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A Price-at-Risk approach for the German commercial real estate market

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Non-technical summary

Research Question

From a financial stability perspective, it is important to assess the downside risks to the German commercial real estate market. Our focus is on events that are unlikely to occur but have potentially far-reaching consequences for the financial system, such as a significant decrease in real estate prices. For this purpose, we develop a commercial real estate price-at-risk model for the German market that focuses primarily on the left tail of the conditional CRE price distribution. In other words, we focus on quantifying the 5th percentile of the future CRE price distribution and its evolution over time.

Contribution

This paper describes the methodology and application of the commercial real estate price-at-risk model for the German market, which we use to analyze the downside risk to price growth for the 2024 Financial Stability Review (Deutsche Bundesbank, 2024). The model is based on the seminal paper of Adrian et al. (2019) and estimates the conditional distribution for future CRE price growth. More specifically, the model uses historical data from the period Q1 2011 to Q4 2023 and estimates the relationship between future CRE price growth and endogenous regressors such as the spread between the net initial yield and the yield of 10-year German government bonds, mortgage growth, growth in building permits and financial stress. The model does not focus on point estimates of future growth rates, but derives an entire conditional distribution.

Results

We find that the forecast distribution of CRE prices has shifted strongly to the left since the COVID-19 pandemic. The shift in the distribution is mainly driven by a worsening of macroeconomic conditions, an increase in interest rates and an increase in the net-initial yield. Based on the latest data available, our model predicts a higher likelihood of further year-on-year CRE price declines, with projections indicating a potential decline in CRE prices of -24.8% at the 5th percentile of the distribution for Q4 2024 - one of the lowest values observed through-out our sample period.

Nichttechnische Zusammenfassung

Fragestellung

Aus Finanzstabilitätssicht ist es wichtig, Abwärtsrisiken für den deutschen Gewerbeimmobilienmarkt zu bewerten. Unser Fokus liegt auf solchen Ereignissen, deren Eintreten unwahrscheinlich ist, die aber potenziell weitreichende Folgen für das Finanzsystem haben, wie etwa ein erheblicher Rückgang der Immobilienpreise. Hierzu entwickeln wir ein Gewerbeimmobilienpreis-at-Risk Modell für den deutschen Markt, welches sich in erster Linie auf das untere Ende der bedingten CRE-Preisverteilung konzentriert. Dafür liegt der Fokus auf der Quantifizierung des 5. Perzentils der zukünftigen CRE-Preisverteilung und ihrer Entwicklung im Zeitverlauf.

Beitrag

Dieses Papier beschreibt die Methodik und Anwendung des Gewerbeimmobilienpreis at-Risk Modells für den deutschen Markt, das wir benutzen, um für den Finanzstabilitätsbericht 2024 (Deutsche Bundesbank, 2024) das Abwärtsrisiko des Preiswachstums zu analysieren. Das Modell basiert auf der Arbeit von Adrian et al. (2019) und schätzt die bedingte Verteilung für das zukünftige Preiswachstum von Gewerbeimmobilien. Das Modell verwendet historische Daten von Q1 2011 bis Q4 2023 und schätzt die Beziehung zwischen zukünftigem Preiswachstum für Gewerbeimmobilien und endogenen Regressoren wie dem Spread zwischen der Nettoanfangsrendite und dem Yield 10jähriger deutscher Staatsanleihen, Hypothekarkreditwachstum, Wachstum bei Baugenehmigungen sowie Finanzmarktstress. Das Modell konzentriert sich nicht auf Punktschätzungen zukünftiger Wachstumsraten, sondern erlaubt es, eine vollständige bedingte Verteilung zu berechnen.

Ergebnisse

Wir zeigen, dass sich die Verteilung der prognostizierten Preise für Gewerbeimmobilien seit der Covid-19-Pandemie stark nach links verschoben hat. Die Verschiebung ist primär auf eine Verschlechterung der makroökonomischen Bedingungen, einen Anstieg der Zinssätze sowie einen Anstieg der Nettoanfangsrendite zurückzuführen. Basierend auf den neuesten verfügbaren Daten prognostiziert unser Modell eine höhere Wahrscheinlichkeit eines weiteren Rückgangs der Gewerbeimmobilien-Preise im Jahresvergleich, wobei die Projektionen einen potenziellen Rückgang von -24,8% für das fünfte Perzentil der Verteilung für 2024 Q4 anzeigen, was zu den niedrigsten Werten gehört, die während des gesamten Beobachtungszeitraums auftreten.

A Price-at-Risk Approach for the German Commercial Real Estate Market*

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Abstract

We apply the *growth-at-risk* model of Adrian et al. (2019) to the German commercial real estate (CRE) market. We derive a distribution for CRE price growth four quarters ahead conditional on macro-financial variables. This approach allows us to make probability statements about the downside risk to future CRE price growth, which serve as an input to financial stability analyses. We find that the conditional distribution has shifted strongly to the left since the COVID-19 pandemic, in line with deteriorating macroeconomic conditions, an increase in long-term interest rates and a decline in the net initial yield, resulting in lower expected CRE price growth rates across the entire distribution.

Keywords: Commercial Real Estate, Quantile Regression, Growth-at-Risk, Germany

JEL Codes: C32, E37, G01, R33

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1 Introduction

This paper studies the downside risk for the German commercial real estate market. We obtain estimates for the distribution of future price growth. This analysis is a central component of the broader set of results presented in the 2024 Financial Stability Review (Deutsche Bundesbank, 2024). This technical paper explains the rationale for and implementation of the underlying methodological approach, lays out the main findings, and provides additional robustness checks.

The commercial real estate (CRE) market is economically significant. Measured by its share of gross domestic product (GDP) in Germany, the economic importance of the commercial real estate sector increased from around 13% in 2010 to nearly 17% in 2023 (MSCI 2024). This is roughly in line with the international average. Although commercial real estate markets alone have never yet triggered a financial crisis, the global financial crisis showed that risk materialization in the commercial real estate market can aggravate crisis periods substantially. Particular characteristics of the commercial real estate markets – such as the large share of non-recourse loans, bullet loans and variable rate loans – increase the vulnerabilities of the financial system (Deutsche Bundesbank 2022). In addition, commercial real estate markets are tightly interwoven with the rest of the real economy, giving rise to feedback effects between financial stability risks and economic activity.

These characteristics have prompted regulatory authorities to tighten macroprudential surveillance of commercial real estate markets. In recent years, CRE markets have slowed down and prices have dropped to a lower level due to several factors. On the structural side, the COVID-19 pandemic has accelerated a *work-from-home* culture, which has depressed the demand for office spaces substantially (IMF 2024). Furthermore, climate-related considerations have shifted demand towards energy-efficient buildings, leading to a further decline in the prices of commercial real estate with low energy standards (ECB 2024). Finally, the shift in preferences of consumers from traditional in-store to online shopping has contributed greatly to a decline in CRE prices for retail buildings (Deghi et al. 2022). On the other hand, interest rate hikes starting in 2022 have led to tighter financing conditions for borrowers, whilst also making long-term government bonds an attractive alternative for investors again.

Against this background, it is important to quantify further downside risks to CRE markets. Tail risks, in particular, have become the focus of macroprudential authorities' interest. Tail risks in the financial system describe events that have only a low probability of occuring. However, if they materialize, this has far-reaching consequences for financial stability. In light of these considerations, we propose a model that allows us to make probability statements about future realizations of commercial real estate price growth. More specifically, based on the seminal paper by Adrian et al. (2019), we develop a *CRE price at-risk model* that enables us to predict the conditional distribution of future commercial real estate prices. We condition the distribution on current macrofinancial aggregates. The core of our model is based on a quantile regression, which was first introduced by Koenker & Bassett (1978) and from which we derive a conditional probability distribution with the help of a skewed t-distribution (Azzalini & Capitanio 2003). The conditional distribution allows us to make conditional probability statements regarding the realization of future tail risks in commercial real estate prices.

We find that the conditional real estate price growth distribution shifted to the left after the COVID-19 pandemic, indicating a higher likelihood of year-on-year declines in CRE prices. The shift in the distribution is mainly driven by a worsening of macroeconomic conditions, an increase in interest rates and an increase in the net-initial yield. At the current end of our sample period, our model predicts a year-over-year CRE price decline of -24.8% for the 5th percentile in Q4 2024. Compared with the previous year, the expected situation has deteriorated on average and higher price declines have become more likely overall. At the same time, the probability of particularly low growth rates for commercial real estate prices has risen. We perform a visual out-of-sample forecast evaluation and find that our estimated conditional distributions adequately capture the realized values of CRE price growth over time.

1.1 Related literature

The seminal work by Adrian et al. (2019) introduces the growth-at-risk (GaR) approach. It quantifies the severity of systemic risk based on the existing level of macro-financial vulnerabilities by linking real GDP growth in the United States to macroeconomic and financial variables in a non-linear way. The authors demonstrate that while macroeconomic variables help predict the median of the growth forecast distribution, tighter financial conditions amplify adverse shocks and therefore lead to an increase in downside risks to economic growth. The GaR method uses quantile regression techniques, in particular the approach proposed by Koenker & Bassett (1978) and further developed by Bassett & Koenker (1982). The GaR method estimates the conditional distribution of future growth under current macro-financial conditions. By focusing on the lower quantiles of the distribution, GaR captures the downside risks to economic growth arising from financial imbalances and vulnerabilities.

The GaR approach can be used for analyses in a variety of areas. With regard to the development of real estate prices, Hafemann (2023) develops a house price-at-risk model for the German residential real estate market. The results of the quantile regression for this market show that interest rate, risk premium and employment fluctuations mainly influence the lower quantiles of the house price forecast distribution, while past house prices have a stronger influence on the median of the forecast.

In relation to the overall real estate market, Galán & Rodríguez-Moreno (2020) develop a model for Spain in which forecasts of real housing price growth rates are positively associated with lagged values of house price growth and population growth. Conversely, their model shows that house price overvaluation and credit growth have a negative association with forecasted real house price increases.

Alter & Mahoney (2020) develop a house price-at-risk model for the United States and Canada. They show that supply-side factors, valuations, household debt, financial conditions, and capital flows play a key role in forecasting potential house price risks and vulnerabilities.

The International Monetary Fund and the European Central Bank use house price-at-risk models for risk assessment in the *Global Financial Stability Report*, the *Financial Stability Review* and the *Macroprudential Bulletin* (IMF 2024 ,ECB 2020, ECB 2024, Jarmulska et al. 2022). For example, the ECB applies a panel quantile regression to a sample of 19 euro area countries, taking into account historical price trends, current market valuations, and broader economic indicators. Key elements of the assessment include systemic risk measures, consumer sentiment, and various financial market metrics.

Deghi et al. (2020) forecast downside risks in 32 advanced and emerging economies. They show that overvalued house prices, tighter financial conditions and excessive credit growth lead to greater downside risks to real house prices. Furthermore, they show that the easing of conventional monetary policy reduces the downside risk in advanced economies. Tightening macroprudential policy, on the other hand, is effective in the short and long term for both advanced and emerging market economies. In addition, the results of the study show that house price-at-risk can be used as an indicator of risks in the housing sector.

In a further step, the GaR method has been adapted for the analysis of risks in other sectors and markets. Goel & Miyajima (2021) and Gelos et al. (2022) develop capital flows at-risk models. They use the GaR method to examine the future probability distribution of capital flows to emerging markets. This approach makes it possible to quantify the risks posed by international capital movements and to evaluate policy instruments to mitigate said risks.Lang & Forletta (2020) use a representative panel of EU banks to show that high cyclical systemic risk in the present predicts large declines in average bank profitability in 3 to 5 years.

The GaR framework has been applied specifically to the context of macroprudential policy, yielding valuable insights into the assessment and surveillance of systemic risk. One notable application is the analysis of macroprudential policy effectiveness. Galán (2020) investigates the impact of macroprudential policies and finds that such policies can mitigate downside risks to economic growth. This study is in line with Aikman et al. (2019), who, using a panel of 16 advanced economies, find that credit booms, property price booms, and wide current account deficits pose material downside risks to medium-term GDP growth, but that these risks can be partially mitigated by increasing bank capital. Duprey et al. (2017) utilize the GaR approach to date systemic financial stress episodes in EU countries, highlighting its usefulness in identifying periods of heightened macro-financial vulnerabilities. Drenkovska & Volčjak (2022) examine the relationship between financial vulnerabilities and downside risks to economic growth in Slovenia. The results show that prevailing financial conditions influence tail risks to growth across all time horizons, with medium-term risks being more dependent on systemic financial vulnerabilities such as excessive credit growth. Figueres & Jarocinski (2020) find the *Composite Indicator of Systemic Stress* (CISS) to be an important variable for forecasting the GDP growth distribution. In addition, Szendrei & Katalin (2023) highlight the importance of bankingrelated variables when modelling euro area growth-at-risk.

With regard to international financial stability linkages, Lloyd et al. (2024) explore how foreign financial conditions influence the forecast distribution of domestic GDP growth for a panel of advanced economies. Beutel et al. (2022) show by incorporating the global financial cycle into a GaR model that contractionary shocks to US monetary policy and financial conditions increase downside risks to GDP growth in other economies.

To the best of our knowledge, we are the first to develop an at-risk model for the commercial real estate sector.

The remainder of the paper is structured as follows. In Section (2), we present our methodology to derive a conditional distribution for CRE price growth. In Section (3), we apply the methodology to the CRE market in Germany. We present our dataset, before outlying our results. We run several robustness checks in Section (4). Section (5) concludes.

2 Methodology

Following the approach of Adrian et al. (2019), we base our model on a quantile regression that relates future commercial real estate prices to current macro-financial conditions by choosing the slope coefficient β_τ from a quantile regression of y_{t+h} on x_t, such that the sum of quantile weighted absolute value of error terms is minimized:

$$\hat{\beta}_\tau = \underset{\beta_\tau \in \mathbb{R}}{\text{arg min}} \sum_{t=1}^{T-h} (\tau \cdot \mathbf{1}_{(y_{t+h} \geq x_t \beta)} |y_{t+h} - x_t \beta_\tau| + (1-\tau) \cdot \mathbf{1}_{(y_{t+h} < x_t \beta)} |y_{t+h} - x_t \beta_\tau|), \tag{1}$$

where τ refers to the respective quantile, **1** to an indicator function and T to the end of the sample period. The predicted value $\hat{y}_{t+h}$ at quantile τ is then the result of the following:

$$\hat{Q}_{y_{t+h}|x_t}(\tau|x_t) = x_t \hat{\beta}_\tau \tag{2}$$

In order to relate the conditional quantile function to a conditional distribution, we again follow Adrian et al. (2019) and recover the conditional quantile function by fitting a skewed t-distribution developed by Azzalini & Capitanio (2003):

$$f(y;\mu,\sigma,\alpha,\nu) = \frac{2}{\sigma}t(\frac{y-\mu}{\sigma};\nu)T(\alpha\frac{y-\mu}{\sigma}\sqrt{\frac{\nu+1}{\nu+(\frac{y-\mu}{\sigma})^2}};\nu+1) \tag{3}$$

We rely on the skewed t-distribution because it has proven to be extremely flexible and is described by only four parameters. In comparison to the normal t-distribution, the skewed t-distribution allows us to reflect the expected skewness of CRE price growth distribution in our estimation. We choose the parameter of the distribution $(\mu, \sigma, \alpha, \nu)$ for every quarter t, such that we minimize the distance between the estimated quantile function $\hat{Q}_{y_{t+h}|x_t}(\tau|x_t)$ and the quantile function of the skewed t-distribution $F^{-1}(\tau_t, \mu_t, \sigma_t, \alpha_t, \nu_t)$ to match the 5th, 25th, 75th and 95th percentiles such that the estimation is exactly identified:

$$\{\hat{\mu}_{t+h}, \hat{\sigma}_{t+h}, \hat{\alpha}_{t+h}, \hat{\nu}_{t+h}\} = \underset{\mu,\sigma,\alpha,\nu}{\text{arg min}} \sum_{\tau}(\hat{Q}_{y_{t+h}|x_t} - F^{-1}(\tau;\mu,\sigma,\alpha,\nu))^2 \tag{4}$$

Obtaining the shape parameters then allows us to recover a conditional distribution function in order to derive conditional probability statements.[1]

3 Application to the German commercial real estate market

This section sketches out the application of the commercial real estate price-at-risk model. We first present the data that we use in the analysis and then outline our results.

3.1 Data

Our sample includes quarterly observations from Q1 2011 to Q4 2023. The dependent variable is the year-over-year growth rate of a commercial real estate price index that captures retail as well as office properties in percent.[2] Figure (1) shows the commercial real estate price growth series. After more than a decade of continued growth and a short-lived price decline during the

[1] For a detailed description of the procedure, we refer the reader to Adrian et al. (2019).

[2] We create the price index series as a weighted average of a price series for office and retail. We weight office by about four quarters and retail by abound one quarter. This roughly reflects the ratio of usable space of the segments. We keep the weights constant over time, such that overall price changes can be attributed to changes in the underlying price series and are not driven by changes in weights. All index series in our data are normalized to 100 in 2010. In line with the ESRB definition of commercial real estate, further yield producing segments belong to the commercial real estate sector. However, data gaps prevent us from including further segments, such as logistics. As many of the above-mentioned structural factors are of particular concern to the office and retail markets and driving factors may differ, we also abstain from including commercial housing, although it accounts for a non-negligible part of the commercial real estate sector in Germany.

COVID19-pandemic, prices in commercial real estate started to decline persistently in Q4 2022. We include variables that cover economic developments, the macro-financial environment and financing conditions. The choice of our variables is based on their significance in the following estimation, performance of the forecast distribution over time and expert judgment. Hence, we include the following explanatory variables:

- the year-over-year growth rate of building permits
- the year-over-year growth rate of total mortgage loans to domestic enterprises (minus mortgage loans for residential real estate to domestic enterprises)
- the spread between the net yield rate of commercial real estate and the yield of 10-year German government bonds
- the Bundesbank Financial Stress Indicator
- lagged values of the dependent variable, i.e. CRE price growth rates.

Figure (2) plots these data series. The growth rate of building permits exhibits rather erratic behavior over the entire sample period, while showing a pronounced decline in 2023. Mortgage growth steadily increased after the sovereign debt crisis until around 2022, while the net initial yield spread hovered between 3 and 4% in this time period. The financial stress indicator peaked during the sovereign debt crisis around 2013 and increased again with the start of the Russian invasion of Ukraine.

The choice of our set of regressors x_t is driven by several theoretical and empirical considerations. We control for real economic developments in our model and include an index that measures growth in building permits, and thus captures the effects of business cycle developments on commercial real estate markets. New planning and building permissions are a leading indicator for future developments. By including the growth rate of new permits, we predominantly capture future supply developments of commercial real estate. Including the mortgage growth rate allows us to take into account the current and future debt-financed demand for commercial real estate. We further include the spread between the initial net return on office and retail real estate and 10-year German government bonds. On the one hand, this choice allows us to control for monetary policy developments, as long-term maturity rates serve as a benchmark for the financing costs of CRE-related investments.[3] On the other hand, long-term

[3] We measure monetary policy in a more straightforward manner on page 14.

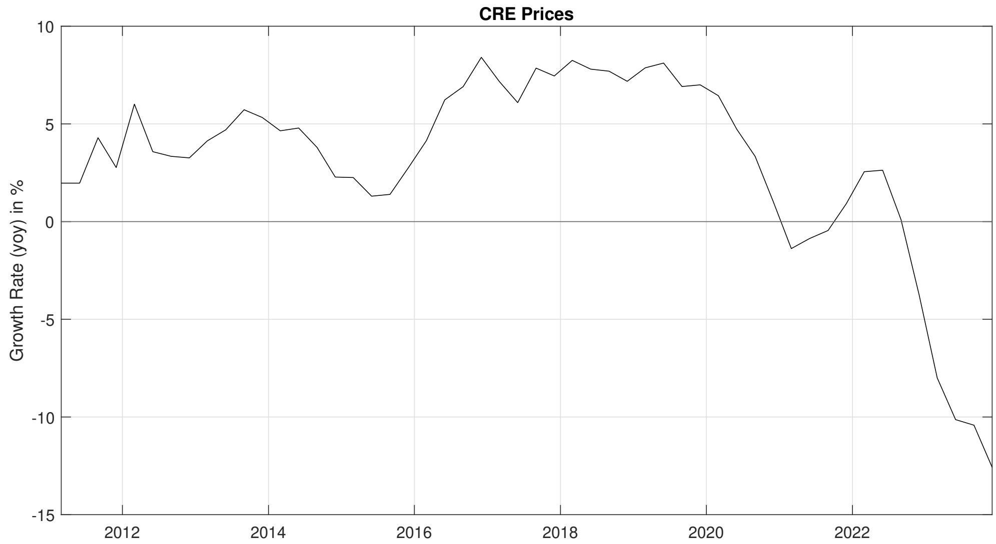

Figure 1: **Commercial real estate price growth rate from 2011 to 2023**

government bonds are arguably close substitutes for commercial real estate due to their maturity length and a suitable benchmark interest rate for long-term financing decisions from a borrower's point of view. Including the spread reflects the trade-off between investing in CRE or other investments in the bond market with a long-term maturity.

We further include an index of financial stress that captures short-term developments on financial markets and controls for the financial market sentiments of borrowers, lenders and investors. Finally, as commercial real estate prices are fairly persistent, we include a lagged value of commercial real estate growth in our model to capture autoregressive developments that are not explained by the other variables in our model. All explanatory variables enter our model contemporaneously, whereas our dependent variable is shifted four quarters ahead. This model setting allows us to project the commercial real estate price distribution within a projection horizon of four quarters.

3.2 Results

Our approach allows us to analyze all percentiles of the conditional distribution. However, for the purpose of this exercise, we focus on the 5th percentile. We aim to capture tail events, which, by definition of the percentile, are unlikely to materialize but are still plausible in their design. The materialization of such events can have far-reaching consequences for financial stability considerations. Table (1) in Appendix (A) presents the quantile regression estimation results, whereby the first six columns present results for different percentiles of the distribution and the last column shows the OLS estimates for comparison. We derive standard errors

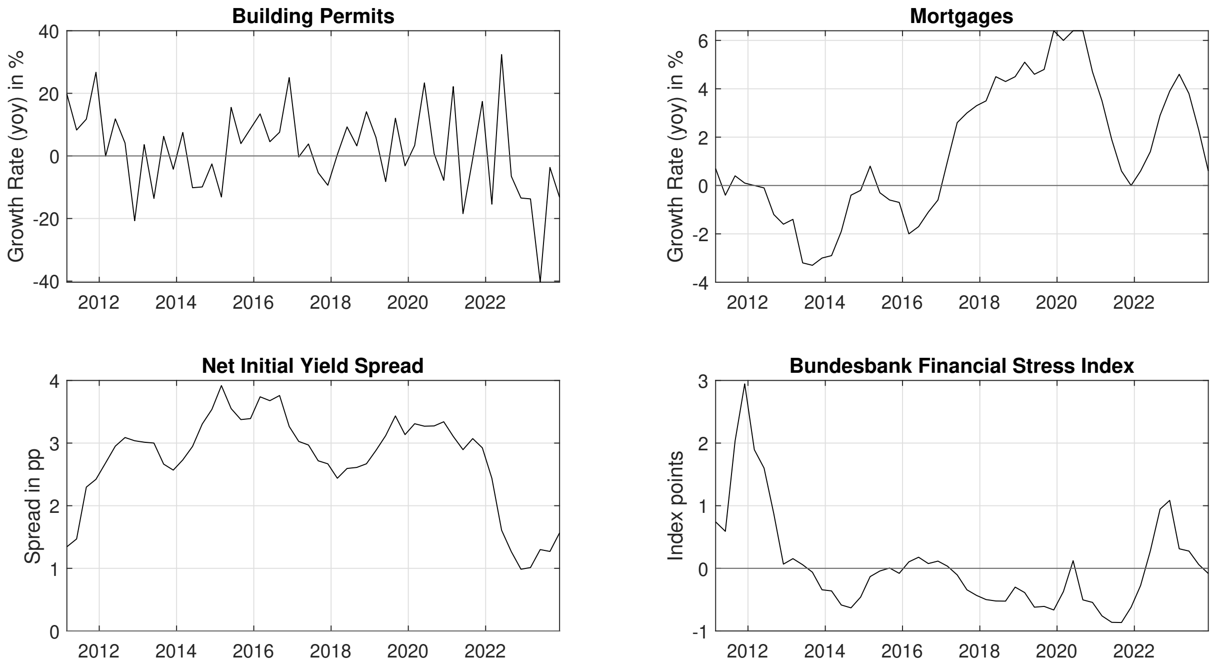

Figure 2: **Time Series Plot of Explanatory Variables**

from a bootstrap procedure for all relevant quantiles, similarly to Hafemann (2023). For percentiles at the lower end of the distribution, most of the explanatory variables are significant. An increase in the spread between the net yield and the government bond yield increases CRE price growth, as it makes investing in CRE property relatively more profitable compared to investing in government bonds with a long-term maturity structure. In addition, whilst an increase in the growth rate of building permits is associated with an increase in supply in the medium term, in the short run it is associated with an increase in CRE price growth, as it signals an acceleration of CRE property demand. Furthermore, as expected, the autoregressive component has a positive sign (larger than one), which indicates that CRE price dynamics are persistent and path dependent.

For illustration purposes, Figure (3) displays the decomposition of the four-quarters ahead prediction of the 5th percentile into the different explanatory variables over time.[4] The corresponding results for the 10th percentile are shown in Appendix (A). The spread between the net initial yield and the 10-year German government bonds plays a decisive role in explaining CRE price developments. Its share in the total decomposition was particularly large in the low interest rate environment and only started to decline when long-term interest rates rose. Financial market

[4]The historical decomposition of the four-quarters ahead prediction uses the fixed estimated coefficients from the quantile regression model for the 5th percentile and evaluates the model using historical data.

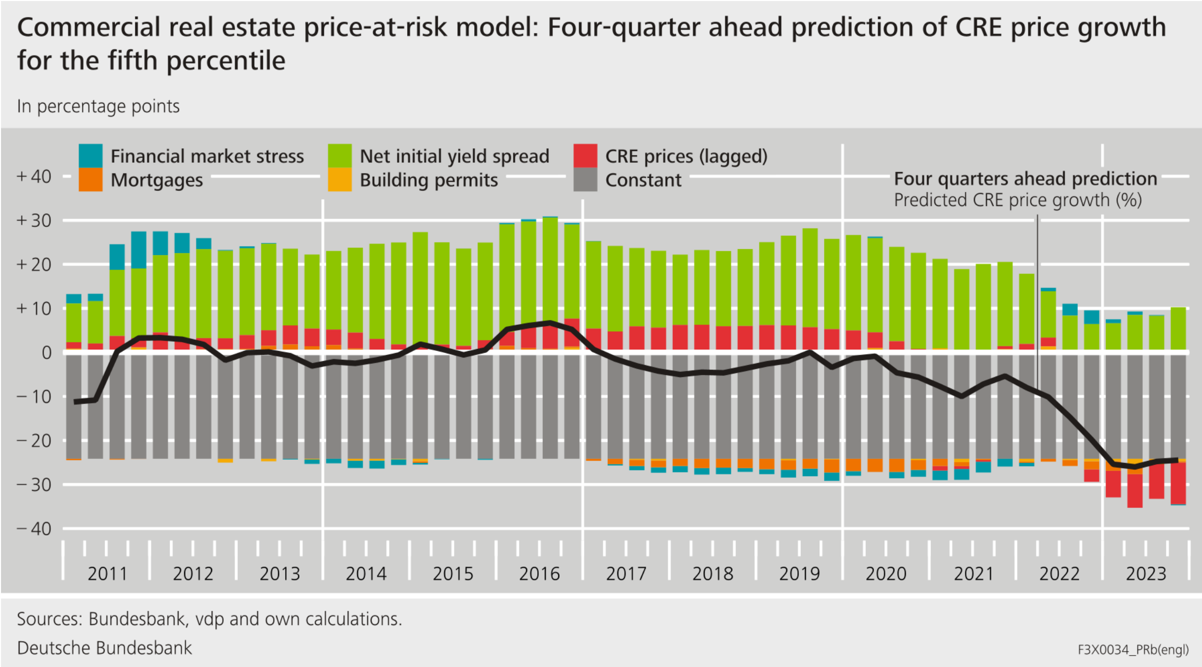

Figure 3: **Decomposition of four quarter ahead prediction for commercial real estate price growth for the fifth percentile**

Note: *The years on the horizontal line represent the date until which data is available. I.e., at the current end, the estimation represents the prediction of the fifth percentile for 2024 Q4 based on data available until 2023 Q4.*

stress played a role during the sovereign debt crisis by lifting up the lower tail of the distribution. While this sign might be counterintuitive, it would be consistent with the interpretation that during this financial stress episode, commercial real estate might have served as a safe harbour (*flight to safety*), leading to a higher demand for these asset classes and a corresponding decrease in short-run downside price risk. The autoregressive component has primarily influenced the fluctuation of commercial real estate prices during periods of substantial and rather abrupt price increases or declines. However, factors such as mortgage growth and the issuance of building permits have played a minor additional role in shaping the trajectory of CRE price growth rates.

For the 2024 Financial Stability Review (Deutsche Bundesbank, 2024), we apply our model in order to compare estimated distributions for 2023 and 2024. As explained in Section (2), our model allows us to derive a conditional distribution for CRE price growth rates. The conditional distribution shows the distribution of the probability mass attached to certain outcomes of CRE price growth conditioned on the variables in our model. Figure (4) shows the results, i.e. the conditional four-quarters ahead distributions for 2023 and 2024. The risk of further significant price declines has tended to increase relative to the previous year. Unlike for the residential

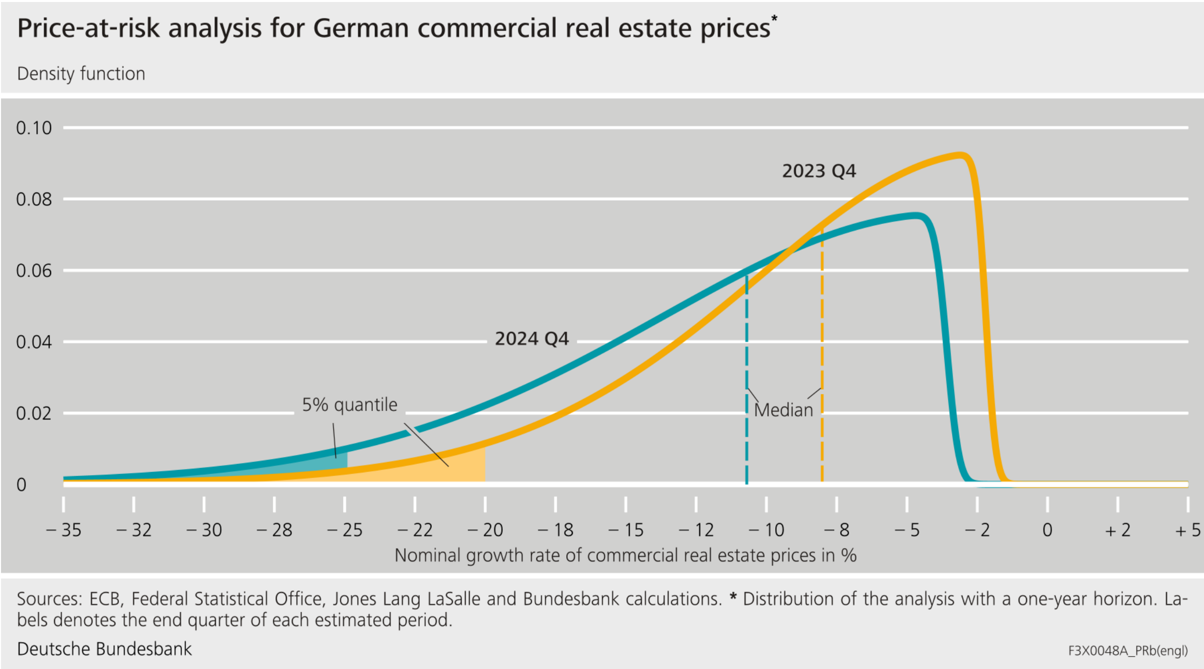

Figure 4: **Conditional four quarter ahead distributions for 2023 and 2024**

real estate market, however, the likelihood of further price declines has increased year-on-year. The estimated distribution of the price growth rate for the fourth quarter of 2024 shifted further to the left compared with the same quarter of the previous year, with the median distribution also decreasing. For the fourth quarter of 2023, the median of the estimated distribution of price growth was still -8%, while for the fourth quarter of 2024 it is now -11%. Compared with the previous year, the expected situation has thus deteriorated on average, and greater price declines have become more likely overall. At the same time, the probability of particularly low growth rates in commercial real estate prices (5% quantile) has also risen again.

Looking at a longer time horizon, we also plot the conditional forecast distribution for the end quarter of the last three years as well as for Q4 2020 in order to contrast the distributional shift with a pre-pandemic estimate in Figure 5. It is evident that between the data was available at Q4 2019 and at Q4 2023, the conditional distribution shifted continuously to the left. While the prediction of the 5th percentile based on the data available up to Q4 2019 was at around -6%, this value dropped to -25% in Q4 2023. Furthermore, over the depicted time horizon, the skewness of the conditional distributions widened and developed a more pronounced fat tail at the lower end.

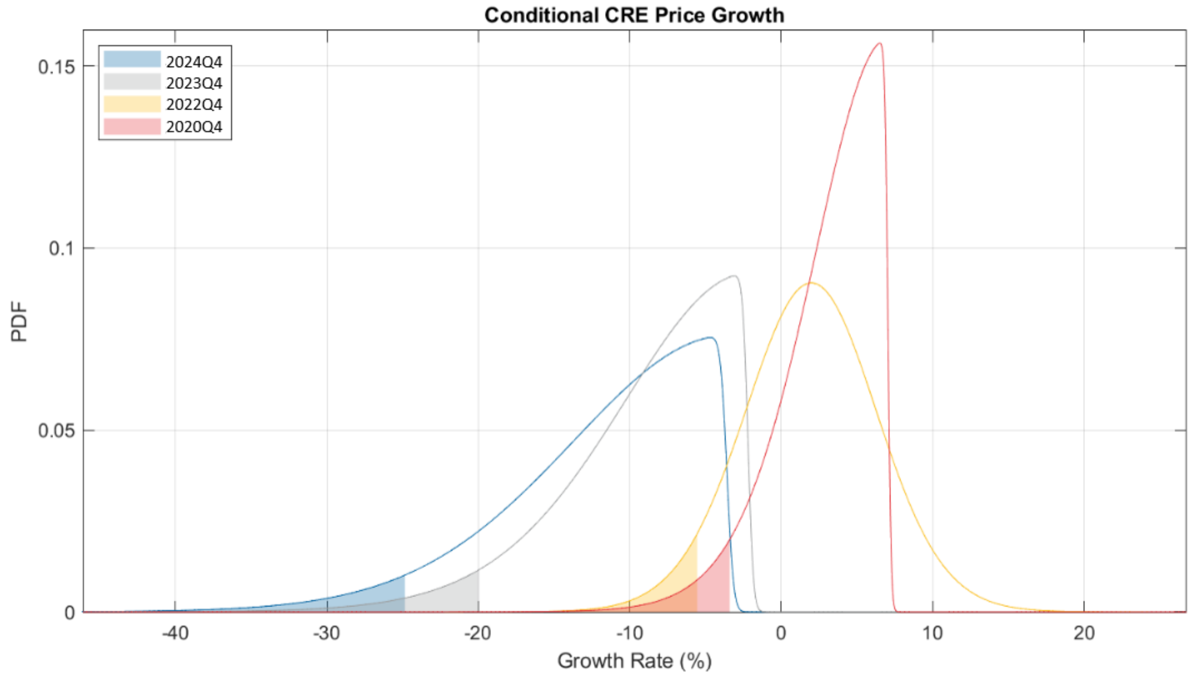

Figure 5: **Conditional four quarter ahead distributions for different time periods**

Note: The figure displays the conditional probability density function. The shaded area refers to the fifth percentile of the distribution and the date refers to the date for which the model was estimated with data available a year ago, i.e., 2024 Q4 refers to the conditional distribution for 2024 Q4 based on data until 2023 Q4.

In order to cross-check our model, we compare out-of-sample estimates with realized price growth. Figure (6) shows the results. The figure summarizes the forecast distribution with an expanding window approach in which we only use data available up to a certain point in time to estimate the model, i.e. we allow for varying coefficients. The dates on the x-axis refer to the end of the forecast horizon. The blue dots reflect the realized values for the dates displayed on the x-axis. For example, 2023-12 displays the four-quarters ahead forecast distribution based on the data available up to Q4 2022 (boxplot) and the realized value for CRE price growth in Q4 2023 (blue dot). Almost all realized values are between the 5th and 95th percentile of our forecast distributions, which is indicated by the whiskers in Figure (6). Up until Q4 2022, the realized growth rates were almost exclusively above the projected median forecast depicted by the red line. It is worth emphasizing that we do not try to forecast the point estimate for average (or median) CRE price growth, but that our interest lies in deriving a conditional distribution that provides us with a reliable estimate for downside risks. As such, our model is tailored to the lower end of the CRE price distribution, and the results should be interpreted against this background. It is thus reassuring from a financial stability perspective that our forecast

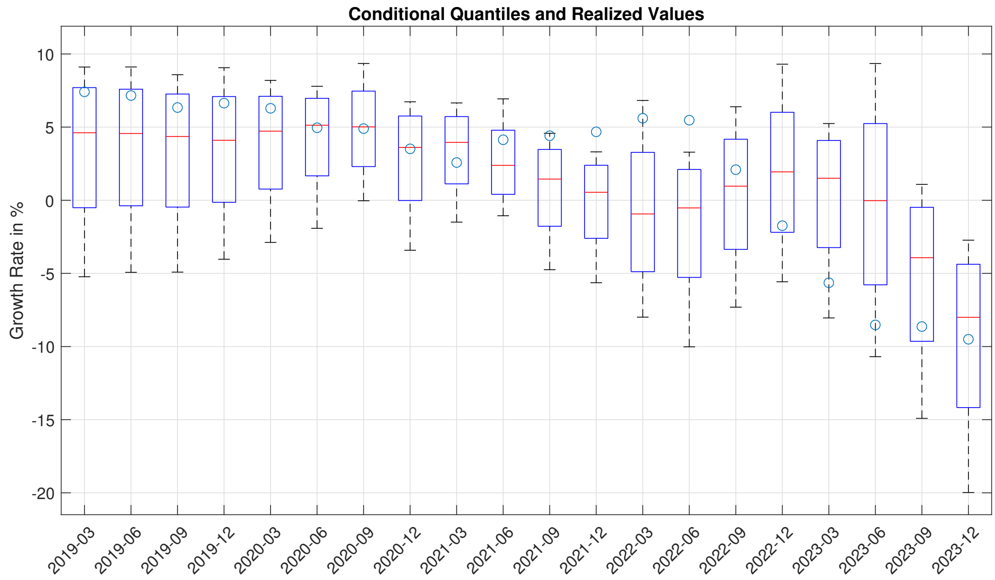

Figure 6: **Out of sample forecast evaluation**

Note: The figure displays the conditional distribution obtained after fitting the skewed t-distribution with an expanding window approach. Here, the legend refers to the end of the respective forecast horizon. I.e. 2023-12 displays the conditional distribution for data available until 2022-12. The box displays the interquartile range of the conditional distribution, while the whiskers show the 5th and 95th percentile respectively. The dot shows the realized CRE price growth rate for the date depicted on the x-axis.

distribution does not systematically underestimate CRE price growth, as the realized values for a large part of the sample lie in the upper part of the projected distributions. Furthermore, the large decline in CRE price growth starting from Q4 2022 is well captured by our model. Over the course of 2023, the realized values are in the lower part of our forecast distribution, indicating that tail risk materialized during 2023. Over the course of 2023, the entire forecast distribution shifted downwards (to the left), such that the realized value for Q4 2023 ranges around the 40th percentile of the forecast distribution, whilest at the same time, the price decline hovered above a historical low.

4 Robustness analysis

In order to validate our estimation results, we run several robustness checks in which we alter the composition of explanatory variables or change the dependent variable in our estimation.

Alternative measure of financial stress In place of the Bundesbank Financial Stress Indicator, we include the country-level index of financial stress (CLIFS) for Germany developed by Duprey et al. (2017). The CLIFS index focuses more on those stress episodes that have consequences for the real economy, whereas the Bundesbank stress indicator focuses more on market, liquidity and credit risk. The results, which can be found in Appendix B.1, do not change qualitatively, although the form of the estimated conditional distribution is altered for the estimation based on the data available up to Q4 2019 and Q4 2021. The financial market stress, captured by the CLIFS, has a larger impact on the commercial real estate price distribution than the financial stress index in our baseline estimation.

10-year German government bond yield instead of CRE yield spread Furthermore, we exchange the net initial yield spread and include only the 10-year German government bond yield. The estimation results are in Appendix B.2. Again, the results do not change qualitatively, although the conditional distributions seem to shift to the left, indicating greater downside risk for CRE price growth in our estimation. The sign of the government bonds at the 5th percentile reveals some seemingly counterintuitive results. At the lower end of the distribution, an increase in long-term government bonds is associated with an increase of CRE price growth.

Office buildings only Lastly, we also run our model with only office real estate price growth as the dependent variable, while keeping the other variables unchanged from our main model. The results are presented in Appendix B.3. First, the signs of the coefficients are mostly the same as in our benchmark model, in which we use an index that captures both, office and retail real estate. At the end point, our model predicts a slight rebound of the lower tail of office price growth, albeit the left tail remains fairly depressed, characterized by negative growth rates. The distributional form depends heavily on the time period considered and changes from a left to a right skewed distribution between Q4 2019 and Q4 2022.

5 Conclusion

We develop an at-risk model that allows us to predict the conditional distribution of commercial real estate price growth in Germany. Our model is able to capture the historical development of tail risk (5th percentile) over time and reflects the CRE boom after the sovereign debt crisis as well as the recent price declines which coincided with the interest rate reversal as a reaction of rising inflation. We are able to derive conditional distributions by fitting a skewed t-distribution to the estimated conditional quantiles. We show that the conditional distribution has shifted since the COVID-19 pandemic such that the lower tail of the distribution has decreased strongly. When applied to policy, our model allows us to predict the conditional four-quarters ahead distribution based on the latest available data. This enables us to quantify tail risk to CRE price growth and to make probability statements about future CRE price growth developments.

The at-risk approach is known to be subject to the limitation that the shape of the conditional distribution can depend on the choice of the selected variables and may change slightly with a different set of endogenous variables (see, e.g., Prasad et al. 2019). In our application of the model, we select our variables based on economic considerations and significance, while keeping the model parsimoniously small. As we show in Section (4), our qualitative results are robust to using other variables.

Overall, the specification of the model is suitable for quantifying the downside risk for CRE price growth in Germany and for observing developments over time. In addition, the decomposition into the individual factors allows current developments to be analyzed in more detail. The at-risk model is therefore a valuable tool for monitoring risks in the commercial real estate sector and provides relevant information for policy applications such as the Bundesbank's 2024 Financial Stability Review (Deutsche Bundesbank, 2024).

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A Benchmark model - estimation results

Table 1: Estimation results from the quantile regression on four quarter ahead CRE price growth.

Quantile	**5**	**10**	**25**	**50**	**75**	**95**	**OLS**
CONS	-24***	-18***	-14**	-6.9	3.1	4	-8.3***
Building Permits (in %)	0.042	-0.046	-0.011	0.04	0.045	0.12*	0.028
Mortgages (in %)	-0.47**	-0.67**	-0.48**	-0.22	-0.47	-0.59	-0.37*
CRE Prices (in %)	0.76**	0.58**	0.75***	0.84***	0.69***	0.58***	0.87***
Net Initial Yield Spread (in %)	6.5**	5.3**	4.2**	2.5	0.085	0.38	2.8***
Financial Stress (in idx. pts.)	2.9*	2.2*	1.1*	0.23	-1	-2.2	0.37

Note: *,** and *** refer to the 10%, 5% and 1% significance level.

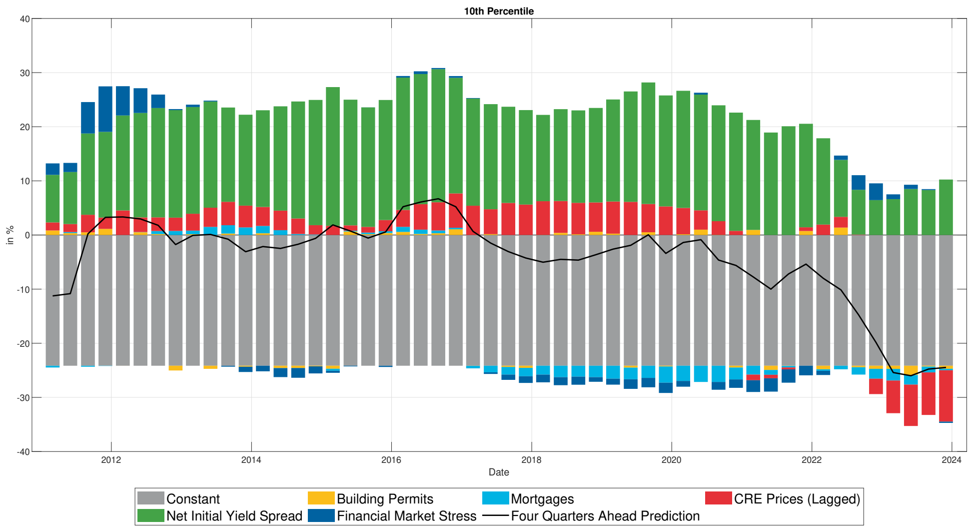

Figure 7: Decomposition of four quarter ahead prediction for commercial real estate price growth over time for the tenth percentile.

B Robustness checks

B.1 Robustness analysis 1: Stress Indicator CLIFS

Table 2: Robustness Analysis 1: Estimation results from the quantile regression on four quarter ahead CRE price growth.

Quantile	**5**	**10**	**25**	**50**	**75**	**95**	**OLS**
CONS	-13	-14	-1.2	2.6	4.3	2.6	-0.85***
Building Permits	0.027	0.027	0.078	0.049	0.1**	0.12*	0.061
Mortgages	-0.18	-0.41	0.13	-0.32	-0.26	-0.74	-0.2*
CRE Prices (lagged)	0.79***	1***	0.7***	0.76***	0.65***	0.72**	0.68***
Net Initital Yield Spread	3.8	3.9	1.2	0.78	0.89*	1.9**	1.7***
Financial Stress	-28*	-28*	-46**	-38**	-43**	-37	-36

Note: *,** and *** refer to the 10%, 5% and 1% significance level.

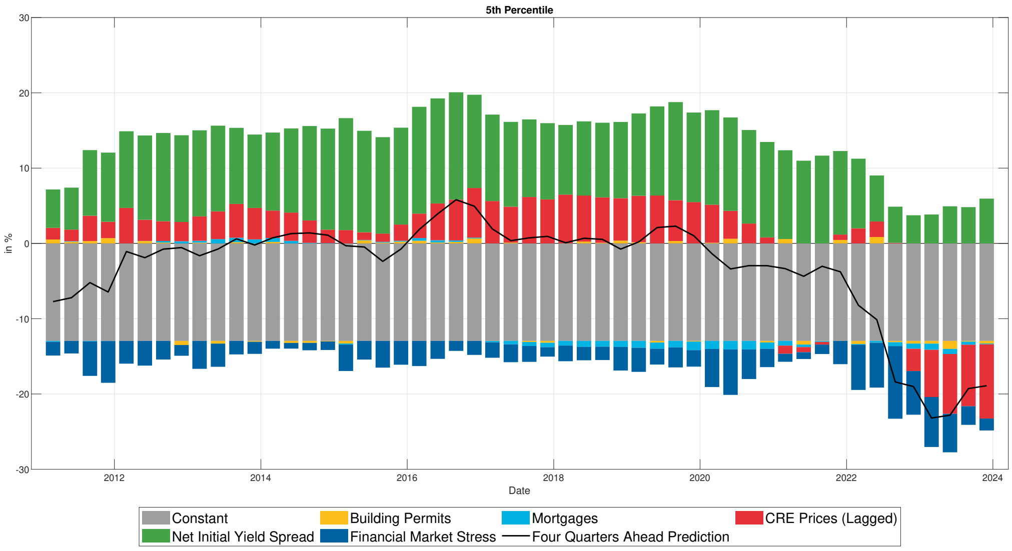

Figure 8: Robustness Analysis 1 - Decomposition of four quarter ahead prediction for commercial real estate price growth for the fifth percentile from 2011 Q1 to 2023 Q4.

Note: *The years on the horizontal line represent the date until which data is available. Hence, at the current end, the estimation represents the prediction of the fifth percentile for 2024 Q4 based on data available until 2023 Q3.*

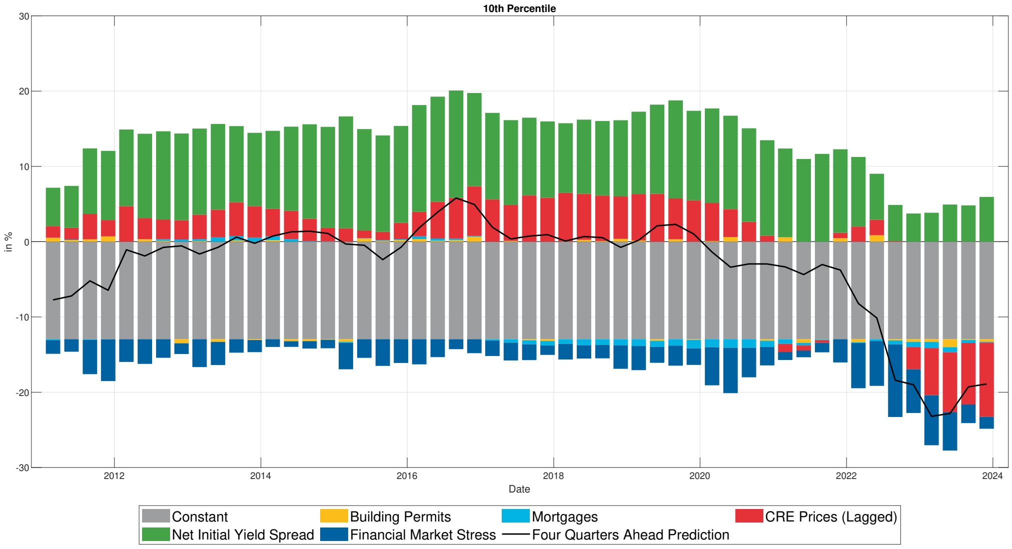

Figure 9: Robustness Analysis 1 - Decomposition of four quarter ahead prediction for commercial real estate price growth for the tenth percentile from 2011 Q1 to 2023 Q4.

Note: *The years on the horizontal line represent the date until which data is available. Hence, at the current end, the estimation represents the prediction of the fifth percentile for 2024 Q4 based on data available until 2023 Q3.*

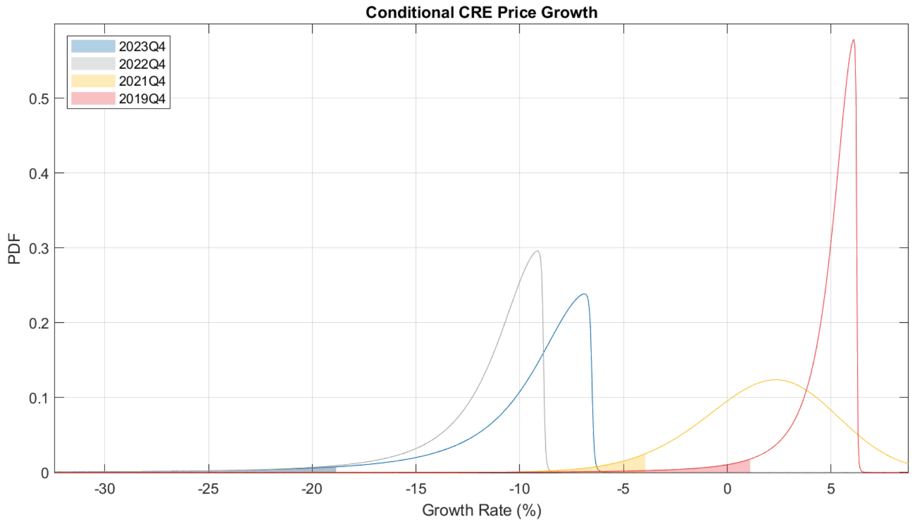

Figure 10: Robustness analysis 1 - Conditional four-quarters ahead distributions for different time periods

Note: The figure displays the conditional probability density function (PDF). The shaded area presents the 5th percentile of the distribution and the dates are the date up to which the data was available, i.e. Q4 2023 refers to the conditional distribution for Q4 2024 based on the data available up to 2023.

B.2 Robustness analysis 2: 10-year German government bonds

Table 3: Robustness analysis 2: Estimation results from the quantile regression on four-quarters ahead CRE price growth

Quantile	**5**	**10**	**25**	**50**	**75**	**95**	**OLS**
CONS	-17*	-7.6*	-3.5	0.063	3.2**	5.6***	-0.16
Building Permits	-0.1	-0.089	-0.03	0.12	0.039	0.11*	0.033
Mortgages	0.056	-0.86	-0.62*	-0.43*	-0.42*	-0.59*	-0.58
CRE Prices (lagged)	2.6***	2***	1.4***	0.95***	0.63***	0.52**	1***
10yr Gov. Bonds	2.7	-1.7	-1.3	0.36	0.62	-0.25	-0.41**
Financial Stress	0.048	1.6	1	-1.1	-1.4	-2.1	-0.32***

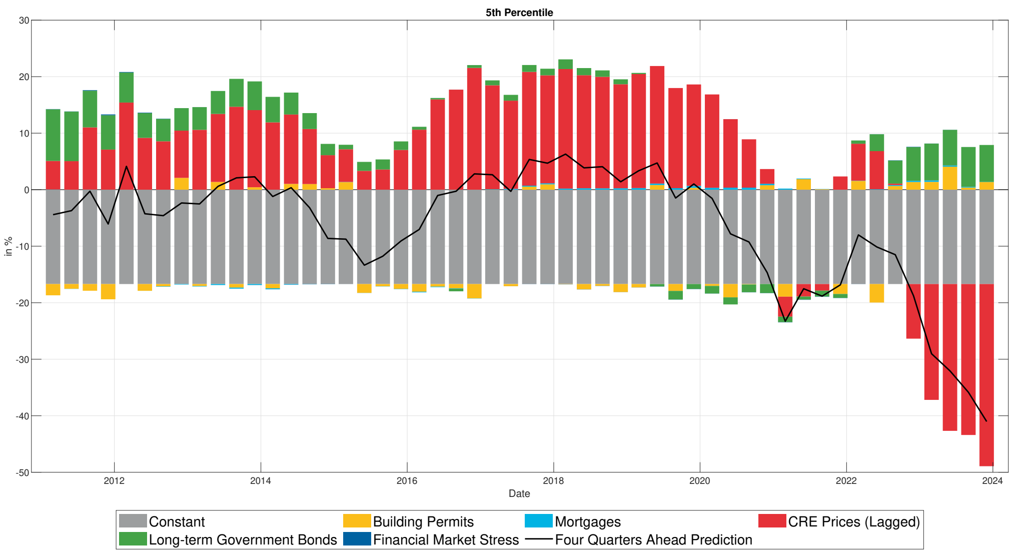

Figure 11: Robustness analysis 2 - Decomposition of four-quarters ahead prediction for commercial real estate price growth for the fifth percentile from Q1 2011 to Q4 2023

Note: *The years along the horizontal line represent the date up to which data is available, i.e. at the current end, the estimation represents the prediction of the 5th percentile for Q4 2024 based on data available until Q3 2023.*

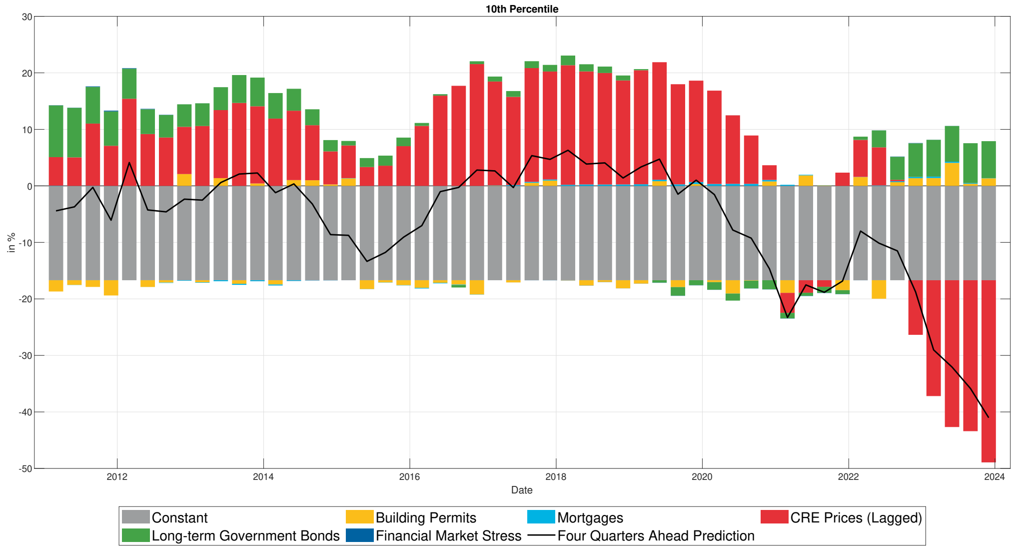

Figure 12: Robustness analysis 2 - Decomposition of four-quarters ahead prediction for commercial real estate price growth for the tenth percentile from Q1 2011 to Q4 2023

Note: *The years along the horizontal line represent the date up to which data is available, i.e. at the current end, the estimation represents the prediction of the 5th percentile for Q4 2024 based on data available until Q4 2023*

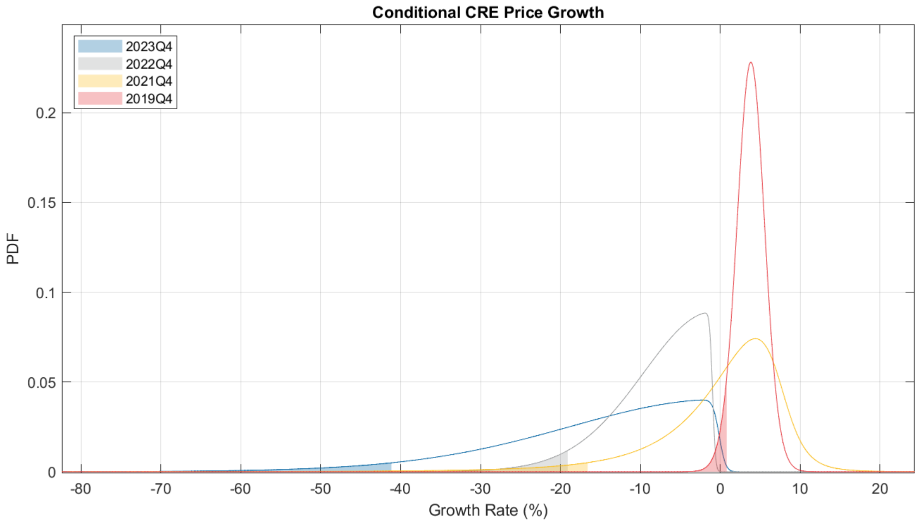

Figure 13: Robustness analysis 2 - Conditional four-quarters ahead distributions for different time periods

Note: The figure displays the conditional probability density function. The shaded area presents the 5th percentile of the distribution and the date represents the date up to which the data is available, i.e. Q4 2023 refers to the conditional distribution for Q4 2024 based on data until Q4 2023

B.3 Robustness analysis 3: Office real rstate only

Table 4: Robustness analysis 3: Estimation results from the quantile regression on four-quarters ahead CRE price growth.

Quantile	5	10	25	50	75	95	OLS
CONS	-25***	-24***	-19**	-9.4	4.7	9.9	-9.1*
Building Permits	0.063	0.043	0.01	0.078	0.083	0.071	0.052
Mortgages	-0.68**	-0.64**	-0.46*	-0.17	-0.19	-1	-0.33
CRE Prices (lagged)	0.3**	0.32**	0.71**	0.54***	0.53***	0.61**	0.69***
Net Initital Yield Spread	7.7**	7.4**	5.8**	3.6	0.077	-0.87	3.3***
Financial Stress	2.3**	2.4**	1.5**	0.15	-1.5	-2.4	0.068

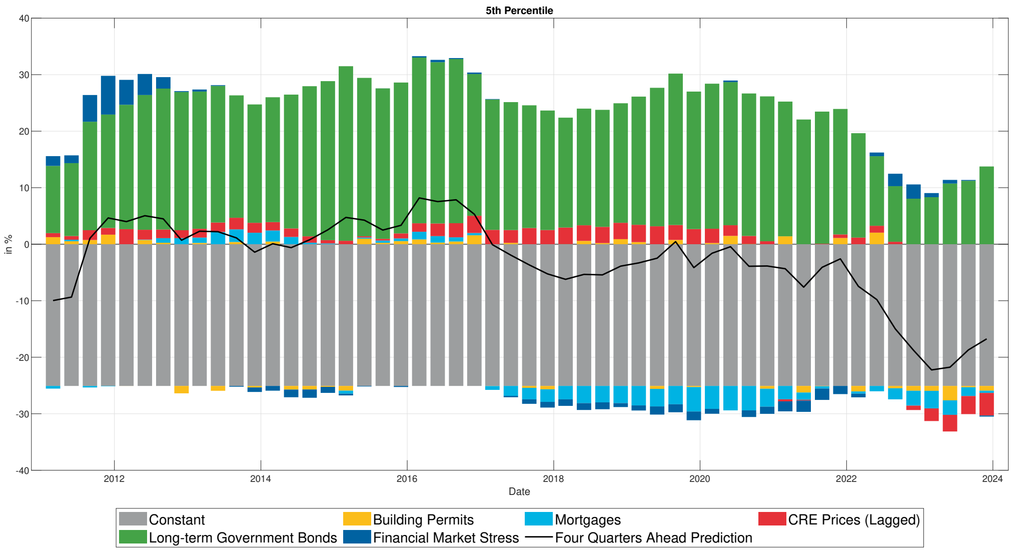

Figure 14: Robustness Analysis 3 - Decomposition of four-quarters ahead prediction for commercial real estate price growth for the fifth percentile from Q1 2011 to Q4 2023

Note: *The years along the horizontal line represent the date up to which data is available, i.e. at the current end, the estimation represents the prediction of the 5th percentile for Q4 2024 based on data available until Q4 2023.*

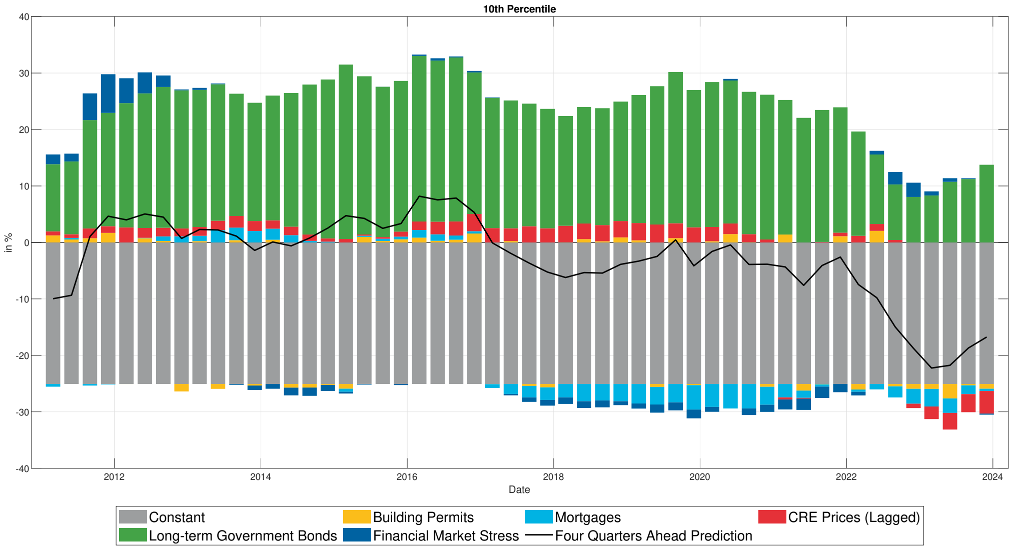

Figure 15: Robustness analysis 3 - Decomposition of four-quarters ahead prediction for commercial real estate price growth for the tenth percentile from Q1 2011 to Q4 2023

Note: *The years along the horizontal line represent the date until which data is available, i.e. at the current end, the estimation represents the prediction of the 5th percentile for Q4 2024 based on data available until Q4 2023*

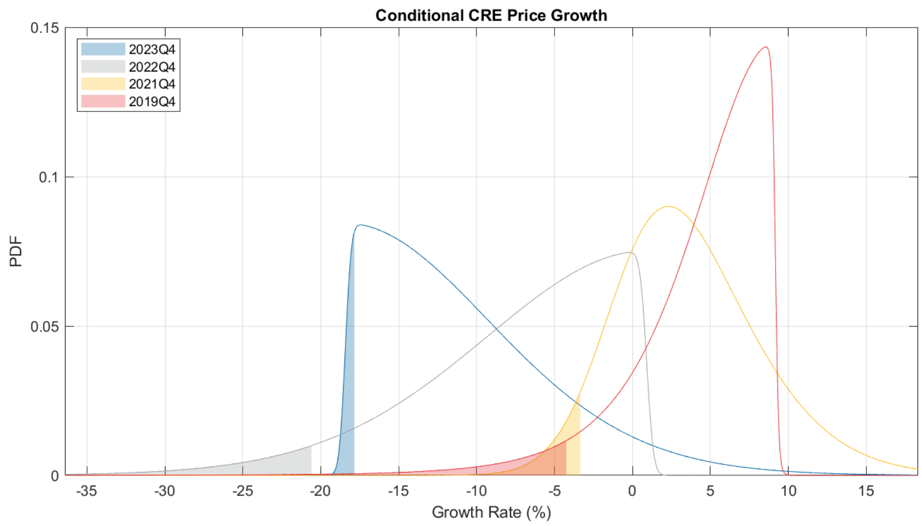

Figure 16: Robustness Analysis 3 - Conditional four-quarters ahead distributions for different time periods

Note: The figure displays the conditional probability density function (PDF). The shaded area presents the 5th percentile of the distribution and the date represents the date up to which the data was available, i.e. Q4 2023 refers to the conditional distribution for Q4 2024 based on data available up to Q4 2023.