with formulating the combined balance sheet of the government and the central bank, see Table 5-1. The assets of the sovereign country consist of four items: (i) Foreign currency reserves including actual reserves and contingent reserves from international financial institutions such as the IMF and other governments; (ii) The net fiscal assets which equal the government's budget surplus or deficit on taxes and revenues minus expenditures; (iii) Credit to other sectors such as the corporate, financial and household sector; and (iv) Other public assets such as the equity of public enterprises.

Table 5-1: Combined balance sheet of the government and the central bank

Assets	**Liabilities**
Foreign reserves	Guarantees
Net fiscal assets	Foreign currency debt
Credit to other sectors	Local currency debt
Other public assets	Monetary base

Note: the equity of the country is represented by the sum of the local currency debt and the monetary base which we call local currency liabilities (LCL). The debt of the country is represented by the foreign currency debt. Financial guarantees are hard to measure and are therefore not explicitly included in the analysis. Implicitly the guarantees are subtracted from the asset side of the balance sheet, similar to Bodie and Brière (2014).

The liabilities also contain four items: (i) (Implicit) financial guarantees to the so-called too-big-to-fail entities as we have seen in the government support and bailouts of large financial institutions during the financial crisis of 2008 to 2012; (ii) Foreign currency debt which is issued by the public sector and denominated in a foreign currency; (iii) Local currency debt which is issued by the public sector and denominated in the local currency; and (iv) The monetary base which is related to the money supply in the country's economy. The monetary base consists of the commercial banks' reserves maintained in accounts of the local central bank plus the total currency circulating in the public.

Gray et al. (2007) argue that the balance sheet of the country’s public sector and the balance sheet of a corporation show important similarities in both structure and priority of the claims. Local currency debt and the monetary base are called local currency liabilities and have certain features similar to the equity of a corporation. The public sector controls the money supply and therefore they have the option to repay their local currency debt by creating more domestic currency. However, expansion of the money supply can cause inflation, which lowers the real value of the payments to the local currency debt holders. This is similar to equity of corporations because excessive issuance of shares dilutes existing holders’ claims and reduces the price per share on the balance sheet of a corporation.

The foreign currency debt is analogous to the risky debt of a corporation because here the public sector cannot easily create more foreign currency since excessively creating domestic currency will lower the demand of the domestic currency and hence depreciate the foreign exchange rates. Moreover, Sims (1999) considers foreign currency debt to be senior to local currency liabilities because in stress situations most governments prefer to inflate local currency debt instead of defaulting on foreign currency debt. Finally, financial guarantees are hard to measure and are therefore not explicitly included in the analysis. Implicitly the guarantees are subtracted from the asset side of the balance sheet, similar to Bodie and Brière (2014).

The sovereign Contingent Claims Approach (CCA) model is similar to the corporate CCA model with local currency liabilities modeled as an implicit call option on the country’s assets and foreign currency debt modeled as a distress barrier minus an implicit put option on the country’s assets. The distress barrier is based on the book value of the foreign currency debt using the empirical rule that it is equal to the short-term debt plus fifty percent of the long-term debt.

An important feature of the sovereign CCA model is that the balance sheet items are measured in one currency unit, commonly a "hard" currency such as the U.S. Dollar or the Euro, with the corresponding risk-free interest rate. This means that the local currency debt and the monetary base are converted to the U.S. dollar using the market price of the foreign exchange rate.

Essentially, the sovereign CCA model is the same as the corporate CCA model. We get two equations with two unknowns, the market value of the assets (A) and the volatility of the market value of the assets (σ_A). The market value of the equity of the corporation is replaced by the market value of the local currency liabilities (LCL), the equity volatility by the volatility in LCL (σ_{LCL}), and the distress barrier (B_f) is based on the book value of the foreign currency debt. We then get the following two equations:

$$LCL = AN(d_1) - B_f e^{-rT} N(d_2) \qquad (5\text{-}1)$$

$$\sigma_{LCL} = \frac{A}{LCL}\sigma_A N(d_1) \qquad (5\text{-}2)$$

where

$$d_1 = \frac{\ln(A/B_f) + (r + \frac{1}{2}\sigma_A{}^2)T}{\sigma_A\sqrt{T}}, \; d_2 = d_1 - \sigma_A\sqrt{T},$$

r is the risk-free rate of interest and $N(.)$ is the cumulative normal distribution function. To test the model we analyze the contemporaneous correlation between the model implied credit spread and 5-year CDS spread changes. We also use the model spread changes to predict CDS returns in a trading strategy. Ang and Longstaff (2013) argue that the CDS spread is a more direct measure of sovereign credit risk than a spread based on government bonds. Sovereign debt spreads contain more noise from other factors like changes in the supply of the underlying bond and illiquidity effects in sovereign debt prices. To maintain consistency for the maturity of the CDS contracts we set T to be equal to 5 in the model.

The foreign exchange rate is indirectly an important input parameter because it largely influences the value and volatility of the assets and the local currency liabilities. All input parameters are directly observable except for the market value and volatility of the assets of the sovereign which, therefore, can be estimated from equations (5-1) and (5-2).

There are a few important risk measures that can be derived from the model output. First, the risk-neutral probability of default of the sovereign is equal to $N(-d_2)$. Second, the distance to default is d_2. Finally, to find the model-implied credit spread we first need to find the current value of the risky debt with promised payments B_f. The value of the risky debt at time T is exactly the same as B_f minus the payoff of a put option on the assets, with exercise price equal to B_f. Since the liabilities of the sovereign are equal to the assets of the sovereign, we could also derive the value of the risky debt D_f by subtracting the value of the local currency liabilities from the assets:

$$D_f = A - LCL$$

Then the yield-to-maturity of the risky debt is

$$y = \frac{\ln(B_f / D_f)}{T}$$

and the model-implied credit spread is equal to the difference between this yield and the risk-free rate, r,

$$s = y - r \qquad (5\text{-}3)$$

In this study we are interested how fast information from the sovereign CCA model is incorporated in CDS spreads. We formulate two testable implications of the sovereign structural model:

Hypothesis 1: model spreads are correlated with market spreads

The changes of the sovereign credit spread based on the structural model are empirically correlated to the changes of sovereign market spreads during the same time period.

Hypothesis 2: Estimated model spreads contain useful information about future market spread dynamics

The model spread may contain information that is not priced in yet by the sovereign market spread. Using the model spread dynamics we may be able to predict future changes of the market spreads.

In the analyses we will not only focus on changes model spreads but also on changes in the other model outputs, the distance-to-default and the probability of default. We will also compare changes in credit spreads with changes in exchange rate returns. The latter is an input in the sovereign CCA model.

5.3 Data

We apply the model of Gray et al. (2007) to emerging markets. There are several reasons why the sovereign CCA model is not applicable to developed countries. First, developed countries have direct access to large and liquid international markets to issue debt in their domestic currency and that is why developed countries have no or only a small amount of foreign currency debt. Therefore, the foreign distress barrier of most developed countries will be zero. Moreover, countries from the Economic and Monetary Union (EMU) have very limited control over the money supply of the European Central Bank (ECB) and therefore the analogy between local currency liabilities and equity disappears. This leads us to the conclusion that emerging countries with a considerable amount of foreign currency debt are the best test cases to apply the sovereign CCA model to.

The empirical analysis includes fourteen emerging market (EM) countries: Argentina, Brazil, Chile, Colombia, Hungary, Indonesia, Malaysia, Mexico, Peru, the Philippines, Poland, South Africa, South Korea and Turkey. This choice is based on the availability of local and external debt as covered by JP Morgan and Barclays indices and the liquidity and nature of the emerging currencies and credit default swap (CDS) contracts: a country enters the dataset when its currency is floating and when the CDS contract is liquid. CDS liquidity is based on the inclusion of countries in the Markit CDX emerging market index. The CDX index is a weighted index of country CDS contracts and rolls semi-annually in March and September. A wide dealer and industry support allows for significant liquidity in all market conditions and the CDX index is accepted as a key benchmark of the overall market credit risk in emerging markets. We use the same dates as De Zwart et al. (2009) to determine when a currency becomes floating. Since 2009 no new relevant emerging currencies became floating[55].

The six countries China, Czech Republic, Egypt, India, Slovakia and Thailand do have outstanding local and external debt, but have not been included in the historical composition of the CDX index. The four countries Bulgaria, Venezuela, Panama, and

[55] Perhaps an exception could have been made for Russia, which according to the Central Bank of the Russian Federation (BIS Papers No 57, http://www.bis.org/publ/bppdf/bispap57u.pdf) has gradually moved toward a floating currency. Including Russia from March 2009 onwards does not materially affect our results and conclusions.

Ukraine which are or have been included in the CDX index are not included in our research because of not having local or external debt listed in the JP Morgan and Barclays indices. Romania was recently added to the local debt index, but is no longer included in the CDX index. Table 5-2 shows the data availability for the 14 countries included in the analysis.

Table 5-2: Data availability and regions

	First month	Last month	Region
Argentina	Sep 2005	Jun 2014	Latam
Brazil	May 2002	Jun 2014	Latam
Chile	Mar 2014	Jun 2014	Latam
Colombia	Jan 2003	Jun 2014	Latam
Hungary	Mar 2009	Mar 2013	EMEA
Indonesia	Mar 2006	Jun 2014	Asia
Malaysia	Jul 2005	Jun 2014	Asia
Mexico	Jan 2002	Jun 2014	Latam
Peru	Oct 2006	Jun 2014	Latam
the Philippines	Oct 2010	Jun 2014	Asia
Poland	Feb 2004	Sep 2004	EMEA
South Africa	Dec 2001	Jun 2014	EMEA
South Korea	Feb 2002	Apr 2004	Asia
Turkey	Apr 2004	Jun 2014	EMEA

Note: the data availability is based on the availability of local debt, external debt, the monetary base, the composition of the CDX index and whether the country has a fully floating FX rate. Hungary is dropped from the CDX index in April 2013, Poland is dropped from the CDX index in October 2004 and South Korea is dropped from the JP Morgan EMBI global index in May 2004 (and in March 2006 also from the CDX index).

We obtain daily data from Bloomberg for the period from December 2001 to June 2014 on exchange rates, 5-year CDS spreads and U.S. 5-year government bond yields for the risk free discount factor in the model, assuming a 5-year horizon to match the CDS maturity. We collect data on the market value of local currency bonds from the JP Morgan GBI EM broad index (broadest local currency index with longest data history) and the Barclays Emerging Markets Inflation Linked Bond Index for respectively the nominal and inflation-linked bonds. The inclusion of inflation linked bonds is important. According to Swinkels (2012) less than 1% of the emerging market local currency bonds were inflation linked in 2003, but that percentage increased to more than 14% in 2011. Local currency bond data for South Korea are obtained from the JP Morgan GBI broad index for developed markets[56]. The

[56] According to the World Bank classification South Korea is considered to be a developed market. The major index providers JP Morgan and FTSE therefore decided to include the country in their developed markets index universe for respectively bonds and equities. Due to accessibility issues and in particular a lack of full currency

local currency liabilities, *LCL,* are the sum of the market values of the local currency nominal and inflation-linked debt. For all countries we express these local liabilities in U.S. dollars. In addition we add the size of the monetary base (M0) based on IMF data[57]. The sum of the LCL and M0 act in the same way as the market value of the equity does in the application of the Merton model for corporations.

For the default barrier, B_f, we use the market value of the foreign currency debt. We aggregate the debt in USD and EUR as included in the JP Morgan EMBI global and the Euro EMBIG indices[58]. B_f is also expressed in U.S. Dollar terms.

The final input parameter is the volatility of *LCL*. The volatility is defined as the standard deviation of daily returns of *LCL* over the past three months giving it both some stability but also being able to timely react to new information. Note that this volatility will depend on the volatility of the market value of the local debt and the exchange rate volatility. As one would expect the main driver of the volatility is the exchange rate volatility. One discomforting aspect of the volatility of *LCL* is that there are jumps due to the redemption or issuance of new local debt. For computing the volatility of *LCL* we try to remove such jumps when they are likely connected to redemptions or new issuance by excluding daily changes of *LCL* (in local currency) larger than 5% removing about 0.6% of all observations. We will analyze the sensitivity of our results to the chosen threshold level of 5%.

Table 5-3 shows the average and standard deviation of the CDS spreads, the amount of *LCL*, B_f and the standard deviation of the exchange rates (FX volatility). The average CDS spread of the fourteen countries is 270 basis points, with the Latin American region having the largest spreads and the Asian region the smallest. Latin America is also the region with on average the relatively largest size of hard currency debt at USD 19.5 billion and the lowest ratio of local divided by hard currency debt of 4.8. The EMEA region has the largest average currency volatility at 12.0%, compared to 8.8% for Latin-America and 8.6% for Asia. EMEA also has the largest monetary base of 47.1 billion USD on average.

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convertibility two other major index providers Barclays and MSCI consider South Korea as emerging market for respectively bonds and equities.

[57] For Argentina and South Korea we use data from the local central bank, and for Peru and the Philippines we use M1 instead of M0 since we could not obtain M0 data from Bloomberg. In addition to the monetary base M1 also includes demand deposits, but not savings accounts.

[58] Book values of the Euro EMBIG country indices are not available, and we use the market value instead. We checked the robustness of results using the book value of the EMBI global mixed with the market value of the Euro EMBIG, results are robust and somewhat stronger. We use the market value of the EMBI global and the Euro EMBIG indices in the remainder of the paper.

Table 5-3: Average and standard deviation spreads, debt and FX volatility

		Latam	EMEA	Asia	Portfolio
CDS	Avg	375.5	228.9	153.9	270.3
spread (bp)	St dev	438.0	156.6	96.2	302.3
LCL	Avg	110.7	100.5	91.9	101.5
bln USD	St dev	141.2	65.4	75.5	93.7
B_f	Avg	19.5	10.3	8.2	12.2
bln USD	St dev	17.0	10.4	6.3	12.0
Ratio LCL / B_f	Avg	4.8	17.9	14.4	12.6
bln USD	St dev	2.5	13.8	20.2	14.1
M0	Avg	39.2	47.1	30.3	39.8
bln USD	St dev	53.2	49.0	10.7	41.9
	Avg	8.8%	12.0%	8.6%	9.9%
FX volatility	St dev	3.6%	4.4%	4.1%	4.2%

Note: Sample averages and standard deviations CDS spread (basis points), local currency liabilities in bln USD (*LCL*), default barrier in bln USD (B_f), the ratio between LCL and B_f, monetary base in bln USD (M0) and the annualized FX volatility from December 2001 - June 2014. The final column is the equal weighted average of the fourteen countries. Latam (Latin America) is the equal weighted portfolio of Argentina, Brazil, Chile, Colombia, Mexico and Peru. EMEA includes Hungary, Poland, South-Africa and Turkey. Asia includes Indonesia, Malaysia, The Philippines and South-Korea.

5.4 Testing the implications of the sovereign structural model

In Section 5.4.1 we report on the contemporaneous correlations between CDS spread changes and changes in variables based on the structural model. The outcomes of various trading strategies based on the structural model are presented in Section 5.4.2. We prefer using trading strategies over predictive regressions following the arguments of Thornton and Valente (2012)[59]. Moreover applying a standard regression approach is not straightforward for the changing composition of our dataset with countries entering and leaving over time.

5.4.1 Correlations CDS spread changes and structural variables

We first analyze the correlations between 1-month and 3-month changes in model inputs and outputs with 1-month and 3-month changes in market CDS spreads. By looking at two different frequencies we can observe whether input for and information from the sovereign

[59] Thornton and Valente show that the Cochrane and Piazzesi's (2005) forward rates factor, found to be successful in in-sample predictive regressions for excess bond returns, actually has no economic value in a true real-time exercise.

CCA model is immediately incorporated in market CDS spreads or with a delay. A similar correlation at the two frequencies suggests an immediate response of market CDS spreads, whereas a higher correlation at the 3-month frequency suggests market CDS spreads only slowly adopt information from the CCA model. The results are shown in Table 5-4. As expected, the changes in the distance-to-default, d_2 from equation (5-1), are negatively correlated with the changes in CDS spreads. A larger distance-to-default implies a lower probability of default and hence a lower CDS spread. As expected the changes in the model-implied probability of default, $N(-d_2)$, are positively correlated with changes in CDS spreads. The positive correlations between changes in exchange rate volatility and *LCL* volatility (of the *LCL* expressed in local currency) with CDS spreads are also logical as an increase in either the currency or the interest rate volatility makes it more likely the distance-to-default can be bridged and hence increases the probability of default, all else equal. The negative correlation between changes of the local debt and CDS spreads also makes sense given the lower implied probability of default for a higher level of the local debt. Finally, the positive correlation between CDS spreads and FX returns (measured as local currency units expressed in U.S. dollars) is as expected given that a weaker currency is linked to a higher CDS spread.

Looking at Panel A and B in Table 5-4 it is clear that correlations are rising when increasing the window from 1 to 3 months implying noise in the shorter windows and possibly a delayed response of either model-variables or market CDS spreads. We will investigate the latter in the next section. We get the highest positive correlations at 51 and 33 percent between and 3-month changes in CDS spreads and respectively the 3-month spot return of the exchange rates and the changes in exchange rate volatility. Hence a substantial amount of the change in CDS spreads can be explained by changes in the level and volatility of exchanges rates. The level of the correlation between CDS spread changes and FX volatility changes is similar to the 36 percent correlation found in Avramov et al. (2007) between changes in corporate bond spreads and changes in idiosyncratic equity volatility. The 3-month correlation between changes of the distance to default and the CDS spread is also -20% and significant. On a one month horizon the correlation is insignificant though, indicating a potential delayed response of either the distance to default or the market CDS spread. The correlations with the model spread, the model implied probability of default and the change in the local current debt volatility are not significantly different from zero for both the 1-month and 3-month changes for the portfolio of all countries. We conclude that the first hypothesis that model spreads are correlated with market spreads must be rejected. Perhaps the information in the model spread is able to forecast the market spread. We will investigate that question in the next section.

Table 5-4: Correlations of CDS spread changes with model inputs and outputs

	Latam	EMEA	Asia	Portfolio
Panel A: 1-month changes				
Spread	-1%	1%	3%	0%
N(-d_2)	0%	2%	3%	1%
d_2	-12%	-10%	-5%	-9%
σ_{FX}	21%**	21%**	20%**	20%**
FX	49%***	57%***	49%***	49%***
σ_{Debt}	8%	-2%	5%	5%
Local debt	-22%***	-10%	-4%	-15%*
Panel A: 3-month changes				
Spread	9%	9%	14%*	10%
N(-d_2)	12%	11%	15%*	12%
d_2	-18%**	-31%***	-20%**	-20%**
σ_{FX}	30%***	37%***	38%***	33%***
FX	50%***	60%***	46%***	51%***
σ_{Debt}	13%	15%*	13%	13%
Local debt	-30%***	-10%	-2%	-20%**

Note: Correlations between the relative change in 5-year CDS spreads and (i) the change in the model-implied spread from equation (5-3); (ii) the change in the model-implied probability of default, N(-d_2); (iii) the change in the model-implied distance-to-default, d_2; (iv) the change in the exchange rate volatility, σ_{FX}; (v) FX, the spot return of local currency units expressed in U.S. dollars; (vi) the change in the LCL volatility expressed in the local currency, σ_{Debt}; (vii) and Local debt, the relative change in the value of the local currency liabilities expressed in local currency. In the upper panel we look at 1-month changes, in the lower panel at 3-month changes. Latam is short for Latin America, and represents the equal weighted portfolio of Argentina, Brazil, Chile, Colombia, Mexico and Peru. EMEA includes Hungary, Poland, South-Africa and Turkey. Asia includes Indonesia, Malaysia, The Philippines and South-Korea. The sample period is December 2001 to June 2014 resulting in 151 monthly observations. Overlapping data are used for 3-month changes, every time shifting time by one month. The 1%, 5% and 10% significance levels the correlations are denoted by ***, ** and *. The test is based on the standard significance test for correlation $Test = \frac{r}{\sqrt{(1-r^2)(n-2)}}$, where r is the correlation and n is the number of observations. The significance of the test depends on the t-distribution with $n-2$ degrees of freedom.

5.4.2 Trading strategies

Analogous to the analysis of Gebhardt et al. (2005b) for corporations we test whether the Merton model can *forecast* CDS spread changes for countries. The test comprises two different trading strategies.

5.4.2.A Relative strategies

In the trading strategies we will predict the relative movement of the CDS spreads for each pair of countries. Reason for a relative strategy is that we want to benefit from the dynamics predicted by the Gray et al. (2007) model while hedging against a market-wide spread widening or tightening as a consequence of global (event) risk (see Pan and Singleton, 2008) or global risk appetite or changing global economic conditions (see Baek et al., 2005; Weigel et al., 2006; and Longstaff et al., 2011). The correlation between monthly changes of CDS spreads between countries is 59% on average and positive for all regions[60].

We use 3-month changes of the seven model in- and outputs analyzed in Table 5-4 to predict the relative return of two CDS contracts in the next month. For example, if the exchange rate volatility in Brazil has declined more than in Hungary, we expect the CDS spread of Brazil to decline relative to the CDS spread of Hungary. We therefore take a short position in the Brazilian CDS (selling default protection), and a long position in the Hungarian CDS (buying default protection). Since we have data for fourteen countries, each country is compared to thirteen other countries leading to a potential amount of 91 unique relative trades in total.

Ben Dor et al. (2007a; 2007b) show that the risk of a CDS contract depends on the level of the spread times the duration. Given that we enter 5-year CDS contracts for both countries and hence durations are approximately equal we simply scale the positions by the CDS spreads. If, for example, the CDS spread is 300 basis points for Brazil and 50 basis points for Hungary this scaling implies the position in the CDS for Hungary is 6 times as large as the one for Brazil. Added benefit is that the periodic spread payments add up to zero as we have a matching long and short position. Hence the profit of the trade only depends on the spread changes in both countries and we create a zero-investment strategy. In equation form we get the following expression for the 1-month return in month *t* from the opposing CDS positions in countries *i* and *j*,

$$Return_t^{ij} \approx D_{t-1} position_{t-1} \left[\left(\frac{CDS_t^i - CDS_{t-1}^i}{CDS_{t-1}^i} \right) - \left(\frac{CDS_t^j - CDS_{t-1}^j}{CDS_{t-1}^j} \right) \right] \qquad (5\text{-}4)$$

[60] This is similar to the finding of a large common component for corporate bonds by Collin-Dufresne and Goldstein (2001) and Elton et al. (2001).

where D_{t-1} is the duration (5 years), $position_{t-1}$ is a scaling factor related to the total position size, and CDS_t^i is the CDS spread in month *t* in country *i*. For the Sharpe ratio the total position size does not matter. The risk-scaling to match the risks (and payments) of the two CDS positions is reflected in the denominators in equation (5-4).

For the position size we can take simple long/short positions ($position_{t-1} = \pm 1$), but alternatively we can let the position size depend on the magnitude of the changes in the predictive variables over time. The larger the change, the more spread movement we can expect. We set the position size proportional to a standardized value by computing the current difference in 3-month changes of for example model spreads or exchange rate volatilities, deducting its own average over the previous 5 years and dividing by its own 5-year standard deviation.

5.4.2.B Relative strategy results

Table 5-5 shows the Sharpe ratios for the CDS strategy based on 3-month changes of the seven model in- and outputs analyzed in Table 5-4. The results are positive for all seven indicators. The best indicator is the change of the model spread with a Sharpe ratio of 0.52. Results are strong for EMEA, but weaker for Latin America and Asia. An explanation may be the lower currency volatility. Also, results for one region may be influenced by the other regions because all positions in one country are vis-à-vis another country. In the next section we investigate the results for individual countries.

This strong result proves that the sovereign CCA model of Gray et al. (2007) is a nice step toward better understanding sovereign credit risk. Furthermore this result shows that the market does not fully incorporate information from the aggregate sovereign balance sheets in the CDS market. The low contemporaneous correlation between the changes in model spreads and market spreads in Table 5-4 already indicated that the market does not react directly on the information embedded in the model spread.

The Sharpe ratios of the change of the probability of default (N(-d_2)) and the change of the distance to default (d_2) are respectively 0.49 and 0.48 and similar to the Sharpe ratios of the change of the model spread, showing that the sovereign Merton model has a robust predictive power for CDS returns.

Table 5-5: CDS relative strategy

	Latam	EMEA	Asia	Portfolio	Return	p-value
Spread	-0.06	0.71	0.19	0.52	3.0%	0.13
N(-d_2)	-0.09	0.75	0.09	0.49	2.8%	0.15
d_2	0.25	0.63	-0.07	0.48	2.2%	0.02
σ_{FX}	-0.17	0.76	-0.01	0.25	1.0%	0.42
FX	0.02	0.21	-0.40	-0.04	-0.2%	0.88
σ_{Debt}	0.04	0.65	-0.09	0.29	1.6%	0.28
Local debt	0.15	0.03	0.27	0.28	1.4%	0.30

Note: Sharpe ratios for the relative strategy trading market CDS country spreads based on seven model in- and outputs (see Table 5-4). For the portfolio the return and the Newey-West corrected p-values have been added. At the end of each month we compute the 3-month change in the model spread for each country. For each country pair we compute the difference in the 3-month changes, as well as the 5-year average and the 5-year standard deviation of these differences. The resulting z-score is used as position size in equation (5-4). The movements in the CDS spreads in the next month (t) are used to compute the performance of the trade using equation (5-4). We follow this strategy from December 2001 to June 2014. The table shows the Sharpe ratios of the three regions and the average portfolio of all the fourteen countries. Latam is short for Latin America, and represents the equal weighted portfolio of Argentina, Brazil, Chile, Colombia, Mexico and Peru. EMEA includes Hungary, Poland, South-Africa and Turkey. Asia includes Indonesia, Malaysia, The Philippines and South-Korea.

Finally, the FX factor (the spot return of local currency units expressed in U.S. dollars) achieves the weakest Sharpe ratio of -0.04. The FX factor also shows the highest correlation with the CDS market spread changes in Table 5-4. The high correlation may indicate that direct FX returns are priced in more efficiently by the CDS market, contrary to the information embedded in the model spread. The results support the second hypothesis that indicators based on the model contain useful information about future sovereign default spread changes.

5.4.2.C Directional strategies

The directional strategy intends to profit from the movement of the CDS spread of an individual country. Contrary to the relative strategy, the directional strategy is subject to a market-wide spread widening or tightening and the return of the directional strategy depends on the carry of the CDS contract.

For the direction of the trade we look at 3-month changes in the same seven model in- and outputs. For example, if the exchange rate volatility in Brazil has declined we expect the Brazilian CDS spread to decline as well. We therefore take a short position in the Brazilian CDS contract (selling default protection).

Similar to the relative strategy the position size is proportional to the CDS spread in order to obtain a similar risk per country. In equation form we then get the following expression for the 1-month return in month t from the CDS position (long position is buying default protection) in country i,

$$Return_t^i \approx \frac{position_{t-1}}{CDS_{t-1}^i}\left[D_{t-1}\left(CDS_t^i - CDS_{t-1}^i\right) - \frac{CDS_{t-1}^i}{12}\right] \qquad (5\text{-}5)$$

where D is the duration (5 years), $position_{t-1}$ is a scaling factor related to the total position size, and CDS_t^i is the CDS spread in month t in country i. For the success ratio and Sharpe ratio the total position size does not matter. Because the size of the position is adjusted for the level of the CDS spread, the carry return is the same for each month and each country: the position size divided by 12.

5.4.2.D Directional strategy results

Table 4-6 shows the Sharpe ratios for the CDS strategy based on changes in the seven model in- and outputs. Except for the directly observable sovereign CCA model inputs, local debt and exchange rate returns, the results are strong for all other model in- and outputs with Sharpe ratios between 0.34 and 0.54. Compared to the relative strategy, the Sharpe ratio of the local interest rate volatility has a much higher Sharpe ratio of 0.54. Contrary to the relative strategy, Sharpe ratios are more positive for Latam and Asia. The strategy does not suffer from the larger risk exposure to market-wide changes and is more stable over the regions.

Again the explanation for the weaker predictive results for local debt and currency returns is the higher contemporaneous correlation we find in Table 5-4. Hence directly observable quantities are efficiently incorporated in market CDS spreads. But the not directly observable currency volatility and all sovereign CCA outputs are not efficiently incorporated in CDS spreads.

Hence also the directional strategies support the second hypothesis that the change in the model spread and its related indicators contain important information for future spread changes.

Table 5-6: CDS directional strategy

	Latam	EMEA	Asia	Portfolio	Return	p-value
Spread	0.22	0.66	0.41	0.49	10.7%	0.13
N(-d_2)	0.21	0.69	0.32	0.48	10.3%	0.13
d_2	0.21	0.67	0.25	0.48	6.3%	0.04
σ_{FX}	0.13	0.57	0.27	0.34	6.3%	0.20
FX	0.05	0.00	-0.39	-0.07	-1.6%	0.77
σ_{Debt}	0.25	0.72	0.21	0.54	6.5%	0.07
Local debt	-0.16	-0.29	-0.31	-0.31	-4.2%	0.39

Note: Sharpe ratios from the directional strategy trading market CDS based on seven model in- and outputs (see Table 5-4). For the portfolio the return and the Newey-West corrected p-values have been added. At the end of each month we compute the 3-month change in the model spread. We compute the average and the standard deviation of these 3-month changes in the past 5 years. The resulting z-score is used as position size in equation (5-5). The movement in the CDS spread in the next month (t) is used to compute the performance of the trade using equation (5-5). We follow this strategy from December 2001 to June 2014. The table shows the Sharpe ratios of the three regions and the average portfolio of all the fourteen countries. Latam is short for Latin America, and represents the equal weighted portfolio of Argentina, Brazil, Chile, Colombia, Mexico and Peru. EMEA includes Hungary, Poland, South-Africa and Turkey. Asia includes Indonesia, Malaysia, The Philippines and South-Korea.

5.4.3 Robustness analyses

We have investigated the sensitivity of the results for the threshold level we use to omit redemptions or issuance of new local debt. In addition we analyze whether the investment strategy returns are significant and not subsumed by the term, default and liquidity premiums in bond markets.

5.4.3.A Sensitivity analysis threshold level

We have analyzed the sensitivity of the results[61] to the threshold level we use to omit large daily changes in the *LCL* input factor. The default threshold level has been chosen at a level of 5% removing about 0.6% of all observations. We analyze the results of different threshold levels for both the relative and directional trading strategies based on the three month change of the model spread.

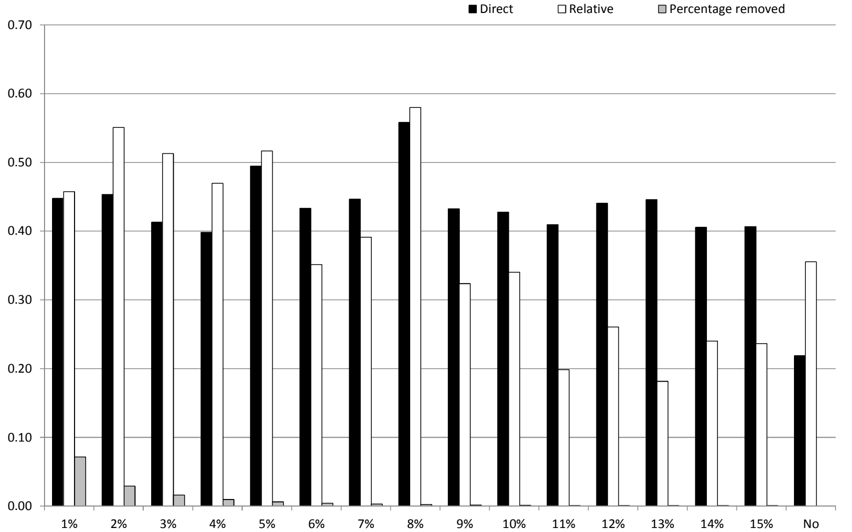
Large changes of the *LCL* may have been caused by a redemption or issuance of new local debt and are not necessarily a sign of higher risk. Therefore, removing these jumps may improve the effectiveness of the model in predicting future CDS spread changes. Since we

[61] We focus on the results for the trading strategies. The correlations in Table 5-4 are also robust for the threshold level but are not included here to safe space. Results are available upon request.

cannot directly observe redemptions and new issuance in our database we simply omit extreme absolute changes of the LCL.

Results are shown in Figure 5-1: Results strategies based on the model spread. The highest Sharpe ratios are obtained at the threshold level of 8% for both the relative and directional strategies. Without a threshold (far right in Figure 5-1: Results strategies based on the model spread) the directional strategy becomes weaker with a Sharpe ratio of 0.22, while the relative strategy still obtains a reasonable Sharpe ratio of 0.36. With a low threshold (far left in Figure 5-1: Results strategies based on the model spread) of 1% about 7% of observations are omitted and the predictive power of the model is robust. A low threshold also omits large moves of the interest rate markets, muting the volatility and leaving out valuable information from the model. The default setting of 5% seems reasonable and results are robust for this choice.

Figure 5-1: Results strategies based on the model spread



Note: the LCL input of the model contains jumps due to the redemption or issuance of new local debt. In the calculation of the volatility of the LCL we try to remove such jumps by excluding daily changes of LCL larger than 5%, removing about 1% of all observations. We show the sensitivity of the Sharpe ratio (y-axis) of the relative and direct trading strategies based on three month changes in model spreads for different threshold levels (shown on x-axis) over the period from December 2001 to June 2014. The Sharpe ratios of the trading strategies and the percentage of observations are shown in bars.

5.4.3.B Regression analysis

Gebhardt et al. (2005b) find that the term premium and default premium are priced risk factors for corporate bond returns. Longstaff (2004) finds a priced liquidity measure based on the market cap weighted excess return of RefCorp[62] compared to U.S. treasuries. We run the following regression of the returns of the relative and directional strategies on the default premium, term premium and liquidity premium:

$$R_t = \alpha + \beta_1 DEF_t + \beta_2 TERM_t + \beta_3 LIQ_t + \varepsilon_t \qquad (5\text{-}6)$$

where R_t are the relative or directional strategy returns based on the seven model in- and outputs analyzed in Table 5-4, α the unexplained return, DEF_t the default premium, $TERM_t$ the term premium and LIQ_t the liquidity premium. Over the sample period from December 2001 to June 2014 the term premium is 2.83% per annum, the default premium 5.98% per annum and the liquidity premium -0.03% per annum. The results of the regression in equation (5-6) are presented in Table 5-7 (relative strategy return) and Table 5-8 (directional strategy returns).

Table 5-7: Regression relative strategy

	α	$p-value\ \alpha$	β_1	β_2	β_3	R^2
Spread	2.4%	0.14	0.02	0.14	-0.19	2%
N(-d_2)	2.3%	0.17	0.03	0.14	-0.19	2%
d_2	2.4%	0.02	-0.04	0.03	-0.05	1%
σ_{FX}	1.5%	0.20	-0.12***	0.07	0.16	10%
FX	0.7%	0.51	-0.16***	0.00	-0.25**	10%
σ_{Debt}	1.2%	0.42	0.00	0.14*	0.05	2%
Local debt	1.5%	0.28	-0.02	0.00	-0.26*	1%

Note: This table presents the alphas of the regression in equation (5-6),

$$R_t = \alpha + \beta_1 DEF_t + \beta_2 TERM_t + \beta_3 LIQ_t + \varepsilon_t$$

R_t is the return of the portfolio formed by the relative strategies (see Table 5-5 for more information and details), DEF is the return of the EMBI+ market index over U.S. Treasuries. $TERM$ is the return of U.S. Treasuries over cash. LIQ is the excess return of RefCorp bonds over maturity matched U.S. Treasuries. The constant (α) is expressed per annum, its p-value is denoted in the second column. The 1%, 5% and 10% significance levels for β_1 and β_2 are denoted by ***, ** and *, respectively. We use Newey-West standard errors to correct for heteroscedasticity and autocorrelation. The sample period is from December 2001 to June 2014.

[62] RefCorp is short for the Resolution Trust Corporation which is a U.S. government corporation established to rescue savings and loan institutions that failed during the savings and loan crisis. RefCorp provided liquidity to these organizations by issuing bonds. RefCorp's bonds have the same standing as Government bonds in case of a credit event. Hence price differences are only due to liquidity differences.

Table 5-8: Regression directional strategy

	α	$p-value\ \alpha$	β_1	β_2	β_3	R^2
Spread	12.4%	0.05	-0.07	-0.46	-1.37	2%
N(-d_2)	12.0%	0.05	-0.07	-0.44	-1.30	2%
d_2	7.9%	0.01	-0.19	-0.21	0.45	2%
σ_{FX}	9.5%	0.04	-0.33	-0.51*	0.19	4%
FX	6.2%	0.31	-0.96***	-0.84**	0.80	20%
σ_{Debt}	6.0%	0.10	0.08	0.00	0.04	0%
Local debt	-1.8%	0.65	-0.43**	0.01	0.41	10%

Note: This table presents the alphas of the regression in equation (5-6),

$$R_t = \alpha + \beta_1 DEF_t + \beta_2 TERM_t + \beta_3 LIQ_t + \varepsilon_t$$

R_t is the return of the portfolio formed by the directional relative strategy (see Table 5-6 for more information and details), DEF is the return of the EMBI+ market index over U.S. Treasuries. $TERM$ is the return of U.S. Treasuries over cash. LIQ is the excess return of RefCorp bonds over maturity matched U.S. Treasuries. The constant (α) is expressed per annum, its p-value is denoted in the second column. The 1%, 5% and 10% significance levels for β_1 and β_2 are denoted by ***, ** and *, respectively. We use Newey-West standard errors to correct for heteroscedasticity and autocorrelation. The sample period is from December 2001 to June 2014.

For the relatively strategies in Table 5-7 only the ones based on currency returns and changes in currencies volatility have a significant negative loading on the default premium. Given the positive default premium this actually adds to the alpha but these alphas are not significantly different from zero. The relative strategy based on the changes in the volatility of local debt returns loads significantly on the term premium which reduces alpha. The only statistically significant alpha (p-value 0.02) is the one for the relatively strategy based on the distance-to-default. The returns of this strategy do not load on the default and term premium, and the alpha is equal to 2.4% per annum. The other model outcomes, spreads and probabilities of default, have similar alphas as the distance-to-default but these are not significant. One possible explanation is that the distance to default can take values with a more uniform distribution compared to the model spread and probability of default. The probability of default is equal to zero in 44% of the observations and has a maximum of 9.3%. The skewness of the probability of default is also extreme with a value of 13.3, whereas the skewness of the distance to default is more benign with a value of 3.0. The distance to default is therefore better able to distinguish a safe country from a safer country.

For the directional strategies in Table 5-8, the one based on past local debt returns significantly loads on the default premium with a coefficient of -0.43. This benefits the alpha but it does not overcome the large negative total return of -4.2% in Table 5-6. In terms of the alphas all but the ones based on currency and local debt returns are significant at least at the

10% significance level. Also here the directional strategy based on the distance-to-default is the most significant with a p-value of 0.01. Its (insignificant) negative loadings on the default and term premiums make sense since the strategy invests in countries with a declining implied credit risk.

Hence, corrected for the market and default premiums not all information from the aggregate sovereign balance sheets is fully incorporated in the CDS market. The strongest significance is visible for the strategies based on changes in the distance-to-default.

5.5 Conclusion

We provide an extensive empirical study into the Gray et al. (2007) structural model for sovereigns. We show that the structural approach for emerging countries that issue both local and foreign currency denominated debt has its merits. In the model the exchange rate dynamics play an important role. Specifically, the model predicts a close link between exchange rate returns and volatility changes on the one hand, and market CDS spread movements on the other hand.

The model outcomes such as the distance-to-default, the default probability, and spreads are strongly correlated with market CDS spreads. Also exchange rate dynamics, an important input for these model outcomes, are strongly correlated with market CDS spreads. This is a similar role to what other studies find for equity returns and volatility in Merton's structural model for corporations. The results reject our first hypothesis that the changes of the sovereign credit spreads based on the structural model should be empirically correlated to changes of sovereign market spreads during the same time period.

The second hypothesis is that information embedded in the model spreads may contain information that is not priced in yet by the sovereign market spreads. Because the currency market is more efficient than the sovereign CDS market, exchange rate information could have predictive power for future CDS spread changes. We build strategies based on the model spreads that indeed show a strong and significant performance. This indicates that the market does not fully price the sovereign balance sheet information into CDS spreads.

For further research it will be interesting to look for improvements to the Merton framework applied to sovereigns. The structural model may be improved with suggestions from the study of Eom et al. (2004) on corporations regarding the use of a different model set-up allowing for a stochastic interest rate and a recovery at default among others. In addition, Aktug (2014) applies the Merton model to three emerging markets and argues that more precise data on the debt and the addition of other volatility measures like the equity market volatility may help.

Finally, including alternative factors in a reduced form model set-up like Ang and Longstaff (2013) use for EMU countries is another possibility for further research.

6. Riding the swaption curve

Based on Duyvesteyn and de Zwart (2015), published in the Journal of Banking and Finance. We thank Robert Berry for excellent research assistance. We are grateful for the useful comments from the participants of the 2008 2nd Investing and Trading in Volatility conference in New York, the 2012 15th Annual Conference of the Swiss Society for Financial Market Research in Zurich, the 2013 EFA Meetings in Cambridge, seminar participants at Robeco, Guido Baltussen, Kees Bouwman, Nick Firoozye, Winfried Hallerbach, Roy Hoevenaars, Roger Lord, Kasper Lorenzen, Martin Martens, Philippe Mueller (discussant), Sebastian Paik (discussant), Patrick Verwijmeren, Yu-Min Yen and three anonymous referees.

6.1 Introduction

Previous research in equity and fixed income show that the market price of volatility risk is negative for both markets. In contrast, investors trade volatility very differently in these markets. The commonly used trading instrument in the equity market is the variance swap (Carr and Wu, 2009), which pays the difference between realized variance and a benchmark variance rate that is set at the start of the contract.[63] On the other hand, institutional investors in the fixed income market hardly use variance swap contracts, but are very comfortable trading over-the-counter (OTC) swaptions to get volatility exposure. An important reason behind this might be a lack of clear benchmark points for volatility trading in the fixed income market. This is illustrated by a gap of 20 years between the introduction of the VIX in 1993 (Whaley, 1993) as a benchmark in the equity markets and the recent introduction of the SRVX index as the first interest rate-based volatility index (Mele and Obayashi, 2012). Only recently, equity variance swaps have been generalized to the fixed income market by Trolle (2009), Mele and Obayashi (2013), Mueller et al. (2013), Li and Song (2013) and Trolle and Schwartz (2014). This is most likely because of the 'non-trivial design issues' (Li and Song, 2013) and a lack of public data due to the OTC market structure. This might explain why, apart from Mueller et al. (2013), these studies focus on studying and replicating

[63] See Carr and Wu (2009) for a detailed discussion on variance swaps in equity markets.

variance swap contracts at a single maturity and pay little attention to the term structure of the volatility risk premium. However, swaptions naturally give rise to a maturity term structure.[64]

This paper complements the literature by providing a comprehensive empirical analysis of the term structure in the volatility risk premium for the four major swaption markets (USD, JPY, EUR and GBP).[65] We build on Low and Zhang (2005), who relate the volatility risk premium to straddle returns by proving that the average return of a delta-neutral straddle must not be zero if volatility risk is priced. We argue that conclusions can be inferred on the term structure of the volatility risk premium by studying the average return of a long-short combination of two delta-neutral straddles with different maturities. In particular, we study long-short straddle combinations which are either delta-gamma or delta-vega neutral. We are the first to apply these two strategies in the fixed income market. Hence, we provide results showing it is plausible that the delta-gamma and delta-vega neutral strategies can be linked to volatility risk and jump risk respectively, corroborating the equity market findings of Cremers et al. (2015). Since sellers of volatility risk might also desire a jump risk premium to compensate for sudden and extreme losses caused by the unexpected nature of jumps, we use this link to better understand our empirical results. The presence of a jump risk premium is not unlikely because there is evidence for the presence of jumps in interest rates. Johannes (2004) reports a significant impact of jumps on the pricing of fixed income derivatives on Treasury bills. Dungey et al. (2009) relate jumps in the fixed income market to the release of macroeconomic data and show that about 2/3 of jumps can be explained by these releases. Using variance swaps, Li and Song (2013) show that jump tail

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[64] A seemingly related, but nonetheless unrelated, line of previous work studies riding strategies on the yield curve instead of the swaption volatility curve. Yield curve-riding strategies are popular investment approaches for fixed income managers to achieve additional returns and have been widely documented; see for example the study of Dyl and Joehnk (1981). Basically ‘yield curve-riding’ or ‘rolling down’ strategies buy longer-dated bonds and sell before maturity. When these bonds approach maturity and the yield curve is upward-sloping, they will be valued at a lower yield. A profit will be realized when the bond is sold at the higher price. In contrast to these yield curve-riding strategies, this study is the first empirical research on the significance of long-short straddle combinations that ‘ride’ the swaption curve. Riding the swaption curve and riding the yield curve thus have in common that their respective forward curves are not realized over time.

[65] Straddles are typically used to speculate on future changes of volatility. A straddle has zero delta exposure at inception. Straddles comprise a combination of a call option (receiver swaption) and a put option (payer swaption) on a swap with the same maturity and the same underlying strike rate. A receiver swaption is a call option on a receive fixed swap where the swaption holder has the right to receive a fixed rate on a swap in the future. A payer swaption is a call option on a pay fixed swap (or a put option on a receive fixed swaption) where the holder has the right to pay a fixed rate on a swap in the future.

risk is time varying in the swaption market.

Our research provides a number of new results. We use a large data set of at-the-money implied volatility quotes on the 10-year swap rate and 1 to 12-month swaption maturities between April 1996 and December 2011 to calculate the returns of the long-short straddle strategies. First, our main finding is that we find statistically significant returns for all markets and for both delta-gamma and delta-vega neutral strategies. This finding is consistent with an upward-sloping term structure in the volatility risk premium implying a less negative premium for longer-term swaption maturities. The strategy returns consistently decrease across maturities, which suggests that the risk premium curve flattens for longer maturities. The low, although increasing, correlations between the delta-gamma and delta-vega neutral strategies, that is -23% for the 3 vs 6-month maturity strategy, -4% for 6 vs 9-month and 38% for the 9 vs 12-month, indicate that the two strategies are uncorrelated and probably capture different effects. This suggests that the term structure of the volatility risk premium is affected by both jump risk and volatility risk, especially at short-term maturities. In general, all these empirical findings are consistent across the four individual markets.

Second, it is important to recognize that our strategy is based on the Black (1976) model to estimate the risk exposures for hedging and to calculate the returns. We re-run our strategies on the Vasicek (1977) model for all markets and on the stochastic volatility model proposed by (Hagan et al., 2002) for the vega neutral strategy in the USD market.[66] The Hagan et al. (2002) model is also known as the Stochastic Alpha Beta Rho (SABR) model. In the Vasicek (1977) framework we find comparable summary statistics to our main findings for all markets. The vega neutral returns under the SABR model seem, in general, comparable to the returns under the Black model. For example the 3 vs 6-month strategy has a return (Sharpe ratio) of 0.89% (0.60) under the SABR model and 0.85% (0.54) under the Black model. Additionally, we do robustness checks of our findings on the 2-year swap rate and the USD swaption smile, we analyze the impact of macroeconomic announcements, and we empirically check the exposure of the strategy returns to the underlying swap rate.

Third, we study the economic importance of our results. For example, the average return across the four markets for the 3 versus 12-month delta-gamma neutral strategy is 1.89% (*t*-stat = 4.33) and an annualized Sharpe ratio of 1.35. The delta-vega neutral strategy

[66] The additional data which is required to estimate the SABR model is not available for other markets.

reports a return of 1.14% (t-stat = 3.69) and an annualized Sharpe ratio of 0.95. However, after calculating break-even costs and comparing these with expected trading costs, we conclude that the returns of the strategies are not realizable by investors and therefore are not economically significant. This corroborates the findings for equity option strategies obtained by Santa-Clara and Saretto (2009).

Our research relates to several strands of the literature. Most importantly, our study is directly related to the literature on the volatility risk premium in fixed income. Earlier studies, such as Goodman and Ho (1997) and Duarte et al. (2007), examine the presence and sign of the volatility risk premium in the fixed income market by analyzing the returns of a delta-hedged investment strategy. Since then, Almeida and Vicente (2009) have studied the volatility risk premium of fixed income Asian options, and Fornari (2010) has studied the volatility risk premium by calculating the difference between the implied volatility and forecast of realized volatility using a GARCH model. Recently, a growing body of literature which explores variance swap contracts in fixed income markets is emerging. Variance swap contracts provide model-free estimates of the variance risk premium because no assumptions are made about the price process of the underlying swap rate. Trolle (2009) studies the variance risk premium in the U.S. Treasury market by estimating variance swaps under simplifying assumptions and concludes that the variance risk premium is negative. Merener (2012) studies a variance strategy on forward swap rates. Mueller et al. (2013) and Mele and Obayashi (2013) both analyze variance contracts on Treasury futures. Mele and Obayashi (2013) mainly focus on the theoretical derivation of the contract. Mueller et al. (2013) introduce a variance contract that is robust to jumps and can be replicated in the market at daily frequency. This approach helps them to empirically analyze the variance premium across the maturity and tenor spectrum, and leads them to conclude that the variance risk premium is negative, but less negative for longer maturities (increasing in maturity), and more negative for longer-term swap rates (decreasing in tenor). We see our work complementing theirs, because our data is on swaptions which is a different market, we focus on a straddles trading strategy and we make a distinction between volatility and jump risk. Trolle and Schwartz (2014) and Li and Song (2013) both study variance swaps in the swaption market and both have large and proprietary 'swaption cube' data sets from different providers that include data along three dimensions: swap tenors, swaption maturities and strike rates. Li and Song (2013) focus on jump risk and conclude that jump risk is time varying, while Trolle and Schwartz (2014) study variance and skewness risk premiums which are reported to be time varying and negative.

Our paper is also related to the strand of literature on test design for the existence of volatility risk premiums. An important contribution in this field includes Branger and Schlag (2008) who provide a detailed discussion on the limitations of hedging-based strategies. In particular, discrete trading and model misspecification may cause tests to yield unreliable results. Doran (2007) demonstrates that delta-gamma hedged option portfolios are less subject to these discrete trading and model misspecification problems than traditional delta-hedged portfolio tests. Since we construct our long-short straddle combinations so that they are either delta- gamma or delta-vega neutral, our strategy returns are most likely less prone to the limitations raised by Branger and Schlag (2008).

Finally, our paper is related to Aït-Sahalia et al. (2012) who study the term structure of variance swaps in the equity market and reveal a significant jump component embedded in the variance swaps, especially at short-term maturities. Their analysis leads them to the conclusion that the variance risk premium is negative, becoming more negative for longer maturities, but we do not find this result in the fixed income market.

The remainder of the chapter is organized as follows. Section 6.2 addresses our methodology and Section 6.3 describes the data. Section 6.4 presents our main empirical findings for the delta-gamma and delta-vega hedged long-short straddle combinations. Section 6.5 provides a robustness and sensitivity analysis on the efficiency of the delta-hedge, scheduled macroeconomic announcements, choice of the pricing model and additional data sets. Section 6.6 discusses the economic importance of our results and we conclude in Section 6.7.

6.2 Methodology

Straddles are commonly used to speculate on, or to hedge for, future volatility changes because they give exposure to volatility and have no exposure to the underlying. In this study we analyze long-short combinations of at-the-money swaption straddles with different maturities. The purpose of this section is to describe the valuation of swaption straddles, the method to calculate the straddle risk parameters and to determine the hedge ratios for long-short straddle combinations that are either delta-gamma or delta-vega neutral.

6.2.1 Computing straddle returns

A swaption straddle is a combination of a payer swaption plus a receiver swaption, both with the same exercise level.[67] In order to value the straddle we follow market practice and use the Black (1976) pricing model to convert quoted implied volatilities into straddle prices (Chaput and Ederington, 2005). To do so, consider a specific payer swaption giving the right to pay the fixed swap strike rate (F_X) and to receive the floating rate in a swap contract that will last *n* years (the tenor), starting in *T* years (the maturity), with *m* coupon payments per year and principal *L*. Let $t_i = T + i/2$ be the times of each of the coupon payments. Then, the contribution of the value of each individual cash flow (coupon payment) of the underlying swap to the swaption is:

$$V_{CF,i} = \frac{L}{m} e^{-r_i t_i} [FN(d_1) - F_X N(d_2)] \quad \text{(6-1)}$$

where *F* is the forward swap rate with the same maturity as the swaption, *N* is the cumulative normal distribution function, $d_1 = \frac{ln\left(F/F_X\right)+\sigma^2 T/2}{\sigma\sqrt{T}}$, $d_2 = d_1 - \sigma\sqrt{T}$ and $r_i t_i$ is the spot rate that corresponds to the maturity of cashflow *i* at t_i. The sum of the values of the individual cash flows determines the total value of the payer swaption (V_p):

$$V_P = \sum_i V_{cf,i} = \frac{LA}{m} [FN(d_1) - F_X N(d_2)] \quad \text{(6-2)}$$

Where $A = \sum_i e^{-r_i t_i}$. Here the presumption made by Black (1976) is that the forward swap rate follows a geometric Brownian motion (dW) where the volatility is a constant:

$$dF_X = \sigma F_X dW, F_X(0) = f \quad \text{(6-3)}$$

The value of a corresponding receiver swaption giving the right to receive strike rate F_X and pay the floating rate in a swap contract is equal to (V_R):

$$V_R = \frac{LA}{m} [-FN(-d_1) + F_X N(-d_2)] \quad \text{(6-4)}$$

The value of a straddle, S, (both long receiver and long payer swaption) with the same strike rate F_X is given by the sum of (2) and (4):

$$S = V_P + V_R = \frac{LA}{m} [F(2N(d_1) - 1) - F_X(2N(d_2) - 1)] \quad \text{(6-5)}$$

Notice that the Black model is a model and therefore does not necessarily have a perfect fit with empirical data. The basic premise of a constant volatility is not supported by

[67] At inception, the ATM swaption strike rate is set equal to the swap forward rate.

market dynamics, because swaption implied volatilities tend to vary for different strikes and swaption maturities (swaption smile). We discuss our data set later, but at this stage we emphasize that we only have swaption smile data for the USD and not for the other markets in our data set. As such we assume a horizontal smile and rely on the Black model (Black, 1976) to convert implied volatility quotes into prices. We will use USD swaption smile data for a robustness analysis in Section 6.5.4.

We calculate the return of a straddle as follows. Let S_t be the value of a particular straddle position at time t. Then the return of holding the straddle position, including funding costs, during the period from t - 1 to t is:

$$R_t = \frac{S_t - S_{t-1}\left(1 + \frac{\#Days_{t,t-1}}{360} ir_{t-1}\right)}{L} \tag{6-6}$$

Where ir_{t-1} is the annualized floating interest rate that is paid to borrow money to buy the swaption straddle position for the period from t - 1 to t which comprises $\#Days_{t,t-1}$ number of days. In calculating the returns we ignore the bid-offer spread as well as impact of margin that would be required to back the straddle trades and limit the ability to leverage. Since trading costs and collateral requirements can be substantial for short option positions, as shown by Santa-Clara and Saretto (2009), we separately analyze the economic importance in Section 6.6. In this section we also discuss how the swaption market changed after the Global Financial Crisis (GFC) in 2008.

6.2.2 Calculating the risk parameters

Next to the valuation of the swaption straddles we also want to estimate the associated risks for hedging purposes and exposure analysis. These risk parameters are collectively known as the `Greeks' and quantify the influence of changes in market factors on the straddle value. Using the Black model, the analytical delta, gamma and vega can be obtained in closed-form formulas (Martellini et al., 2003).

Delta (Δ), describes the price change of a straddle with respect to the underlying swap forward rate. Technically speaking it is the first derivative of the straddle price with respect to the swap forward rate:

$$\Delta = \frac{\partial S}{\partial F} = \frac{LA}{m}\left[N(d_1) - N(-d_1)\right] \tag{6-7}$$

At inception an at-the-money delta-neutral straddle position has a delta equal to zero according to the Black model. This means that the straddle value is not sensitive to a small change in the underlying swap forward rate. Straddle exposures to the other Greeks are, however, not zero.

Gamma (Γ) is the second derivative of the straddle to the underlying swap forward rate and is the rate of change of the delta to the underlying swap forward rate:

$$\Gamma = \frac{\partial S^2}{\partial F^2} = \frac{LA}{mF\sigma\sqrt{T}}[N'(d_1) + N'(-d_1)] \qquad (6\text{–}8)$$

where N' is the probability density function of the normal distribution.

Vega (v) is the sensitivity of the straddle price to the implied volatility. In fact a straddle is quite vulnerable to volatility changes. Technically, vega is the first derivative of the straddle price with respect to the volatility parameter σ:

$$v = \frac{\partial S}{\partial \sigma} = \frac{LAF\sqrt{T}}{m}[N'(d_1) + N'(-d_1)] \qquad (6\text{-}9)$$

Note that under the assumptions of the Black model vega is a comparative statistic and not a sensitivity to a variable that is dynamic such as delta or gamma.

We use the Black model in this study because of limitations on data availability for the EUR, GBP and JPY markets. However, just because financial markets quote implied volatility in the Black framework does not imply that risk parameters should be calculated from the Black model without an adjustment for the presumption of constant volatility across strike rates. Hence, as discussed by Levin (2004), the return distribution of swap rates is not necessarily lognormal as assumed by the Black model. We use USD swaption smile data for robustness analysis in Section 6.5.3 and 6.5.4 and show that our results are robust.

6.2.3 Specification of the hedging-based strategy

Low and Zhang (2005) relate the volatility risk premium to straddle returns by proving that the average return of a delta-neutral straddle must not be zero if volatility risk is priced. Following Low and Zhang (2005) we argue that studying the returns of a long-short combination of delta neutral straddles with different maturities will enable us to analyze the difference between the volatility risk premium across swaption maturities. Then, the obvious question is: what should be the ratio between the two straddles? In the spirit Cremers et al. (2015) we construct two combinations which are orthogonal and either exposed to volatility risk (delta-gamma neutral combination) or to jump risk (delta-vega neutral combination). This approach does not only enable us to analyze the term structure of the volatility risk premium but we might also be able to infer conclusions on the drivers of the term structure.

A long-short straddle strategy constructed to be delta and gamma neutral is vega positive and would be subjected to volatility risk but almost not impacted by jump risk. Since gamma is not constant in time to maturity we construct the delta-gamma neutral strategy using the Black risk parameters. The strategy consists of two positions (i) a short position in 1 delta-neutral straddle contract with maturity T_s and (ii) a long position in Q_{ls}^{gamma} delta-neutral straddle contracts with maturity T_l with $T_s < T_l$. Q_{ls}^{gamma} is chosen such that the long straddle position creates an overall position in the long-short straddle combination that is not only delta but also gamma neutral (Equation 6-8):

$$Q_{ls}^{gamma} = \frac{\sqrt{T_l}\,\sigma_l F_l}{\sqrt{T_s}\sigma_s F_s} \tag{6-10}$$

where T_s is the swaption maturity, σ_s is the implied volatility and F_s the swap forward rate of the short straddle position and T_l, σ_l, and F_l are the swaption maturity, the implied volatility and the swap forward rate of the long straddle position respectively. The shorter dated swaptions have larger gammas such that the number of straddles bought to offset the gamma exposure of the short position is more than 1 ($Q_{ls}^{gamma} > 1$). This results in a positive vega exposure for the long-short combination because vega is increasing in time to maturity such that the shorter dated straddle has a smaller vega than the longer dated straddle. Doran (2007) also emphasizes the importance of controlling a delta hedged portfolio for gamma exposure to enable a more precise inference on the volatility risk premium.

Analogously, a long-short straddle strategy constructed to be delta and vega neutral is gamma negative and would be subjected to jump risk but almost not impacted by volatility risk. Since vega is not constant in time to maturity we construct the delta-vega neutral strategy using the Black risk parameters. The strategy consists of two positions (i) a short position in one delta-neutral straddle contract with maturity T_s and (ii) a long position in Q_{ls}^{vega} delta-neutral straddle contracts with maturity T_l with $T_s < T_l$. Q_{ls}^{vega} is chosen such that the long straddle position creates an overall position in the long-short straddle combination that is not only delta but also vega neutral (Equation 9-9):

$$Q_{ls}^{vega} = \frac{\sqrt{T_s}\,F_s}{\sqrt{T_l}F_l} \qquad (6\text{-}11)$$

Since the shorter dated straddle has a smaller vega, the number of straddles bought to offset the vega exposure of the short position is less than 1 ($Q_{ls}^{vega} < 1$). This results in a negative gamma exposure because shorter dated swaptions have larger gammas.

In the remainder of this study we analyze the profitability of these long-short straddle combinations for various swaption maturities. The long-short portfolio is formed at month end and rebalanced monthly in the spirit of Broadie et al. (2009). Intra-month, we neither change the two straddle positions nor delta-hedge the long-short portfolio using the underlying swap forwards. All risk exposures that get into the straddles during the month are supposed to cancel out as a result of offsetting long and short straddle positions. Notwithstanding, we do analyze the risk exposures on a daily basis in Section 6.5.1.

We follow Bakshi and Kapadia (2003) and Low and Zhang (2005) to apply a *t*-test for testing the null hypothesis that the long-short profit or loss is zero. We adjust the *t*-statistics according to Newey and West (1987, 1994) to correct for heteroscedasticity and serial correlation. Positive average returns of the strategy would suggest that the volatility risk premium for the shorter term swaption maturity is higher than the longer-term maturity. There would be evidence for a downward-sloping term structure in the volatility risk premium if the long-short returns show positive returns along a range of subsequent long-short straddle maturities.

6.3 Data and volatility risk premium

In this section we first describe our data set. We then provide empirical estimates of the volatility risk premium across different swaption maturities.

6.3.1 Data description

We use an extensive data-set of swap forward rates and swaptions that we obtain from Bloomberg and an anonymous major broker dealer. The advantage of two data sources is that this enables cross-checking to get a high quality data-set. If available we use Bloomberg data, otherwise broker data. The Bloomberg data are based on the most recent trades and quotes from multiple pricing sources for each country, among other ICAP which is the largest inter-dealer broker in the swap rate derivative market Trolle and Schwartz (2014). We may therefore expect the quotes to be timely and accurate. Given the average swaption trading volume in excess of USD 150 billion notional, we assume that the Bloomberg data represent quotes that can be traded in practice.

Our sample covers the four largest and most liquid swap markets and spans a period of almost 16 years, from April 1996 to December 2011. Daily close prices (midpoint) of the implied Black volatility are available for at-the-money (ATM) swaptions with maturities of one, three, six, nine and twelve months for USD, EUR, JPY and GBP swaptions.[68] Before 1999 the EUR data are based on Germany, the most liquid fixed income market in the European Monetary Union. Bloomberg only provides ATM data because ATM swaptions are actively quoted in the market. Data on other strike rates is proprietary and broker dealer specific.[69] Furthermore, we focus on the 10 year swap tenor because swaption contracts for this maturity are the most liquid.[70]

Figure 6-1 plots the time series behavior of the implied volatility of 3-month swaptions and shows that its' values have varied greatly over the course of the sample. We make two observations. Firstly, markets seem to show common moves with spikes during major stress events in the market in 1998 (unwinding LTCM), 2001 (bursting IT bubble and subsequent recession), 2008 (Lehman Brothers default) and 2011 (FED announced a stimulus policy that was called Operation Twist). Secondly, we note historically high values for the Japanese implied volatility in 2003. This jump is related to the sharp rise of the 10-year swap rate in Japan. On June 12th, 2003 the Japanese 10-year swap rate had an all time low at 0.43%. One month later it had more than doubled to a level at about 1%, while the rate further increased to 1.5% in September. The sharp increase was aggravated by many Japanese banks who were forced to sell government bonds due the limits on their value-at-

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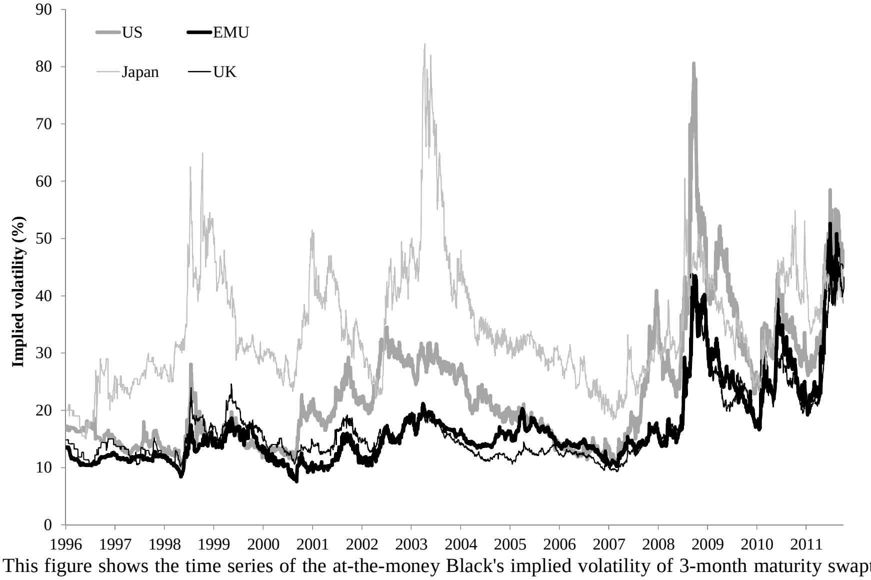
[68] At inception, the ATM swaption strike rate is set equal to the swap forward rate. We use the New York close, which is at EST 17:00, as the closing price for all four markets.

[69] In addition, our broker-dealer provides 5 strikes for USD swaptions (ATM, $\text{ATM} \pm 50$, $\text{ATM} \pm 100$). In section 6.5.4 we use this USD data to test the robustness of our empirical findings.

[70] This is illustrated by the options on the 10 year U.S. Treasury futures contracts. Open interests and daily volumes of the options on the 2y, 5y and 30y futures contracts options are up to ten times lower than for the 10y futures. Source: CME Group, www.cmegroup.com.

risk; see BIS (2003) for more details.[71]

Figure 6-1: Time series of swaption implied volatility



This figure shows the time series of the at-the-money Black's implied volatility of 3-month maturity swaptions with 10-year swap tenor for the USD, EUR, GBP and JPY markets. The sample period is from April 1996 to December 2011 and the EUR quotes before 1999 are implied volatility quotes for 3-month maturity swaptions on the German (DEM) swap rate.

Table 6-1 reports the summary statistics of the swaption data across different maturities. We report the mean, standard deviation, skewness, kurtosis, minimum, and maximum for the month end implied volatility quotes in our sample. The number of monthly observations in each series is 189. We make several observations. The average volatility of Japanese swaptions is about twice as high as the volatility of the other three markets, as we already have seen in Figure 1. Furthermore, implied volatilities for shorter maturities are higher and more volatile than for longer maturities in all four markets. This higher standard deviation gradually decreases for longer maturities. Finally, we also notice that the range between the minimum and maximum is the largest for the shortest maturities and narrows when maturity goes up. Together, this illustrates a higher risk embedded in shorter maturity

[71] A similar but smaller effect can be observed in the U.S. data for the same period. The USD 10-year swap rate was at a low of 3.46% on June 13th, 2003 and rose back to about 5% in only two months due to mortgage hedging activity (see Duarte (2008)).

swaption contracts. Low and Zhang (2005) argue that this higher risk warrants a decreasing volatility risk premium in maturity.

Table 6-1: Summary statistics of swaption implied volatilities

	Maturity	Mean	Stdev	Skew	Kurt	Min	Max
USD	1m	23.5%	12.2%	1.88	4.87	9.7%	94.8%
	3m	23.2%	10.8%	1.53	2.97	10.2%	80.6%
	6m	22.6%	9.6%	1.32	1.81	11.0%	67.4%
	9m	22.1%	8.9%	1.25	1.44	11.3%	61.4%
	12m	21.6%	8.1%	1.18	1.07	11.6%	55.6%
EUR	1m	17.2%	8.1%	2.08	4.53	6.5%	54.9%
	3m	16.9%	7.5%	2.02	4.21	7.6%	52.6%
	6m	16.5%	6.8%	1.93	3.84	8.8%	50.2%
	9m	16.2%	6.4%	1.87	3.57	9.4%	47.8%
	12m	15.8%	6.0%	1.83	3.36	9.4%	45.3%
JPY	1m	34.4%	11.9%	1.54	3.65	15.0%	97.0%
	3m	34.3%	10.3%	1.23	2.68	15.0%	84.0%
	6m	33.2%	9.1%	0.82	1.41	14.0%	77.0%
	9m	32.1%	8.2%	0.64	1.04	14.6%	71.0%
	12m	31.3%	7.7%	0.40	0.59	13.0%	67.0%
GBP	1m	17.2%	7.2%	1.98	4.34	9.1%	49.5%
	3m	16.8%	6.4%	1.98	4.35	9.3%	45.9%
	6m	16.5%	5.7%	1.90	4.03	9.4%	42.3%
	9m	16.3%	5.2%	1.85	3.89	9.5%	40.3%
	12m	15.9%	4.7%	1.90	4.48	9.7%	38.2%

Note: This table reports summary statistics of annualized, at-the-money swaption implied volatilities on the 10-year swap forward yield for four markets (USD, EUR, GBP and JPY). For each combination of market and swaption maturity, the table shows the sample mean (Mean), standard deviation (Stdev), skewness (Skew), kurtosis (Kurt), minimum (Min), and maximum (Max) of implied volatility mid-quotes for maturities ranging from one to twelve months. The number of observations in each series is 189 and runs from April 1996 to December 2011. Data are obtained from Bloomberg and an anonymous broker.

So far, we analyze the data separately and do not address the issue of commonalities between the four markets. To address this question we compute the correlations between the swap yields and between the implied volatilities. Table 6-2 presents the correlation between pairs of monthly changes in the swap yield (below diagonal) and between pairs of monthly changes in the implied volatility (above diagonal). We can observe a strong and positive correlation (0.70 - 0.79) between the monthly changes in the USD, EUR and GBP swap rates, indicating that these markets comove strongly. We make a similar observation for the 1-month change in the implied volatilities. In a similar vein we document a weak relationship between these three markets and the JPY market. The 0.15 correlation between the monthly changes of the USD and JPY implied volatility is a good example of this. This latter result suggests that the JPY swap rate and implied volatility move rather independently from the other three markets.

Table 6-2: Correlation Δ10Y swap rate and Δ implied volatility

	USD	EUR	JPY	GBP
USD	-	0.59	0.15	0.57
EUR	0.74	-	0.20	0.68
JPY	0.27	0.26	-	0.22
GBP	0.70	0.79	0.19	-

Note: This table reports correlation statistics between the four markets in our sample (USD, EUR, JPY and GBP). Correlations between the monthly changes in the 10 years swap rate are presented below the diagonal. Correlations between the monthly changes in the implied volatility are presented above the diagonal and averaged across the 3, 6, 9 and 12 month swaption maturities. The EUR data before 1999 is from Germany. The number of monthly strategy return observations is 189 and each series runs from April 1996 to December 2011.

A potential concern about our data set could be that the data characteristics suggest that the assumptions of the Black model are violated. It seems that implied volatilities are not log-normally distributed and that jump dynamics are probably in play. The counterfactual on Black does not influence its ability to follow market practice and convert implied volatility quotes into prices but may influence the effectiveness of hedging on basis of the Black model. To alleviate concerns on the hedge ratios we analyze the robustness of our results when the greeks are based on the Vasicek (1977) model and on a stochastic volatility model (SABR) in Section 6.5.3. Moreover, implied volatility from the Black model tends to have a negative correlation with the underlying swap rate (Chan et al., 1992). This might impact the delta-neutrality of our straddles. We work with the constraints of the data by investigating delta-neutrality in section 6.5.1.

6.3.2 Delta hedged straddle returns

Using our swap forward and swaption data, we empirically examine the compensation for volatility risk following the method proposed by Bakshi and Kapadia (2003) and Low and Zhang (2005), based on gains/losses by a delta-hedged strategy. We compute daily delta-hedged returns of swaption straddles for various maturities and re-sample the returns at a monthly frequency. After one month the straddle and swap forward position will be closed and a new straddle will be initiated. It is important to note that we have a holding period of one month for all maturities, whereas most academic studies either limit their analysis to a single short maturity (1-month) or study hold-to-expiration effects. In our view, hold-to-expiration returns for maturities longer than one month raise issues that complicate the interpretation of straddle returns versus the maturity. The main issue is that hold-to-expiration returns for maturities larger than one month overlap and might bias any analysis on the relationship between the swaption maturity and the volatility risk premium.

Table 6-3 gives the summary statistics for daily delta-hedged straddle returns maturing in either 1, 3, 6, 9 or 12 months with a one month holding period. Not surprisingly, the average hold-to-expiration returns for the 1-month maturity swaption straddles are negative for all markets and statistically significant at the 1% level for the USD, JPY and GBP swaptions. This result is consistent to those in Duarte et al. (2007), Fornari (2010) and Mueller et al. (2013) who also report average delta-hedged returns which are negative. Fornari (2010) also finds negative returns for Euro swaptions, which are not statistically significant. Second, for all markets we observe a term structure in the average returns which is similar. The term structure is upward-sloping with the largest negative return for the 1-month maturity. However, unlike Mueller et al. (2013) and Fornari (2010), who report negative volatility risk premiums across all swaption maturities up to 12 months, we find average returns which are positive for the longest maturities. A potential explanation for this is our one month rebalancing frequency against the hold-to-expiration set-up in the latter two studies.

Table 6-3: Pricing of volatility risk

	Maturity	Mean	t-stat	Stdev	Skew	Kurt	AC(1)	Sharpe
USD	1m	-1.49%	-2.60	2.66%	0.16	6.68	-13.20%	-0.56
	3m	-0.43%	-0.66	2.14%	1.87	8.93	19.80%	-0.20
	6m	0.53%	0.71	2.42%	2.51	15.39	22.70%	0.22
	9m	0.99%	1.25	2.62%	2.88	19.88	20.30%	0.38
	12m	1.56%	1.82	2.78%	2.90	20.57	22.20%	0.56
EUR	1m	-0.42%	-0.87	1.68%	-0.05	3.10	6.00%	-0.25
	3m	0.11%	0.24	1.32%	1.47	5.01	27.70%	0.08
	6m	0.73%	1.47	1.52%	2.12	9.00	20.70%	0.48
	9m	0.95%	1.84	1.65%	2.20	9.80	13.90%	0.57
	12m	1.14%	2.09	1.75%	2.26	9.99	16.20%	0.65
JPY	1m	-1.05%	-2.53	1.71%	0.74	4.08	-7.60%	-0.61
	3m	-0.82%	-2.43	1.25%	1.07	2.73	-2.70%	-0.66
	6m	-0.05%	-0.14	1.39%	1.16	2.94	-9.10%	-0.04
	9m	0.22%	0.60	1.38%	1.08	2.48	-6.30%	0.16
	12m	0.45%	1.24	1.45%	0.84	3.22	3.60%	0.31
GBP	1m	-1.39%	-3.24	1.61%	0.16	3.64	4.50%	-0.86
	3m	-0.70%	-1.66	1.39%	1.17	2.36	25.30%	-0.50
	6m	0.21%	0.46	1.48%	1.35	3.07	27.40%	0.14
	9m	1.23%	2.11	1.87%	2.18	9.41	29.20%	0.66
	12m	1.01%	1.97	1.60%	1.44	3.25	26.70%	0.63
EQW	1m	-1.09%	-3.03	1.35%	-0.22	3.69	3.50%	-0.81
	3m	-0.46%	-1.21	1.14%	1.32	2.64	33.40%	-0.40
	6m	0.36%	0.81	1.29%	1.75	4.75	33.70%	0.28
	9m	0.85%	1.82	1.40%	1.78	5.42	32.80%	0.61
	12m	1.04%	2.11	1.43%	2.07	7.85	36.80%	0.73

Note: This table reports annualized summary statistics of non-overlapping monthly returns on a swaption straddle strategy with daily delta hedging and a one month holding period. The maturities of the underlying swaptions are 1, 3, 6, 9 and 12 months, respectively. We set the notional value of the straddle position equal to one and compute the returns from a long straddle perspective. In addition to the USD, EUR, JPY and GBP markets, we compute the summary statistics of an equally-weighted (EQW) portfolio. Summary statistics include annualized sample mean (Mean), annualized standard deviation (Stdev), skewness (Skew), kurtosis (Kurt), first-order autocorrelation (AC(1)) and annualized Sharpe ratio. t-statistics are adjusted according to Newey and West (1987) to correct for heteroscedasticity and serial correlation up to four lags. The number of observations in each series is 189 and runs from April 1996 to December 2011.

6.4 Empirical results Riding the swaption curve

Following the strategy set-up that was discussed in Section 6.2, we now calculate the empirical returns of the delta-vega and delta-gamma neutral strategies. We report the outcomes for four swaption maturity combinations: short 3-month and long 6-month maturity straddles (3 vs 6), 6 vs 9, 9 vs 12 and 3 vs 12. For each maturity combination we report the return statistics per individual market and for an equally weighted portfolio that comprises all four markets. Table 6-4 shows the summary statistics, including the average annualized return, standard deviation, *t*-statistic, skewness, kurtosis, Sharpe ratio, first order autocorrelation and the hit ratio.

Most importantly, Table 6-4 shows consistent positive average returns across all maturities and markets for both delta-gamma and delta-vega neutral strategies. All of the delta-gamma neutral returns have statistically significant means, while 13 out of 16 average returns for the delta-vega neutral strategy are statistically significant. For example, focusing on the 3 vs 6-month delta-gamma neutral strategy average annualized returns are between 0.64% (JPY) and 0.94% (USD), and Sharpe ratios between 0.72 (JPY) and 0.89 (GBP). For the delta-vega neutral strategies returns are slightly wider dispersed with average returns between 0.52% (EUR) and 1.09% (GBP), and Sharpe ratios between 0.54 (USD) and 1.21 (GBP). The Sharpe ratios are comparable to those reported by Cremers et al. (2015) for a similar strategy in the U.S. equity market.[72] In light of our research question, to analyze the term structure of the volatility risk premium, the positive returns are intuitively consistent with an upward-sloping term structure in the volatility risk premium. This is consistent with Fornari (2010) and Mueller et al. (2013) who both report negative risk premiums and a downward-sloping term structure of the volatility risk premium (in absolute terms) for the fixed income market.

Next, note that looking across the maturity spectrum, we observe the largest average returns for the shortest maturity combination (3 vs 6-month) and then a decreasing pattern. This pattern is consistent for all markets. For example, the equally weighted portfolio that comprises all four markets earns 0.75% per year on average (*t*-stat of 3.65) with a Sharpe ratio of 1.18 for the 3 vs 6-month delta-gamma neutral portfolio. The returns for the 6 vs 9-month and 9 vs 12-month portfolios are 0.40% (*t*-stat of 3.89) and 0.35% (*t*-stat of 4.25), respectively. Comparable, we see the equally weighted portfolio returns decrease with the maturity for the delta-vega neutral strategy with average annualized returns of 0.81% (*t*-stat of 4.23) for the shortest maturity combination, 0.29% (*t*-stat of 2.50) and 0.23% (*t*-stat of 2.51). Based on this, we conclude that our results suggest that the term structure of the volatility risk premium is concave.

Table 6-4: Summary statistics for long-short straddles trading strategies

[72] Cremers et al. (2015) report a Sharpe ratio of -0.55 for a 1vs2-month delta-gamma neutral strategy and -0.93 for a 1vs2-month delta-vega neutral strategy. Note that these strategies are 'long-short' while our strategies are 'short-long' which explains the opposite sign.

	Maturity	Mean	t-stat	Stdev	Skew	Kurt	AC(1)	Sharpe	Hit
Panel A: Delta-Gamma neutral combination									
USD	3 vs 6	0.94%	2.68	1.20%	2.33	14.88	13.99%	0.78	55%
	6 vs 9	0.62%	3.19	0.76%	2.38	19.42	-2.71%	0.81	62%
	9 vs 12	0.47%	3.35	0.56%	0.33	1.06	-1.65%	0.84	56%
	3 vs 12	2.57%	3.29	2.71%	1.86	11.89	9.46%	0.95	62%
EUR	3 vs 6	0.72%	2.99	0.88%	2.01	9.06	-3.32%	0.81	60%
	6 vs 9	0.29%	2.54	0.55%	0.92	9.35	-20.67%	0.53	58%
	9 vs 12	0.34%	2.92	0.49%	1.23	5.74	-4.14%	0.69	61%
	3 vs 12	1.72%	3.41	2.07%	2.50	14.66	-11.06%	0.83	61%
JPY	3 vs 6	0.64%	2.72	0.89%	1.71	8.90	-6.79%	0.72	59%
	6 vs 9	0.32%	2.13	0.55%	0.82	3.64	-1.68%	0.59	51%
	9 vs 12	0.35%	2.53	0.56%	-0.01	2.46	-7.32%	0.62	59%
	3 vs 12	1.66%	3.1	2.06%	1.34	6.77	-8.70%	0.81	62%
GBP	3 vs 6	0.69%	2.97	0.78%	0.88	1.51	13.10%	0.89	56%
	6 vs 9	0.37%	2.53	0.55%	0.00	1.52	1.40%	0.68	57%
	9 vs 12	0.23%	1.71	0.50%	-0.40	3.52	-2.49%	0.45	55%
	3 vs 12	1.60%	3.02	1.72%	0.95	1.78	15.78%	0.93	58%
EQW	3 vs 6	0.75%	3.65	0.63%	1.36	3.26	19.31%	1.18	59%
	6 vs 9	0.40%	3.89	0.37%	1.34	5.51	4.64%	1.10	63%
	9 vs 12	0.35%	4.25	0.29%	0.28	1.88	10.98%	1.17	66%
	3 vs 12	1.89%	4.33	1.40%	1.65	5.37	16.42%	1.35	63%

	Maturity	Mean	t-stat	Stdev	Skew	Kurt	AC(1)	Sharpe	Hit
Panel B: Delta-Vega neutral combination									
USD	3 vs 6	0.85%	2.51	1.57%	-2.73	12.81	-6.74%	0.54	70%
	6 vs 9	0.36%	1.84	0.91%	-3.05	16.74	-1.52%	0.40	67%
	9 vs 12	0.26%	1.76	0.67%	-1.27	5.65	0.62%	0.39	62%
	3 vs 12	1.25%	2.34	2.47%	-2.87	14.05	-3.68%	0.51	69%
EUR	3 vs 6	0.52%	2.17	0.90%	-1.48	5.63	3.83%	0.58	65%
	6 vs 9	0.11%	0.73	0.54%	-1.61	6.32	8.51%	0.20	64%
	9 vs 12	0.14%	1.27	0.45%	-0.13	6.44	3.24%	0.32	59%
	3 vs 12	0.68%	1.78	1.39%	-1.76	7.11	7.59%	0.48	64%
JPY	3 vs 6	0.79%	3.17	1.06%	-2.65	12.60	-8.50%	0.75	74%
	6 vs 9	0.23%	1.29	0.74%	-2.48	16.14	-7.03%	0.31	64%
	9 vs 12	0.29%	2.09	0.50%	-1.15	6.30	5.57%	0.58	65%
	3 vs 12	1.10%	2.71	1.68%	-2.96	16.02	-5.87%	0.65	71%
GBP	3 vs 6	1.09%	5.05	0.90%	-2.46	12.00	-0.63%	1.21	74%
	6 vs 9	0.44%	3.50	0.55%	-0.77	2.22	-3.28%	0.80	67%
	9 vs 12	0.21%	1.65	0.45%	-0.11	2.30	7.04%	0.47	59%
	3 vs 12	1.52%	4.46	1.34%	-2.08	9.37	4.90%	1.13	72%
EQW	3 vs 6	0.81%	4.23	0.76%	-2.01	8.32	6.00%	1.07	68%
	6 vs 9	0.29%	2.50	0.44%	-1.76	6.44	10.78%	0.66	64%
	9 vs 12	0.23%	2.51	0.34%	-0.91	2.89	6.31%	0.66	61%
	3 vs 12	1.14%	3.69	1.19%	-1.99	7.72	8.94%	0.95	67%

Note: This table reports annualized summary statistics of non-overlapping monthly returns on long-short swaption straddles strategies. Each month a swaption straddle with the lowest maturity is sold with a notional of one, and held for one month. At the same time an additional long straddle position, with a higher maturity, is bought at a notional that either neutralizes the vega or gamma exposure of the combined long-short position. The straddles are initiated on the last business day of the month. In addition to the USD, EUR, JPY and GBP markets, we compute the summary statistics of an equally-weighted (EQW) portfolio. Summary statis-tics include annualized sample mean (Mean), annualized standard deviation (Stdev), skewness (Skew), kurtosis (Kurt), first-order autocorrelation (AC(1)), annualized Sharpe ratio and the percentage of months with a positive return (Hit). t-statistics are adjusted according to Newey and West (1987, 1994) to correct for heteroscedasticity and serial correlation up to four lags. The number of observations in each series is 189 and runs from April 1996 to December 2011.

In the spirit of Cremers et al. (2015) we conjecture that the consistent positive strategy returns reported in Table 6-4 suggest that both volatility risk (delta-gamma) and jump risk (delta-vega neutral) contribute to the term structure in the volatility risk premium. In the remainder of this section we investigate the difference between the delta-gamma and delta-vega neutral strategies in more detail.

In Table 6-5 we present the pairwise correlations between the delta-gamma and delta-vega neutral strategies for each maturity-market combination. The mean correlation across the four markets is -23.2% for the 3 vs 6-month strategy. This indicates that the two strategies are uncorrelated and probably capture a different effect. The increasing correlations (-3.6% and 37.8%) for longer maturities suggest that both strategies are distinctive but get more in common when maturity increases. The maturity structure in the correlations may be linked to how volatility and jump risk is perceived by investors. Aït-Sahalia et al. (2012) for example find that a jump component is embedded in the volatility risk premium in the U.S. equity market and that "short-term variance risk premiums mainly reflect investors' fear of a market crash, rather than the impact of stochastic volatility on the investment opportunity set".

Table 6-5: Pairwise correlations

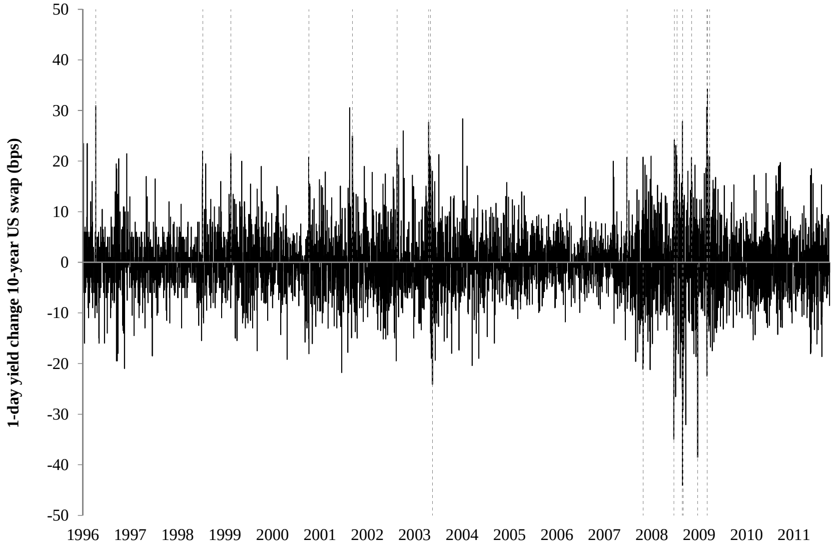
	3 vs 6	6 vs 9	9 vs 12	3 vs 12
USD	-38.4%	-30.0%	30.7%	-34.7%
EUR	-19.5%	-8.2%	28.2%	-32.0%
JPY	-31.1%	0.6%	40.3%	-33.7%
GBP	-3.8%	23.3%	51.8%	-21.4%
average	-23.2%	-3.6%	37.8%	-30.5%

Note: This table reports pairwise correlations between the delta-gamma and delta-vega neutral strategy returns. Correlations are computed separately for the combinations of market and swaption maturities. The number of monthly strategy return observations is 189 and each series runs from April 1996 to December 2011.

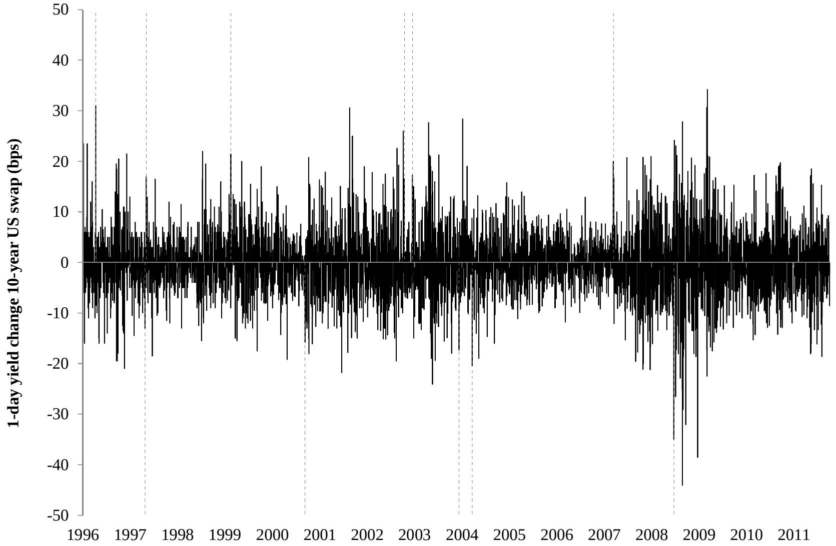
Next, we investigate the link between jump risk and the delta-vega neutral strategy in more detail. The delta-vega strategy has negative gamma exposure. We expect the strategy to make a large negative return when a jump occurs and will analyze the strategy returns during jumps. In Figure 6-2 we show the time-series of the daily changes in the 10-year USD swap rate. The vertical lines in Panel A indicate the 1% largest daily changes (absolute) in the daily swap rate. Some of these largest changes could however coincide with periods of high volatility, which might misclassify an observation as a jump. For this reason the vertical lines in Panel B indicate realized jumps according to the non-parametric jump test of Lee and Mykland (2008). If we take out these jump days from our delta-vega strategy returns we expect the returns to be higher. This aligns with our results in Panel B in Table 6-6. In this table we take out the 1% days with the largest change in the 10-year swap rate from the strategy returns. We do the same for the days with realized jumps according to Lee and Mykland (2008). In both analyses we observe consistent higher returns than the full sample results presented in Table 6-4. From this finding we infer that there seems to be a link between jump risk and the delta-vega neutral strategy returns. From Panel A in Table 6-6 we also observe that the returns of the delta-gamma neutral strategy are hardly affected by taking out the jumps.

Figure 6-2: Time series of daily swap rate changes and realized jumps

(a) Realized jumps defined as 1% largest absolute changes



(b) Realized jumps according to Lee and Mykland (2008)



This figure illustrates the difference between detection methods for jumps in the times series of daily changes of the 10 years swap rate for the USD market. The vertical, dashed lines in Panel A represent realized jumps defined as the 1% largest absolute changes in the daily swap rate (41 observations). The vertical, dashed lines in Panel B represent realized jumps (22 observations) according to Lee and Mykland (2008). The sample runs from April 1996 to December 2011 and includes 4,110 daily observations.

Finally, we investigate the link between volatility risk and the delta-gamma neutral strategy in more detail. The delta-gamma strategy has positive vega exposure and is constructed such that it makes a positive return if the market expectation of future volatility rises. For this reason we expect the delta-gamma strategy returns to be lower if we take out the months with the largest increase in volatility. This is what we find in Panel A in Table 6-6 where we take out the strategy return for the 5% months with the largest increase in realized volatility. We note that all maturity combinations have mean returns lower than the full sample results presented in Table 6-4. For example, the average return for the 3 vs 6-month USD delta-gamma neutral strategy decreases from 0.94% to 0.47%. This result suggests that there might be a link between the delta-gamma strategy returns and the volatility risk premium. From Panel B in Table 6-6 we also observe that the returns of the delta-gamma neutral strategy are positively affected by taking out the 5% months with the largest increase in realized volatility. It may be the case that these months (partly) overlap with jumps in the underlying swap rate.

Table 6-6: Effect of jumps on strategy returns

Panel A: Delta-Gamma neutral combination		*excl. Jumps(1%)*			*excl. Jumps(LM2008)*			*excl. ΔVol(5%)*		
		Mean	t-stat	Sharpe	Mean	t-stat	Sharpe	Mean	t-stat	Sharpe
USD	3 vs 6	0.84%	2.54	0.76	0.90%	2.51	0.77	0.47%	1.74	0.50
	6 vs 9	0.52%	2.86	0.74	0.59%	3.29	0.79	0.36%	2.29	0.61
	9 vs 12	0.43%	3.13	0.75	0.43%	3.13	0.76	0.37%	2.80	0.68
	3 vs 12	2.27%	3.31	0.97	2.42%	3.23	0.94	1.56%	2.50	0.72
EUR	3 vs 6	0.54%	2.83	0.70	0.71%	3.02	0.81	0.30%	1.66	0.46
	6 vs 9	0.27%	2.62	0.53	0.29%	2.50	0.52	0.07%	0.79	0.17
	9 vs 12	0.30%	2.57	0.61	0.35%	2.89	0.71	0.22%	2.06	0.51
	3 vs 12	1.44%	3.38	0.79	1.73%	3.42	0.84	0.80%	2.07	0.53
JPY	3 vs 6	0.34%	1.85	0.44	0.56%	2.42	0.65	0.28%	1.47	0.40
	6 vs 9	0.21%	1.86	0.39	0.26%	1.65	0.48	0.17%	1.28	0.34
	9 vs 12	0.37%	2.36	0.53	0.89%	1.50	0.38	0.28%	2.04	0.52
	3 vs 12	1.26%	2.86	0.63	2.47%	2.00	0.50	0.95%	2.22	0.56
GBP	3 vs 6	0.65%	3.03	0.83	0.68%	2.94	0.85	0.33%	1.87	0.51
	6 vs 9	0.26%	1.74	0.48	0.38%	2.61	0.70	0.23%	1.70	0.44
	9 vs 12	0.28%	1.91	0.53	0.22%	1.65	0.43	0.11%	0.89	0.22
	3 vs 12	1.50%	2.93	0.86	1.59%	3.02	0.91	0.84%	2.11	0.58
EQW	3 vs 6	0.59%	3.51	1.04	0.71%	3.49	1.13	0.33%	1.46	0.77
	6 vs 9	0.31%	3.38	0.90	0.38%	3.89	1.07	0.19%	1.80	0.75
	9 vs 12	0.34%	4.27	1.09	0.47%	2.77	0.73	0.23%	3.10	0.91
	3 vs 12	1.62%	4.34	1.26	2.05%	3.96	1.16	0.98%	2.48	1.06

Panel B: Delta-Vega neutral combination		*excl. Jumps(1%)*			*excl. Jumps(LM2008)*			*excl. ΔVol(5%)*		
		Mean	t-stat	Sharpe	Mean	t-stat	Sharpe	Mean	t-stat	Sharpe
USD	3 vs 6	1.43%	4.29	1.13	1.05%	3.24	0.70	1.32%	3.80	0.97
	6 vs 9	0.64%	4.19	0.87	0.45%	2.27	0.52	0.68%	4.00	0.90
	9 vs 12	0.42%	3.05	0.67	0.30%	2.08	0.46	0.46%	2.96	0.75
	3 vs 12	2.11%	4.56	1.10	1.53%	3.01	0.66	2.05%	3.86	0.97
EUR	3 vs 6	0.76%	3.28	0.91	0.60%	2.56	0.70	0.65%	2.78	0.79
	6 vs 9	0.30%	2.38	0.61	0.15%	1.00	0.28	0.23%	1.61	0.47
	9 vs 12	0.24%	2.39	0.56	0.17%	1.59	0.38	0.27%	2.48	0.65
	3 vs 12	1.10%	3.17	0.87	0.79%	2.16	0.60	0.96%	2.62	0.76
JPY	3 vs 6	1.11%	5.53	1.45	0.83%	3.37	0.82	1.09%	5.27	1.25
	6 vs 9	0.48%	3.75	0.90	0.25%	1.48	0.35	0.47%	2.82	0.78
	9 vs 12	0.49%	3.61	0.86	0.79%	1.62	0.40	0.46%	4.31	1.08
	3 vs 12	1.70%	5.50	1.41	1.43%	3.53	0.78	1.66%	5.04	1.24
GBP	3 vs 6	1.31%	6.21	1.60	1.18%	5.62	1.43	1.36%	6.59	1.87
	6 vs 9	0.49%	4.28	0.93	0.49%	3.99	0.94	0.64%	5.58	1.33
	9 vs 12	0.35%	2.51	0.75	0.23%	1.85	0.51	0.33%	2.71	0.79
	3 vs 12	1.85%	5.66	1.50	1.65%	4.99	1.34	1.99%	6.36	1.83
EQW	3 vs 6	1.15%	6.48	1.81	0.91%	5.06	1.29	1.05%	5.92	1.71
	6 vs 9	0.48%	5.66	1.26	0.34%	3.08	0.81	0.48%	5.15	1.41
	9 vs 12	0.38%	4.73	1.17	0.38%	2.72	0.63	0.36%	5.62	1.25
	3 vs 12	1.69%	6.46	1.71	1.35%	4.86	1.17	1.57%	5.97	1.67

Note: This table reports annualized summary statistics of non-overlapping monthly returns on long-short swaption straddles strategies for three differently truncated samples. First, we take out the days on which the absolute daily change in the 10-year swap rate belongs to the 1% largest changes in our sample period (excl. Jumps(1%)). Secondly, we take out the days on which the 10-year swap rate jumped (excl. Jumps(LM2008)) according to Lee and Mykland (2008). Thirdly, we take out the 5% months with the largest increase in realized volatility (excl. ΔVol(5%)). The realized volatility is calculated as the standard deviation of daily changes of 10 years swap rate during the month. Summary statistics include annualized sample mean (Mean), t-statistics (t-stat) and annualized Sharpe ratio (Sharpe). t-statistics are adjusted according to Newey and West (1987, 1994) to correct for heteroscedasticity and serial correlation up to four lags. The samples run from April 1996 to December 2011.

The evidence presented in this section, which essentially shows that long-short swaption straddles strategies produce positive average returns that decrease in maturity, is consistent with a concave, upward-sloping term structure in the volatility risk premium. The fact that both delta-vega and delta-gamma neutral strategies earn positive returns that seem uncorrelated suggests that the term structure of the volatility risk premium is affected by both jump risk and volatility risk. This finding contributes to recent studies on the pricing of jump and volatility risk in the fixed income market such as Trolle and Schwartz (2014) and Li and Song (2013).

6.5 Robustness and Sensitivity analysis

In this section we present a variety of additional sensitivity and robustness analysis of our main findings. We first test the delta-neutrality of our strategy and analyze the empirical relationship between the strategy returns and rate changes. Moreover, we investigate the impact of macroeconomic releases. Next, we check if our main results can be confirmed using the Vasicek (1977) model and a stochastic volatility model. Finally, we re-run our strategies on two additional data sets which include the 2-year tenor and swaption smile data for the USD.

6.5.1 Hedging Efficiency

A potential concern might be that our straddles are not delta neutral but exposed to changes in the underlying swap rate. This exposure could originate from at least two channels: monthly rebalancing instead of daily rebalancing and a violation of the assumptions of the Black model in our data set. To examine the impact of monthly rebalancing, we graphically analyze the daily intra-month Black risk exposures for the 3- vs 6-month strategies. Next, to investigate the exposure to the underlying empirically, we regress the strategy returns on the rate changes. The specification of this model is:

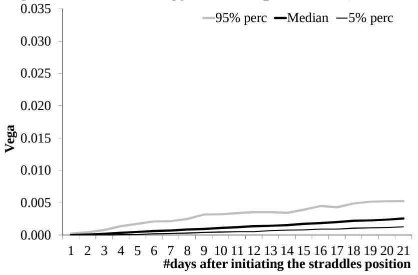
$$RLS_t = \beta_0 + \beta_1 \Delta SR_t^{10Y} + \varepsilon_t \qquad (6\text{-}12)$$

where RLS_t is the return of the long-short straddles strategy in month t and ΔSR_t^{10Y} is the difference between the 10-year swap rate in month t and t - 1.

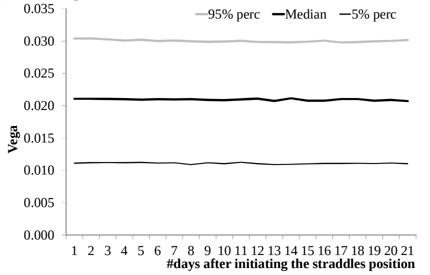
Most likely, risk exposures will change during the month because of the changes in the underlying and in the implied volatility. This could potentially impact the strategy returns and bias our conclusions. To address this discretization error, as highlighted by Branger and Schlag (2008), Figure 6-3 plots the average daily risk exposures for the USD 3 vs 6-month strategies and illustrates how the Black delta, gamma and vega develop between two monthly rebalances.[73] Each panel plots a single risk exposure and shows the 5% percentile, median and 95% percentile across all months in our data sample. Most importantly, we note that the median delta exposures for both the delta-vega hedge (Panel E) and the delta-vega hedge (Panel F) stay very close to zero and are 0.04 and 0.06 respectively after one month. Notwithstanding, the 90% bandwidth for the delta-gamma neutral strategy is smaller than for the delta-vega neutral strategy. Based on this observation, we conclude that it seems unlikely that the outcomes are the result of a large exposure to the underlying.

[73] The results for the other maturities and markets are similar and available upon request.

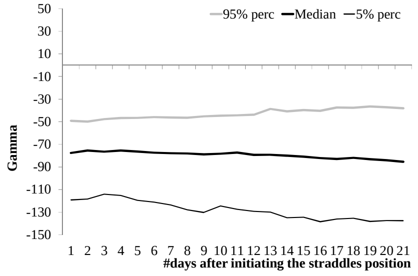
Figure 6-3: Strategy risk exposures ("Greeks") during the month



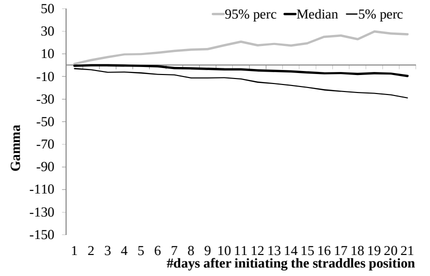
(a) Vega – *vega neutral*



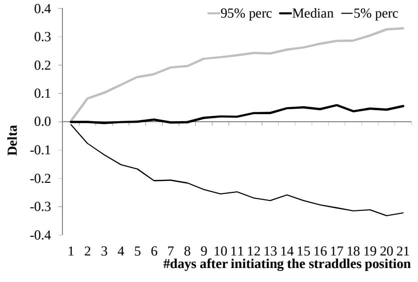
(b) Vega – *gamma neutral*



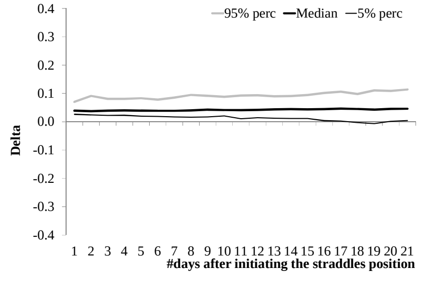
(c) Gamma – *vega neutral*



(d) Gamma – *gamma neutral*



(e) Delta – *vega neutral*



(f) Delta – *gamma neutral*

This figure plots the average (over time series) risk exposures (`Greeks') of the Delta-Gamma and Delta-Vega neutral 3 vs 6 month calendar spread straddles strategy in the USD market. For each working day of the month, the Greeks are calculated using the Black model. Delta is the sensitivity of the straddle to the underlying swap forward rate, vega is the sensitivity to the implied volatility and gamma is the sensitivity of the delta to the underlying swap forward rate.

Continuing on the exposure to the underlying, Table 6-7 reports the results from estimating Equation 6-12 and shows some interesting features. For the delta-gamma-neutral strategy we observe negative estimates for β_1, that are statistically significant for the USD, EUR and GBP markets. The coefficients for JPY are not statistically significant. This being said, 15 out of 16 estimates for β_0 are statistically significant, indicating that the strategy returns do not appear to be explained by exposure to the underlying swap rate. These results contrast with the results for the delta-vega neutral strategy. Here we see only two positive estimates for β_1, that are statistically significant; all other coefficients are not statistically significant. The strategy returns after correcting for the change in the swap rate remain statistically significant for 13 out of 16 strategies and are very close to the unadjusted returns reported in Table 6-4.

Table 6-7: Regression of strategy returns on swap rate changes

		Gamma neutral					Vega neutral				
		β_0	t-stat	β_1	t-stat	R^2	β_0	t-stat	β_1	t-stat	R^2
USD	3 vs 6	0.83%	2.71	-0.35	-1.74	0.09	0.88%	2.52	0.09	0.27	0.00
	6 vs 9	0.51%	3.38	-0.36	-3.31	0.22	0.36%	1.87	0.00	-0.01	0.00
	9 vs 12	0.43%	3.14	-0.15	-2.75	0.07	0.28%	1.76	0.04	0.30	0.00
	3 vs 12	2.23%	3.35	-1.12	-2.89	0.17	1.28%	2.35	0.11	0.20	0.00
EUR	3 vs 6	0.57%	2.72	-0.52	-2.92	0.14	0.60%	2.48	0.28	1.46	0.04
	6 vs 9	0.19%	2.05	-0.37	-3.68	0.18	0.15%	0.99	0.14	1.20	0.03
	9 vs 12	0.25%	2.41	-0.31	-4.00	0.16	0.16%	1.46	0.09	1.02	0.01
	3 vs 12	1.29%	3.16	-1.58	-3.59	0.23	0.79%	2.08	0.43	1.37	0.04
JPY	3 vs 6	0.68%	2.73	0.29	1.04	0.03	0.72%	2.77	-0.44	-1.15	0.05
	6 vs 9	0.32%	2.06	0.01	0.08	0.00	0.17%	0.94	-0.38	-1.35	0.07
	9 vs 12	0.34%	2.35	-0.03	-0.21	0.00	0.26%	1.74	-0.17	-1.07	0.03
	3 vs 12	1.70%	2.95	0.25	0.40	0.00	0.98%	2.29	-0.79	-1.23	0.06
GBP	3 vs 6	0.62%	2.93	-0.20	-1.93	0.03	1.23%	5.95	0.37	1.84	0.08
	6 vs 9	0.30%	2.28	-0.19	-2.86	0.06	0.50%	4.26	0.15	1.52	0.04
	9 vs 12	0.17%	1.35	-0.13	-2.31	0.04	0.25%	2.14	0.10	1.51	0.02
	3 vs 12	1.34%	2.86	-0.67	-2.94	0.08	1.72%	5.52	0.53	1.79	0.08

Note: This table presents estimated results for the contemporaneous regression of the monthly strategy returns on the monthly change of the 10-year swap rate

$$RLS_t = \beta_0 + \beta_1 \Delta SR_t^{10Y} + \varepsilon_t$$

where RLS_t is the return of the long-short straddles strategy in month *t* and ΔSR_t is the difference of the 10-year swap rate (SR_t^{10Y})in month *t* and *t-1*. For each market and long-short maturity combination we estimate the model separately. *t*-statistics are adjusted according to Newey and West (1987, 1994) to correct for heteroscedasticity and serial correlation up to four lags. The number of observations in each series is 189 and runs from April 1996 to December 2011.

Finally, we expand the model in Equation 6-12 with three additional factors; the monthly change of the slope of the yield curve ($\Delta 10Y3M_t$), the monthly change of the implied volatility ($\Delta\sigma_t$), and the delta-hedged return of a 1-month short straddle position ($R_t^{straddle}$). We define the slope of the yield curve as the difference between the 3-month rate and the 10-year swap rate. That is, the model is given by

$$RLS_t = \beta_0 + \beta_1 \Delta SR_t^{10Y} + \beta_2 \Delta 10Y3M_t + \beta_3 \Delta\sigma_t + \beta_4 R_t^{straddle} + \varepsilon_t \qquad (6\text{-}13)$$

The four factor model is estimated and the estimation results are reported in Table 6-8. Most importantly, we observe that 15 out of 16 and 11 out of 16 estimates for the intercept, β_0, are statistically significant at a 10% level for the delta-gamma neutral and delta-vega neutral strategies respectively. This suggests that the strategy returns do not appear to be explained by the four factors. Additionally, we see negative sensitivities for the change in volatility and positive sensitivities for the 1-month straddle returns for the delta-vega neutral strategy. Furthermore, the returns for the delta-gamma neutral strategy are positively correlated with the change in the implied volatility, as evidenced by the positive and significant estimates of β_3. Finally, the estimates for the coefficients of the change of the 10-year yield and the slope are insignificant for the majority of maturity-market combinations.

We close this section by concluding that the evidence presented in this section suggest that it seems unlikely that the strategy returns can fully be explained by exposures to the underlying swap rate, the slope of the yield curve, the implied volatility or 1-month delta-hedged returns.

Table 6-8: Regression of strategy returns on swap rate, yield curve steepness and relative volatility changes and the daily delta-hedged straddle return

Panel A: Delta-Gamma neutral combination

		β_0	t-stat	β_1	t-stat	β_2	t-stat	β_3	t-stat	β_4	t-stat	R^2
USD	3 vs 6	0.80%	3.36	-0.11	-1.06	0.16	2.17	0.06	5.54	-0.01	-0.31	0.55
	6 vs 9	0.51%	3.99	-0.15	-2.64	0.04	0.82	0.04	6.38	-0.01	-0.61	0.53
	9 vs 12	0.39%	2.90	-0.09	-1.64	0.03	0.86	0.02	2.54	0.01	0.78	0.12
	3 vs 12	1.99%	3.97	0.06	0.28	0.32	1.96	0.29	8.85	0.03	0.56	0.69
EUR	3 vs 6	0.54%	3.52	-0.11	-1.07	0.10	1.49	0.08	10.72	0.04	1.46	0.65
	6 vs 9	0.17%	2.28	-0.09	-1.65	-0.01	-0.25	0.05	9.06	0.01	0.74	0.51
	9 vs 12	0.23%	2.36	-0.15	-2.26	0.01	0.39	0.03	4.91	0.03	1.13	0.31
	3 vs 12	1.14%	4.48	0.02	0.12	0.04	0.33	0.32	8.64	0.08	1.26	0.83
JPY	3 vs 6	0.54%	2.76	0.01	0.03	0.22	1.23	0.04	8.22	0.08	2.02	0.52
	6 vs 9	0.32%	2.46	-0.27	-1.04	0.35	1.32	0.02	4.23	-0.02	-0.62	0.24
	9 vs 12	0.33%	2.11	0.19	0.86	-0.14	-0.65	0.02	4.08	0.01	0.23	0.12
	3 vs 12	1.59%	3.13	0.78	1.29	0.59	1.10	0.14	6.43	0.01	0.17	0.55
GBP	3 vs 6	0.52%	3.52	0.03	0.32	0.12	1.37	0.08	9.36	0.04	1.40	0.56
	6 vs 9	0.24%	2.34	-0.07	-1.13	0.06	1.27	0.04	4.70	0.03	1.18	0.26
	9 vs 12	0.19%	1.55	-0.12	-1.70	0.09	2.30	0.02	1.94	-0.02	-1.15	0.11
	3 vs 12	1.11%	4.04	0.19	0.85	0.16	0.92	0.32	13.48	0.10	1.85	0.74

Panel B: Delta-Vega neutral combination												
		β_0	t-stat	β_1	t-stat	β_2	t-stat	β_3	t-stat	β_4	t-stat	R^2
USD	3 vs 6	0.72%	2.44	-0.21	-0.85	-0.12	-1.04	-0.06	-3.69	0.12	2.90	0.35
	6 vs 9	0.32%	2.15	-0.21	-1.56	-0.14	-2.11	-0.05	-5.19	0.06	3.08	0.46
	9 vs 12	0.23%	1.77	-0.18	-1.90	-0.04	-1.29	-0.04	-6.94	0.04	2.41	0.37
	3 vs 12	0.96%	2.04	-0.41	-1.11	-0.32	-1.78	-0.13	-3.57	0.28	5.61	0.32
EUR	3 vs 6	0.51%	2.80	0.04	0.28	-0.02	-0.16	-0.03	-2.01	0.20	3.28	0.32
	6 vs 9	0.11%	0.99	-0.02	-0.19	-0.08	-1.41	-0.03	-3.68	0.11	3.15	0.37
	9 vs 12	0.14%	1.54	-0.11	-2.03	-0.02	-0.55	-0.03	-5.66	0.07	5.83	0.35
	3 vs 12	0.64%	2.23	0.07	0.28	-0.12	-0.81	-0.07	-1.97	0.36	5.45	0.32
JPY	3 vs 6	0.56%	2.54	-0.33	-0.75	-0.09	-0.28	-0.02	-2.16	0.19	2.64	0.35
	6 vs 9	0.09%	0.57	-0.49	-1.36	0.07	0.27	-0.02	-2.43	0.09	2.29	0.39
	9 vs 12	0.20%	1.45	-0.01	-0.04	-0.25	-1.40	-0.01	-1.66	0.06	3.33	0.20
	3 vs 12	0.57%	1.46	-0.72	-0.90	-0.31	-0.59	-0.03	-1.36	0.40	4.42	0.30
GBP	3 vs 6	0.89%	4.52	0.30	1.54	-0.11	-0.76	-0.02	-1.38	0.24	5.26	0.34
	6 vs 9	0.34%	3.49	0.02	0.30	-0.03	-0.62	-0.03	-3.92	0.11	5.85	0.37
	9 vs 12	0.20%	1.97	-0.05	-0.97	0.01	0.13	-0.04	-6.14	0.04	2.49	0.32
	3 vs 12	1.18%	4.33	0.34	1.28	-0.14	-0.72	-0.05	-2.32	0.38	7.66	0.39

Note: This table presents estimated results for the following contemporaneous regression model

$$RLS_t = \beta_0 + \beta_1 \Delta SR_t^{10Y} + \beta_2 \Delta 10Y3M_t + \beta_3 \Delta\sigma_t + \beta_4 R_t^{straddle} + \varepsilon_t$$

where RLS_t is the return of the long-short straddles strategy in month t, ΔSR_t^{10Y} is the difference of the 10-year swap rate (SR^{10Y}) in month t and t-1, $\Delta\sigma_t$ is the difference of the relative implied volatility (σ) in month t and t-1 and $R_t^{straddle}$ is the daily delta-hedged return on a delta neutral straddle in month t. For each market and long-short maturity combination we estimate the model separately. t-statistics are adjusted according to Newey and West (1987, 1994) to correct for heteroscedasticity and serial correlation up to four lags. The number of observations in each series is 189 and runs from April 1996 to December 2011.

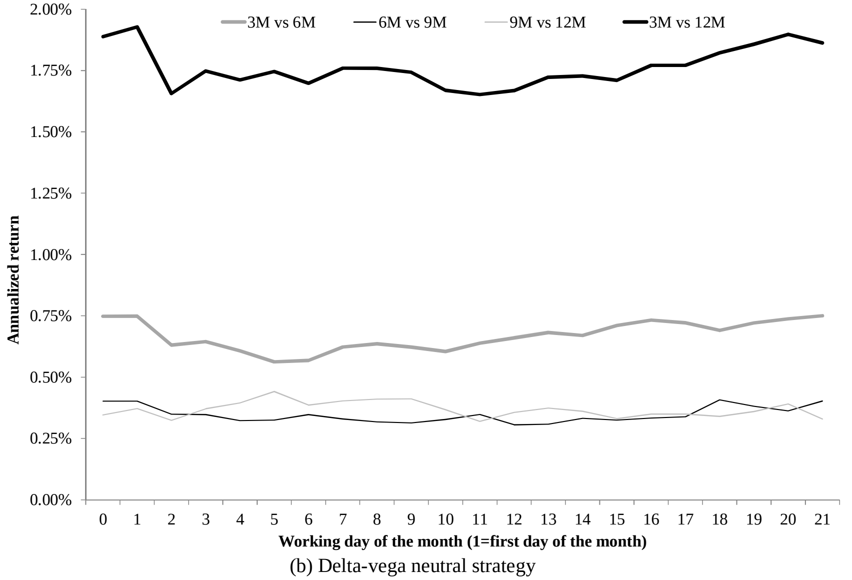
6.5.2 Day of the month

Several studies have documented that bond markets respond to scheduled macroeconomic announcements, even more strongly than the stock markets (see e.g. Andersen et al. (2007)). In this section we consider a possible day-of-the-month effect because the majority of these macroeconomic measures is released around the turn of the month. Since the scheduled macroeconomic announcements impact bond yields but also the volatility risk (Fornari, 2010) and jump risk (Li and Song, 2013) premiums, these announcements might also influence the returns of the delta-vega and delta-gamma neutral strategies. Announcements might have a larger impact on the long-short returns when the position is not delta, gamma or vega neutral. Therefore, the specific day of the month that we have chosen to open and close our positions may impact our earlier results. Until now, we used the data of the last trading day of the month to open new straddle positions and to close the previous straddle positions. To assess whether our earlier results are impacted by macroeconomic announcements we initiate the monthly straddle combinations for each individual working day of the month. For example, we open the long-short straddles position on the first day of the month instead of the last day, etc.

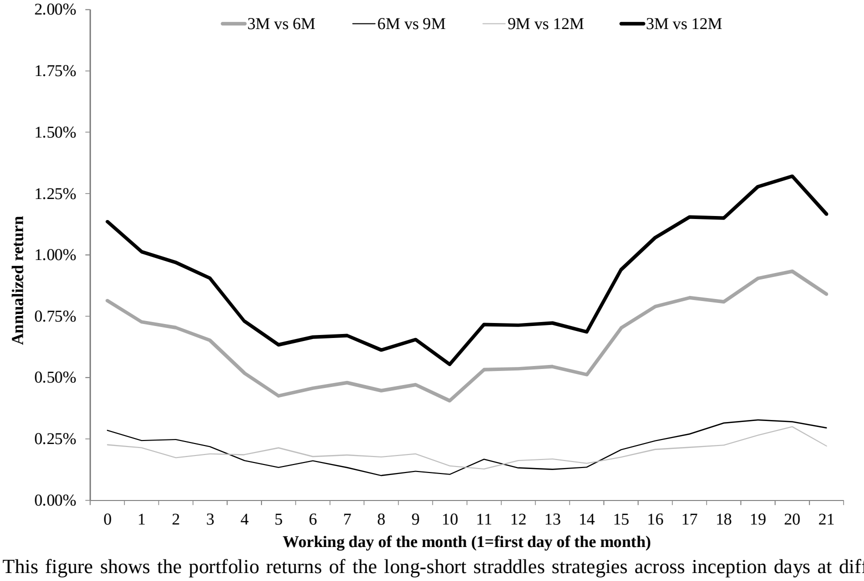
In Figure 6-4 we plot the average strategy returns across different inception days of the month. For the delta-gamma neutral strategy (Panel A) we observe almost no differences between the average returns across different days of the month. In contrast, we see a small day-of-the-month effect in the returns for the delta-vega neutral strategy (Panel B). Average returns are somewhat higher around month end and lower in the middle of the month, but all returns are statistically significant. Further analysis (not shown) indicates that volatilities of the returns are stable over the month implying that the differences between returns are not caused by a higher risk. As Dungey et al. (2009) relates jumps to the release of macroeconomic data in the fixed income market, the day-of-the-month results seem to confirm the link between the delta-vega hedged results and jump risk. Overall, the day-of-the-month analysis which essentially shows statistically significant and positive returns for all days of the month, indicates that our results are not driven by a specific choice of the inception day.

Figure 6-4: Day-of-the-month return effect

(a) Delta-gamma neutral strategy



(b) Delta-vega neutral strategy



This figure shows the portfolio returns of the long-short straddles strategies across inception days at different working days of the month. Portfolio returns are the equally weighted (EQW) average returns for the USD, EUR, GBP and JPY markets. The number of observations in each series is 189 and runs from April 1996 to December 2011. $t = 0$ is the last working day of the previous month.

6.5.3 Beyond Black's model

To address the concern that the assumptions behind the Black model can be violated in practice and might affect the effectiveness of our hedges, we analyze the robustness of our main findings by re-running our strategies on the Vasicek (1977) model and the SABR model.

6.5.3.A Vasicek model

The assumptions behind the Vasicek model are almost equal to the Black model. The only difference is that the Vasicek model assumes a constant absolute volatility (normal distribution) while the Black model assumes a constant relative volatility (lognormal distribution).[74] The consequence is that the gamma of a straddle in the Vasicek model differs from the gamma of the Black model:

$$\Gamma_{\text{Vasicek}} = \frac{\partial S^2}{\partial F^2} = \frac{LA}{m\sigma_{abs}\sqrt{T}}[N'(d_1) + N'(-d_1)] \qquad (6\text{-}14)$$

where σ_{abs} is the absolute volatility that is equal to σF. Numerically the delta-gamma neutral hedge on basis of the Vasicek model is exactly the same as the delta-gamma neutral hedge on basis of Black's gamma (see Section 6.2.3). The delta-vega neutral hedge ratio is different though. The vega risk parameter on basis of the Vasicek model is equal to:

$$v_{\text{Vasicek}} = \frac{\partial S}{\partial \sigma_{abs}} = \frac{LA\sqrt{T}}{m}[N'(d_1) + N'(-d_1)] \qquad (6\text{-}15)$$

To obtain a delta-vega neutral hedge we can now derive that the hedge ratio on basis of the Vasicek model should be equal to $\frac{\sqrt{T}}{\sqrt{T_{hedge}}}$

Table 6-9 shows the return statistics for the delta-vega neutral strategies. For all markets we find comparable statistics to our main findings reported in Table 6-4. This suggests that our findings are robust for assuming a constant absolute volatility.

[74] In the Vasicek model the volatility is measured as an absolute value and not relative to the underlying swap forward as in the Black model. For example, a volatility of 50% for a swap rate of 2% implies an absolute volatility of 100 bp. The same absolute volatility of 100 bp leads to a relative volatility of 20% for a swap rate of 5%.

Table 6-9: Summary statistics for trading strategies on the Vasicek model

		Vega neutral			
		Mean	t-stat	Stdev	Sharpe
USD	3 vs 6	0.86%	2.60	1.53%	0.56
	6 vs 9	0.38%	2.10	0.85%	0.45
	9 vs 12	0.25%	1.70	0.68%	0.37
	3 vs 12	1.28%	2.44	2.41%	0.53
EUR	3 vs 6	0.52%	2.21	0.88%	0.59
	6 vs 9	0.11%	0.79	0.52%	0.22
	9 vs 12	0.15%	1.40	0.43%	0.35
	3 vs 12	0.69%	1.85	1.36%	0.51
JPY	3 vs 6	0.78%	3.32	1.01%	0.78
	6 vs 9	0.23%	1.41	0.69%	0.34
	9 vs 12	0.27%	2.04	0.48%	0.56
	3 vs 12	1.10%	2.84	1.61%	0.68
GBP	3 vs 6	1.09%	5.06	0.90%	1.21
	6 vs 9	0.44%	3.57	0.54%	0.82
	9 vs 12	0.22%	1.76	0.44%	0.50
	3 vs 12	1.52%	4.54	1.32%	1.16
EQW	3 vs 6	0.81%	4.34	0.74%	1.09
	6 vs 9	0.29%	2.73	0.41%	0.71
	9 vs 12	0.22%	2.53	0.33%	0.67
	3 vs 12	1.15%	3.82	1.16%	0.99

Note: This table reports annualized summary statistics of non-overlapping monthly returns on long-short swaption straddles strategies. Each month a swaption straddle with the lowest maturity is sold with a notional of one, and held for one month. At the same time an additional long straddle position, with a higher maturity, is bought at a notional that neutralizes the vega exposure of the combined long-short position according to the Vasicek (1977) model. The straddles are initiated on the last business day of the month. In addition to the USD, EUR, JPY and GBP markets, we compute the summary statistics of an equally-weighted (EQW) portfolio. Summary statistics include annualized sample mean (Mean), annualized standard deviation (Stdev), skewness (Skew), kurtosis (Kurt), first-order autocorrelation (AC(1)), annualized Sharpe ratio and the percentage of months with a positive return (Hit). *t*-statistics are adjusted according to Newey and West (1987, 1994) to correct for heteroscedasticity and serial correlation up to four lags. The number of observations in each series is 189 and runs from April 1996 to December 2011.

6.5.3.B SABR model

This section considers a stochastic volatility model as alternative to the deterministic volatility models that we have used so far. We select the SABR model, introduced in Hagan et al. (2002), because it is widely used in the market (Rebonato et al., 2009).

The SABR model allows for a relation between the implied volatility (σ) and the underlying swap forward rate *F*. For this reason the delta in the SABR model (Δ_{SABR}) differs from the delta in the Black model. We use the (Bartlett, 2006) modified SABR delta.

$$\Delta_{SABR} = \Delta + \upsilon \left[\frac{\partial \sigma}{\partial F} + \frac{\partial \sigma}{\partial \alpha} \frac{\rho \mathrm{v}}{F^{\beta}} \right] \qquad (6\text{-}16)$$

where Δ and v on the right hand side are the original Black delta (7) and Black vega (9) respectively.

According to the SABR model, the at-the-money straddle position is not necessarily delta neutral. Therefore, we analyze a SABR delta neutral strategy using a long-short combination of two straddles, instead of a delta-gamma neutral strategy. Likewise, we also analyze a SABR vega neutral strategy using the adjusted vega formula from Bartlett (2006) with the caveat that the vega hedge on basis of the SABR model is not necessarily delta neutral under the SABR model.

$$v_{SABR} = v\left[\frac{\partial\sigma}{\partial\alpha} + \frac{\partial\sigma}{\partial F}\frac{\rho F^{\beta}}{\mathrm{v}}\right] \quad (6\text{-}17)$$

Similarly to our main analysis, we take a short position of one straddle contract in the shorter-term maturity and a long position in the longer-term maturity with a hedge ratio that either neutralizes the estimated SABR delta or SABR vega. For the empirical analysis we have gathered swaption smile data for USD swaptions from JP Morgan because we need smile data to estimate the SABR model. We estimate the parameters of the SABR model with a fixed beta parameter of 0.5, which seems to be market practice in the U.S. according to Rebonato et al. (2009).

Table 6-10: Summary statistics for trading strategies on SABR model

		Delta neutral				*Vega neutral*			
		Mean	t-stat	Stdev	Sharpe	Mean	t-stat	Stdev	Sharpe
USD	3 vs 6	0.96%	2.36	1.75%	0.55	0.89%	2.42	1.48%	0.60
	6 vs 9	1.27%	1.79	3.42%	0.37	0.31%	1.77	0.91%	0.34
	9 vs 12	0.46%	1.19	1.19%	0.39	0.19%	1.01	0.63%	0.30
	3 vs 12	1.77%	2.14	2.84%	0.62	1.21%	2.10	2.40%	0.50

Note: This table reports annualized summary statistics of non-overlapping monthly returns on long-short swaption straddles strategies using the SABR model for hedging. The combined long-short straddles position either neutralizes the vega or the delta exposure according to the SABR greeks. The straddles are initiated on the last business day of the month. Summary statistics include annualized sample mean (Mean), annualized standard deviation (Stdev), skewness (Skew), kurtosis (Kurt), first-order autocorrelation (AC(1)), annualized Sharpe ratio and the percentage of months with a positive return (Hit). *t*-statistics are adjusted according to Newey and West (1987, 1994) to correct for heteroscedasticity and serial correlation up to four lags. The number of observations in each series is 189 and runs from April 1996 to December 2011.

Table 6-10 tabulates the summary statistics for the delta neutral and vega neutral long-short strategies using the SABR model for hedging. The average returns are positive across all maturities for both delta and vega neutral strategies. Both strategies have statistically significant means for 3 vs 6 and 6 vs 9-month maturity combinations at a 90% confidence level. In general, the vega neutral returns and Sharpe ratios under the SABR model seem comparable to the returns and Sharpe ratios under the Black model. For example the 3 vs 6-month strategy has a return (Sharpe ratio) of 0.89% (0.60) under the SABR model and 0.85% (0.54) under the Black model. Based on these results we conclude that our main findings are robust.

6.5.4 Swaption smile and 2-year tenor

As a final robustness check of our main findings we re-run our analysis on two additional data sets, (i) USD data for 5 different strike levels (ATM, ATM $\pm$ 50, ATM $\pm$ 100) and (ii) implied volatility data for at-the-money (ATM) swaptions on 2-year swap rates.

Table 6-11 reports USD summary statistics for the delta-vega and delta-gamma neutral strategies where the straddles are valued on an implied volatility data set with 5 different strike levels. For the delta-gamma neutral strategy we see that the average returns and Sharpe rations are higher than in our main findings (Table 6-4) for all maturity combinations. A possible explanation for the higher returns is that the strategy has positive vega exposure in combination typical higher out-of-the-money volatilities (smile or smirk pattern). For the delta-vega neutral strategy we observe a similar return and Sharpe ratio for the 3 vs 6-month strategy and slightly lower returns for the other two maturity combinations. Overall we conclude that our main findings are confirmed after controlling for the existence of an implied volatility smile or smirk.

Table 6-11: Summary statistics for trading strategies on swaption smile

		Gamma neutral				*Vega neutral*			
		Mean	t-stat	Stdev	Sharpe	Mean	t-stat	Stdev	Sharpe
USD	3 vs 6	1.50%	3.31	1.64%	0.91	0.89%	2.39	1.49%	0.60
	6 vs 9	0.89%	3.40	1.01%	0.88	0.29%	1.71	0.92%	0.31
	9 vs 12	0.62%	3.43	0.57%	1.08	0.18%	0.92	0.64%	0.28
	3 vs 12	3.76%	3.48	3.71%	1.01	1.19%	2.06	2.42%	0.49

Note: This table reports annualized summary statistics of non-overlapping monthly returns on long-short swaption straddles strategies for the USD market. Each month a swaption straddle with the lowest maturity is sold with a notional of one, and held for one month. At the same time an additional long straddle position, with a higher maturity, is bought at a notional that either neutralizes the vega or gamma exposure of the combined long-short position according to the Black (1976) model. The results differ from the results in Table 6-4 because swaption smile data is used to calculate the returns. Swaption data is available at 5 different strike levels (ATM, ATM ± 50, ATM ± 100). Summary statistics include annualized sample mean (Mean), *t*-statistics (t-stat), annualized standard deviation (Stdev) and annualized Sharpe ratio. *t*-statistics are adjusted according to Newey and West (1987, 1994) to correct for heteroscedasticity and serial correlation up to four lags. The number of observations in each series is 189 and runs from April 1996 to December 2011.

Table 6-12: Summary statistics for trading strategies on 2-year tenor

		Gamma neutral				*Vega neutral*			
		Mean	t-stat	Stdev	Sharpe	Mean	t-stat	Stdev	Sharpe
USD	3 vs 6	0.22%	2.12	0.37%	0.58	0.06%	0.84	0.34%	0.19
	6 vs 9	0.18%	2.96	0.25%	0.70	0.03%	0.67	0.22%	0.15
	9 vs 12	0.07%	1.39	0.22%	0.33	-0.04%	-0.96	0.19%	-0.23
	3 vs 12	0.61%	2.48	0.98%	0.62	0.06%	0.48	0.55%	0.11
EUR	3 vs 6	0.17%	2.13	0.27%	0.63	0.05%	0.76	0.25%	0.21
	6 vs 9	0.07%	1.54	0.19%	0.38	-0.01%	-0.21	0.16%	-0.06
	9 vs 12	0.09%	2.18	0.17%	0.52	0.03%	0.62	0.17%	0.15
	3 vs 12	0.44%	2.23	0.68%	0.64	0.05%	0.48	0.40%	0.14
JPY	3 vs 6	0.08%	1.17	0.25%	0.30	0.03%	0.89	0.18%	0.19
	6 vs 9	-0.02%	-0.31	0.21%	-0.09	-0.02%	-0.80	0.12%	-0.19
	9 vs 12	0.29%	3.70	0.22%	1.31	0.51%	2.27	0.85%	0.61
	3 vs 12	0.70%	3.68	0.60%	1.16	0.23%	2.15	0.43%	0.54
GBP	3 vs 6	0.07%	0.82	0.30%	0.24	0.15%	1.80	0.28%	0.53
	6 vs 9	0.07%	1.23	0.22%	0.30	0.07%	1.44	0.21%	0.34
	9 vs 12	0.10%	2.19	0.19%	0.54	0.08%	1.83	0.16%	0.48
	3 vs 12	0.35%	1.68	0.72%	0.48	0.23%	1.79	0.45%	0.51
EQW	3 vs 6	0.13%	2.09	0.20%	0.65	0.07%	1.54	0.17%	0.43
	6 vs 9	0.07%	1.89	0.14%	0.53	0.02%	0.58	0.11%	0.16
	9 vs 12	0.14%	5.10	0.11%	1.24	0.14%	2.20	0.24%	0.60
	3 vs 12	0.52%	3.71	0.49%	1.06	0.14%	1.67	0.30%	0.48

Note: This table reports annualized summary statistics of non-overlapping monthly returns on long-short swaption straddles strategies on a 2-year maturity of the underlying swap rate. Each month a swaption straddle with the lowest maturity is sold with a notional of one, and held for one month. At the same time an additional long straddle position, with a higher maturity, is bought at a notional that either neutralizes the vega or gamma exposure of the combined long-short position. The straddles are initiated on the last business day of the month. In addition to the USD, EUR, JPY and GBP markets, we compute the summary statistics of an equally-weighted (EQW) portfolio. Summary statistics include annualized sample mean (Mean), *t*-statistics (t-stat), annualized standard deviation (Stdev) and annualized Sharpe ratio. *t*-statistics are adjusted according to Newey and West (1987, 1994) to correct for heteroscedasticity and serial correlation up to four lags. The number of observations in each series is 189 and runs from April 1996 to December 2011.

Table 6-12 shows summary statistics for our trading strategies on the 2-year swap rate. On this data set, the patterns in the average returns are in general similar to the 10-year swap rate data, essentially showing positive returns that decrease in maturity. Yet, we note that average returns and Sharpe ratios are lower and in some case slightly negative. For the delta-gamma neutral strategy 10 out of 16 strategies have average returns that are statistically significant at the 10% level. For the vega-neutral strategy, the average USD and EUR returns are not statistically significant and 5 out of 8 strategies for the JPY and GBP. A potential explanation might come from Trolle and Schwartz (2014) who analyze the relationship between the tenor of the underlying swap rate and the variance risk premium. They document a hump-shaped function and report more negative returns for the 10-year tenor than for the 2-year tenor in both USD and EUR markets. We leave this issue for future work.

6.6 Economic importance

In this section we explore the economic importance of our findings. This is motivated by the findings of Santa-Clara and Saretto (2009), who show a large disparity between the profitability of option strategies in the equity market before and after taking costs into account. Transaction costs can be substantial and collateral requirements, to limit counterparty default risk, may further reduce profitability. Hence, the tensions in the funding markets during the Global Financial Crisis taught swaption dealers that funding costs embedded in derivative operations should not be ignored and might result in higher costs for investors.

We start from an investor's perspective. So far, the Sharpe ratios of our delta-gamma and delta-vega neutral strategies might look appealing to investors. Since the returns of both strategies are positive (Table 6-4) and mutual correlations are low (Table 6-5), investors might consider combining the two strategies to benefit from diversification. Panel A in Table 6-13 reports the summary statistics for an equally weighted mix of the two strategies. Combining the two strategies proves to be successful, in the sense that returns are strongly significant and Sharpe ratios are higher for the combinations. For example, the return of the 3 vs 12-month maturity portfolio has a Sharpe ratio of 2.22 for the combined strategies compared to 1.35 and 0.95 for the individual delta-gamma and delta-vega neutral strategies respectively. In addition, Figure 6-5 provides another way of presenting the combined results by plotting the cumulative wealth curves for the two individual strategies as well as the 50/50 combination. It is clear that all three curves show a positive drift. The combination, however, shows a further smoothing of the returns.

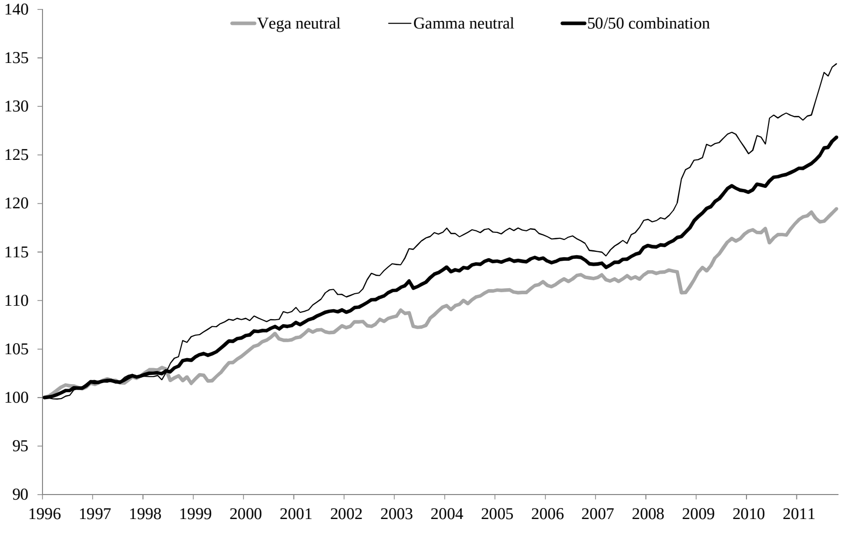
To study the left tail risks in the strategies' returns, we study the worst loss in any losing period during the historical simulation. This measure is called the maximum drawdown and is defined as the percent retrenchment from a peak-to-trough decline in the cumulative return. We analyze the worst three strategy drawdowns for the various countries and maturities in our data set. We focus on the 3 vs 12-month strategy, with the results of the other maturities generally being in line with this strategy. Table 6-14 presents the maximum drawdown and the time between the strategy's retrenchment until a new high is reached. For the vega neutral strategy, which is subject to jump risk, we observe large losses that coincide with the default of Russia in 1998 and the default of Lehman Brothers in 2008. For the gamma neutral strategy, which is subject to volatility risk, we observe the largest drawdowns during the steady decline of worldwide volatilities during 2004-2007. The 50/50 mix of the two strategies has much smaller drawdowns. The largest drawdown of the equally weighted country portfolio is less than 1%, which is less than a seventh of the largest drawdown that occurred in the gamma neutral strategy in the U.S..

Table 6-13: Return statistics and break-even spread for the 3 vs 12m mixed strategy

	Panel A: 50/50 combination				Panel B: break-even spread		
	Mean	t-stat	Stdev	Sharpe	Gamma neutr.	Vega neutr.	50/50 mix
USD	1.91%	4.77	1.48%	1.29	0.25	0.34	0.3
EUR	1.20%	4.23	1.05%	1.14	0.22	0.22	0.22
JPY	1.38%	5.15	1.09%	1.27	0.34	0.65	0.49
GBP	1.56%	5.39	0.97%	1.61	0.18	0.45	0.31
EQW	1.51%	7.29	0.68%	2.22	0.24	0.39	0.31

Note: This table shows summary statistics for a 50% delta-vega and 50% delta-gamma neutral mixed strategy (Panel A) and the break-even spread for the delta-gamma neutral, delta-vega neutral and mixed strategies respectively (Panel B) for the 3 vs 12-month strategy. The break-even spread is defined as the bid-offer implied volatility spread that makes the strategy unprofitable and expressed as implied volatility points.

Figure 6-5: Wealth curve swaption riding strategy



This figure shows the wealth curve of a long-short straddles strategies with swaption maturities of 3 months (short) and 12 months (long) respectively. Portfolio returns are the equally weighted (EQW) average returns for the USD, EUR, GBP and JPY markets.

Considering the economic significance we look at the break-even bid-offer spread for the 3 vs 12-month swaption maturity strategy. The break-even spread is defined as the bid-offer implied volatility spread that makes the strategy unprofitable and is expressed as implied volatility points. Panel B in Table 6-13 reports the break-even bid-offer spreads for the delta-gamma, delta-vega and combined strategies. The result shows that the break-even spreads for the equally weighted portfolio are 0.24, 0.39 and 0.31 volatility points for the delta-gamma, delta-vega and 50/50 mix strategies, respectively. These break-even spreads are within the bid-offer spreads in the market, which typically is 0.50 volatility points according to two major broker-dealers. This leads us to conclude that, taking into account trading costs, the returns of the delta-gamma, delta-vega and 50/50 mix strategies are not realizable by investors and therefore are not economically significant. This corroborates the findings for equity option strategies obtained by Santa-Clara and Saretto (2009).

Table 6-14: Maximum drawdowns for the 3 vs 12-month strategy

		Gamma neutral			*Vega neutral*			*50/50 combination*		
		Drawdown	#Months	Start	Drawdown	#Months	Start	Drawdown	#Months	Start
USD	Largest	-7.08%	54	Mar 2004	-4.54%	12	Oct 2008	-2.94%	32	Jun 2005
	2nd largest	-3.61%	10	Nov 2009	-4.42%	21	Apr 2003	-2.04%	14	Nov 2009
	3rd largest	-2.06%	24	Oct 1996	-1.93%	6	Jul 1998	-1.94%	15	Mar 2004
EUR	Largest	-2.21%	40	Jun 2005	-3.21%	24	Jun 1998	-1.52%	25	Nov 2006
	2nd largest	-1.94%	15	Oct 2001	-2.61%	28	Nov 2006	-1.20%	18	Oct 2001
	3rd largest	-1.84%	11	Aug 2010	-2.34%	17	Jul 2010	-0.78%	10	Dec 2005
JPY	Largest	-2.81%	32	May 2000	-5.17%	24	Apr 1998	-1.50%	5	May 1999
	2nd largest	-2.36%	28	Jun 2006	-2.74%	10	Feb 2003	-1.40%	16	May 2000
	3rd largest	-2.28%	26	Oct 2009	-1.78%	20	Jul 1996	-0.95%	20	Jun 2006
GBP	Largest	-2.51%	58	May 2003	-3.24%	14	Apr 2008	-1.06%	14	Nov 2006
	2nd largest	-2.12%	19	Mar 1997	-1.52%	6	Jun 2011	-0.90%	11	Mar 1997
	3rd largest	-2.07%	26	Aug 1999	-1.41%	16	Nov 2006	-0.68%	8	Jul 2000
EQW	Largest	-2.44%	46	Mar 2004	-2.05%	8	Aug 2008	-0.94%	13	Oct 2006
	2nd largest	-1.74%	9	Nov 2009	-1.63%	10	Apr 2003	-0.67%	5	Jun 2003
	3rd largest	-0.70%	7	Dec 2001	-1.59%	16	Jul 1998	-0.55%	6	Nov 2009

Note: This table reports the three largest maximum drawdowns on the delta-gamma neutral, delta-vega neutral and mixed strategies for the 3 vs 12-month strategy. The maximum drawdown is defined as the worst cumulative loss in any losing period in the historical simulation (April 1996 to December 2011) of the strategy. The length of the drawdown (#Months) is the number of months between the strategy's retrenchment until a new high is reached in the cumulative strategy returns.

The Global Financial Crisis and subsequent monetary policy decisions by central banks have caused derivative dealers to change their dealing practices. This might affect the profitability of our strategy. In particular, credit and liquidity risks are now recognized as having an impact on the economic value of a derivative security and have changed the manner in which derivative trades are conducted. First, the default of Lehman Brothers showed that counterparty credit risk cannot be ignored. Counterparty credit risk in a derivative trade should be carefully managed and either be priced or mitigated with the help of collateral. Today, derivative dealers make a credit value adjustment (CVA) in the pricing of a transaction to reflect the counterparty credit risk in uncollateralized transactions. On the other hand, fully collateralized transactions will rarely be subject to default risk and therefore CVA will be close to zero in these transactions. Second, banks became reluctant to lend to one other after the default of Lehman Brothers, and the subsequent liquidity squeeze made funding difficult and costly. For quite a while, derivative dealers were faced with a large gap between the funding costs of their institution and the risk-free rate in the option pricing model for trades that were not collateralized. This resulted in derivative dealers charging a funding value adjustment (FVA) to recover their funding costs. From Hull and White (2014) we know that the inclusion of FVA is a controversial issue that has resulted in much discussion between practitioners, academics and accountants. There are no simple solutions to the use of FVA because an FVA violates the law of one price in the market and can lead to conflicts between accountants and traders. Hull and White (2014) conclude that “an FVA is justifiable only for the part of a company's credit spread that does not reflect default risk.” Overall, this gives rise to the question whether the profitability of our strategy is impacted by collateralized transactions and potential tensions on funding. We argue that the impact will be limited because in our long-short strategy both collateral as well as funding exposures will largely be set-off against one another.

To conclude, a remark on the economic importance should be made. Transaction costs have typically not been included in related literature on the volatility risk premium in general, nor interest rate derivatives specifically. For example, Trolle (2009) and Doran (2007) both indicate that more research in the direction of including trading and commission costs in the implementation could be done in future.[75]

Interestingly, our strategy framework motivates us to consider the economic importance of our results. Based on the results in this section we conclude that the returns of the delta-gamma and delta-vega neutral strategies are not realizable by investors. However, the main goal of this chapter is to identify the existence of a difference in the volatility risk premium across the term structure of fixed income derivatives. Our results support this for all four swaption markets.

6.7 Conclusion

Existing work has demonstrated that the volatility risk premium is more negative for short-term maturities than for longer maturities. However, while the existence of the volatility risk premium in the fixed income market has recently been analyzed by various papers, the maturity effect was only documented by Fornari (2010) and Mueller et al. (2013) and, to our knowledge, has not been analyzed in detail. Our paper contributes to the literature by providing a strategy framework to test and analyze the maturity effect in the volatility risk premium in fixed income markets. Specifically, we analyze the returns of two long-short straddle strategies which both 'ride' the swaption curve. The straddle combinations are either delta-vega neutral and subjected to jump risk, or delta-gamma neutral and subjected to volatility risk.

Using a large database (April 1996 - December 2011) of implied volatility quotes of the four major bond markets, we find statistically significant returns, which incrementally decrease in swaption maturity for all markets. This finding is consistent with a concave, upward-sloping term structure in the volatility risk premium. The fact that both delta-vega and delta-gamma neutral strategies earn positive returns that seem uncorrelated suggests that the term structure of the volatility risk premium is affected by both jump risk and volatility risk. This effect seems most pronounced at shorter maturities. Additional robustness analysis indicates that the results seem robust when using the Vasicek (1977) and Hagan et al. (2002) SABR models instead of the Black model. The results are also robust for macroeconomic announcements, although we do observe a small effect for the day-of-the-month.

[75] To our knowledge, the only exception is Duarte et al. (2007) who report returns that are statistically and economically significant for their strategy of selling interest rate volatility through delta-hedged caps.

Specifically, delta-vega neutral portfolios initiated around the turn of the month report higher returns than mid-month portfolios. Finally, our framework allows more detailed assessment of the economic importance. Transaction costs and margin requirements are typically not included in related literature on the volatility risk premium. Our break-even cost analysis points to the conclusion that the returns of the delta-gamma and delta-vega neutral strategies are not realizable by investors. This corroborates the findings for equity option strategies obtained by Santa-Clara and Saretto (2009). This limit may prevent markets from taking advantage of 'riding the swaption curve', but does not detract from our established conclusion that there is a statistically significant difference in the volatility risk premium across the swaption maturity term structure.

Since the maturity effect of the volatility risk premium seems to have received limited attention in the literature, we encourage future research. A prominent issue that requires attention concerns the changes in the swaption market after the Global Financial Crisis. Prior to the crisis, swaption dealers relied on a single curve to forecast rates depending on an underlying index, e.g. LIBOR or Euribor, and to discount cash flows. The changes in market conditions and regulations have resulted in a different method for how swaptions are valued and risk is managed. In particular, a new multi-curve pricing framework that uses separate forecasting and discounting curves became market-standard for new swaption trades. Assuming mutual collateral agreements, the market has evolved toward discounting future cash flows using Overnight Index Swap (OIS) rates. The separation between the index rates and the OIS rates fundamentally changed the framework for swaption modeling. During the crisis the market slowly transitioned from the single curve methodology to the multi-curve methodology. For example, in September 2010 one of the leading international swaption dealers, ICAP, switched to OIS discounting and published both LIBOR- and OIS-based swaption implied volatilities. In January 2012, ICAP stopped publishing LIBOR-based volatilities and has since then only published OIS-based volatilities (Bianchetti and Carlicchi, 2013). January 2012 coincides exactly with the end of the empirical data set of this study. Further research using OIS-based swaption implied volatilities data post 2011 could give important complementary evidence on the consistency of our strategy. This investigation, however, lies beyond the scope of this chapter.

7. Conclusions

Sovereign fixed income market returns can be attributed to two sources: interest rate income and price changes caused by interest rate changes. The influence of interest rate changes on the return is very important. For a typical fixed income investment portfolio with a duration of 7, it takes 7 years to recover an initial loss from a rising interest rate, also known as the immunization period. A better understanding of what is driving interest rate changes and what might predict these changes is therefore very relevant.

Academic research on the nature of interest rate changes, the related returns and the price efficiency is a more recent development in the literature. Recent studies by Ludvigson and Ng (2009), Dahlquist and Hasseltoft (2013), Mylnikov (2014) and Kamstra, Kramer and Levi (2015) show that government returns are predictable with factors like macro-economic data, forward yields and seasonal patterns. Predictability of corporate bond market returns can also be applied to the sovereign fixed income market. Relatively newer parts of the sovereign fixed income market such as the local currency debt market for emerging markets and the swaption market have been studied less. This dissertation contributes to the literature with five studies showing that sovereign fixed income markets are not always price efficient: future returns of the sovereign fixed income market can be predicted. This is relevant for market participants because it can influence their decisions and goals.

The emerging local currency debt market has grown to a large size of more than 1.5 trillion U.S. Dollars at the end of 2012. Chapter 2, “Emerging government bond market timing”, confirms that three factors known to predict developed markets can also predict the emerging local currency bond markets. Hence, in this respect emerging local currency bond markets behave similar to the developed bond markets. The result shows that the emerging government bond market does not fully incorporate the information that triggered recent bond and equity returns, and that the steepness of the curve contains information about future bond returns.

A recent study by Bekaert et al. (2014) shows that the *level* of political risk can *explain* a third of the spread between emerging market dollar bonds and U.S. Treasuries. Chapter 3, “Political risk and expected government bond returns”, shows that *changes* in political risk can *predict* future government bond returns. Countries with improving political risk will achieve higher future risk-adjusted returns than countries with deteriorating political risk. The result is consistent for both the developed EMU bond market and the emerging dollar debt market. Hence, the bond market does not efficiently incorporate changes in political risk.

Kamstra, Kramer and Levi (2015) document a new seasonal pattern in U.S. Treasury returns: bond returns are better in the fall when investors get depressed and sell equities for bonds and worse in spring when equity and bond positions are reversed. In Chapter 4, “Inflation and seasonality in bond returns”, a new and more consistent seasonal pattern in international developed government bonds returns is documented. International government bond returns are 3.8 percentage points higher in the second half of the calendar year than in the first half of the calendar year. This seasonal pattern is largely explained by an opposite pattern in not seasonally adjusted U.S. inflation which is 3.0 percentage points lower in the second half of the calendar year. Market participants can benefit from this seasonal pattern by structurally buying bonds at the end of June and selling bonds at the end of December.

Gray, Merton and Bodie (2007) have adapted the famous Merton model for corporate bonds to be able to use it for government bonds. Chapter 5, “Forecasting sovereign default risk with Merton’s model”, focuses on predicting the default risk premium using this adapted Merton model. C*hanges* in the Merton model spread are correlated with *changes* in CDS market spreads and can even predict these spread changes. Hence, using information from the emerging government bond market, the sovereign CDS market returns can be predicted. Our finding implicates that the emerging market sovereign CDS market is not fully price efficient.

Finally, Cremers, Halling and Weinbaum (2014) find that the volatility risk and jump risk premiums are priced for equity options. Chapter 6 of this dissertation, “Riding the swaption curve” confirms the existence of volatility risk and jump risk premiums in fixed income markets. Contrary to equity volatility, the model to hedge fixed income volatility related instruments like swaptions is not evident. We contribute to the literature showing that the results are robust for alternative swaption models all assuming a different behavior of interest rates. Combining the two risk premiums provides a strong diversification. By “riding the swaption curve” the market participants can gain positive returns from these two risk premiums.

Market participants can benefit from the evidence of the five studies in this dissertation by obtaining more stable and higher returns. Other researchers can use the insights by incorporating these in their studies and to extend the insights to other markets. A follow-up research question could be the relationship between political risk changes and the output of the sovereign Merton model. Perhaps both indicators contain overlap or could add mutual value when combined. Further research on why fuel and gasoline prices increase in the first half of the year would further strengthen our understanding of the new bond seasonal pattern. For the option markets it would be interesting to know whether the volatility and jump risk premiums are also priced in other markets, like the option market for commodities. Trading swaptions and the related transaction costs are also new and interesting terrains for further research.

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Abstract

The sovereign fixed income market covers more than a third of the total capital market and is important for many market participants. Governments need the market to finance their debt, central banks for their monetary policy, pension funds and insurance companies for liability management and asset managers and investors to achieve positive returns. This dissertation presents five studies showing that sovereign fixed income markets are not always price efficient. This evidence is relevant for the market participants because it can influence their decisions and goals. We summarize the most important insights from the five studies:

The emerging local currency debt market has grown to a large size of more than 1.5 trillion U.S. Dollars at the end of 2012. The factors that can predict developed market government bond returns can also predict emerging market government bond returns. We have further applied the famous Merton model for corporate bonds on government bonds of emerging markets. Changes in the Merton model spread can predict country credit default swap returns.

The euro crisis and the October 2013 debate between the Republicans and Democrats on the U.S. debt-ceiling highlight the importance of political risk in government bond markets. Changes in political risk can predict future government bond returns. Market participants should avoid bond markets with higher political risk and rather invest in bond markets with lower political risk.

Government bond returns are 3.8 percentage points higher in the second half of the calendar year than in the first half of the calendar year. This seasonal pattern is largely explained by an opposite pattern in the not seasonally adjusted U.S. inflation rate, which is 3.0 percentage points lower in the second half of the calendar year. Market participants can benefit from this seasonal pattern by structurally buying bonds at the end of June and selling bonds at the end of December.

Swaptions are options on interest rate swaps. The swaption market has become the largest non-cleared interest rate derivative market with a (notional) size of 30 trillion USD as of April 2014. Although swaption models are different from equity options models, the swaption market contains volatility risk and jump risk premiums consistent with equity

options. Combining the two risk premiums provides a strong diversification. By “riding the swaption curve” the market participants can gain positive returns from these two risk premiums.

Samenvatting

(Summary in Dutch)

De soevereine vastrentende obligatiemarkt beslaat meer dan een derde van de totale kapitaalmarkt en is belangrijk voor veel marktdeelnemers. Overheden hebben de markt nodig om hun schulden te financieren, centrale banken voor hun monetair beleid, pensioenfondsen en verzekeraars voor het beheersen van verplichtingen (*liability management*) en vermogensbeheerders en beleggers om positieve rendementen te behalen. Dit proefschrift omvat vijf studies die laten zien dat de soevereine vastrentende obligatiemarkt niet altijd efficiënt is. De vijf studies zijn relevant voor marktdeelnemers omdat het hun beslissingen en doelen kan beïnvloeden. Wij vatten de belangrijkste inzichten uit de vijf studies samen:

De markt voor obligaties van opkomende landen in lokale valuta is gegroeid tot een grootte van meer dan 1.5 biljoen Amerikaanse dollars eind 2012. De factoren die de rendementen voor overheidsobligaties van ontwikkelde markten kunnen voorspellen hebben ook voorspelkracht voor obligatierendementen van opkomende markten. Wij hebben ook het bekende Merton model voor bedrijven toegepast op overheidsobligaties van opkomende markten. Veranderingen van de model spread van het Merton model zijn een goede voorspeller voor rendementen van credit default swap instrumenten op landen.

De euro crisis en het debat in oktober 2013 tussen de republikeinen en democraten over het schuldenplafond van de V.S. onderstrepen het belang van politiek risico voor de markt voor overheidsobligaties. Veranderingen van politiek risico kunnen toekomstige rendementen van overheidsobligaties voorspellen. Marktdeelnemers kunnen het beste de landen met gestegen politiek risico vermijden en beleggen in de landen met lager politiek risico.

Rendementen van overheidsobligaties zijn 3.8 procentpunt hoger in de tweede helft van het kalenderjaar dan in de eerste helft van het kalenderjaar. Dit seizoenspatroon kan grotendeels verklaard worden door een tegenovergesteld seizoenspatroon in niet seizoens-aangepaste inflatie in de V.S., die 3.0 procentpunt lager is in de tweede helft van het kalenderjaar.

Marktdeelnemers kunnen profiteren van dit seizoenspatroon door eind juni structureel obligaties te kopen en eind december deze weer te verkopen.

Swaptions zijn opties op rente swaps. De markt voor swaptions is de grootste (niet-geclearde) rente derivatenmarkt geworden met een grootte van 30 biljoen Amerikaanse dollars in april 2014. Hoewel swaption modellen anders zijn dan de modellen voor aandelenopties, bevat de swaption markt dezelfde volatiliteitsrisico en jump risicopremies, consistent met de markt voor aandelenopties. Een combinatie van de twee risicopremies biedt sterke diversificatievoordelen. Door het "berijden van de swaption curve" kunnen marktdeelnemers positieve rendementen behalen met deze risicopremies.

Resumo

(Summary in Portuguese)

O mercado de renda fixa soberano cobre mais de um terço do total do mercado de capitais e é importante para muitos participantes do mercado. Os governos precisam do mercado para financiar suas dívidas, os bancos centrais da sua política monetária, os fundos da pensão e as companhias dos seguros para a gestão dos passivos, e gestores dos ativos e os investidores para obter retornos positivos. Esta dissertação apresenta cinco estudos que mostram que o mercado de renda fixa soberano nem sempre é eficiente. Esta prova é relevante para os participantes do mercado, pois pode influenciar as suas decisões e objetivos. Resumimos as idéias mais importantes dos cinco estudos:

O mercado dívida emergente em moeda local tem crescido a capitalização maior que 1,5 trilhão dólares no final de 2012. Os fatores que podem predizer retornos dos títulos do governo dos mercados desenvolvidos também podem prever retornos dos títulos do governo dos mercados emergentes. Nós também aplicamos o modelo famoso do Merton para títulos corporativos em títulos do governo dos mercados emergentes. Mudanças de *credit spread* do modelo do Merton pode prever retornos de *credit default swaps* dos países emergentes.

A crise do euro e o debate de Outubro 2013 entre os republicanos e democratas sobre a dívida teto dos EUA destaca a importância do risco político nos mercados das obrigações da dívida pública. As alterações no risco político podem prever retornos futuros dos títulos do governo. Os participantes do mercado devem evitar os mercados dos títulos com maior risco político e investir em mercados dos títulos com menor risco político.

Retornos dos títulos do governo são 3,8 pontos percentuais mais elevado no segundo semestre do ano do que no primeiro semestre do ano. Esse padrão sazonal é em grande parte explicado por um padrão oposto em não inflação ajuste sazonal dos EUA, que é 3,0 pontos percentuais menor no segundo semestre do ano. Os participantes do mercado podem beneficiar deste padrão sazonal por estruturalmente comprar de títulos no final do junho e vender de títulos no final do dezembro.

Swaptions são opções sobre *swaps* de taxas de juro. O mercado de *swaptions* se tornou o maior mercado dos derivativos de taxa de juro (*non-cleared*) com capitalização (*notional*) de 30 trilhão dólares a partir do abril de 2014. Embora os modelos de *swaptions* são diferentes dos modelos das opções das ações, o mercado de *swaptions* contém o risco da volatilidade e risco *jump* prémios consistente com opções das ações. A combinação dos dois prémios do risco fornece uma forte diversificação. Por "Andando a curva de *swaptions*" os participantes do mercado podem obter retornos positivos destes prémios dos dois riscos.

About the author

Johan Duyvesteyn was born on June 11, 1977 in Delft, the Netherlands. He studied econometrics at the Erasmus University Rotterdam from 1995 – 2000. He wrote his master thesis on basis of a six month internship at Robeco's quantitative research department on the topic of country allocation in emerging equity markets. After the internship he started to work as a fixed income researcher at Robeco in June 2000. In June 2005 he completed the CFA study and was awarded with the CFA charter. He organized various training and teaching activities for the academic programme of the Kuwait Investment Authority and the master of financial management programme of the Rotterdam School of Management from 2005 – 2007.

In 2008 he started writing academic articles based on the work at Robeco. Supervising multiple internships of master students he worked on several innovative and new research topics. He has published his work in the Journal of Fixed Income (2010, 2014 and 2015) and the Journal of Banking and Finance (2015). Currently he works as a senior quantitative researcher and portfolio manager with Robeco. He is responsible for the so called quant duration capability that encompasses the prediction of sovereign bond returns for both developed and emerging government bond markets. His academic research findings are partly incorporated in the quant duration capability of Robeco. The capability is available to clients of Robeco via the investment funds Lux-o-rente, Flex-o-rente and Emerging lux-o-rente that currently have a joint fund size of more than EUR 2.5 billion.

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EMPIRICAL STUDIES ON SOVEREIGN FIXED INCOME MARKETS

This dissertation presents evidence of five studies showing that sovereign fixed income markets are not always price efficient.

The emerging local currency debt market has grown to a large size of more than 1.5 trillion US Dollars at the end of 2012. The factors that can predict developed market government bond returns can also predict emerging market government bond returns. Changes in an adapted Merton model for government bonds can predict emerging market country credit default swap returns.

The euro crisis has highlighted the importance of political risk in government bond markets. Changes in political risk can predict future government bond returns. Market participants should avoid bond markets with higher political risk and rather invest in bond markets with lower political risk. Government bond returns are 3.8 percentage points higher in the second half of the calendar year than in the first half of the calendar year. This seasonal pattern is largely explained by an opposite pattern in not seasonally adjusted U.S. inflation which is 3.0 percentage points lower in the second half of the calendar year.

The swaption market has become the largest non-cleared interest rate derivative market with a (notional) size of 30 trillion USD as of April 2014. Although swaption models are different from equity options models, the swaption market contains volatility risk and jump risk premiums consistent with equity options. Combining the two risk premiums in a "riding the swaption curve" strategy provides a strong diversification.

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