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The sensitivity of European publically-listed real estate to interest rates

Content table

Chyi Lin Lee –
Senior Lecturer in property at the University of Western Sydney

Alexey Akimov –
Lecturer in finance at the University of Lancaster

Simon Stevenson –
Professor of Real Estate Finance & Investment at the Henley Business School, University of Reading



Dr. Alexey Akimov is a Lecturer in Finance at University of Lancaster. He joined Lancaster in 2012 following the completion of his PhD from the University of Reading. His research covers areas such as interest rate sensitivity & monetary shocks; commonalities in asset cycles and inflation forecasting.
Dr. Chyi Lin Lee is a Senior Lecturer in Property at University of Western Sydney. He has published more than 20 papers on a variety of topics relating to property investment and finance. He received his PhD from the University of Melbourne.
Professor Simon Stevenson is Professor of Real Estate Finance & Investment at the Henley Business School, University of Reading. He has published over 70 papers in a variety of leading real estate and finance journals. His primary research interests are in listed real estate; housing economics; investment modelling & portfolio management and international financial markets.

Contact

Contact Author:
Simon Stevenson
(s.a.stevenson@reading.ac.uk)

Fraser Hughes, EPRA Deputy CEO: f.hughes@epra.com

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Executive summary

This report examines the exposure of European public real estate markets to interest rates, a topic of evident importance given the events of the last decade. While events in the credit markets played a pivotal role in the 2007-09 financial crisis, the broader relevance of monetary policy and interest rates was clearly seen both in the preceding boom and in the resulting financial and economic crisis. This report contributes to the existing literature in a number of respects. Firstly, it considers the sensitivity at both a market/sector and firm level. Secondly, in both cases we expand upon the methodological analysis commonly adopted. Finally, with the exception of the UK, very little research has been conducted on this topic in the context of European markets.

Using a sample period from 1996-2013 we consider a total of seven countries at a market level, a coverage that is expanded to 15 when individual firms are examined. The first stage of the analysis considers the market level exposure of European public real estate using an empirical specification that allows consideration of both sensitivity in returns and risk. The analysis considers both short and long-term interest rates as well as a measure of the term spread. The results highlight the overall sensitivity of the listed property sector to interest rates.

With the exception of Belgium, in the case of volatility, and Switzerland, for both returns and volatility, significant results are reported in every case. However, in common with the broader literature there is evidence of time-variation in the results and diverging sensitivity depending on the interest rate proxy modelled. In the baseline specifications it is interesting that the temporal instability does not necessarily point to heightened sensitivity in more recent past. The empirical analysis of the index data is then extended to consider a broader analysis of the entire term structure. The additional specifications that consider the full-range of the yield curve and regime switches find broadly similar results. However, the regime-switching results do show that interest rate risk is predominately significant during the periods of instability (bear states).

The firm-level analysis reveals a number of interesting findings. We find evidence that firm characteristics, and especially gearing levels, have a significant impact on the degree of exposure observed. Compared to previous studies the results do reveal more significant findings. As with the market level analysis we further observe time-variation in the results. However, in this case the impact of the financial crisis is more distinct. We find that in a number of cases, e.g. asset-structure and book-to-market, the results are more evident since the financial crisis.

The results also highlight the importance of considering the legal structure in place. This is especially important given that in most of the countries examined REITs were introduced during the sample period. Despite the fact that REITs were more prominent in the second half of the sample around the financial crisis, we still observe that REITs display reduced exposure than property companies.

A number of broader implications for investors are apparent from the results Firstly, at both a market and firm level we analysis the sensitivity of returns as well as volatility. The results vary in many cases, highlighting the need to consider both components when analysing the impact of interest rates. Secondly, the temporal instability in the findings reinforces the importance of considering prevailing market conditions.

1. Introduction

Many of the events surrounding the 2007-09 financial crisis were in some way related to interest rates and the credit markets. This wasn't just concerned with the immediate impact of the credit crisis and the drying up of liquidity. It also related to a number of factors preceding the crisis, including relaxation of lending policies, which had contributed to a credit boom occurring in many markets. Furthermore, in response to the worsening economic climate post 2007, a loose monetary policy was widely implemented by many central banks. This has not only involved the reduction of interest rates but also in many markets quantitative easing.

The relationship between interest rate changes and the asset markets has therefore attracted a considerable degree of attention over the course of the last decade investors, policy-makers and academics. This interest is enhanced by the concerns over the impact on inflation, and thus interest rates, following the exit from quantitative easing.

A large number of papers have considered the impact of monetary policy generally and interest rates specifically in the context of real estate. That literature, which is briefly reviewed in the following section, has included a number of papers to have considered the public real estate sector. However, that literature has largely considered index level data. Few studies have analysed individual company data, and fewer have extended that analysis to consider the degree to which firm characteristics, such as leverage, are related to interest rate sensitivity.

This study intends to investigate the impact of interest rate changes on European listed real estate companies. Specifically, the research examines the following questions:

1. Do interest rate changes have a significant impact on European real estate stocks?
2. Do real estate stocks in different markets behave differently in terms of their interest rate sensitivities?
3. Do firm characteristics affect the interest rate sensitivity of real estate stocks?
4. Has the interest rate sensitivity of real estate stocks changed pre-, during and post the financial crisis and quantitative easing ?

The paper offer contributions in the following areas. First, we extend the limited studies on interest rate sensitivity to European real estate markets. The majority of papers to have considered the issue have focused on the US REIT market. Whilst a number of papers have examined the larger Asia-Pacific markets studies in Europe have largely been limited to the UK. Given the growth in European public real estate, as witnessed through both the growth in market size and the introduction of dedicated traded futures contracts (Lee, Stevenson & Lee, 2014), a specific study of interest rate sensitivity of European real estate stocks is a compelling topic for research to enable more informed and practical investment decision-making.

More importantly, studies such as Barry & Rodriguez (2004) and Lee & Lee (2014) have demonstrated that real estate stocks in emerging markets have different return, risk and inflation-hedging properties compared with developed markets. The fuller consideration of these markets, provides some important insights to investors who have exposure to the listed real estate sectors.

Second, this study is the first to explicitly examine the linkages between firm characteristics and interest rate sensitivity based on a large international sample. A firm-level study is particularly important in a European context in light of the presence of a single monetary regime within the Eurozone. This characteristic makes European real estate markets a natural laboratory for evaluating the role of firm characteristics. Importantly, unlike US REITs, European real estate stocks have significantly different firm characteristics in terms of legal regime (REITs and non-REITs), leverage, capital structure etc. Therefore, a dedicated analysis of European real estate stocks will assist real estate investors in having an enhanced understanding of whether real estate stocks with certain characteristics are more sensitive to interest rate changes.

Thirdly, this is one of the first pieces of research to examine the impact of the financial crisis and quantitative easing on the interest rate sensitivity of listed real estate vehicles. An in-depth understanding of interest rate sensitivity over different market conditions is critical in terms of investor decision-making. The remainder of the report is structured as follows. We firstly briefly consider the existing literature. Sections 3 and 4 then report the main empirical results using both market and firm level data. Section 5 provides concluding comments.

2. Existing literature

As noted in the introduction, the events of the last decade brought into sharp focus the importance of the credit markets and how interest rate dynamics can feed through and investment assets. In the specific context of the equity markets, Bernanke & Kuttner (2005) highlight how interest rates can impact upon stocks in three ways. Firstly, due to the impact on expected future dividends. Secondly, changes in the discount rate used in the context of future dividends, and thirdly the impact on the equity risk premium.

Real estate securities provide an interesting arena in which to consider the sensitivity of stocks to interest rates. In part this is due to the macroeconomic role that interest rates have (Bernanke & Blinder, 1992) and that the underlying assets of real estate stocks, i.e. the actual properties, are both real and investment assets. Therefore, changes in rates may, if of sufficient magnitude, directly lead to changes in the operating performance and cash flows of the firms. This may arise due to the impact of the economy on conditions in the underlying property market, e.g. rental growth, vacancy rates etc. Furthermore, interest rate risk can also be transmitted via the yields used to capitalise the rental income from the properties underlying the firms. The result is that interest rates are a key risk factor for real estate (e.g. Ling & Naranjo, 1997). Plazzi, Torous & Valkanov (2008) document that risk changes can be explained by short-term rates and the term-spread.

In addition to these fundamental economic issues there are further reasons why the examination of real estate securities is of particular interest. As studies such as Bredin, O'Reilly & Stevenson (2007) have frequently noted, real estate firms, both REITs and corporates, utilise relatively high degrees of leverage. This use of debt will naturally make the firms display potentially heightened sensitivity to interest rate movements. In addition, the use of leverage alters a company's cost-of-capital and therefore can affect the future availability of external debt facilities. Subsequent interest rate changes and the interactions between firms' investment and financing activities may therefore be reflected in a company's share price (Bernanke & Gertler, 1995).

Finally, there is also the specific issue of the mandatory minimum dividend present in the majority of REIT markets. The high-yield status of REITs means that the impact of interest rate fluctuations on the present value of dividends is likely to be greater than in a non-REIT context (Bernanke & Kuttner 2005). Furthermore, the high dividend and coupon-like nature of the underlying rental income have been frequently identified as key reasons why REITs are felt to share some characteristics with fixed-income securities (e.g. Cheong, Gerlach, Stevenson, Wilson & Zurbruegg, 2009).

A large number of studies have previously examined the effect of interest rate changes on the listed real estate market. The results have frequently observed that the sensitivity is time-varying and dependent on the time period examined (Chen & Tzang, 1988; Liang, McIntosh & Webb, 1995; Swanson, Theis & Casey, 2002; He, Webb & Myer, 2003). Bredin, O'Reilly & Stevenson (2007) highlight the importance of analysing unexpected changes in interest rates. Importantly, their empirical results show that monetary shocks have a strong impact on both US REIT returns and volatility. Bredin, O'Reilly & Stevenson (2011) expand upon these findings and observe that monetary policy surprises consistently have an impact upon US REIT returns and that the driving force behind this influence is via the dividend channel. In addition, in a further expansion Xu & Yang (2011) reveal how international real estate firms are sensitive to US monetary shocks.

A number of papers have reported that REITs are predominantly exposed to longer-term rates, for example Devaney (2001) finds heightened sensitivity to 10-year government bond yields. Similar findings are also reported by Chen & Tzang (1988) and He, Webb & Myer (2003). However, He, Webb & Myer (2003) emphasise that their conclusions may be biased by the interest rate proxy chosen. Against this background, Allen, Madura & Springer (2000) report significant sensitivity of REITs to both short and long-term government bonds, as well as the stock market. They further argue that firms can adjust their exposure to the market by changing financial leverage, but not the exposure to interest rates. A recent paper by Akimov, Stevenson & Zagonov (2014) provides additional evidence regarding the sensitivity of the findings to the proxy chosen in examining the sensitivity to the entire yield curve rather a single proxy.

In comparison to the relatively large number of papers to have considered the US REIT market, the European listed real estate sector has received very little attention in the academic literature; two notable exceptions being Lizieri & Satchell (1997) and Stevenson, Wilson & Zurbruegg (2007) who both consider the UK prior to the introduction of REITs. Stevenson, Wilson & Zurbruegg (2007) consider a sample period (1993-2005) that is characterised by low and stable interest rate and yet continue to find evidence of significant sensitivity to changes in interest rates. Lizieri & Satchell (1997) find that the link between interest rates and real estate securities is sensitive to high and low interest rate regimes.

Comparable evidence is also documented by Chang (2011) for the US REIT market. Chang, Chen & Leung (2011) employ a regime-switching model to examine the impact of changes in the monetary policy on US Equity REITs, housing and stock returns. The results suggest that interest rate spread seems to amplify the effect on REIT returns. Akimov & Stevenson (2013) examine regime-switching behaviour using a crises-rich sample period of 1993-2010, finding that listed real estate returns can be characterised by two distinct regimes that are substantially different from the underlying stock markets. They differ in terms of both the duration and risk-return characteristics of the regimes in each market.

The aforementioned studies have however, focused on aggregate index level data. Few studies have been undertaken on firm-level data. Liow, Ooi & Wang (2003) examine the interest rate sensitivity of 18 individual real estate securities in Singapore. Their study shows that the interest rate risk of property stocks is systematically priced and sensitive to prevailing market conditions. Importantly, they also find that the sensitivity of individual stocks differs widely.

One possible explanation is the asset composition and capital structure of the firms (i.e. asset maturity, leverage, dividend policy). Using 46 US REITs, Allen, Madura & Springer (2000) investigate the linkages between interest-rate sensitivity and REIT characteristics. However, little empirical evidence is available to show that REIT characteristics such as asset structure, financial leverage, management strategy or degree of specialisation are related to interest rate sensitivity. In short, little attention has been placed to compare the interest rate sensitivity of individual real estate securities.

3. Empirical results I: market-level analysis

3.1: Methodological framework

This paper involves two empirical components, which consider index-level and firm-level data respectively. The first component initially adopts the now standard GARCH (Generalised Autoregessive Conditional Heteroscedasticity) framework in considering the sensitivity of listed real estate interest rates. Following studies such as Devaney (2001) and Stevenson, Wilson & Zurbruegg (2007) we adopt a GARCH-M framework, as first used in this context by Elyasiani & Mansur (1998) in their empirical analysis of financial institutions.

The advantage of using a GARCH framework over a simpler factor model is that it allows the examination of interest rate sensitivity with respect to both returns and volatility. The GARCH-M specification differs from the basic GARCH form in that it models the mean of the excess returns as a function of the conditional variance. This thereby allows the incorporation of a time-varying risk premia, thus acknowledging the fact that investors will take into account the volatility of an asset in relation to the risk premia they will seek. In comparison, the basic GARCH model assumes that the risk premia required is constant across the sample period.

A further advantage to this specification is that by not making the implicit assumption that the risk premia is constant and not time-varying, this can be explicitly tested. The model specification used in this study follows that adopted in papers such as Stevenson, Wilson & Zurbruegg (2007) and includes interest rate volatility directly into the variance equation.

A basic GARCH-M process can be displayed as follows:

$$y_t = \gamma x_t + \delta h_t + \varepsilon_t \tag{1}$$

$$h_t = \alpha_0 + \sum \alpha_i \varepsilon_{t-i}^2 + \sum \beta_j h_{t-j}^2 \tag{2}$$

$$\varepsilon_t | I_{t-1} \sim N(0, H_t) \tag{3}$$

Where Equation 1 models the conditional mean and Equation 2 the conditional variance. This specification therefore models the excess returns of the real estate securities (*y*) in relation to the vector of exogenous variables (*x*) and its own conditional variance (*h*). The variance equation models the conditional variance on both lagged squared errors (e^2) and a moving average of lagged conditional variances (h^2).

While a GARCH-M specification is not directly linked to a theoretical framework it can be justified in the context of asset pricing models such as the CAPM and APT. Engle, Lillian & Robbin (1997) provide a theoretical linkage between volatility and mean return. A key element is that the GARCH-M specification allows the risk-premia to vary, thus allowing for the effect of volatility clustering. Neuberger (1994) notes that as volatility clustering will impact upon the certainty of returns the risk premia will also be affected, thus providing justification for including the conditional volatility measure in the mean equation. Therefore, the GARCH-M specification can be viewed as being consistent with asset pricing models such as the intertemporal CAPM and the APT.

The model specification used in this study follows that adopted in papers such as Stevenson, Wilson & Zurbruegg (2007) and includes interest rate volatility directly into the variance equation. We incorporate the conditional variance of the exogenous variables used in the mean equation in the variance equation as well. The final specification used can be displayed as follows:

$$r_{i,t} = \mu_0 + \delta_1 \cdot h_{i,t} + \beta_1 \cdot r_{i,t}^{M} + \beta_2 \cdot ir_{i,t-1} + \varepsilon_{i,t} \quad (4)$$

$$h_{i,t} = a_0 + a_1 \cdot \varepsilon_{i,t-1}^{2} + b_1 \cdot h_{i,t-1} + g_1 \cdot h_{i,t-1}^{M} + g_2 \cdot h_{i,t-1}^{IR} \quad (5)$$

$$\varepsilon_{i,t} \left| \mathbf{\Omega}_{i,t-1} \sim N\left(0, h_{i,t}\right) \right. \quad (6)$$

In this specification r_i represents the listed real estate market returns, r^M_i is the return of the appropriate market equity index and *ir* is the respective interest rate series. The volatility equation is augmented by the respective conditional volatilities.

3.2: Baseline GARCH specification

The various GARCH models are estimated for seven European markets, namely Belgium, France, Germany, Netherlands, Sweden, Switzerland and the UK. These are not only the largest markets but those which have the longest time series available. The methodological approach adopted in the firm level analysis does allow the examination of firms beyond these seven markets.

The results are estimated across the entire sample period of 1995-2013, alongside two sub-periods (1995-2003, 2004-2013). Table 1 reports the results for the baseline GARCH-M model with market interest rates. Standard errors are corrected using the quasi-maximum likelihood procedure of Bollerslev & Wooldridge (1992). In general, we document weaker evidence of public real estate sensitivity to changes in market interest rates than the literature initially suggests. We find no significant results in the mean equation across the entire sample period for France, Germany, Netherlands or Switzerland. Sweden and the UK are found to react to changes in the short-term rates, while Belgium is sensitive to the changes in ten-year interest rates as well as the term spread.

In the majority of cases, the results for 1995-2013 are supported by the later sub-sample period. Public real estate markets in Germany and the Netherlands are also found to be sensitive during the 2004-2013 sub-period. However, Germany displays a strong negative reaction to three-month interest rates, while the Netherlands is positively affected by the ten-year rate. The results for Germany and the Netherlands are consistent with Lizieri & Satchel (1997) and Lizieri et al. (1998) who reported no sensitivity in either the US or UK to interest rate changes during the periods of high volatility. In both countries interest rate volatility was lower during 2004-2013 period. Stevenson et al. (2007) also document significance of interest rates for the listed real estate during the period of stable interest rates in the UK.

The conditional volatility coefficients of interest rates are estimated based on Equation (5). Generally we document stronger evidence of significance in comparison with the results for the mean equation. We find that the volatility of each of the public real estate markets, with the exception of Belgium and Switzerland, is affected by the conditional volatility of interest rates. However, only two markets react to interest rate volatility consistently, namely the Netherlands and Sweden.

Significance in the cases of Germany, France and the UK appear only in our sub-sample analysis. Moreover, the coefficients vary in terms of both the sign and magnitude. For instance, we often observe an inverse reaction of public real estate volatility to heightened volatility of the interest rates, namely the

UK (three-months during 1995-2003, ten-year and term spread during 2004-2013), Sweden (ten-year during 2004-2013), the Netherlands (three-months, term spread during both 1995-2013 and 1995-2003).

One possible explanation for the inverse relationship between the variance of listed real estate and the conditional volatility of interest rates lies behind the risk management practices used by the firms. Even if the majority of the companies in our sample attempt to hedge their interest rate risk, the hedging effectiveness might be more apparent when lower frequency data is used. The negative interest rate coefficient in the volatility equation also represents the reduced future volatility clustering as a result of new information arrival. In other words, in the event of increased fluctuations in interest rates at time t, the information becomes absorbed very quickly by the market and calms the sector's variance in the period t+1. The information regarding interest rate volatility may also reduce some proportion of the noise presented in the daily data as our GARCH model treats the total measure of listed real estate sector risk and not its systematic component. Overall, these findings are in contrast with those reported by Stevenson, Wilson & Zurburegg (2007) for UK property companies.

Table 1: Baseline GARCH-M Model

	1995-2013			1995-2003			2004-2013		
	3M	10Y	Term	3M	10Y	Term	3M	10Y	Term
Panel A: Belgium									
Mean Equation									
Garch	0.012	0.013	0.014	0.019	0.021	0.028	0.012	0.010	0.011
	(0.028)	(0.028)	(0.028)	(0.057)	(0.060)	(0.059)	(0.038)	(0.037)	(0.036)
Const	-0.001	-0.002	-0.003	0.001	-0.001	-0.004	-0.010	-0.009	-0.010
	(0.018)	(0.018)	(0.018)	(0.028)	(0.029)	(0.029)	(0.025)	(0.025)	(0.025)
Market	0.198***	0.200***	0.199***	0.046***	0.048***	0.047***	0.417***	0.417***	0.416***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.018)	(0.018)	(0.018)
Int.Rate	0.074	-0.591**	-0.515**	0.255	-0.346	-0.405	-0.155	-0.672*	-0.497
	(0.333)	(0.266)	(0.231)	(0.360)	(0.308)	(0.281)	(0.570)	(0.378)	(0.329)
Variance Equation									
Const	0.011***	0.011***	0.011***	0.028***	0.032**	0.026**	0.012**	0.013**	0.013**
	(0.003)	(0.004)	(0.003)	(0.010)	(0.015)	(0.011)	(0.006)	(0.006)	(0.006)
Arch	0.073***	0.070***	0.074***	0.105***	0.094***	0.103***	0.077***	0.077***	0.079***
	(0.011)	(0.011)	(0.011)	(0.022)	(0.021)	(0.022)	(0.018)	(0.018)	(0.018)
Garch	0.907***	0.912***	0.906***	0.847***	0.864***	0.851***	0.875***	0.875***	0.872***
	(0.014)	(0.013)	(0.014)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.034)
MarketVol.	0.002	0.002	0.002	-0.002**	-0.002***	-0.002**	0.018**	0.019**	0.018**
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.009)	(0.009)	(0.009)
Int.RateVol.	0.698	-0.417	0.860	1.577	-2.618	1.552	0.202	-0.994	0.417
	(0.459)	(1.339)	(0.874)	(1.208)	(4.254)	(1.865)	(0.792)	(1.952)	(1.501)
Panel B: France									
Mean Equation									
Garch	0.001	0.004	0.001	0.003	0.004	-0.001	-0.040	-0.042	-0.045
	(0.022)	(0.022)	(0.022)	(0.066)	(0.068)	(0.065)	(0.036)	(0.037)	(0.035)
Const	0.042**	0.040**	0.043**	0.022	0.021	0.025	0.083**	0.091**	0.088**
	(0.019)	(0.019)	(0.019)	(0.031)	(0.032)	(0.031)	(0.036)	(0.037)	(0.035)
Market	0.282***	0.281***	0.282***	0.125***	0.124***	0.125***	0.703***	0.690***	0.702***
	(0.011)	(0.011)	(0.011)	(0.012)	(0.012)	(0.012)	(0.015)	(0.016)	(0.015)
Int.Rate	-0.272	-0.017	0.201	-0.439*	-0.180	0.189	0.495	0.558	-0.044
	(0.265)	(0.256)	(0.223)	(0.254)	(0.275)	(0.212)	(0.467)	(0.471)	(0.349)
Variance Equation									
Const	0.013***	0.018***	0.013***	0.144***	0.108**	0.124***	0.012***	0.036***	0.010**
	(0.004)	(0.005)	(0.004)	(0.047)	(0.051)	(0.047)	(0.004)	(0.013)	(0.005)
Arch	0.076***	0.074***	0.076***	0.165***	0.155***	0.160***	0.044***	0.095***	0.049***
	(0.010)	(0.010)	(0.010)	(0.051)	(0.050)	(0.050)	(0.009)	(0.017)	(0.010)
Garch	0.907***	0.909***	0.906***	0.117	0.169	0.123	0.945***	0.859***	0.937***
	(0.011)	(0.011)	(0.011)	(0.126)	(0.134)	(0.130)	(0.011)	(0.026)	(0.012)
MarketVol.	0.003	0.003	0.003	0.096**	0.087**	0.097**	-0.002	0.008	-0.003
	(0.003)	(0.003)	(0.003)	(0.039)	(0.038)	(0.039)	(0.002)	(0.006)	(0.002)
Int.RateVol.	0.070	-3.183*	0.142	1.550**	17.314	5.510**	2.305*	1.171	3.554**
	(0.168)	(1.678)	(0.330)	(0.745)	(14.515)	(2.386)	(1.223)	(5.381)	(1.712)

Panel C: Germany									
Mean Equation									
Garch	-0.006	-0.002	-0.001	0.008	0.003	0.015	-0.019	-0.011	-0.012
	(0.012)	(0.011)	(0.012)	(0.016)	(0.013)	(0.018)	(0.022)	(0.022)	(0.022)
Const	0.020	0.011	0.008	-0.014	0.004	-0.038	0.029	0.019	0.020
	(0.020)	(0.020)	(0.022)	(0.036)	(0.026)	(0.045)	(0.028)	(0.028)	(0.028)
Market	0.368***	0.369***	0.375***	0.173***	0.160***	0.171***	0.556***	0.554***	0.554***
	(0.014)	(0.017)	(0.017)	(0.020)	(0.021)	(0.022)	(0.018)	(0.018)	(0.018)
Int.Rate	-0.403	0.486	0.443	0.313	0.926	0.976	-4.768**	0.318	0.536
	(1.039)	(0.422)	(0.465)	(1.007)	(0.601)	(0.686)	(2.068)	(0.484)	(0.483)
Variance Equation									
Const	0.009*	-0.003	0.008	0.002	-0.037	0.058*	0.024***	0.018	0.016
	(0.005)	(0.017)	(0.008)	(0.025)	(0.037)	(0.031)	(0.008)	(0.011)	(0.010)
Arch	0.074***	0.093***	0.087***	0.066***	0.101***	0.089***	0.094***	0.091***	0.091***
	(0.012)	(0.014)	(0.013)	(0.019)	(0.026)	(0.023)	(0.015)	(0.014)	(0.014)
Garch	0.924***	0.902***	0.909***	0.932***	0.899***	0.902***	0.884***	0.893***	0.893***
	(0.012)	(0.017)	(0.015)	(0.015)	(0.026)	(0.028)	(0.017)	(0.015)	(0.015)
MarketVol.	0.001	0.004	0.003	0.002	0.011	0.008	0.001	-0.002	-0.004
	(0.005)	(0.010)	(0.009)	(0.011)	(0.019)	(0.020)	(0.005)	(0.006)	(0.006)
Int.RateVol.	12.190	14.493	6.125	27.414	31.640	-9.909	50.858*	5.270	8.849
	(7.522)	(16.761)	(7.465)	(29.417)	(27.139)	(9.033)	(30.660)	(8.412)	(7.753)
Panel D: Netherlands									
					Mean Equation				
Garch	0.005	0.011	0.006	0.073	0.138*	0.119	-0.023	-0.027	-0.030
	(0.020)	(0.020)	(0.020)	(0.058)	(0.082)	(0.080)	(0.028)	(0.029)	(0.029)
Const	0.018	0.012	0.016	-0.021	-0.044*	-0.038	0.032	0.037	0.039
	(0.015)	(0.015)	(0.015)	(0.015)	(0.025)	(0.024)	(0.027)	(0.028)	(0.028)
Market	0.193***	0.192***	0.193***	0.104***	0.104***	0.104***	0.687***	0.685***	0.685***
	(0.008)	(0.009)	(0.008)	(0.009)	(0.009)	(0.009)	(0.018)	(0.018)	(0.018)
Int.Rate	0.083	0.200	0.106	0.177	0.097	-0.013	0.267	1.005**	0.588
	(0.361)	(0.251)	(0.223)	(0.356)	(0.260)	(0.224)	(0.510)	(0.488)	(0.376)
Variance Equation									
Const	0.011***	0.015**	0.011***	0.135***	0.105**	0.116***	0.032***	0.013	0.017*
	(0.004)	(0.006)	(0.004)	(0.036)	(0.050)	(0.038)	(0.011)	(0.014)	(0.010)
Arch	0.076***	0.077***	0.072***	0.201***	0.191***	0.190***	0.096***	0.087***	0.096***
	(0.009)	(0.009)	(0.009)	(0.042)	(0.042)	(0.042)	(0.020)	(0.017)	(0.020)
Garch	0.914***	0.914***	0.918***	0.235**	0.337***	0.348***	0.818***	0.867***	0.821***
	(0.010)	(0.010)	(0.009)	(0.118)	(0.127)	(0.128)	(0.044)	(0.031)	(0.047)
MarketVol.	-0.001	0.000	0.000	0.020**	0.016**	0.016**	0.029**	0.020**	0.022*
	(0.001)	(0.001)	(0.001)	(0.008)	(0.007)	(0.007)	(0.014)	(0.010)	(0.012)
Int.RateVol.	-0.556***	-3.356	-0.761***	-2.260***	3.310	-2.791**	11.358**	5.470	14.725**
	(0.187)	(2.660)	(0.237)	(0.330)	(13.739)	(1.309)	(4.617)	(11.943)	(7.389)
Panel E: Sweden									
Mean Equation									
Garch	0.006	0.007	0.006	0.036	0.027	0.037	0.016	0.013	0.018
	(0.018)	(0.017)	(0.017)	(0.044)	(0.043)	(0.044)	(0.024)	(0.025)	(0.024)
Const	0.032	0.032	0.033*	-0.008	-0.004	-0.009	0.014	0.021	0.013
	(0.020)	(0.019)	(0.020)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
Market	0.362***	0.364***	0.362***	0.236***	0.234***	0.236***	0.693***	0.693***	0.693***
	(0.011)	(0.011)	(0.011)	(0.012)	(0.012)	(0.012)	(0.019)	(0.019)	(0.018)
Int.Rate	-0.633*	-0.228	0.175	-0.375	-0.325	-0.208	-0.660*	0.772	0.714**
	(0.330)	(0.340)	(0.243)	(0.641)	(0.337)	(0.324)	(0.351)	(0.515)	(0.299)
Variance Equation									
Const	0.019***	0.024***	0.016**	0.070**	0.047**	0.046**	0.011*	0.028**	0.011
	(0.007)	(0.006)	(0.006)	(0.027)	(0.022)	(0.023)	(0.007)	(0.011)	(0.007)
Arch	0.095***	0.095***	0.095***	0.186***	0.193***	0.189***	0.067***	0.064***	0.069***
	(0.015)	(0.015)	(0.014)	(0.059)	(0.057)	(0.054)	(0.016)	(0.017)	(0.016)
Garch	0.888***	0.894***	0.890***	0.670***	0.634***	0.655***	0.921***	0.919***	0.919***
	(0.017)	(0.017)	(0.016)	(0.080)	(0.090)	(0.084)	(0.020)	(0.022)	(0.020)
MarketVol.	0.001	0.000	0.001	0.012*	0.018**	0.015**	0.004	0.010	0.004
	(0.002)	(0.002)	(0.002)	(0.006)	(0.008)	(0.007)	(0.005)	(0.006)	(0.005)
Int.RateVol.	1.229*	-1.418	1.434	13.715*	13.560*	12.449	0.379	-10.936*	0.650
	(0.657)	(1.539)	(1.139)	(7.512)	(7.039)	(8.285)	(0.447)	(5.855)	(0.925)
Panel F: Switzerland									
Mean Equation									
Garch	-0.010	-0.008	-0.009	0.030	0.046	0.052*	-0.054	-0.056	-0.054
	(0.022)	(0.022)	(0.022)	(0.027)	(0.031)	(0.031)	(0.037)	(0.038)	(0.037)
Const	0.036***	0.035**	0.035**	-0.005	-0.011	-0.014	0.053***	0.055***	0.054***
	(0.014)	(0.014)	(0.014)	(0.018)	(0.020)	(0.020)	(0.021)	(0.021)	(0.021)

Market	0.126***	0.127***	0.129***	0.047***	0.048***	0.048***	0.311***	0.312***	0.310***
	(0.011)	(0.011)	(0.011)	(0.010)	(0.011)	(0.011)	(0.020)	(0.020)	(0.020)
Int.Rate	0.211	0.166	-0.112	0.328	-0.293	-0.309	0.038	0.561	0.106
	(0.238)	(0.318)	(0.203)	(0.365)	(0.368)	(0.283)	(0.234)	(0.525)	(0.223)
Variance Equation									
Const	0.019***	0.022**	0.019***	0.012**	0.005	0.003*	0.026**	0.021	0.026**
	(0.007)	(0.011)	(0.007)	(0.006)	(0.003)	(0.002)	(0.010)	(0.021)	(0.010)
Arch	0.126***	0.115***	0.120***	0.149***	0.029***	0.024***	0.151***	0.153***	0.150***
	(0.019)	(0.019)	(0.019)	(0.025)	(0.010)	(0.008)	(0.034)	(0.036)	(0.034)
Garch	0.856***	0.871***	0.862***	0.832***	0.968***	0.974***	0.769***	0.757***	0.770***
	(0.019)	(0.017)	(0.018)	(0.032)	(0.010)	(0.008)	(0.040)	(0.040)	(0.041)
MarketVol.	-0.001	0.000	-0.001	-0.001	0.000	0.000	0.027**	0.025**	0.027**
	(0.002)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.013)	(0.013)	(0.013)
Int.RateVol.	0.394	-4.349	0.228	4.910	-1.963	-0.489	-0.364	8.345	-0.287
	(0.383)	(4.988)	(0.318)	(3.168)	(1.626)	(0.392)	(0.262)	(18.250)	(0.460)
Panel G: UK									
					Mean Equation				
Garch	-0.047**	-0.043**	-0.044**	0.182**	-0.058	-0.050	-0.049**	-0.051**	-0.045*
	(0.019)	(0.019)	(0.019)	(0.081)	(0.059)	(0.059)	(0.024)	(0.024)	(0.023)
Const	0.065***	0.062***	0.063***	-0.164**	0.049	0.045	0.062***	0.063***	0.058***
	(0.016)	(0.016)	(0.016)	(0.078)	(0.031)	(0.031)	(0.021)	(0.021)	(0.021)
Market	0.460***	0.460***	0.460***	0.273***	0.259***	0.259***	0.852***	0.847***	0.848***
	(0.013)	(0.012)	(0.013)	(0.018)	(0.017)	(0.017)	(0.019)	(0.019)	(0.019)
Int.Rate	-0.738**	-0.188	0.147	-0.099	-0.410	0.095	-0.090	0.273	0.272
	(0.310)	(0.236)	(0.196)	(0.375)	(0.285)	(0.220)	(0.855)	(0.363)	(0.357)
Variance Equation									
Const	0.008***	0.012***	0.009***	0.489	0.009	0.009	0.004*	0.010***	0.006**
	(0.003)	(0.004)	(0.003)	(0.361)	(0.009)	(0.009)	(0.002)	(0.003)	(0.003)
Arch	0.068***	0.067***	0.069***	0.017	0.088***	0.084***	0.041***	0.035***	0.042***
	(0.008)	(0.008)	(0.008)	(0.024)	(0.020)	(0.017)	(0.007)	(0.006)	(0.007)
Garch	0.921***	0.923***	0.920***	0.531	0.865***	0.877***	0.954***	0.959***	0.955***
	(0.010)	(0.010)	(0.010)	(0.351)	(0.044)	(0.032)	(0.007)	(0.006)	(0.006)
MarketVol.	0.001	0.002	0.002	-0.021	0.005	0.003	0.001	0.007**	0.004
	(0.002)	(0.002)	(0.002)	(0.017)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)
Int.RateVol.	0.590	-1.378	-0.019	-5.392***	4.608	2.184	0.973	-4.712***	-1.816*
	(0.736)	(1.649)	(0.790)	(1.198)	(4.141)	(1.586)	(1.028)	(1.461)	(0.938)

*Notes: *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.*

3.3: Yield Curve model

While the analysis contained in the preceding section does provide valuable insights about interest rate risk exposure, it may still provide conflicting results with regards to the subjective choice of the interest rate proxy. In particular, such an analysis does not provide reasons for the selection of interest rate of a particular maturity. Additionally, different interest rate proxies cannot be used simultaneously in a single model[1].

Diebold, Piazzesi, & Rudebusch (2005) argue that information about bond yields is underlined by the small number of sources of systematic risk implying a high correlation between different maturities[2]. Therefore, we follow the recent paper by Akimov, Stevenson & Zagonov (2014) in using the dynamic version of Nelson & Siegel (1987) exponential components yield curve model as suggested by Diebold & Li (2006). The model is able to summarise the pricing information on a large range of interest rates in a small number of parameters, namely level, slope and curvature of the yield curve.

[1] For example, interest rate maturities of 1-month, 3-months, 6-months, and 12-months are likely to have a common driver and are almost equally likely to be regarded as the “short-term”.

[2] The early work of Litterman & Scheinkman (1991), based on principal components analysis, shows that information about a large set of interest rates can be summarised using a small number of common factors. The authors refer to those factors as the term structure level, steepness, and curvature.

The model provides enough flexibility to capture a range of monotonic, S-type and humped shapes typically observed in yield curve data. This is a key advantage over the use of yield spread variable, which has been used in previous papers such as Swanson, Theis & Casey (2002), as this assumes parallel shifts in the term structure. The model's ability to provide a good fit of the yield curve is illustrated in a wide variety of papers including Diebold & Li (2006) and Fabozzi, Martellini & Priaulet (2005).

The Diebold & Li (2006) specification can be displayed as follows:

$$y_t(\tau) = \beta_{1t} + \beta_{2t}\left(\frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau}\right) + \beta_{3t}\left(\frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau} - e^{-\lambda_t\tau}\right) \tag{7}$$

where $y_t(\tau)$ is the yield of a zero-coupon bond, with time-to-maturity τ at t. The respective beta coefficients represent the level, slope and curvature of the yield curve respectively. Finally, λ represents the exponential decay rate.

The Nelson-Siegel model fits the term structure using a flexible, smooth parametric function based on a Laguerre function. Since the value of a stock can be considered as being the present value of future cash-flows, a downward shift in the term structure of interest rates, as captured by the level factor, should lead to higher prices. We would also expect an inverse relationship between the slope, our proxy for short-term interest rates, and prices.

Consistent with the ideas of Mishkin (1996) and Reinhart & Simin (1997), short-term rates will be heavily influenced by Central Banks through inflation targets and the setting of prime/base rates. Existing empirical evidence, that has documented an inverse relationship with rates of maturities ranging from one month to 20 years, would support this premise (e.g. Chen & Tzang, 1988; Devaney, 2001; Swanson, Theis & Casey, 2002; Stevenson, Wilson & Zurbruegg, 2007). However, none of these studies consider a range of interest rates jointly. Therefore, using the factors we extract from the dynamic Nelson-Siegel model, we test the hypothesis that there is an inverse relationship between returns and the changes in level, slope and curvature of the yield curve.

The empirical GARCH specification based upon the Diebold & Li (2006) yield curve model can be displayed as follows:

$$r_{i,t} = \mu_{0,i} + \beta_{1,i}\cdot L_{i,t} + \beta_{2,i}\cdot \hat{s}_{i,t} + \beta_{3,i}\cdot \hat{c}_{i,t} + \beta_{4,i}\cdot r_{i,t}^{M} + \varepsilon_{i,t} \tag{8}$$

$$\varepsilon_{i,t} = z_{i,t}\cdot\sigma_{i,t} \tag{9}$$

$$\sigma_{i,t}^2 = a_{0,i} + a_{1,i}\cdot\varepsilon_{i,t}^2 + b_{1,i}\cdot\sigma_{i,t-1}^2 \tag{10}$$

Where $L_{i,t}$, $\hat{s}_{i,t}$, $\hat{c}_{i,t}$ denote the changes in the level, slope and curvature of the domestic zero-coupon yield curve respectively. $z_{i,t}$ is a sequence of independent, identically distributed random variables zero mean and unit variance, implying $\varepsilon_{i,t}\left|\mathbf{\Phi}_{i,t-1} \sim N\left(0,\sigma_{i,t}^2\right)\right.$ is conditionally normal heteroscedastic error term, $\mathbf{\Phi}_{i,t-1}$ is the information set available at time $t-1$. $\sigma_{i,t}^2$ is the conditional variance of the listed real estate index returns at time *t*. The results for the four-factor GARCH model, are reported in Table 2.

As before, in addition to the overall sample period we run the empirical tests using two sub-samples, year-end 2003 being the mid-point. For the full period of study, we find Belgium, Germany, Sweden, Switzerland and the UK are affected by at least one of the yield curve parameters. In the case of Sweden, all three factors are inversely related to public real estate returns at statistically significant at levels of 5%. We also document negative relationship between public real estate price changes and curvature in Belgium over the full sample period. The inverse relationship is as anticipated. Existing empirical evidence, that has documented an inverse relationship with rates of maturities ranging from one month to 20 years, would support this premise (e.g. Chen & Tzang 1988; Devaney 2001; Swanson, Theis & Caset, 2002; Stevenson, Wilson & Zurbruegg, 2007)[3].

Another finding that is quite noticeable is that the results across the two sub-samples differ quite substantially. There are no markets that were affected by the same yield curve factors throughout the sub-sample analysis. For instance, the aforementioned result for Sweden is found to be mainly driven by the 1995-2003 period where we document similar exposures to changes in the yield curve. The same yield curve factors are however insignificant when we consider the 2004-2013 sub-period. The time-varying nature of the interest rate sensitivity reported is consistent with Devaney (2001) and Stevenson, Wilson & Zurbruegg (2007).

Overall our findings suggest that interest rates exposure should be modelled beyond a single interest rate factor, and the factors from the Nelson-Siegel yield curve model are good candidates for such a task. Our Wald test results shown in Table 2 largely support this notion. These χ^2-statistics test for the joint significance of the interest rate factors (i.e. $\beta_{1,i} = \beta_{2,i} = \beta_{3,i} = 0$). Additionally, the results are consistent with the general theoretical formulation of the relationship between stocks/REITs and interest rates. However, it would be hard to describe the results as homogeneous, which is not surprising given the structural and legal differences across the markets considered.

[3] In two cases, namely Germany and the UK, we find positive exposure to changes in level of the yield curve. However, this result is not robust to the sub-sample analysis. There are two additional results that revealed an unexpected positive sign. Switzerland is found to be exposed to positive changes in slope, while the impact of curvature on public real estate in Germany is significant in all three sub-periods.

Table 2: GARCH Multifactor model results using the Yield Curve parameters

	$\mu_{0,i}$	$\beta_{1,i}$	$\beta_{2,i}$	$\beta_{3,i}$	$\beta_{4,i}$	$a_{1,i}$	$b_{1,i}$	$Adj.R^2$	Wald
Belgium									
1995-2013	0.006	-0.296	-0.299	-0.256***	0.193***	0.072***	0.913***	0.12	12.00***
	(0.01)	(0.24)	(0.20)	(0.08)	(0.01)	(0.01)	(0.01)		(0.01)
1995-2003	0.008	-0.579**	-0.143	-0.029	0.053***	0.033***	0.961***	0.01	4.90
	(0.01)	(0.28)	(0.22)	(0.10)	(0.01)	(0.01)	(0.01)		(0.18)
2004-2013	-0.002	-0.480	-0.231	-0.182	0.419***	0.080***	0.905***	0.27	3.52
	(0.02)	(0.41)	(0.39)	(0.13)	(0.02)	(0.02)	(0.02)		(0.32)
France									
1995-2013	0.044***	0.240	-0.181	0.054	0.281***	0.077***	0.909***	0.24	2.10
	(0.01)	(0.25)	(0.18)	(0.09)	(0.01)	(0.01)	(0.01)		(0.55)
1995-2003	0.031**	-0.411	-0.293*	-0.081	0.125***	0.096***	0.822***	0.07	6.55*
	(0.02)	(0.31)	(0.16)	(0.11)	(0.02)	(0.02)	(0.05)		(0.09)
2004-2013	0.051***	-0.694	0.524	-0.213	0.707***	0.071***	0.908***	0.48	6.71*
	(0.02)	(0.44)	(0.80)	(0.16)	(0.02)	(0.01)	(0.02)		(0.08)
Germany									
1995-2013	0.009	1.065***	-0.113	0.474***	0.362***	0.083***	0.916***	0.17	24.75***
	(0.02)	(0.37)	(0.55)	(0.13)	(0.02)	(0.01)	(0.01)		(0.00)
1995-2003	-0.009	-0.853	-1.361	0.354*	0.163***	0.090***	0.909***	0.05	4.94
	(0.03)	(0.67)	(1.42)	(0.19)	(0.02)	(0.03)	(0.02)		(0.18)
2004-2013	0.008	0.384	0.415	0.357**	0.541***	0.091***	0.894***	0.35	5.36
	(0.02)	(0.46)	(0.60)	(0.18)	(0.02)	(0.01)	(0.01)		(0.15)
Netherlands									
1995-2013	0.018	0.316	0.114	0.072	0.193***	0.081***	0.907***	0.19	2.30
	(0.01)	(0.26)	(0.33)	(0.08)	(0.01)	(0.01)	(0.01)		(0.51)
1995-2003	0.000	-0.278	0.197	-0.101	0.103***	0.154***	0.599***	0.09	3.35
	(0.01)	(0.28)	(0.36)	(0.08)	(0.01)	(0.03)	(0.09)		(0.34)
2004-2013	0.016	0.840*	0.856	-0.116	0.686***	0.074***	0.915***	0.46	5.85
	(0.02)	(0.50)	(0.60)	(0.15)	(0.02)	(0.01)	(0.02)		(0.12)
Sweden									
1995-2013	0.040***	-0.460**	-0.627**	-0.355***	0.370***	0.093***	0.895***	0.28	23.64***
	(0.01)	(0.23)	(0.29)	(0.09)	(0.01)	(0.01)	(0.01)		(0.00)
1995-2003	0.016	-1.237***	-0.386	-0.533***	0.245***	0.152***	0.751***	0.21	38.23***
	(0.02)	(0.28)	(0.34)	(0.10)	(0.01)	(0.04)	(0.06)		(0.00)
2004-2013	0.033	0.163	-0.040	0.120	0.688***	0.066***	0.927***	0.45	0.52
	(0.02)	(0.49)	(0.58)	(0.21)	(0.02)	(0.02)	(0.02)		(0.92)
Switzerland									
1995-2013	0.029***	-0.100	0.756**	0.003	0.132***	0.118***	0.864***	0.08	5.80
	(0.01)	(0.12)	(0.32)	(0.11)	(0.01)	(0.02)	(0.02)		(0.12)
1995-2003	0.009	-0.368**	1.095***	-0.122	0.055***	0.028***	0.970***	0.02	17.78***
	(0.01)	(0.17)	(0.30)	(0.14)	(0.01)	(0.01)	(0.01)		(0.00)
2004-2013	0.036***	0.012	0.092	0.071	0.306***	0.136***	0.836***	0.21	0.19
	(0.01)	(0.21)	(0.78)	(0.17)	(0.02)	(0.03)	(0.03)		(0.98)
UK									
1995-2013	0.035***	0.881***	-0.136	0.073	0.451***	0.068***	0.923***	0.30	16.95***
	(0.01)	(0.23)	(0.18)	(0.10)	(0.01)	(0.01)	(0.01)		(0.00)
1995-2003	0.019	0.343	0.012	0.076	0.255***	0.088***	0.882***	0.16	2.40
	(0.01)	(0.28)	(0.19)	(0.10)	(0.02)	(0.02)	(0.03)		(0.49)
2004-2013	0.031*	-0.119	0.056	-0.324**	0.861***	0.042***	0.955***	0.46	5.69
	(0.02)	(0.35)	(0.33)	(0.14)	(0.02)	(0.01)	(0.01)		(0.13)

*Notes: Standard errors are in parentheses. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.*

Table 3: Augmented Multifactor Yield Curve results

	a) $\mathbf{ir}_{i,t-1} =$				b) $\mathbf{h}^{ir}_{i,t-1} =$			
	$L_{i,t-1}$	$\hat{s}_{i,t-1}$	$\hat{c}_{i,t-1}$	Wald	$h^L_{i,t-1}$	$h^S_{i,t-1}$	$h^C_{i,t-1}$	Wald
Belgium								
1995-2013	-0.036	-0.060	-0.011	0.40	0.053	0.199**	-0.050**	8.15**
	(0.19)	(0.13)	(0.04)	(0.94)	(0.12)	(0.09)	(0.03)	(0.04)
1995-2003	-0.175	-0.316	0.056	2.43	0.113	0.151	0.034	3.26
	(0.21)	(0.21)	(0.07)	(0.49)	(1.55)	(0.10)	(0.08)	(0.35)
2004-2013	-0.779	0.080*	-0.118	7.43*	-1.199	2.149*	-0.118	3.53
	(1.66)	(0.04)	(0.07)	(0.06)	(1.72)	(1.19)	(0.10)	(0.32)
France								
1995-2013	-0.096	0.081	-0.045	1.78	0.110	-0.013	-0.207***	7.43*
	(0.13)	(0.13)	(0.05)	(0.62)	(0.21)	(0.16)	(0.08)	(0.06)
1995-2003	-0.635*	-0.942	0.036	2.96	-0.872	0.040	-0.143	3.82
	(0.38)	(0.72)	(0.09)	(0.40)	(0.72)	(0.09)	(0.14)	(0.28)
2004-2013	-1.263	0.108	-0.042	1.13	-1.552	5.504	0.302	3.35
	(1.85)	(0.12)	(0.31)	(0.77)	(3.27)	(4.48)	(0.29)	(0.34)
Germany								
1995-2013	0.267	-1.021**	-0.064	4.74	0.955	-1.115**	0.194	6.43*
	(0.48)	(0.51)	(0.13)	(0.19)	(0.75)	(0.53)	(0.20)	(0.09)
1995-2003	-0.011	-0.462	-0.174	2.70	3.450	-2.619	0.794	2.32
	(0.33)	(0.55)	(0.13)	(0.44)	(5.82)	(3.36)	(0.57)	(0.51)
2004-2013	22.137	-9.458	0.943	2.68	-0.697	-0.150	0.768*	3.37
	(20.72)	(9.65)	(1.14)	(0.44)	(2.45)	(1.89)	(0.44)	(0.34)
Netherlands								
1995-2013	0.289*	0.149	-0.042	6.24	1.310***	0.195	-0.181**	170.87***
	(0.17)	(0.22)	(0.06)	(0.10)	(0.23)	(0.39)	(0.08)	(0.00)
1995-2003	-0.009	-0.816**	-0.110	7.39*	-1.720	2.434	-0.125	2.43
	(0.31)	(0.36)	(0.09)	(0.06)	(1.73)	(2.41)	(0.16)	(0.49)
2004-2013	-8.012	-0.018	0.521	0.92	2.115	2.865	0.192	2.12
	(13.18)	(6.88)	(0.64)	(0.82)	(5.21)	(2.51)	(0.50)	(0.55)
Sweden								
1995-2013	-0.158	0.164	-0.042	1.15	-0.305	0.222	-0.164	3.37
	(0.25)	(0.20)	(0.08)	(0.77)	(0.42)	(0.35)	(0.11)	(0.34)
1995-2003	-0.267	-0.439	0.025	1.50	-0.888	0.474	0.198	1.05
	(0.36)	(0.36)	(0.14)	(0.68)	(1.07)	(0.88)	(0.30)	(0.79)
2004-2013	2.505	0.055	-0.107	1.24	-3.455**	2.389*	1.920**	8.81**
	(2.52)	(2.60)	(0.35)	(0.74)	(1.58)	(1.39)	(0.97)	(0.03)
Switzerland								
1995-2013	0.252***	-1.033***	0.168**	507.07***	0.217**	-0.887***	0.050	60.13***
	(0.02)	(0.10)	(0.07)	(0.00)	(0.09)	(0.13)	(0.07)	(0.00)
1995-2003	0.045	-1.316***	0.034	14.49***	0.084	4.370	-0.791	2.54
	(0.15)	(0.36)	(0.18)	(0.00)	(0.18)	(3.30)	(0.58)	(0.47)
2004-2013	0.117	11.094*	-1.379*	3.25	-0.967*	1.670	0.898	3.87
	(0.11)	(6.40)	(0.81)	(0.36)	(0.56)	(4.49)	(1.01)	(0.28)
UK								
1995-2013	-0.209	-0.116	-0.037	2.13	-0.240*	0.214	-0.061	7.72*
	(0.17)	(0.16)	(0.05)	(0.55)	(0.14)	(0.15)	(0.05)	(0.05)
1995-2003	-0.055	-0.218	-0.016	0.58	-1.217	0.307	0.075	3.21
	(0.27)	(0.31)	(0.06)	(0.90)	(0.92)	(0.20)	(0.13)	(0.36)
2004-2013	0.439	0.323	-0.019	1.29	-0.734	1.114	0.115	3.72
	(1.54)	(0.33)	(0.29)	(0.73)	(0.86)	(0.70)	(0.26)	(0.29)

*Notes: Standard errors are in parentheses. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.*

To examine impact of the term structure of interest rates on the volatility of public real estate we extend the initial GARCH specifications in two alternative ways. Firstly, the volatility equation is augmented with one-period lagged changes in the level, slope and curvature factors. Secondly, we replace the lagged factor changes with their respective conditional volatilities. The results are reported in Table 3.

It is evident that in many instances volatility is negatively affected by changes in the yield curve factors (e.g. France, Germany, the Netherlands, Switzerland and the UK). This would suggest that changes in the yield curve factors translate into lower volatility of listed real estate returns in the subsequent period.

Effectively, there is less volatility clustering since the markets adjust their expectations more efficiently using information from the money markets. The impact of the interest rate variables on volatility is stronger over the longer sample period (i.e. 1995-2013) with the majority of the significant findings observed. However, this result is not robust to the sub-sample analysis. Among the significant results from the full sample analysis, we find consistent signs of the coefficients in one sub-sample, but most of the time the relationship is statistically insignificant.

3.4: Regime Switching models

The final empirical element to examine market level data considers the question of whether interest rate sensitivity varies during persistent periods of turbulence (bear state) in comparison with periods of market tranquillity and high returns (bull state).We consider a dynamic Markov-Switching model of the following form;

$$r_{i,t} = c_{i,s_t} + b_{1s_t} \cdot r_{i,t}^{m} + b_{2s_t} \cdot ir_{i,t-1} + e_{i,t};\ e \sim N(0,\sigma_{i,s_t}^{2}) \tag{11}$$

$$c_{s_t} = \begin{cases} c_0 & \text{if} \quad s_t = 0 \text{ (low return} - \text{high volatility)} \\ c_1 & \text{if} \quad s_t = 1 \text{ (high return} - \text{low volatility)} \end{cases} \tag{12}$$

Where *c* is the regime switching intercept. Table 4 reports the estimates of the dynamic regime-switching model over the period of 1995-2013. The MS-DR model recognises the distinct differences between state-dependent variances in each country with Regime 1 displaying either negative or near zero average return c_1 alongside with high variance σ_1^2. In turn, in the majority of countries Regime 2 can be characterised by significantly positive return (c_1) and low variance (σ_2^2). This result is largely much consistent across markets. The model reveals an interesting feature of public real estate returns. During both states of the market stock market risk betas $(b_{11} \text{ and } b_{12})$ are consistently below unity.

This indicates that the real estate market maintains low systematic risk levels across our sample time period. This result is also consistent across countries. This finding isn't that surprising given public real estate's reputation as a defensive and counter-cyclical sector (Glascock, Michayluk & Neihauser, 2004).

With respect to the interest rate results, the evidence is consistent with what we previously reported for market interest rates. Firstly, two markets are found to display no interest rate exposure, namely Belgium and Switzerland. For the rest of the sample, interest rate risk is predominately significant during the periods of instability (bear states). In particular, Germany and the Netherlands are found to be sensitive to changes in long-term rates and the term spread. France is also exposed to long-term interest rate risk. However, exposure in all three markets is of the unexpected positive sign. Short-term interest rates are significant for Sweden and the UK.

The UK is the only market found to display significant interest rate sensitivity during the bull state of the market. There are two possible explanations for the insignificance of the results and the positive exposure during market instability. Firstly, in the case of insignificance the analysis may suffer from interest rate risk exposure shifting from long to short rates, an affect that is hard to capture with just two maturities and the term spread. Positive exposure is likely to be driven by the events of 2007-09 when we observed simultaneous fall in real estate security prices and market interest rates.

Table 4: Dynamic Regime Switching model

	c_1	c_2	b_{11}	b_{12}	b_{21}	b_{22}	σ_1^2	σ_2^2
Belgium								
3-Month	-0.021	0.015	0.481***	0.125***	1.533	0.013	1.338***	0.524***
	(0.036)	(0.010)	(0.025)	(0.010)	(0.706)	(0.314)	(0.034)	(0.011)
10-Year	-0.027	0.014	0.480***	0.124***	-0.687	-0.425	1.339***	0.524***
	(0.036)	(0.010)	(0.025)	(0.010)	(0.673)	(0.259)	(0.034)	(0.011)
Term Spread	-0.023	0.014	0.482***	0.124***	-1.389	-0.333	1.335***	0.523***
	(0.036)	(0.010)	(0.025)	(0.010)	(0.542)	(0.226)	(0.034)	(0.012)
France								
3-Month	0.017	0.053***	0.814***	0.120***	0.222	-0.210	1.230***	0.649***
	(0.030)	(0.013)	(0.021)	(0.011)	(0.535)	(0.214)	(0.025)	(0.012)
10-Year	0.018	0.053***	0.815***	0.121***	1.657**	-0.265	1.229***	0.648***
	(0.030)	(0.013)	(0.022)	(0.011)	(0.651)	(0.266)	(0.025)	(0.012)
Term Spread	0.016	0.053***	0.813***	0.119***	0.582	0.028	1.230***	0.648***
	(0.030)	(0.013)	(0.021)	(0.011)	(0.428)	(0.191)	(0.025)	(0.012)
Germany								
3-Month	-0.031	-0.006	0.597***	0.254***	-0.933	-1.196	2.346***	0.788***
	(0.062)	(0.015)	(0.032)	(0.015)	(2.885)	(0.851)	(0.057)	(0.018)
10-Year	-0.022	-0.006	0.596***	0.254***	3.029**	0.100	2.340***	0.788***
	(0.061)	(0.015)	(0.032)	(0.016)	(1.200)	(0.403)	(0.057)	(0.018)
Term Spread	-0.031	-0.006	0.596***	0.254***	2.900**	0.336	2.342***	0.789***
	(0.061)	(0.015)	(0.032)	(0.015)	(1.148)	(0.390)	(0.057)	(0.018)
Netherlands								
3-Month	-0.026	0.029***	0.804***	0.111***	0.220	0.184	1.239***	0.498***
	(0.030)	(0.010)	(0.020)	(0.007)	(0.700)	(0.370)	(0.024)	(0.009)
10-Year	-0.024	0.029***	0.804***	0.111***	2.348***	0.062	1.234***	0.499***
	(0.030)	(0.010)	(0.020)	(0.007)	(0.663)	(0.234)	(0.024)	(0.009)
Term Spread	-0.027	0.029***	0.803***	0.111***	1.172**	-0.016	1.236***	0.498***
	(0.030)	(0.010)	(0.020)	(0.007)	(0.493)	(0.203)	(0.024)	(0.009)
Sweden								
3-Month	0.008	0.056***	0.826***	0.218***	-0.891*	-0.264	1.520***	0.713***
	(0.038)	(0.014)	(0.024)	(0.012)	(0.525)	(0.365)	(0.033)	(0.013)
10-Year	0.011	0.056***	0.825***	0.219***	0.217	-0.158	1.523***	0.714***
	(0.038)	(0.014)	(0.024)	(0.011)	(0.667)	(0.283)	(0.033)	(0.013)
Term Spread	0.010	0.056***	0.825***	0.219***	0.737	-0.004	1.523***	0.712***
	(0.038)	(0.014)	(0.024)	(0.011)	(0.446)	(0.243)	(0.033)	(0.013)
Switzerland								
3-Month	0.023	0.025***	0.348***	0.072***	0.039	0.043	1.228***	0.428***
	(0.028)	(0.009)	(0.021)	(0.009)	(0.369)	(0.199)	(0.024)	(0.010)
10-Year	0.023	0.025***	0.348***	0.072***	0.171	-0.108	1.228***	0.428***
	(0.028)	(0.009)	(0.021)	(0.009)	(0.676)	(0.266)	(0.024)	(0.010)
Term Spread	0.023	0.025***	0.348***	0.072***	0.013	-0.073	1.228***	0.429***
	(0.028)	(0.009)	(0.021)	(0.009)	(0.344)	(0.167)	(0.024)	(0.010)
UK								
3-Month	-0.082	0.031***	0.932***	0.380***	1.911**	-0.662*	1.785***	0.693***
	(0.059)	(0.012)	(0.034)	(0.013)	(0.965)	(0.320)	(0.049)	(0.010)
10-Year	-0.087	0.031***	0.930***	0.378***	1.224	-0.129	1.784***	0.695***
	(0.058)	(0.012)	(0.035)	(0.013)	(0.927)	(0.249)	(0.049)	(0.011)
Term Spread	-0.092	0.031***	0.926***	0.379***	-0.283	0.187	1.784***	0.692***
	(0.058)	(0.012)	(0.034)	(0.013)	(0.670)	(0.202)	(0.049)	(0.011)

*Notes: Standard errors are in parentheses. *, **, *** indicate significance at the 10%, 5% and 1% levels, respectively.*

4. Empirical results II: firm-level analysis

4.1: Data and methodological framework

The second component of the empirical analysis considers individual firm data. As noted earlier in the report, very few papers have considered the issue of interest rate risk from a firm level perspective, the majority rather a similar approach to that which we used in Section 4 and consider index level data. The two main exceptions in this regard are Liow, Ooi & Wang (2003) who examine 18 Singaporean real estate firms and Allen, Madura & Springer (2000) who consider 46 US REITs.

To assess the linkages between interest rate sensitivity and real estate stock characteristics, we examine a dataset of 226 publicly traded European real estate securities over the period 1995 to 2013. This dataset was initially based on data from Datastream and SNL Financial. To minimise survivorship bias we also used the EPRA Monthly Statistical Bulletins. The overall sample therefore includes both live and dead firms and firms that are both corporates and REITs. In the case of markets such as the UK, it also includes firms who were originally property companies and then converted into REIT status on the introduction of the relevant legislation.

The country split of the firms is detailed in Table 5, while summary statistics are reported in Table 6. The summary statistics cover more recent sub-periods as well as the entire sample period in order to consider the possible impact of the 2007-9 financial crisis.

Table 5: European Real estate securities by markets

Market	Total
Austria	8
Belgium	12
Finland	4
France	23
Germany	28
Greece	3
Italy	5
Netherlands	9
Norway	2
Poland	3
Spain	9
Sweden	16
Switzerland	5
Turkey	6
UK	93
Total	226

Table 6: Descriptive summary

	Ln(Firm size)	Leverage	Ln(Market -to-Book ratio)	Turnover	REIT	Ln(Age)	Asset Structure
Full sample: 1995-2013							
Mean	12.524	0.407	-0.059	0.511	0.330	2.211	0.649
Std. Dev.	1.936	0.229	0.696	1.057	0.470	0.979	0.346
Min	5.063	0.000	-4.605	0.000	0.000	0.000	0.000
Max	18.622	2.793	4.996	15.857	1.000	3.892	0.996
1995-2007							
Mean	12.515	0.376	0.128	0.552	0.330	2.178	0.660
Std. Dev.	1.918	0.210	0.632	1.145	0.470	1.023	0.335
Min	6.930	0.000	-3.912	0.000	0.000	0.000	0.000
Max	18.622	0.980	4.996	15.152	1.000	3.761	0.996
2008-2010							
Mean	12.483	0.444	-0.311	0.577	0.330	2.057	0.646
Std. Dev.	1.869	0.217	0.707	1.068	0.471	1.031	0.349
Min	6.797	0.000	-3.912	0.000	0.000	0.000	0.000
Max	17.345	0.992	3.323	15.698	1.000	3.829	0.995
2011-2013							
Mean	12.582	0.448	-0.259	0.351	0.330	2.431	0.620
Std. Dev.	2.043	0.270	0.698	0.787	0.471	0.770	0.369
Min	5.063	0.000	-4.605	0.000	0.000	0.000	0.000
Max	17.021	2.793	3.178	15.857	1.000	3.892	0.995
Sweden							

This analysis will offer some further insights into the link between real estate firm characteristics and interest rate sensitivity. The sensitivity of each individual firm will be estimated using models similar to those utilised in Section 4, these coefficients then used as the dependent variable in a firm-level panel regression which is specified as follows:

$$\sqrt{\left|\alpha_{2,t}^{i}\right|} = \lambda_0 + \lambda_1 \ln size_{i,t} + \lambda_2 Leverage_{i,t} + \lambda_3 \ln MtB_{i,t} + \lambda_4 Turnover_{i,t} + \lambda_5 REIT_{i,t} + \lambda_6 \ln Age_{i,t} + \lambda_7 Asset_{i,t} \tag{13}$$

Where $\sqrt{\left|\alpha_{2,t}^{i}\right|}$ is the estimated interest rate coefficient for firm *i*. Similar models have been used extensively in the examination of foreign exchange exposure. However, our study varies in two key respects. Firstly, by using the GARCH-M models detailed earlier we obtain estimates of the sensitivity with to volatility as well as with returns. Secondly, most previous studies of exposure (e.g. Hutson & Stevenson, 2010) have generally estimated their sensitivity coefficients over the entire sample period.

In this study we adopt a different approach in estimating the sensitivity coefficients on an annual basis. Using weekly data we estimate the GARCH-M models for each of the years in question. The rationale in this regard is three-fold. Firstly, it allows us to take into account the fact that the general literature has found interest rate sensitivity to be time-varying. Secondly, it means that we can incorporate changes in sample size more effectively, thus reducing survivorship bias. Thirdly, changes in the corporate level variables (e.g. concerning capital structure) will also be more efficiently controlled for. Each of the dependent variables is explained as follows:

Firm Size

The natural logarithm of market capitalisation is utilised as the measure of firm size. Small firms are generally thought to face more severe financial constraints than large firms due to scale of economies (Vickery, 2008). In other words, smaller firms are more exposed to interest rate shocks.

Debt/Leverage Ratio
The Leverage ratio is defined as the ratio of short-term and long-term debt to total assets. In general, greater leverage usage should be positively related to interest rate risk in line with the arguments of Allen, Madura & Spring (2000) and Mueller & Pauley (1995). They argued that leverage can magnify the firm's investment returns. Therefore, a positive link between leverage and interest rate risk is expected.

Market-to-Book Ratio
The natural log of the market value to book value ratio is used as a proxy for growth opportunities. Hedging theory suggests that high market-to-book firms are more likely to hedge and therefore experience lower exposure (Hutson & Stevenson, 2010).

Turnover
Turnover is measured by a ratio, in natural logarithm form, of trading volume to common shares outstanding. Theoretically, it is expected that a property company with high liquidity is related to lower systematic risk and interest rate risk (Delcoure & Dickens, 2004).

REIT
REIT is a dummy variable which captures the corporate structure difference between REITs and property operating companies. Many countries impose some form of limit of the amount of debt that a REIT can take on. This obviously has a potential impact on the interest rate sensitivity observed. However, as noted in the introduction the minimum mandatory dividend frequently imposed does potentially make REITs more exposed due to the discounting of future dividends. The importance of this variable is an additional reason why the estimation of annual sensitivity measures is important. The introduction of REIT legislation in many of the countries during the sample period allows the splitting of the sample. For example, UK firms such as Land Securities would be classified as corporates pre-2007 and REITs post.

Firm Age
As discussed by Vickery (2008), young firms are more likely expose to interest rate shocks in light of the firms are short of liquid fund. Specifically, Alburcurque & Hopenhayn (2004) suggest that profitable firms, accumulate over time capital and internal funds to finance investment. However, publicly traded real estate companies, particularly REITs have are restricted in their ability to accumulate capital due to the mandatory dividend payments. Due to the underlying complexities, there is no prior expectation for the impact of firm age on the sensitivity of property securities to interest rate shocks.

Asset Structure
Asset structure is measured by the ratio of total property investment to total assets. This measure was proposed by Allen, Madura & Springer (2000). We would hypothesise that as property investment is viewed as a steady and long-term investment (Lee, Robinson & Reed, 2008), the underlying assets of listed real estate firms would be expected to provide stable income. Hence, firms with a high level of asset-backing could be viewed as being expected to have lower market risk and interest rate risk (Decloure & Dickens, 2004).

4.2: Empirical Results

The results from the panel models are detailed in Tables 7 through 9 and consider the sensitivity to short-term rates, long-term rates and the term spread respectively. The first set, which consider short-term rates provide some interesting empirical findings. Unlike Allen, Madura & Springer (2000), the short-term interest rate risk of European real estate stocks is directly related to firm's degree of financial leverage. The results echo the view Mueller & Pauley (1995) in that the firm's investment returns, either positive or negative, will be magnified by leverage. Therefore, it is reasonable to document a positive link between financial leverage and short-term interest rate shocks.

We find that corporate structure does significantly affect the short-term interest rate exposure of a firm. Specifically, the documented negative and statistical significant coefficient of REIT suggests that REITs are less sensitive to interest rate risk compared with real estate operating companies. Asset structure appears as a critical determinant of interest rate espouses, whereas no similar evidence is illustrated for also interest rate volatility. This highlights the differences between interest rate sensitivity and interest rate volatility sensitivity.

Similarly, a positive link is only documented between interest rate volatility sensitivity and market-to-book value. This also provides some indirect support to the finding of Kallberg, Liu & Pasquariello (2002) in which the first moment and second moment contain different sets of information; thereby a dedicated analysis of interest rate volatility is paramount (Bredin, Stevenson & O'Reilly, 2007). Overall, the results suggest that REITs with lesser usage of leverage are less sensitive to short-term interest rate shocks.

Table 7: Panel Model I – Short-term interest rates

Independent variable	Dependent variable	
	Model (1)	Model (2)
	Interest Rate	Interest Rate Volatility
Ln(Size)	-0.004	-0.010*
	(-1.06)	(-1.65)
Leverage	0.062***	0.192***
	(3.05)	(3.55)
Ln(Market to Book Ratio)	0.009	0.042**
	(1.17)	(2.00)
Turnover	0.007	0.027
	(1.44)	(1.22)
REIT	-0.024***	-0.028*
	(-3.78)	(-1.69)
Ln(Age)	0.007*	0.013
	(1.67)	(1.18)
Asset Structure	-0.024**	-0.038
	(-2.08)	(-1.10)
Constant	0.172***	0.205***
	(3.92)	(2.59)

*Notes: Robust Standard errors are utilised. Z-statistics are presented in parentheses. *** p<0.01, **p<0.05, * p<0.1*

Table 8: Panel Model II – long-term interest rates

Independent variable	Dependent variable	
	Model (1)	Model (2)
	Interest Rate	Interest Rate Volatility
Ln(Size)	0.001	-0.007
	(0.61)	(-1.38)
Leverage	0.040***	0.150***
	(3.82)	(3.51)
Ln(Market to Book Ratio)	-0.006	-0.001
	(-1.41)	(-0.06)
Turnover	0.009**	0.027
	(2.06)	(1.20)
REIT	-0.001	-0.012
	(-0.28)	(-0.85)
Ln(Age)	-0.001	-0.012
	(-0.54)	(-1.36)
Asset Structure	-0.022***	-0.066**
	(-2.73)	(-2.32)
Constant	0.115***	0.309***
	(6.49)	(4.97)

*Notes: Robust Standard errors are utilised. Z statistics are presented in parentheses. *** p<0.01, **p<0.05, * p<0.1*

Table 8 presents the long-term interest rate sensitivity of European real estate stocks. The results show that leverage is strongly related to the estimated sensitivity of interest rate changes and interest rate volatility in light of the significant coefficients of leverage. Strong evidence is also found to support the notion of real estate stocks with a higher proportion in property, are less sensitive to long-term interest rate shocks. The coefficient of turnover is positive and statistically significant, reflecting that a liquid property company is more exposed to interest rate sensitivity, whilst no similar evidence is available from interest rate volatility.

As discussed earlier, interest rate movements and interest rate volatility contain different sets of information. Therefore, it is not too surprising to find dissimilar results from both components. The results reported here can be explained in a similar fashion. In brief, heavily-geared firms should consider hedging their long-term interest rate risk in response to the firms being more sensitive to long-term interest rate risk. Table 9 reports the sensitivity of European real estate stocks to the term spread. Obviously, leverage is directly linked with term spread changes and volatility.

Again this signifies that firms with a greater likelihood of financial distress (as proxied by leverage), are more exposed to interest rate movements. Despite turnover and asset structure having some impact on term spread sensitivity; these characteristics are only significant at 10%. The coefficients of logarithm of Size, on the other hand, are negative and statistically significant at 1%, indicating that larger firms are less exposed to term spread volatility. Comparable evidence is also found for growth firms with high market-to-book ratio. Overall, firms with high leverage are more exposed to term spread shocks and volatility. This also highlights the importance of these firms to hedge their interest rate risk.

Table 9: Panel Model III – term spread

Independent variable	Dependent variable	
	Model (1)	Model (2)
	Interest Rate	Interest Rate Volatility
Ln(Size)	-0.002	-0.012***
	(-1.35)	(-2.87)
Leverage	0.035***	0.121***
	(3.76)	(4.78)
Ln(Market to Book Ratio)	-0.003	0.033**
	(-0.52)	(2.14)
Turnover	0.008*	0.010
	(1.78)	(1.18)
REIT	-0.005	-0.020*
	(-1.14)	(-1.74)
Ln(Age)	-0.002	0.004
	(-1.21)	(0.74)
Asset Structure	-0.012*	-0.035*
	(-1.87)	(-1.87)
Constant	0.131***	0.251***
	(7.59)	(5.21)

*Notes: Robust Standard errors are utilised. Z statistics are presented in parentheses. *** p<0.01, **p<0.05, * p<0.1*

4.3: The impact of the financial crisis and quantitative easing

In response to the financial crisis of 2007-09, many central banks implemented a loose monetary policy. This not only involved the reduction of interest rate but also quantitative easing. Given the quite distinct characteristics post-2007, it is therefore of interest to see whether the results reported thus far are sensitive to the time-period examined.

We therefore decompose full sample into three sub-periods: pre-, during and post the financial crisis and quantitative easing. The periods are defined as being pre-2007, 2007-2010 and post 2010. While the second two periods are relatively short, it should be remembered that we are dealing with panel data therefore sample sizes still remain of sufficient size. The results relating to short, long term rates and the term spread are reported in Tables 10 through 12 respectively.

Panel A of Table 10 presents the short-term interest rates sensitivity over the three different periods. Consistent with our full sample results leverage remains positively signed, strongly significant and stable across the sub-periods. Moreover, the results are broadly supportive of the hypothesis that REITs are less sensitive to interest rate exposure than corporates. While this the variable is not significant in Period 1, this could be attributed to the timing of the introduction of REITs in Europe, particularly UK REITs in only 2007. Therefore, it is not too surprising to find an insignificant REIT coefficient in Period 1.

In addition, we also find that asset structure was only significant in Period 1 when it was characterised by a relatively stable market. No similar evidence is found in the more volatile markets of the second and third sub-periods. This finding offers some indirect support to the finding of Liow, Ooi & Wang (2003), and our preceding market level results, that interest rate risk is sensitive to prevailing market conditions.

Table 10: Sub-period analysis for short-term interest rates

Independent variable	Dependent variable		
	Model 1	Model 2	Model 3
	Period 1 (1995-2006)	Period 2 (2007-2010)	Period 3 (2011-2013)
Panel A: Interest rate			
Ln(Size)	-0.001	0.002	0.000
	(-0.27)	(0.58)	(0.12)
Leverage	0.055***	0.106***	0.082**
	(2.75)	(4.45)	(2.20)
Ln(Market to Book Ratio)	0.037***	-0.011	-0.003
	(3.98)	(-1.38)	(-0.26)
Turnover	0.009	0.007	-0.006**
	(1.45)	(1.26)	(-2.35)
REIT	0.015	-0.029***	-0.032***
	(1.18)	(-2.75)	(-2.97)
Ln(Age)	0.015***	-0.002	0.008
	(2.66)	(-0.49)	(1.14)
Asset Structure	-0.044**	-0.026	-0.021
	(-2.45)	(-1.59)	(-1.20)
Constant	0.132***	0.110***	0.099**
	(3.49)	(2.84)	(2.22)
Panel B: Interest rate volatility			
Ln(Size)	0.010	-0.003	-0.003
	(0.80)	(-0.30)	(-0.47)
Leverage	0.104	0.246***	0.209***
	(1.44)	(2.80)	(3.41)
Ln(Market to Book Ratio)	0.115***	-0.012	-0.002
	(2.90)	(-0.59)	(-0.11)
Turnover	0.010	0.059	-0.002
	(0.49)	(1.03)	(-0.37)
REIT	0.022	-0.040	-0.054*
	(0.54)	(-1.47)	(-1.95)
Ln(Age)	0.045**	0.006	-0.009
	(2.50)	(0.49)	(-0.64)
Asset Structure	-0.023	-0.067	0.016
	(-0.41)	(-1.13)	(0.45)
Constant	-0.081	0.097	0.110
	(-0.48)	(1.09)	(1.22)

*Notes: Robust Standard errors are utilised. Z statistics are presented in parentheses. *** p<0.01, **p<0.05, * p<0.1*

Table 11: Sub-period analysis for long-term interest rates

Independent variable	Dependent variable		
	Model 1	Model 2	Model 3
	Period 1 (1995-2006)	Period 2 (2007-2010)	Period 3 (2011-2013)
Panel A: Interest rate			
Ln(Size)	-0.002	0.005**	0.004
	(-1.59)	(2.14)	(1.58)
Leverage	0.034**	0.059***	0.033**
	(2.38)	(4.03)	(2.14)
Ln(Market-to-Book Ratio)	0.021***	-0.018***	-0.026***
	(3.63)	(-3.40)	(-5.08)
Turnover	0.013***	0.010*	-0.004***
	(2.84)	(1.94)	(-2.85)
REIT	0.012*	-0.002	-0.019***
	(1.70)	(-0.34)	(-2.99)
Ln(Age)	0.003	-0.002	-0.004
	(0.80)	(-0.83)	(-1.10)
Asset Structure	-0.023**	-0.012	-0.023**
	(-2.00)	(-1.22)	(-2.05)
Constant	0.139***	0.064***	0.092***
	(7.85)	(2.68)	(3.20)
Panel B: Interest rate volatility			
Ln(Size)	0.020*	-0.004	-0.007
	(1.92)	(-0.42)	(-1.33)
Leverage	0.011	0.226***	0.122
	(0.21)	(3.32)	(1.62)
Ln(Market to Book Ratio)	0.079***	-0.066***	-0.036*
	(3.18)	(-2.81)	(-1.85)
Turnover	0.027	0.046	-0.001
	(1.08)	(1.16)	(-0.16)
REIT	-0.008	-0.003	-0.044***
	(-0.19)	(-0.11)	(-2.72)
Ln(Age)	0.028*	-0.015	-0.011
	(1.89)	(-1.50)	(-1.17)
Asset Structure	0.035	-0.100***	-0.069**
	(0.68)	(-2.60)	(-2.13)
Constant	-0.144	0.263***	0.276***
	(-1.10)	(2.78)	(3.73)

*Notes: Robust Standard errors are utilised. Z statistics are presented in parentheses. *** p<0.01, **p<0.05, * p<0.1*

The results relating to the sensitivity of European real estate securities to short-term interest rate volatility is presented in Panel B of Table 10. Compared with the previously discussed results (Table 8) the documented coefficients of leverage are in line with the results of full sample. Specifically, Leverage is significantly related to short-term interest rate volatility. Conversely, it is not strongly related to short-term interest rate volatility in Period 1. Given that Period 1 was characterised by stable interest rates, it is reasonable to expect a negligible link between interest rate volatility and leverage. This would also suggest that firms are more sensitive to interest rate volatility during periods of heightened volatility. Collectively, European real estate stocks, particularly REITs with low gearing, are less sensitive, though it is dependent to market conditions.

Table 11 shows the corresponding results based upon the sensitivity to long-term rates. Generally, leverage features in all models, showing that leverage is an important firm characteristic in explaining long-term interest rate exposure. The coefficient of asset structure was negative and statistically significant in Periods 1 and 3. This suggests that asset structure is strongly related to long-term interest rate shocks.

Another result worth noting is the market-to-book ratio. The variable is consistently significant over different time periods. However, the sign varies over time. Specifically, the expected negative sign was only demonstrated in Periods 2 and 3, while a positive sign was found in Period 1. This implies that firms with high opportunities for growth probably are only less exposed to long-term interest rates since the financial crisis. This could be attributed to the greater use of interest rate derivatives for hedging during and following the events of 2007-9. As a result of the conditions in the credit markets since 2007 many real estate firms may see hedging as vital. In addition, Turnover appears as a significant factor. Interestingly, unlike the short-term interest rate, legal structure was only significant in Period 3; even so it confirms that the legal structure does have a notable impact on the sensitivity of firms to long-term interest rate. Furthermore, the interest rate volatility sensitivity in Panel B exhibits comparable results in which growth firms, REITs and firms with larger proportion investment in real estate are less sensitive to long-term interest rate volatility since the GFC. Nevertheless, turnover and leverage do not have a considerable impact on interest rate volatility.

The sub-period analysis of term spreads was also performed and reported in Table 12. By simply comparing the magnitudes of firm characteristics in Tables 11 and 12, it is clear that the sensitivity to the term spread is very similar to the long-term rate. Specifically, firms with low leverage, low market-to-book ratio, high level of property investment and high liquidity are less sensitive to interest rate shocks.

Table 12: Sub-period analysis for term spreads

Independent variable	Dependent variable		
	Model 1	Model 2	Model 3
	Period 1 (1995-2006)	Period 2 (2007-2010)	Period 3 (2011-2013)
Panel A: Interest rate			
Ln(Size)	-0.004**	0.003	-0.001
	(-2.35)	(1.45)	(-0.35)
Leverage	0.048***	0.032**	0.053***
	(3.21)	(2.29)	(3.58)
Ln(Market to Book Ratio)	0.016***	-0.012**	-0.026**
	(2.96)	(-2.43)	(-2.34)
Turnover	0.016***	0.006	-0.003*
	(3.15)	(1.42)	(-1.79)
REIT	0.016**	-0.008	-0.006
	(2.54)	(-1.47)	(-0.99)
Ln(Age)	0.004	-0.005*	-0.001
	(1.51)	(-1.91)	(-0.23)
Asset Structure	-0.020*	-0.014*	-0.006
	(-1.91)	(-1.71)	(-0.65)
Constant	0.137***	0.085***	0.092***
	(7.28)	(3.67)	(3.77)
Panel B: Interest rate volatility			
Ln(Size)	0.000	0.001	-0.009*
	(0.01)	(0.25)	(-1.89)
Leverage	0.045	0.158***	0.156***
	(1.31)	(3.83)	(4.35)
Ln(Market to Book Ratio)	0.099***	-0.030**	-0.006
	(3.92)	(-2.03)	(-0.51)
Turnover	0.011	0.005	-0.005**
	(0.91)	(0.29)	(-2.21)
REIT	0.004	0.006	-0.028*
	(0.11)	(0.39)	(-1.94)
Ln(Age)	0.033***	-0.001	-0.003
	(3.06)	(-0.14)	(-0.34)
Asset Structure	0.001	-0.073***	-0.040*
	(0.04)	(-3.00)	(-1.70)
Constant	0.051	0.090*	0.195***
	(0.45)	(1.70)	(3.20)

*Notes: Robust Standard errors are utilised. Z statistics are presented in parentheses. *** p<0.01, **p<0.05, * p<0.1*

6. Conclusion

The importance of interest rate movements to the broad equity market and specifically listed real estate has been placed into sharp focus since 2007. Not only did the credit markets play a central role in the crisis but the contribution that monetary and credit policies over the course of the last cycle has been more astutely considered in recent times. This study considers the exposure and sensitivity of the European listed real estate sector at both a market and firm level. This allows a comprehensive examination of the issues at hand. Throughout the analyses a number of issues do however come to light.

Firstly, in each of the markets bar Switzerland there was evidence of a significant sensitivity at a market level using the baseline GARCH models. This is not only true when the sensitivity with respect to returns is considered. When the relationships in the second moment (volatility) are examined only Belgium and Switzerland fail to provide at least one significant result. The results do however reveal variation across the different markets in terms of whether short or long-term rates are more influential, an impact that is not necessarily consistent across the impact on returns and risk. Furthermore, in common with much of the broader existing literature there is substantial evidence of temporal variation in the findings.

Few markets observe consistent sensitivity, in either returns or volatility, across all of the entire sample period and the two sub-samples. However, it is important to highlight that the time-variation in significance does not necessarily focus upon the later period surrounding the financial crisis. The additional specifications that consider the full-range of the yield curve and regime switches find broadly similar results. However, the regime-switching results do show that interest rate risk is predominately significant during the periods of instability (bear states).

The firm-level analysis expands upon the current literature in a number of respects. It adds to a very small literature that has considered the interest rate exposure of individual real estate firms. However, the examination of both annual sensitivities and the exposure to volatility as well as returns also adds to the broader literature in terms of the methodological framework adopted.

The results do highlight that the individual characteristics of the firms does significantly impact upon their exposure. In particular we note relatively consistent findings that the degree of leverage taken on has a significant positive relationship. In addition, property companies are found to be significantly more exposed than REITs. As with the market level findings we likewise observe time-variation in the results and in this context the impact of the financial crisis is clear. Factors such as the asset structure of the firms and the book-to-market ratio play increasing roles in explaining the variation of interest rate sensitivity.

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