House Prices, (Un)Affordability and Systemic Risk

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Abstract. This is the first paper to examine the role of the real estate sector and housing unaffordability in the determination of systemic risk. We measure the systemic risk of the UK by employing the ΔCoVaR method developed by Adrian and Brunnermeier (2016), and we explore both its cross-sectional and time series behaviour. Regarding the former, we show that when the real estate sector is under distress the tail risk of the entire financial system increases significantly. With respect to the latter, the findings of our dynamic model suggest that sustainable house prices positively contribute to the stability of the financial sector; whilst house price exuberance and rapid increases in housing unaffordability amplify systemic risk. Finally, we examine the conjecture that the banking sector comprises a transmission channel from the housing market to systemic risk. Our empirical results are in line with this argument and highlight the key role of housing unaffordability.

Keywords: affordability, real estate sector, systemic risk

JEL codes: C21, C23, E44

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1 Introduction

The financial crisis of 2007/08 and the Great Recession that followed have led to a vast interest in housing and its effect on the economy. A substantial amount of research has been devoted to better understand the role of housing markets in the lending sector and its effect on the macroeconomy (e.g. Favilukis et al., 2017; Piazzesi and Schneider, 2016; Jordà et al., 2016; Guerrieri and Iacoviello, 2017; Gertler and Gilchrist, 2018). Another strand of literature has examined the impact of housing unaffordability on socio-economic outcomes such as labour supply and demand, consumption, savings, education, health and income inequality (e.g. Quigley and Raphael, 2004; Campbell and Cocco, 2007; Zabel, 2012; Gabriel and Painter, 2018). Policymakers have also expressed their concern about the issue of unaffordability. For instance, in the UK, the housing market has been defined as a "broken market" by the government in the White Paper issued by Department for Communities & Local Government in 2017.

In this paper, we focus on the impact of the housing market and, in particular, housing unaffordability on financial stability. The literature in this area argues that imbalances in the housing market can directly affect the stability of the entire financial system. The banking sector is the main channel of this effect and there are two transmission mechanisms. The first one, the so-called "collateral channel", implies a positive relationship between house prices and financial stability (see Kiyotaki and Moore, 1997; Goodhart and Hofmann, 2008; Daglish, 2009; Niinimäki, 2009). The argument is that rising house prices increase the value of the collateral held by banking institutions enhancing their total capital. This increase in the value of the collateral in turn has two effects. First, the supply of credit to the real estate sector increases. Second, the probability of default drops. Likewise, increasing house prices significantly reduce the probability of default of mortgage borrowers and potential losses to lenders, resulting in a more stable banking industry. The second effect, the "deviations hypothesis", implies a negative relationship between persistent deviations of house prices from fundamentals, or house price bubbles, and financial stability (see Bernanke and Gertler, 1995; Allen and Gale, 2000; Allen and Carletti, 2013). This effect is due to an increase in moral hazard problems, and to excessive risk taking and high risk accumulation.[1] Koetter and Poghosyan (2010), in their analysis of regional house prices and banks in Germany, test for these two transmission mechanisms. Their results support both hypotheses and conclude

[1] Ferrari et al. (2015) consider the housing market as an important source of systemic risk and they present a novel graphical approach to identify early signs of real estate related crisis. They conclude that overvalued properties and increasing household debt are early indicators of a crisis.

that increases in house prices result in more stable banks, but that in periods when prices deviate from fundamental values, the probability of distress is higher.

Overall, the existing literature on housing markets and financial stability has focused on issues such as default rates but it has not yet explored the relationship between the real estate (RE) sector and systemic risk. We argue that the real estate sector contributes to the systemic risk of the financial sector, partly through its impact on the banking sector.[2] In this paper, we quantify for the first time the systemic risk of the housing sector and examine the role of unaffordability in its build-up.

Although a vast literature on systemic risk has emerged in the last decade and systemic risk is nowadays a widely accepted concept, there is still no consensus about its exact definition, neither a universally accepted measure. In 2009, the International Monetary Fund (IMF), the Bank of International Settlements (BIS) and the Financial Stability Board (FSB), in their joint report to the G-20, defined systemic risk as the disruption of the flow of financial services that could have a negative impact on the macroeconomy caused by an institution or by part of the financial system. Similarly, Adrian and Brunnermeier (2016) argue that losses at the firm level that threaten the capacity of the entire system and potentially harm the real economy could be described as systemic risk. On the basis of this definition, the authors propose a systemic risk measure, called ΔCoVaR, which is given by the difference between the Value at Risk (VaR) of the financial system when a particular firm or institution is under distress relative and its median value. This is the measure of systemic risk that we employ in this paper.

Our empirical analysis focuses on the UK because of the importance of its financial sector in the international financial system and because, as mentioned above, its housing sector presents increasing challenges for the public and for policymakers. To estimate the ΔCoVaR of the UK RE sector, we use a large sample of RE firms listed on the London Stock Exchange. Overall, the results of our analysis suggest that there is a strong tail dependency between the RE and the financial sector, with a ΔCoVaR of 8.4%. At the cross-sectional level, we find that systemic risk is associated with firm characteristics, in particular, with firms' size and systematic risk as

[2] The research on the real estate sector's systemic risk is limited. Li et al. (2016) use Contingent Claims Analysis to measure systemic risk in the RE sector in China. They use a Vector Autoregressive (VAR) model and obtain a negative but temporary effect on banking returns in response to a shock in the risk measure. Meng et al. (2014) use Random Matrix Theory to investigate the systemic risk and spatiotemporal dynamics of the US housing market. Their findings suggest that the increasing risk since early 1977 resulted to the 2007 bubble.

measured by the CAPM beta. Movements of ΔCoVaR over time, on the other hand, are associated to a number of housing variables, the macroeconomic environment, and firm characteristics. In line with the collateral and deviations hypotheses, our findings suggest that, while sustainable real house price changes are associated with a decline in systemic risk, house price exuberance (as measured by the GSADF test of Phillips et al. (2015*a*,*b*)) and rapid increases in housing unaffordability are associated with higher levels of systemic risk. With respect to macroeconomic variables, we find that increases in the Bank of England base rate as well the unconventional monetary policies adopted since 2009 are inversely related to systemic risk. Finally, undertaking the analysis separately for commercial and for residential real estate companies yields qualitatively similar results.

The rest of the paper is organised as follows. Section 2 presents the methodology to measure systemic risk, the data employed in the cross-sectional analysis, and the corresponding results. Section 3 describes the dynamic model, the variables employed in the time series analysis, and the main results of the paper. Section 4 provides brief conclusions.

2 Methodology

2.1 Measuring Systemic Risk

One of the most popular measures of a firm's risk is its value at risk, VaR. A main limitation of VaR is that it does not capture possible interactions between different financial institutions. Thus, it can be used to inform microprudential policies but it is not informative for implementing macroprudential policies. Adrian and Brunnermeier (2016) developed the concepts of CoVaR and ΔCoVaR. These two measures of tail dependency capture the association between the risk of the overall financial sector and a particular institution's stress event. ΔCoVaR has already become a popular measure of systemic risk and has been employed in many applications (see e.g. Fong et al., 2009; Borri et al., 2014; Gauthier et al., 2012; Ugolini, 2017; de Mendonça and da Silva, 2018).
The VaR of institution i is defined by:

$$\mathrm{P}(R^i \leq VaR^i_q) = \mathrm{q},$$

where R^i stands for the return of institution i, and q denotes the confidence level. The Conditional VaR (CoVaR) is, in turn, defined as the VaR of the financial system given that institution i is under distress.

The expression of the CoVaR is:

$$P\ (R^s \leq CoVaR_q^{s|i} \mid R^i = VaR_q^i) = \text{q},$$

where R^s is the return of the financial system.[3] The marginal contribution of a particular institution to the system's risk, ΔCoVaR, is computed by comparing the $CoVaR_q$ with the one in "normal" times, at the median (q = 0.5):

$$\Delta CoVaR_q^i = CoVaR_q^{s|R^i=VaR_q} - CoVaR_q^{s|R^i=VaR_{0.5}}.$$

Following Adrian and Brunnermeier, the estimation of the ΔCoVaR is done through quantile regressions. The procedure is described in the following 3 steps:[4]

1. Run the Quantile Regressions: $R_t^s = a_q + b_q R_t^i + e_t$
2. Use the estimates of a_q and b_q, $\hat{a}_q$ and $\hat{b}_q$, from step 1, and the VaR_q^i obtained as the q% of institution i's losses to compute
   $CoVaR_q^{s|i} = \hat{a}_q + \hat{b}_q VaR_q^i$
3. Compute the systemic risk: $\Delta CoVaR_q^{s|i} = CoVaR_q^{s|i} - CoVaR_{0.5}^{s|i}$

2.2 Data description and ΔCoVaR

We construct the RE portfolio using a market-capitalisation weighted average of 81 UK real estate firms listed in the London Stock Exchange.[5] The list of companies together with descriptive statistics are displayed in Appendix B. The financial system index consists of all the banks, insurance, real estate, general financial and investment trusts firms in the FTSE350 index. The banking sector

[3] We note that the systemic risk measure CoVaR examines the system's stress conditional on an individual firm's (or portfolio of firms) stress. This implies that the conditioning set to compute the system's stress varies cross-sectionally. The focus is therefore on the behaviour of the financial system's returns assuming a RE firm (or portfolio of firms) is in distress and to measure their tail dependency employing $\Delta CoVaR$. This approach differs from alternative measures of systemic risk that examine a firm's stress conditional on systemic risk (or on a systemic event such as a financial crisis). This is the case of the Systemic Expected Shortfall (SES) measure developed by Acharya et al. (2017). The attractive feature of SES is that the conditioning set is held constant across firms (as a way of ranking the systemic risk of firms), while CoVaR has the advantage of keeping the analysis within the standard regulatory tool of VaR.

[4] There are alternative methods to obtain the ΔCoVaR. For instance, Girardi and Ergün (2013) employ a multivariate GARCH model. We have also used this method, but the results, presented in Appendix A, suggest that it does not perform as well in capturing the build-up of systemic risk ahead of the crisis.

[5] This data is obtained from Datastream and Morningstar.

index is constructed by using data for all the banks included in the FTSE350 index. The frequency of the data is monthly and the sample period is from June 2002 until July 2018.[6]

Table 1 reports descriptive statistics together with the VaR of the RE portfolio, the financial system, and the banking sector. As can be seen from this table, the overall financial system index is the more diversified of the three, and displays the highest average return and the lowest variability and tail risk for this sample period. The unconditional 95$^{\text{th}}$ percentile VaR of the financial system index is 7.15%. Conditioning on the RE sector being under stress, the VaR increases by 74%. Furthermore, the ΔCoVaR is 8.4%. These statistics suggest a strong tail dependency between the RE sector and the financial system. The RE sector is therefore *systemic as a herd*. Following the theoretical arguments and stylised facts discussed in the introduction, we conjecture that this association between stress in RE firms and the overall risk of the financial system is possibly transmitted through the banking sector. The last row of Table 1 shows that the risk of the banking sector is significantly higher when the RE sector risk is high,[7] providing support to this argument.[8] Overall, the results in this section already endorse the ECB's recommendation in their 2015 report of close supervision to the RE sector and the convenience of macroprudential tools designed for this purpose. We proceed with the cross-sectional analysis of systemic risk and RE firm characteristics.

[Insert Table 1]

2.3 Cross-sectional Results: Systematic, idiosyncratic and systemic risks

Idiosyncratic and systemic risk are different concepts. The former only affects a particular firm and will not ripple out to the rest of the system, while the latter is about the risk that a particular firm induces to the overall financial system. Figure 1a shows that there is no strong cross-sectional

[6] The frequency and period of the analysis is restricted by some of the variables needed to implement the dynamic model described in the next section.

[7] As a robustness exercise, we have also computed the systemic risk measures using the FTSE350 RE index instead of the portfolio of the 81 RE firms described above. The results are similar. We decided to employ the portfolio of 81 companies instead of only the ones in the FTSE350 RE index in our main analysis in order to have a more comprehensive and representative sample of the sector.

[8] The banking sector's VaR increases by 47% conditional on the RE market being under distress. We have also reversed the analysis to check if in periods when banks are stressed, the RE firms' risk increases. The $\Delta CoVaR^{RE}_{bank}$ is 6.78%. Although the effect is sizeable, we note that it is lower than $\Delta CoVaR^{bank}_{RE}$, which may be indicative that the effect of the correlation runs from the real estate sector to the banking institutions.

connection between the VaR and systemic risk. This highlights the importance of having indicators that can capture systemic rather than idiosyncratic risk for macroprudential purposes. The findings are in line with Adrian and Brunnermeier (2016) who support that there is only a weak link between an institution's risk in isolation (VaR), and its marginal contribution to systemic risk (ΔCoVaR). However, they point out that there is a strong positive time series relationship. They argue that a potential explanation behind the lack of cross-section correlation between the two measures of risk is the interlinkages of each firm with the rest of the financial system.

For example, we observe that Harworth Group and Capital & Regional have the highest VaR values of the sample with 24.17% and 23.85%, respectively. However, the values of ΔCoVaR for these two firms are low, 2.63% and 2.35%. Therefore, when the two RE firms are in distress, the VaR of the system only increases slightly. On the other hand, British Land and Land Securities, two of the biggest RE firms in the UK market, contribute significantly to the systemic risk (8%), but the VaR of both of them is relatively low at 10.6% and 12.4%, respectively.

[Insert Figure 1]

Similarly, there is a difference between systemic and systematic or market risk. Systematic risk is the inherent part of the risk of an asset coming from the market that cannot be diversified away. Figure 1b shows the relationship between ΔCoVaR and CAPM beta, the most common measure of market risk. We observe a positive and significant relationship between these two types of risk.[9] Firms that are closely related with the market (high systematic risk) also present high values of ΔCoVaR. For instance, the RE companies that carry the highest systemic risk, such as British Land, Land Securities, Segro, Derwent London and Workspace, also present the highest values for market risk, between 0.7 and 1.01.

2.4 Firm Characteristics

We first examine if the years that a company is on operation affects the value of ΔCoVaR. The results presented in Figure 2a show that this is not the case in our sample. On the other hand, size, measured by the log of the average market capitalisation divided by the cross sectional average, has a statistically significant positive relationship with systemic risk (see Figure 2b). This result is

[9] All the regression analyses of this section are available upon request.

further validated by the use of assets and liabilities as can be seen in figures 2c and 2d. Therefore, the greater the magnitude of the firm's operations the more prominent its systemic risk is.

[Insert Figure 2]

Another firm characteristic that has been typically employed in analyses about systemic risk is leverage. However, this variable is not available at the monthly or even quarterly frequency for the RE companies under consideration. Nevertheless, we have compared the average annual leverage (debt/capital or debt/equity ratios) with the ΔCoVaR. We find a positive relationship but the results are statistically insignificant.

Overall, the results presented in this section suggest that returns in the RE sector and in the UK financial system have a significant left-tail correlation. Furthermore, they suggest that certain factors at the firm level, such as systematic risk and size, affect the value of systemic risk. However, these results are not informative about the time variation in systemic risk since the CoVaR measure provides an estimate of systemic risk of the RE firms over the whole sample period. To study the time-variation in systemic risk and the variables that contributed to its build up before the financial crisis, we introduce a dynamic model of CoVaR in the next section.

3 A Dynamic Model of Systemic Risk

Following Adrian and Brunnermeier (2016), we allow the returns of the real estate firms and of the sector as a whole to depend on a set of state variables, S_t. We note that these variables are not considered to be factors of systemic risk, but they are used because they can capture time variation in the conditional moments of the returns. As suggested by Adrian and Brunnermeier (2016), the state variables should be highly liquid and tractable. We employ changes in the three-month yield, changes in the yield curve, the TED spread, credit spread, FTSE100 volatility (VIX), and returns of the FTSE100. Table 2 presents descriptive statistics of these variables.

[Insert Table 2]

The estimation procedure of the dynamic model for the ΔCoVaR is described by the following five steps:

1. Run the quantile regression: $R_t^i = a_q + c_q S_{t-1}^i + e_t$

2. Use the estimates $(\hat{a^i_q}, \hat{c^i_q})$ to obtain the dynamic VaR, $VaR^i_t(q) = \hat{a^i_q} + \hat{c^i_q} S_{t-1}$
3. Run the quantile regression: $R^s_t = a^{s|i}_q + b^{s|i}_q VaR^i_t(q) + c^{s|i} S_{t-1} + u_t$
4. Use the estimates $(\hat{a}^{s|i}_q, \hat{b}^{s|i}_q$ and $\hat{c}^{s|i})$ to obtain the Conditional VaR: $CoVaR^{s|i}_t(q) = \hat{a}^{s|i}_q + \hat{b}^{s|i}_q VaR^i_t(q) + \hat{c^{s|i}} S_{t-1}$
5. Compute the systemic risk: $\Delta CoVaR^{s|i}_t(q) = CoVaR^{s|i}_t(q) - CoVaR^{s|i}_t(0.5)$

3.1 House prices, affordability and systemic risk

To examine the effect of house prices and housing affordability on systemic risk, we adopt a regression model, similar to that of Brunnermeier et al. (2017) in their analysis of the banking sector of the OECD economies:

$$| \Delta CoVaR^{s|i}_t(q)| = \alpha_i + \beta H_{t-1} + \gamma C_{i,t-1} + \delta M_{t-1} + \epsilon_{i,t}. \quad (1)$$

The dependent variable is expressed in absolute values so that higher values of $|\Delta CoVaR^{s|i}_t(q)|$ correspond to a larger contribution of institution i to systemic risk. H represents the variables related to housing, C denotes firm characteristics, and M refers to the macroeconomic variables. Starting with firm characteristics, C, these include idiosyncratic risk (VaR_i) and size (log of market capitalisation of firm i).[10]

The exogenous aggregate macroeconomic risk factors, M, are controlled for by the growth rate of GDP in the UK, growth of credit and investments, the rate of inflation, returns on the selective stock market index FTSE100, leverage, and the stance of monetary policy. Leverage is measured by net debt divided by the market capitalization of the UK financial sector index provided by Datastream.[11] The stance of monetary policy is measured by two variables due to the presence of the zero lower bound. We employ the Bank of England base rate until 2009 to capture conventional monetary policy, and from then onward, we include the shadow rate computed using the method by Wu and Xia (2016) to control for unconventional policies. Monthly GDP is calculated using the Chow-Lin interpolation method and data for quarterly Real GDP from the FRED database

[10] While there is no significant cross-section relationship between VaR and ΔCoVaR, there is indeed a relationship between those two variables at the time series dimension as can be seen in figure A.3. However, these two variables provide different information. For most of the period ΔCoVaR is above VaR, and specially noteworthy is the difference in the build up of the financial crisis.

[11] We have also considered an alternative measure of leverage, the Leverage Index provided by the Center of Risk Management Lausanne (data available at: `http://www.crml.ch/index.php/systemic_risk/`). The results with this alternative measure of financial leverage, available upon request, were similar to the ones reported below and we have therefore omitted them.

(Federal Reserve Bank of St. Louis) and the monthly Industrial Production index from Bank of England statistics. The inflation rate is computed using the consumer price index (CPI) from the OECD Main Indicators. Finally, to capture credit cycles we use data on investments and credit obtained from the International Financial Statistics (IFS) database and the Bank of England, respectively.[12]

The set of housing market factors, H, includes three variables that are constructed using data from the International House Price Database of the Federal Reserve Bank of Dallas (see Mack et al., 2011; and Pavlidis et al., 2016). The first variable is real house prices. The second is a housing exuberance dummy that takes the value of unity when the recursive right-tail unit root test statistic, BSADF, of Phillips et al. (2015*a*,*b*) exceeds the corresponding critical value. The last variable is a measure of housing affordability. Despite its importance, the measures of affordability available are few (for a survey see Meen, 2018). These measures are based on either low frequency data, a specific part of the population such as first-time buyers, or regional indices. This makes them non-applicable in our context because our aim is to examine affordability at the nationwide level and at a relatively high frequency. To deal with this issue we focus on the time series properties of real house prices to disposable income. Specifically, we construct a housing unaffordability dummy variable which, similarly to the housing exuberance dummy, takes the value of one when the BSADF statistic of the ratio of real house price to real disposable income exceeds the corresponding critical value. Figure 3 presents the estimated recursive unit root test statistics together with the 95% critical values.

[Insert Figure 3]

3.2 Empirical Results

Table 3 presents estimation results for the dynamic model. Overall, the results are in line with both the "collateral" and "deviations" channels. In particular, the relationship between $|\Delta\text{CoVaR}|$ and house prices is negative and statistically significant, which supports the "collateral channel". That is, during periods of increasing prices, the financial system is more stable. However, during periods when house prices display explosive dynamics, their impact on systemic risk reverses and turns positive. The positive impact on systemic risk is even higher when we employ the measure

[12] These two variables have been adjusted to monthly frequency using cubic spline interpolation.

of unaffordability. In this case, the estimated coefficient is significantly larger. These latter results are consistent with the "deviations hypothesis".[13]

Our results also suggest that firm characteristics relate to systemic risk. First, we find that a firm's idiosyncratic risk (VaR) is positively correlated with systemic risk. A positive relationship between these two measures of risk is in line with the work of Adrian and Brunnermeier (2016) for the banking sector. In our case, this suggests that systemic risk closely follows the time-variation of the idiosyncratic risk carried by the RE firms. Second, our results suggest that the larger the size of the firm the higher its systemic risk.

[Insert Table 3]

Turning to the set of variables that control for the macroeconomic environment, we observe that they all have the expected sign. The growth rate of real GDP has a negative effect on systemic risk. Credit booms increase the level of risk, and the Investment-to-GDP ratio is negatively related to $|\Delta$CoVaR$|$. The estimates of the effect of these control variables are in line with the findings of Brunnermeier et al. (2017). In addition, we find that higher levels of financial leverage are associated with higher systemic risk, which is in line with existing literature (Acharya and Thakor, 2016). The positive coefficient on leverage is the expected one given that the (negative) externality of the RE sector on the financial sector is expected to be larger under a less well capitalised system. Regarding the impact of monetary policy, we find that while tightening in "normal" times would reduce the level of systemic risk, during periods of zero-lower-bound, measures of quantitative easing help to tame the risk in the system. Finally, a bear stock market would increase the correlation between downside risk in RE firms and the financial sector.

So far we have not differentiated RE firms according to their type of business: commercial or residential.[14] The distinction between the two groups of RE firms is relevant for policy analysis purposes. This is so because, compared to Residential RE firms (RRE), Commercial RE companies (CRE) account for a larger share of GDP, and are more vulnerable to the business cycles exhibiting

[13] We have also considered an alternative approach to the one of having three separate regressions for each of the variables in the set of housing market factors, H, as reported in Table 3. This approach involved having two separate regression specifications. The first specification included real house prices and the housing exuberance dummy in the same model and the second real house prices and housing affordability. In both cases, the macroeconomic risk factors, M, and the firm characteristic factors, C, remained the same as in Table 3. The results not reported here, but available upon request, were qualitatively similar to the ones in Table 3.

[14] In Appendix C we provide information about the composition of the RE companies by type of business and their corresponding systemic risk measures.

higher default rates. We analyse whether our results differ across these two groups of RE firms and present the results in Table 4.[15] Overall, we observe only small differences. House prices appear to amplify more the tail dependency between CRE firms and the financial sector. However, when housing unaffordability rapidly rises, the increase in systemic risk is greater for RRE than for CRE firms.

[Insert Table 4]

3.3 Exposure of the UK Banking Sector to the Housing Market

In the introduction, we conjectured that the transmission mechanism that makes the RE sector systemically important is the banking sector. Several empirical studies have already provided evidence about the effect of the RE sector on banks' profitability and stability. For instance, Elyasiani et al. (2010) examine the relationship between commercial banks and real estate investment trusts (REITs). They find that financial intermediaries' returns are highly sensitive to the real estate market. A shock to REITs' returns spillovers to the banking sector, as well as to insurance companies and savings and loans companies. Martins et al. (2011) find that the housing market has a significant impact on the profitability and default risk of banks, specially of small size.

We contribute to this growing literature by quantifying the association between stress in RE companies and the banking sector. To do so we run the following regression of $\Delta CoVaR_i{}^{bank}$ on housing and macroeconomic variables, as well as firm characteristics. Similarly to the previous model, the housing variables include house prices and exuberance indicators.

[Insert Table 5]

The results are presented in table 5. First, the coefficient on house prices is negative, implying that sustainable house price growth is associated with less risk in the banking sector, and drop in prices with higher risk, possibly due to more vulnerable balance sheets caused by the exposure to mortgages and properties used as collateral. Second, during periods of house price exuberance, or "bubbles", this relationship is reversed. Furthermore, unaffordability plays a role, increasing the dependency of the RE firms and banks in periods of distress.[16] The effect of the

[15] The coefficients of the variables that control for firm characteristics, C, and macroeconomic environment, M, barely change and are therefore not reported here.

[16] Similarly to the analysis reported in Table 3 and discussed in footnote 13, we have estimated two alternative regression model specifications. One with real house prices and the housing exuberance

firm characteristics and macroeconomic environment is qualitatively similar to the one shown in the previous table of results. We have also examined, as we did in the previous section, whether the effects of house prices and affordability on the co-movement in the tails between RE companies and the banking sector depends upon the type of business. The results in table 6 show that the coefficients on the housing variables, H, are larger for CRE than for RRE firms. House price bubbles and unaffordability strengthen the degree of correlation between banks and CRE companies more than for RRE firms.

[Insert Table 6]

Overall, our findings not only contribute to a better understanding of the links between the RE and the banking sector but also provide additional information about the systemic risk of the banking sector which has been extensively researched in recent times. In addition to this, we provide in Appendix D an analysis about the dependency between risk in the “Big Four” banks in the UK (Lloyds, RBS, Barclays, and HSBC) and the RE sector. We find that while the tail dependency between the RE sector and these four banks is substantial, it decreases with the level of international diversification.

4 Conclusions

Two of the topics that have attracted considerable attention since the financial crisis of 2007-08 are housing and systemic risk. This paper is at the intersection of these two fields and contributes to them by quantifying the systemic risk of the real estate sector. We focus on the UK due to the importance of its financial sector in the international financial system and the role that housing plays in the determination of socio-economic outcomes. Our findings indicate that there is strong dependency between downside risk in the financial system and the real estate sector. In particular, when returns in the real estate sector are in distress, the value-at-risk of the entire financial system is higher by 74%. Looking at the determinants of systemic risk, we find that while moderate house prices movements positively relate to the level of financial stability, exuberance in house prices and housing unaffordability are associated with higher levels of systemic risk. In addition, firm characteristics and macro variables appear to play a role in the tail dependency between RE and

dummy, and another where we included real house prices and housing affordability. The results, available upon request, were similar to the ones in Table 5 for the former specification. For the latter, real house prices were not statistically significant.

financial sector. Most notably, an increase of the Bank of England base rate in normal times and the implementation of unconventional monetary policy are related to lower systemic risk.

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Appendix

A Alternative Methodology: A GARCH Approach

An alternative procedure to estimate the dynamic ΔCoVaR is to use a bivariate GARCH model. The first step is to estimate the dynamic VaR using a GARCH(1,1) model. The main assumptions are:

$\mathrm{R}_{t+1} = \mu + e_{t+1}$

$\sigma^2_{t+1} = \alpha_0 + \alpha_1 e^2_{t+1} + \beta\sigma^2_t$

$e_{t+1} = \sigma_{t+1} z_{t+1},\ where\ z \sim N(0,1)$

$\mid VaR_{t+1} \mid = \hat{\mu} + \hat{\sigma_{t+1}} F_a^{-1}$

Figure A.1 illustrates the VaR obtained by using the two alternative methodologies. For the financial sector, the results are similar for most of the period. The most significant deviation is observed during 2007-2009, when the state variables model implies a higher systemic risk than the one produced with the GARCH method. This pattern is similar for the RE sector.

[Insert Figure A.1]

We now specify the bivariate GARCH model for returns of the financial system and the RE sector that is required to estimate ΔCoVaR. We assume that returns follow a bivariate normal distribution:

$$(R^i_t, R^S_t) \sim N(0, \begin{bmatrix} \sigma^2_{i,t} & \rho\sigma^i_t\sigma^S_t \\ \rho\sigma^i_t\sigma^S_t & \sigma^2_{S,t} \end{bmatrix})$$

Therefore, $R^S_t \mid R^i_t \sim N\left(\frac{R^i_t \sigma_{S,t}\rho^i_t}{\sigma_{i,t}}, (1-\rho^i_t)(\sigma^2_{S,t})\right)$

By the definition of $CoVaR^{s|i}_t(q) : P\left(R^S \mid R^i = VaR^i_t(q) \leq \text{CoVaR}^{s|i}_t(q)\right) = q\%$

From the properties of the bivariate normal distribution, it follows that:

$$P\left((R^S_t - \frac{R^i_t\sigma_{S,t}\rho^i_t}{\sigma_{i,t}})/\sigma_{S,t}\sqrt{1-\rho^2} \mid R^i_t = VaR^i_q(t) \leq (CoVaR^i_q(t) - \frac{R^i_t\sigma_{S,t}\rho^i_t}{\sigma_{i,t}})\sigma_{S,t}\sqrt{1-\rho^2}\right) = q\%$$

Since $(R^S_t - \frac{R^i_t\sigma_{S,t}\rho^i_t}{\sigma_{i,t}})$ & $(CoVaR^i_q(t) - \frac{R^i_t\sigma_{S,t}\rho^i_t}{\sigma_{i,t}})$ are N(0,1) random variables:

$\mathrm{VaR}_q^i(t) = \Phi(q\%)^{-1}\sigma_{i,t}$ *and* $CoVaR_q^i(t) = \Phi(q\%)^{-1}\sigma_{i,t}\sqrt{1-\rho_{i,t}^2} + \Phi(q\%)^{-1}\rho_{i,t}\sigma_{S,t}$

Therefore: $\Delta CoVaR_q^i(t) = \Phi(q\%)^{-1}\rho_{i,t}\sigma_{i,t}$

We note that the main factors affecting the value of systemic risk are the correlation coefficient (ρ_i) and the dynamic volatility of the financial system ($\sigma_{S,t}$). Both the time-varying correlation coefficient and the standard deviation are estimated with a DCC specification. The figure below illustrates the dynamic ΔCoVaR estimated with both methods. We observe that the estimated systemic risk employing the GARCH method increases only right at the inception of the financial crisis. The method employing state variables better captures the build up of systemic risk ahead of the crisis and that this is another reason we employ it in our main analysis of the paper.

[Insert Figure A.2]

B Static ΔCoVaR: Individual Real Estate Firms

Real Estate Firms I						
Name	Mnemonic	VaR	CoVaR^{fin}	ΔCoVaR^{fin}	CoVaR^{bank}	ΔCoVaR^{bank}
Land Securities Group	LAND	12.40%	13.08%	7.78%	15.47%	6.91%
British Land	BLND	10.57%	13.71%	8.29%	16.3%	7.56%
Segro	SGRO	13.26%	12.91%	8.61%	15.78%	8.42%
Hammerson	HMSO	12.50%	11.22%	6.17%	18.23%	7.69%
Derwent London	DLN	12.09%	11.78%	7.41%	17.74%	8.63%
Shaftesbury	SHB	12.55%	11.71%	6.60%	17.30%	8.47%
Intu Properties	INTU	10.81%	9.78%	4.83%	16.49%	7.00%
Capital & Counties Prop	CAPC	10.78%	8.26%	4.18%	14.37%	6.31%
Unite Group	UTG	16.98%	9.59%	4.78%	15.55%	5.41%
Great Portland Estates	GPOR	9.43%	10.07%	5.16%	19.71%	10.29%
Workspace Group	WKP	16.94%	13.84%	8.83%	20.00%	11.02%
Big Yellow Group	BYG	11.31%	10.57%	5.6%	15.82%	5.65%
Assura	AGR	14.32%	7.57%	1.35%	11.74%	1.96%
Grainger	GRI	14.33%	8.80%	2.71%	13.61%	3.45%
Savills	SVS	13.81%	11.30%	5.71%	15.05%	5.20%
Purplebricks Group	PURP	20.96%	6.88%	2.08%	11.05%	3.39%
Safestore	SAFE	12.71%	10.11%	3.07%	13.72%	2.56%
CLS Holdings	CLI	10.9%	11.02%	5.46%	16.31%	6.34%
Daejan Holdings	DJAN	10.35%	10.11%	5.01%	14.65%	5.65%
St Modwen Prop.	SMP	17.66%	11.69%	6.35%	16.77%	7.82%
RDI Reit	RDI	16.61%	9.75%	4.10%	16.02%	6.30%
Londonmetric Prop.	LMP	7.29%	8.45%	1.61%	14.30%	2.96%
Hansteen Holdings	HSTN	9.05%	12.26%	6.77%	20.67%	9.31%
Urban Civic	UANC	18.43%	11.79%	4.41%%	15.57%	5.37%
Helical Reit	HLCL	14.20%	12.02%	4.74%	15.19%	4.64%
Mountview Estate	MTVW	8.69%	11.47%	4.71%	15.64%	5.33%
Capital & Regional	CAL	24.17%	8.85%	2.63%	14.81%	3.89%
Harworth Group	HWG	23.85%	9.89%	2.35%	15.87%	3.59%
Mucklow A&J Group	MKLW	12.00%	10.96%	3.11%	15.32%	4.39%
U & I Group	UAI	15.96%	10.02%	3.97%	17.40%	6.64%

Real Estate Firms II						
Name	Mnemonic	VaR	CoVaR^{fin}	ΔCoVaR^{fin}	CoVaR^{bank}	ΔCoVaR^{bank}
LSL Properties	LSL	20.36%	10.32%	4.03%	14.94%	3.33%
Countrywide	CWD	28.11%	5.10%	1.82%	8.97%	1.18%
McKay Securities	MCKS	8.96%	8.66%	2.89%	14.35%	3.66%
Foxtons Group	FOXT	23.46%	4.96%	1.46%	8.66%	1.31%
Conygar Invest.	CIC	10.26%	8.34%	1.59%	13.18%	2.34%
Palace Capital	PCA	22.84%	6.75%	0.14%	14.09%	3.69%
Town Centre Securities	TOWN	14.00%	11.81%	6.15%	16.77%	7.80%
Inland Homes	INL	19.08%	9.43%	3.30%	14.31%	3.75%
Lok'n Stores Group	LOK	14.10%	11.43%	4.41%	15.95%	5.67%
Real Estate Investors	RLE	13.11%	9.10%	2.34%	15.28%	4.56%
Newriver Reit	NRR	6.35%	8,26%	3,65%	14,60%	5,50%
Highcroft Investments	HCFT	6.11%	9.30%	2.72%	13.56%	2.65%
Property Franchise Group	TPFG	15.06%	6.15%	2.80%	11.48%	4.34%
Caledonian Trust	CNN	12.89%	9.76%	2.67%	14.40%	3.25%
London & Assocs. Prop.	LAS	12.41%	10.06%	2.43%	12.52%	2.17%
Cardiff Properties	CDFF	5.51%	9.22%	1.88%	14.60%	3.14%
Wynnstay Prop	WSP	6.33%	9.58%	1.66%	14.28%	2.67%
Hunters Property	HUNT	11.45%	5.47%	12.24%	9.82%	0.82%
HML Holdings	HMLH	20.04%	8.08%	1.58%	13.94%	2.33%
M Winkworth	WINK	10.64%	6.49%	0.77%	10.91%	1.11%
Safeland	SAF	18.33%	10.11%	2.61%	12.52%	1.58%
Steward & Wight	STE	7.69%	10.73%	2.37%	12.69%	1.22%
Fletcher King	FLK	15.73%	10.64%	4.11%	16.53%	5.44%
Belvoir Lettings	BLV	14.47%	4.58%	0.73%	11.09%	2.32%
Panther Securities	PNS	7.57%	10.52%	3.18%	13.29%	2.02%
Secure Inc. Reit	SIR	7.78%	6.38%	2.96%	9.24%	1.23%
GCP Students Lettings	DIGS	2,91%	5,32%	1,34%	8,95%	1,22%
Local Shop Reit	LSR	15,03%	9,97%	5,10%	13.26%	2,23%
AEW UK Reit	AEWU	3.09%	6,85%	2.83%	11.34%	4.00%
Alpha Real Trust	ARTL	10.61%	9.52%	1.89%	16.42%	4.23%

Real Estate Firms III						
Name	Mnemonic	VaR	CoVaR^{fin}	ΔCoVaR^{fin}	CoVaR^{bank}	$\Delta\text{CoVaR}^{bank}$
Axa Property Trust	APT	9.67%	7.52%	0.61%	11.07%	0.25%
Custodian Reit	CREI	2.38%	5.54%	1.07%	11.84%	2.20%
Drum Inc. Reit	DRIP	4.21%	5.29%	0.65%	9.23%	0.78%
Ediston Prop.	EPIC	2.95%	6.22%	2.09%	12.29%	4.87%
F&C Com. Prop.	FCPT	6.26%	8.69%	2.78%	14.45%	4.28%
KCR Residential Reit	KCR	20.69%	8.69%	2.78%	14.45%	4.28%
Picton Prop. Trust	PCTN	14.12%	8.08%	2.12%	13.87%	3.78%
Regional Reit	RGL	4.49%	7.54%	4.12%	10.39%	3.97%
UK Com. Prop Trust	IKCM	7.05%	12.22%	3.47%	12.60%	1.72%
Tritax Big Box Reit	BBOX	4.21%	5.63%	1.84%	9.21%	1.71%
Target Healthcare Reit	THRL	3.56%	3.17%	0.63%	7.04%	0.94%
Std.Lf.Inv.Prop.Inc Trust	SLI	9.08%	8.84%	3.22%	13.85%	4.03%
F&C UK Rlst. Inv.	FCRE	10.73%	9.47%	4.13%	14.91%	5.04%
Summit Germany	SMTG	5.46%	5.74%	1.64%	12.05%	3.30%
Raven Russia	RUS	18.33%	11.20%	5.33%	16.18%	6.90%
Sirius Real Estate	SRE	18.30%	10.35%	3.70%	18.55%	5.13%
Vordere	VOR	25.18%	2.07%	1.77%	6.16%	2.65%
Alpha Pyrenees Trust	ALPH	40.55%	10.06%	3.33%	12.80%	2.80%
Globalworth Reit	GWI	8.47%	10.06%	3.23%	12.80%	2.80%
Macau Prop.Opp. Fund	MPO	10.29%	11.45%	4.92%	16.51%	6.86%
Schroder Reit	SERE	8.22%	2.21%	3.95%	1.66%	7.91%

Notes: The table reports the average systemic risk contribution of individual UK RE firms. The examined period is 2002m6-2018m7 and all the observations are obtained from Datastream. The system indices are FTSE350 financial system that includes all banks, investment funds, general financial, insurance and RE companies and FTSE350 Banks to measure the dependecy with the banking sector. The measures of risk are estimated for the 95% quantile, and they expressed in absolute values.

C Residential and Commercial Real Estate Firms

We distinguish between firms that focus on commercial property and those that focus on residential property. In the first group we include all the industrial and retail RE firms. These firms hold portfolios of warehouses, shopping centres, hotels, restaurants, storage facilities and medical centres. The second group own and manage properties available for occupation and for no-business purposes, and they are also involved in property development and trading.

Figure A.4 shows the weights of each group in the construction of the RE portfolio. The commercial real estate firms constitute more than 50% of the index, while only one in four firms is residential-focused. For the rest of firms, 16% have a mixed portfolio of commercial and residential and 9% are classified separately as international firms. These are mostly RE companies that are traded in the London Stock Exchange (LSE) but their asset are located in foreign countries.

[Insert Figure A.4]

Table A.1 shows that the systemic risk of commercial RE (CRE) and residential RE (RRE) companies is very similar around 8%, although it is higher for CRE firms when the impact is measured only on the banking sector. This result provides support to the analysis of the ECB's report in 2015 that suggests that CRE companies have higher loan-to-value (LTV) ratios and strong cyclicality leading to higher default risk.

[Insert Table A.1]

D The effect on the "Big Four"

We apply the ΔCoVaR methodology to examine the impact of the real estate market to individual UK banking institutions. For this analysis, we employ the four systemically important banks in the UK, namely, Lloyds Banking Group, Barclays, Royal Bank of Scotland (RBS) and HSBC. These four companies own around 45% of the mortgage market share.[17] Table A.2 presents the market shares of each bank for the UK mortgage gross lending based on the data provided by UK Finance and CML. We first confirm that these four banks are systemically important in the UK by computing their $\Delta CoVaR^i_j$, or the level of risk of the financial system when these banking institutions are under distress.

[17] Nationwide is the second largest mortgage lender (12.3%), but it is a building society hence not in the London Stock Exchange. We also leave out Santander because this company is not traded in the UK stock market either.

[Insert Table A.2]

In Table A.3 we can observe that the systemic importance of the banks is related to their share in the mortgage market. Lloyds and RBS have higher ΔCoVaR than the other two institutions. To examine the exposure of the banks to the real estate market, we estimate the $\Delta CoVaR^{i}_{RE}$, that is, the VaR of each individual bank when the RE portfolio is under distress. RBS and Lloyds are the most vulnerable to the housing market. When the returns of the real estate portfolio are at their $VaR_{95}\%$, the risk measure of the two banks increases by 24.42% and 17.5%, respectively. The exposure of Barclays and HSBC is lower, as expected, due to their more international focus on different banking operations such as investment and corporate banking.

[Insert Table A.3]

Tables

Table 1: Data Description of Sector Indices and RE Portfolio

Index	Mean Returns	St.Deviation	$VaR_{95\%}$
Financial Sector	0.50%	4.43	7.15%
Banking Sector	-0.45%	6.69	11.41%
RE Portfolio	0.35%	5.46	8.59%
Systemic Risk Estimates			
$CoVaR_{95\%}^{fin\|RE}$	$\Delta CoVaR_{95\%}^{fin\|RE}$	$CoVaR_{95\%}^{bank\|RE}$	$\Delta CoVaR_{95\%}^{bank\|RE}$
12.42%	8.43%	16.72%	8.46%

Notes: The table reports summary statistics for the market indices and the real estate portfolio. The sample period is 2002m6-2018m7 and all the quantities are expressed in monthly frequency. All the estimates of risk are expressed in absolute values.

Table 2: State Variables Summary Statistics

Variables	Mean	Std Dev	Skewness	Min	Max
Three month yield (change)	-2.63	20.86	-8.47	-178.8	26.20
Yield Curve (change)	-0.19	24.44	1.39	-52.3	121.7
TED Spread	25.18	31.08	3.37	0.813	215.12
Credit Spread	1.04	29.47	3.64	-95.9	225.87
FTSE100 Volatiliy (VIX)	18.83	7.94	1.61	9.55	54.15
FTSE100 Returns	0.20	3.94	-0.76	-13.96	8.30

Notes: The table reports summary statistics for the state variables employed to estimate the dynamic model of systemic risk. The spreads and changes in spreads are expressed in monthly basis points, and the returns in monthly percentages.

Table 3: Systemic Risk of the RE sector ($\Delta CoVaR_{RE}^{Fin}$)

Variables	Model 1	Model 2	Model 3
ln(HPI)	-2.931 (0.000)		
House Price Exuberance		1.041 (0.000)	
Unaffordability			1.448 (0.000)
VaR_{RE}	0.059 (0.000)	0.058 (0.000)	0.056 (0.000)
Size	0.909 (0.000)	0.800 (0.000)	0.823 (0.000)
GDP growth	-0.147 (0.000)	-0.132 (0.000)	-0.124 (0.000)
Inflation	-0.042 (0.584)	-0.036 (0.643)	-0.056 (0.464)
ΔInvestments	-0.124 (0.000)	-0.114 (0.000)	-0.121 (0.000)
ΔCredit	0.624 (0.000)	0.719 (0.000)	0.682 (0.000)
ln(Leverage)	1.227 (0.000)	1.645 (0.000)	1.648 (0.000)
MP base rate	-0.342 (0.000)	-0.350 (0.000)	-0.328 (0.000)
Shadow rate (QE)	0.314 (0.000)	0.290 (0.000)	0.289 (0.000)
Stock Market	-0.311 (0.000)	-0.310 (0.000)	-0.304 (0.000)
R^2	0.45	0.45	0.45

Notes: This table reports the coefficients from panel regressions of $|\Delta CoVaR_i^{fin}|$ for the sample of the 81 UK RE firms on firm characteristics, housing and macroeconomic variables. The exuberance indicator dummy variables are estimated based on the BSADF approach. The firm size is measured by the log of Market Capitalisation divided by the sector's average. P-values are displayed in parentheses.

Table 4: Systemic Risk of the RE sector
Analysis by type of business

Group:	Residential RE	Commercial RE
ln(HPI)	-2.937	-3.251
	(0.000)	(0.000)
RHPI Exuberance	0.971	1.129
	(0.000)	(0.000)
Unaffordability	1.427	1.337
	(0.000)	(0.000)

Notes: This table reports the coefficients from panel regressions of $|\Delta CoVaR_i^{fin}|$ for two sub-samples of the RE sector (residential and commercial) on firm characteristics, housing and macroeconomic variables. The rest of the variables are not presented since the estimates are qualitatively similar to the previous table. P-values are displayed in parentheses.

Table 5: Dependency between RE and Banking Sector ($\Delta CoVaR_{RE}^{bank}$)

Variables	Model 1	Model 2	Model 3
ln(HPI)	-3.175		
	(0.000)		
House Price Exuberance		1.348	
		(0.000)	
Unaffordability			1.996
			(0.000)
VaR_{RE}	0.076	0.075	0.073
	(0.000)	(0.000)	(0.000)
Size	1.660	1.565	1.605
	(0.000)	(0.000)	(0.000)
GDP growth	-0.313	-0.304	-0.295
	(0.000)	(0.000)	(0.000)
Inflation	0.234	0.263	0.243
	(0.028)	(0.013)	(0.021)
ΔInvestments	-0.260	-0.254	-0.265
	(0.000)	(0.000)	(0.000)
ΔCredit	0.695	0.825	0.784
	(0.000)	(0.000)	(0.000)
ln(Leverage)	1.801	2.275	2.287
	(0.000)	(0.000)	(0.000)
MP base rate	-0.414	-0.432	-0.406
	(0.000)	(0.000)	(0.000)
Shadow rate (QE)	0.420	0.383	0.378
	(0.000)	(0.000)	(0.000)
Stock Market	-0.500	-0.499	-0.490
	(0.000)	(0.000)	(0.000)
R^2	0.48	0.48	0.48

Notes: This table reports the coefficients from panel regressions of $|\Delta CoVaR_i^{bank}|$ for the sample of the 81 UK RE firms on firm characteristics, housing and macroeconomic variables. The exuberance indicator dummy variables are estimated based on the BSADF approach. The firm size is measured by the log of Market Capitalisation divided by the sector's average. P-values are displayed in the parentheses.

Table 6: Dependency between RE sector and Banking sector
Analysis by type of business

Group:	Residential RE	Commercial RE
ln(HPI)	-2.409 (0.000)	-4.272 (0.000)
RHPI Exuberance	1.081 (0.000)	1.653 (0.000)
Unaffordability	1.684 (0.000)	2.278 (0.000)

Notes: This table reports the coefficients from panel regressions of $|\Delta CoVaR_i^{bank}|$ for two sub-samples of the RE sector (residential and commercial) on firm characteristics, housing and macroeconomic variables. The rest of the variables are not presented since the estimates are qualitatively similar to the previous table. P-values are displayed in parentheses.

Table A.1: RE Systemic Risk by type of business

Group	No of Firms	Market Cap	VaR	ΔCoVaR^{fin}	ΔCoVaR^{bank}
All Companies	81	100%	8.59%	8.32%	8.46%
All excl. International	73	91.11%	8.49%	8.38%	8.49%
Commercial	39	50.83%	9.17%	7.87%	9.11%
Residential	21	23.72%	10.41%	7.94%	10.43%
Diversified	13	16.56%	8.12%	5.69%	7.98%
International	8	8.89%	8.07%	3.40%	4.61%

Notes: The table reports the estimates for the systemic risk measures for different sub-sectors of the RE sector. The examined period is 2002m6-2018m7 and all the quantities are expressed in monthly frequency. All the estimates of risk are expressed in absolute values.

Table A.2: UK Mortgage Market Lending Market Shares

Bank	2017	2016	2015	2014
Lloyds Banking Group	16%	15.6%	17.5%	19.5%
Royal Bank of Scotland	12%	12.9%	11.2%	9.7%
Barclays	9%	8.4%	8.6%	10%
HSBC	7.1%	6.4%	5.8%	6.2%
Total	44.1%	43.3%	43.1%	45.4%

*Source: UK Finance and CML

Table A.3: UK Systemic Banks

Bank	$\text{VaR}_{95\%}$	$\Delta\text{CoVaR}_i^{FIN}$	$\Delta\text{CoVaR}_{RE}^i$
Lloyds Banking Group	19.95%	7.99%	17.5%
Royal Bank of Scotland	20.59%	6.10%	24.42%
Barclays	16.01%	5.42%	11.80%
HSBC	10.18%	5.61%	5.51%

Notes: The table reports the estimates for the $\Delta CoVaR$ measures of the banking sector. The examined period is 2002m6-2018m7 and all the quantities are expressed in monthly frequency. All the estimates of risk are expressed in absolute values.

Figures

Fig. 1: Systemic Risk, VaR and CAPM beta

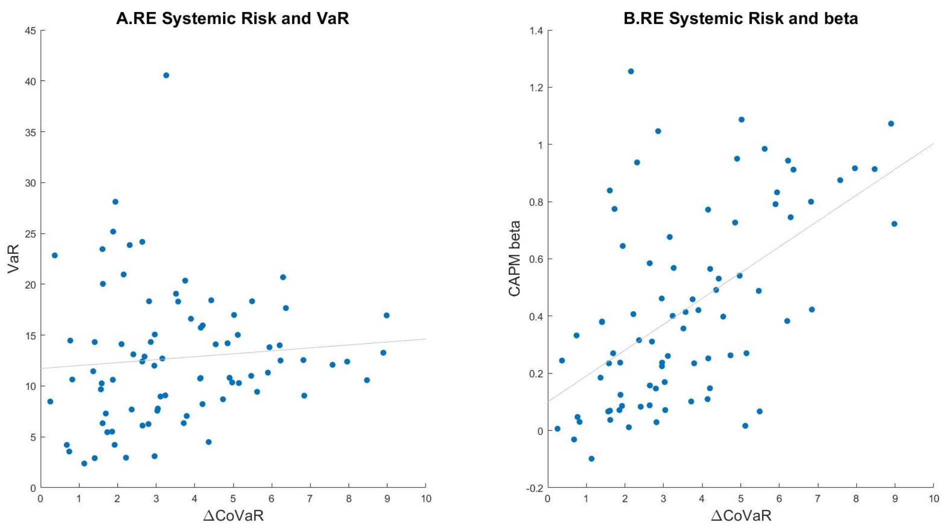

Fig. 2: Firm Characteristics and ΔCoVaR^{fin}

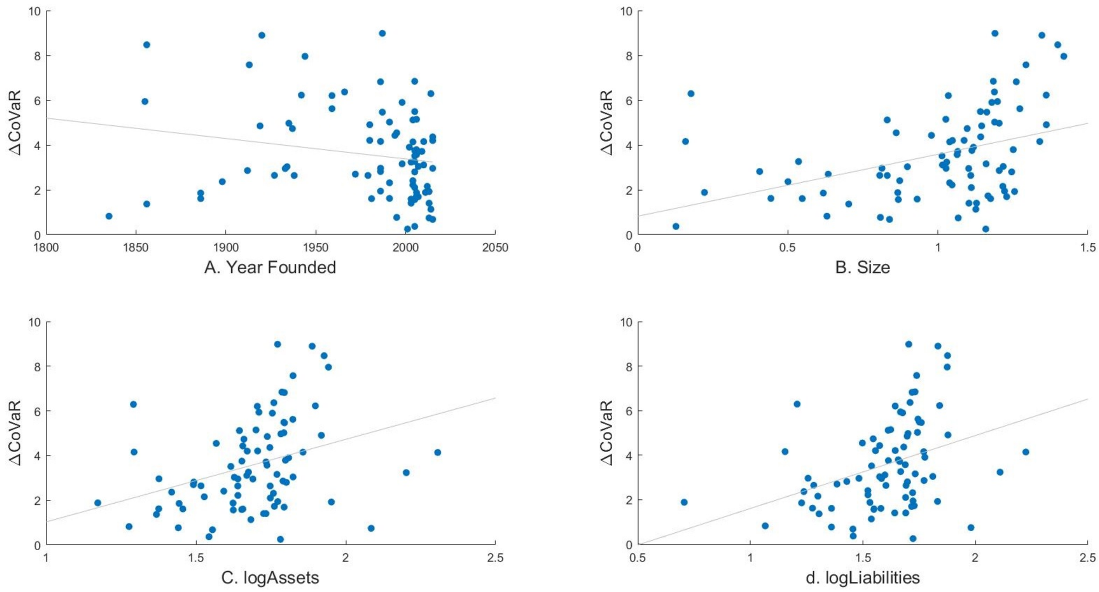

Fig. 3: Exuberance in the UK Housing Market

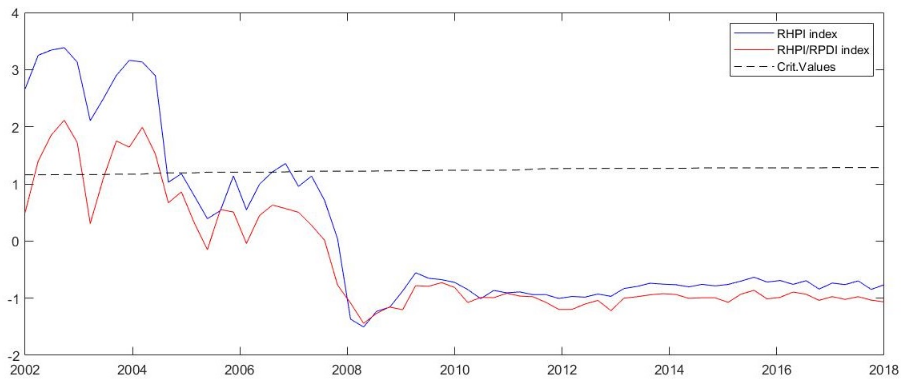

Figure A.1: Dynamic VaR: Alternative Methodologies

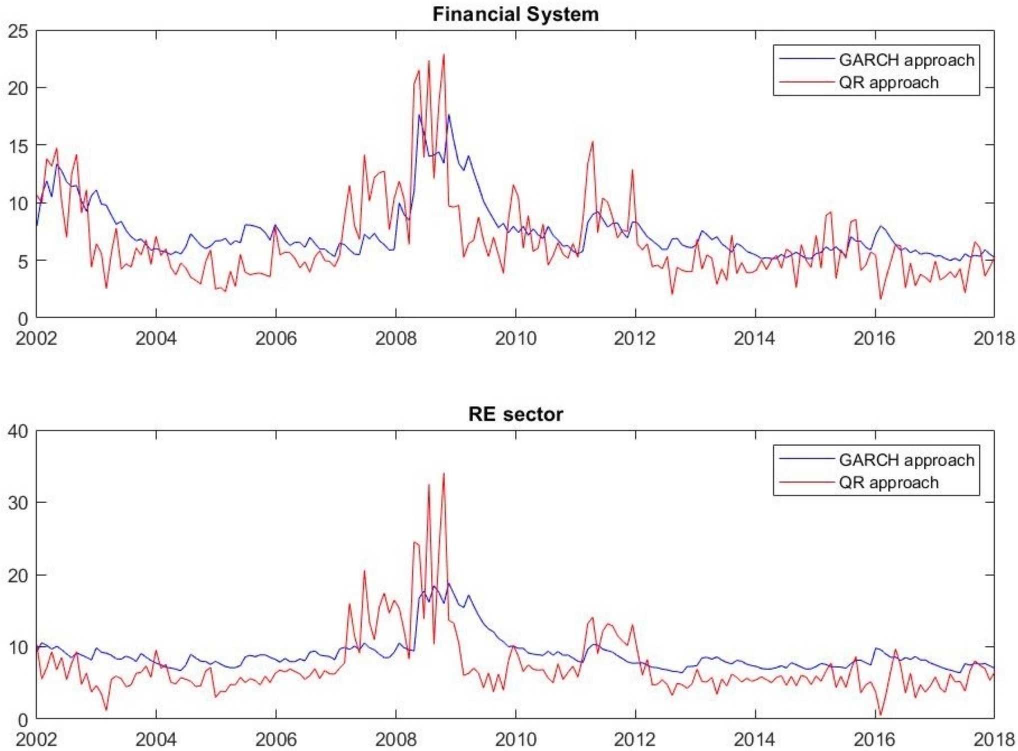

Figure A.2: Dynamic ΔCoVaR: Alternative Methodologies

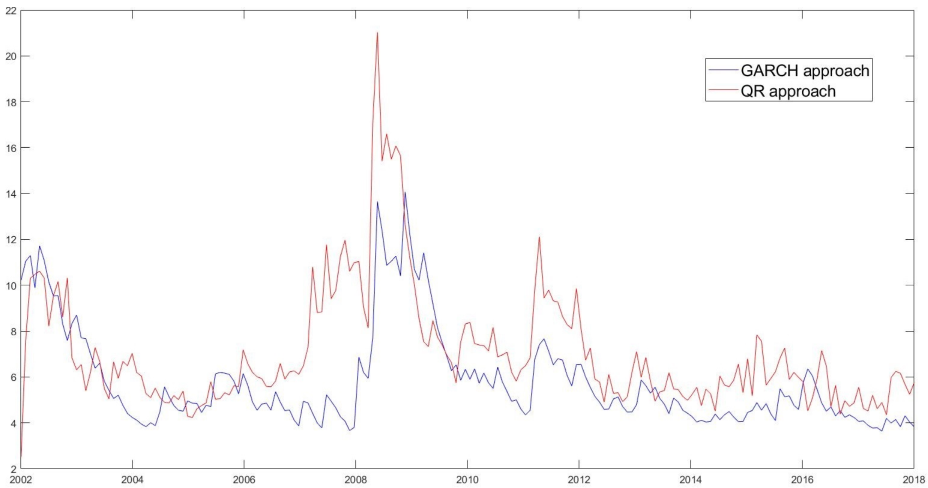

Figure A.3: VaR and CoVaR of the Financial System Index

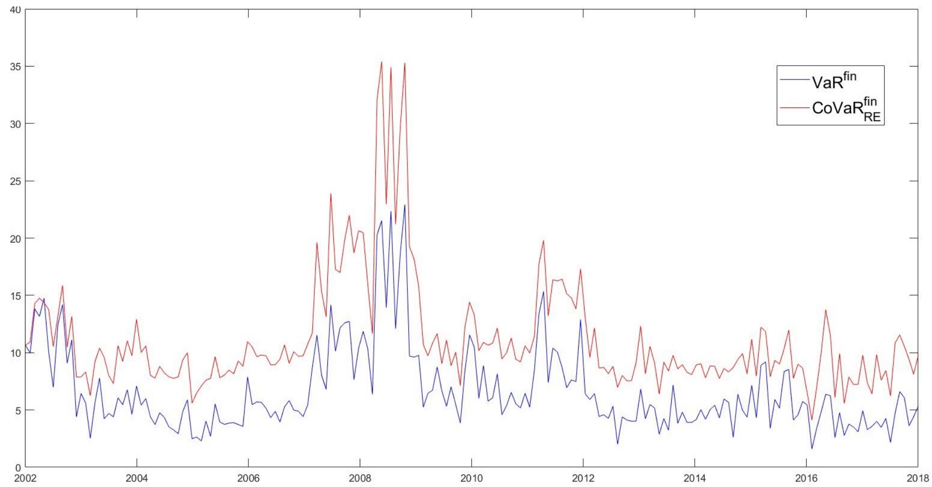

Figure A.4: Weights on the RE Portfolio