"Exploring German Housing Price Determinants: A Dual Approach Through Market Analysis and Hedonic Pricing Models"

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Abstract

This work investigates the determinants of housing prices in the German real estate market by employing a dual methodology, combining market analyses and hedonic pricing models. The study aims to provide a comprehensive understanding of the factors influencing housing prices and sheds light on the role of the European Central Bank's (ECB) interest rate policies in shaping the dynamics of the German housing market. The first aspect of the research involves a detailed market analysis, examining macroeconomic trends, regional variations, and demand-supply dynamics within the German housing market. By employing cross-sectional data, the study identifies key market indicators and assesses their impact on housing prices. In the second part of the analysis, the study employs hedonic pricing models to delve deeper into the intrinsic determinants of housing prices. By considering a diverse set of housing attributes, such as location, size, and amenities, the hedonic pricing models aim to isolate the individual contributions of these factors to overall property values. A significant focus of the research is on the ECB's interest rate policies and their influence on the German housing market. The study explores how accommodative monetary policies, particularly during the recent years leading up to the COVID-19 pandemic, have played a pivotal role in facilitating house price growth. Special emphasis is given to the period of zero interest rates during the pandemic, analysing the unprecedented surge in housing prices during this time. The findings of this research contribute to the existing literature on housing market dynamics, providing valuable insights for policymakers, real estate professionals, and investors. Understanding the interplay between market forces, intrinsic property characteristics, and central bank policies is crucial for developing informed strategies to navigate the complexities of the German housing market.

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1. Introduction

The real estate market is a key economic sector in industrialized nations, exerting a multifaceted influence on economic dynamics. It reaches up to 10 percent of the GDP in Germany and even up to 14 percent in the United States. It holds vital importance in both microeconomics and macroeconomics. At the microeconomic level, it impacts individual wealth, housing choices, consumer behaviour, and resource allocation. At the macroeconomic level, real estate significantly contributes to GDP, employment, monetary policy, financial stability, inflation, government revenue, and overall economic well-being. Its dual significance spans from individual decision-making to national economic policy. In recent years, countries like Germany have seen unprecedented growth in real estate prices. This also comes due to the post-crisis narrative of the European Central Bank and its low-interest monetary policy. The advent of the COVID-19 pandemic saw sudden upheavals in previous monetary practices due to the unique situation of simultaneous demand and supply shocks in several economic sectors. Turning back to policy rates, which Europe has not seen since 2008, brings existential challenges for market participants in the real estate industry, but also for private borrowers. This study aims to shed light on the price determinants of real estate from both a macroeconomic and a microeconomic perspective.

The first part of this work contains a general literature analysis connected to the topic and is being discussed as an initial introduction. More precisely, the literature analyses investigate works dealing with the relationship between macroeconomic factors and the health of the real estate market, which is an important part of the quantitative analysis, and on the so-called hedonic price components of real estate prices, which will be important in the empirical part of this work.

Secondly, by a case study focusing on the German residential real estate market, this work intends to provide a deeper understanding of the intrinsic dynamics prevailing in Germany. The quantitative analysis is based on the previously mentioned scientific research on real estate. Developed countries, characterized by their advanced infrastructure, urbanization, and high living standards, provide a unique platform for studying the comprehensive impact of the real estate sector on economic variables. The real estate sector in developed countries goes beyond the mere exchange of real estate; it encompasses residential, commercial, and industrial sectors, each of which contributes significantly to economic growth, whereas this work focuses primarily on residential real estate. This sector serves as a conduit for investment, employment, and wealth creation, thus occupying a prominent position in the economic landscape. The factors on which economic agents base their expectations for housing price appreciation include supply- and demand-driving determinants that result in a complex intertwining of variables. The unique structure of economies makes an always-valid answer to real estate dynamics unrealistic. Therefore, a case-specific approach is required. Germany is a suitable example as one of the largest and most stable economies in Europe, with interesting and unique features. Also, the data situation provides insight into a wide range of significant variables with the assistance of a well-documented public statistical office, therefore providing an insight into a time horizon that extends far before the financial crisis of 2008.

Lastly, the third pillar of this work addresses the previously mentioned hedonic pricing models, which are well suited to the various types of residential real estate objects. Hedonic pricing models in residential real estate employ statistical analysis to assess the value of a property

based on its individual characteristics. These models break down factors such as the number of bedrooms, square footage, neighbourhood quality, and amenities, associating each with a quantifiable value. Through regression analysis, coefficients are determined to reflect the impact of each attribute on the property's overall worth. The resulting hedonic price function provides a mathematical equation for estimating a property's value. This model is valuable for property stakeholders, offering insights into how specific features influence market prices and aiding informed decision-making in real estate transactions. Therefore, the microeconomic approach focuses on the evaluation of house purchase prices, apartment purchase prices, and apartment rents using a sophisticated cross-sectional data set provided by RWI, the Leibniz Institute for Economic Research (2022). It is important to note that assessing real estate dynamics presents significant challenges, including data quality and availability issues, spatial and regional variations, seasonal fluctuations, market opacity, endogeneity, data measurement limitations, and the impact of external economic shocks and regulatory changes. These complexities necessitate careful consideration of data sources, methodologies, and local market conditions in real estate analysis.

This study's two-pronged approach, supplemented by literature analyses that provide a general background to the topic, aims to accomplish the following: Giving a practical example of real estate dynamics from a macroeconomic perspective helps to classify the theoretical background or even supplement it with new insights. This approach may be useful in drawing conclusions for future market development, both in the private and public sectors. Also, the hedonic price analysis of real estate provides microeconomic insight while also leaving room for debate on the technical implementation of hedonic regression models. This research distinguishes between the traditional OLS approach and the quantile regression method.

2. Literature Review

“Buy the land; they do not make it anymore,” as the famous novelist Mark Twain said more than a century ago, exemplifies the general shortage of housing. The real estate sector is distinguished by its unique characteristics compared to other market types and its importance as a driver of the economic value chain. It has distinctive characteristics, including immobility, heterogeneity, high transaction costs, limited liquidity, longevity, local market dynamics, leverage, tangible nature, income-generating potential, long-term investment horizon, vulnerability to psychological factors, tax advantages, and complex property rights. These characteristics contribute to the special nature of real estate as an asset class and require special consideration in investment and analysis. Therefore, real estate markets can play a dual role: as a consumption good and as an investment (Leung, 2004). The extent of the importance of the real estate sector becomes clear when one looks at the financing markets. Mortgages account approximately for 50% of the gross domestic product of the countries of the European Union (Fiotto et al. 2018). The risks that have developed, especially since the financial crisis of 2008, have repeatedly led economists to better understand the dynamics of the interplay between real estate and its financing markets.

Exemplary of the early research on the relationship between financial stability and real estate markets was the work “The Debt-Deflation Theory of Great Depressions” by Fischer (1933). At the time, he rejected the notion that economic variables remain in long-run equilibrium and therefore emphasized the importance that financial factors play in the modern business cycle.

The “Great Depression” in the U.S. in the 1930s served as his point of reference. Fisher formulated his theory of “debt deflation”, which states that distress sales can cause liquidity problems for banks, which subsequently leads to a contraction of the money supply. Deflationary tendencies increase real debt while exerting downward pressure on nominal prices. This leads to a downward economic spiral in which corporate net worth declines and bankruptcies and unemployment result. The government must respond to this chain of events by lowering the nominal interest rate while real interest rates rise.

Harris (1989), in his paper “The Effect of Real Rates of Interest on Housing Prices,” recognized that the effects of nominal interest rates on housing prices, while negative and strong, were nevertheless insufficient to put them into a simple linear relationship. An example of this was the inflationary years of the 1970s, with interest rates rising at the same time. He therefore concluded that the price determination of real estate depends on an interplay between the real interest rate, the nominal interest rate, the inflation rate, and expectations of price increases. The core principle of his model is based on market participants' expectations, as they depend on all the former variables. He argues that prices can rise even further when inflation is high and nominal interest rates are high because investors can make arbitrage profits. This is possible in such a scenario due to the negativity of real interest rates and the slow absorption of price expectations by nominal interest rates.

Similarly, Wong et al. (2003) examined the role of interest rates on housing prices from an expectations perspective under special economic circumstances, but, unlike Harris (1989), in a deflationary situation. Attention is focused on the years between 1998 and 2001 in the Hong Kong property market. Their results are consistent with those of Harris (1989) in terms of the significant influence of the expectation formation process on property prices, in which inflation and interest rates are the key variables. On the other hand, they point out that the relationship between interest rates and housing prices reverses or decreases under different economic circumstances, namely in inflationary or deflationary situations. They point out that interest rates and real estate prices do not “granger-cause” each other but complement the process of expectation formation based on the market conditions of each real estate environment.

This study also emphasizes the appraisal of real estate values. As a valuation approach, Gallin et al. (2004) compare the rent-price ratio in the housing market to the dividend-price ratio in the stock market. In contrast to the concept of a random price walk, they propose that prices fluctuate in a long-term equilibrium around the fair value of the rent-price ratio. They also include hedonic pricing components in their model to explain price disparities. Gallins et al. (2004) hedonic pricing analysis contributes to this research's microeconomic dimension by providing a granular understanding of how various property attributes influence house prices, thus complementing the comprehensive dual approach. Moreover, this offers valuable insights to address inconsistencies in the relationship between interest rates and house prices.

“Rosen's hedonic price model”, proposed in the pioneering study “Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition” by economist Sherwin Rosen (1974), is one of the most important examples in the hedonic pricing literature. This model is regarded as a seminal contribution in the area, with implications that extend beyond real estate economics to larger applications of hedonic analysis. Rosen's novel technique used hedonic pricing to study the complex link between owner-occupied home prices and the different features connected with these properties. Rosen assessed the implicit values of qualities such

as location, property size, number of bedrooms, and other important factors using regression analysis, showing how these attributes contribute to the total market worth of residential properties.

Belke and Keil's (2018) findings in "Fundamental Determinants of Real Estate Prices: A Panel Study of German Regions" establish a thematic link between the effects of macroeconomic factors on real estate pricing and hedonic pricing on the microeconomic side. Supply factors such as the volume of real estate transactions, existing housing stock, and construction activity all have an impact on prices. On the demand side, regional factors such as the number of households, population age distribution, and infrastructure have a significant impact on real estate prices. While showing a positive correlation with prices as predicted by theory, disposable income varies in importance across geographies and time periods. This demonstrates how income affects home demand and pricing.

The availability of credit has also received much attention in the literature in terms of how it affects pricing in housing markets. In their paper, Zhu & Tsatsaronis (2004) examine the impact of inflation and policy rates on different groups of countries classified according to their macroprudential regulations of the mortgage market. They find that mortgage market heterogeneity accounts for substantial variation in price sensitivity to key macroeconomic data. Moreover, rising price trends in recent years can be attributed to brand-based financing channels and technological improvements in the financial communication process. They argue that financing decisions depend crucially on the availability, cost, and flexibility of financing, which are idiosyncratic to each country-specific market. Markets with less stringent lending rules and variable mortgage rates are subject to higher price volatility as interest rate regimes change. Surprisingly, they found that inflation even impacts housing price appreciation stronger than lending standards, while the endogenous relationship between those covariates cannot be ruled out.

McQuinn et al. (2008) draw a conclusion that is in line with Wong et al. (2003)'s findings: interest rate channels can explain certain price changes. They do point out that the economic modelling framework does not yet adequately incorporate these channels. They discover that rising disposable income and low loan rates create an atmosphere that is conducive to economic growth, which in turn drives up property prices.

McDonald & Stokes (2011) reach a different result from the earlier findings of McQuinn et al. (2008) and Wong et al. (2003), who rule out a causal association between interest rates and house prices. They claim that the US house price increase was driven by the Federal Reserve's "artificially low interest rate" policies between 2001 and 2004. Moreover, they contend that there is a strong causal relationship between credit and housing markets because rising house prices and loosened credit requirements both contributed to housing bubbles. McDonald and Stokes (2011) offer data in support of this view, according to which the subsequent decrease in house prices was caused by the substantial increase in the federal funds rate between 2004 and 2006.

Analysing the effects of macroeconomic variables on home prices, Adam & Fuess (2011) discover that credit supply, transaction costs, and innovations in mortgage products all play significant roles, as they have in earlier research. An alternative to owning a home might be an increase in interest rates, as owning bonds becomes more appealing and financing becomes more costly. They attest to the fact that a high degree of financing activity makes one more

susceptible to macroeconomic shocks since it is characterized by lax credit rules and cheap transaction costs. They also note that in these circumstances, a credit-driven boom can be followed by a drop in housing market prices. Their new contribution to this issue is that the adjustment of house prices to long-run equilibrium is more likely to occur through inflation rather than through price declines under normal economic activity.

One notable aspect of the post-2008 financial crisis literature on the relationship between interest rates and housing prices is the growing emphasis on the role of credit in financial stability (Adam & Fuess 2011; McDonald & Stokes 2011; Jorda et al. 2014; Gambetti et al. 2014; Favara 2015; Fiotto et al. 2018).

Due to their impact on GDP growth and credit, Gambetti & Musso (2014) contend that shocks to the credit supply were a major contributing factor to the financial crisis. They discovered that, although the economies they examined—the US, the UK, and the euro area—had varying response functions to shocks to the credit supply, each one was noteworthy. Similar to earlier research, they demonstrate how financial market conditions can make people vulnerable to shocks (Adam & Fuess 2011; Zhu & Tsatsaronis 2004).

Favara & Imbs developed a novel theory regarding the connection between interest rates and home prices (2015). They discover that credit supply is dependent on asset prices, in contrast to some prior research that suggests the causal relationship between interest rates and housing prices is mutual (McDonald & Stokes 2001), negligible (Wong et al. 2003; Gallin et al. 2004), or influences house prices through the interest rate channel (Zhu & Tsartsonis 2004). They contend that credit responds naturally to the state of the economy and current events, which supports the mortgage market during periods of economic expansion. Additionally, banks can use the rising value of assets as collateral to support their lending operations. Banks before the financial crisis expanded their credit rates with financial organizations. This was possible due to the deregulation implemented in the US markets, explaining more than half of the increase in mortgage loans. They suggest that mortgage expansion and cost saving measures enable lenders to pass through better financing conditions, further increasing housing prices. They also found that in more elastic real estate markets the housing supply increased, while in inelastic markets rather the housing prices increased.

A comprehensive analysis of the European real estate markets is provided by Fiotto et al. (2018). Their contribution is a synopsis of previous research, connecting various real estate dynamics while gathering current knowledge rather than inventing novel ideas. They re-present one of the more recent instances of real estate literature assessing how changes in inflation and GDP growth affect residential loans in a cross-country sample within the European Union. Fiotto et al. (2018) confirm previous studies that show abrupt changes in housing prices can have a detrimental impact on the stability of the financial system. The fact that the mortgage market accounts for half of the average GDP of European nations makes this abundantly evident. They contend that because housing markets serve as both a vehicle for investments and as a means of subsistence, macroeconomic developments have a significant ripple effect on them. The interaction of various expectations appears to have an impact on housing prices, with present and future income playing a significant role in determining whether a home is affordable for individual purchasers. The GDP has a comparable function. Additionally, they discover that since the financial crisis, lending institutions' capital requirements have significantly increased, which has decreased the supply of mortgages and resulted in a more

cautious growth path. The cost of lending is a major factor in the relationship between the supply and demand for mortgages, but lending standards can also have an impact because different lenders have different requirements for loan applications.

A review of the gaps in the traditional macro perspective real estate literature is provided by Lang et al. (2020). They point out that there is a dearth of data for a cross-country analysis of lending criteria, which is essential to understanding patterns of loan growth, thereby contradicting to the findings of Fiotto et al. (2018). Their study contributes to the body of literature by offering comprehensive evaluations of loan standards. They found that, for the first time since the start of the financial crisis, lending regulations in the European Union were relaxed once more between 2016 and 2018. Moreover, the findings support the widely held belief in the literature that countries with laxer lending laws experienced a larger real estate boom than those with more stringent lending regulations. Particularly in countries that did not enact borrower-based macroprudential controls, lending standards deteriorated.

A fundamentally new approach to hedonic pricing, which incorporates machine learning has been provided by Potrawa & Tetereva (2022). This strategy represents a turning point in hedonic price research and has the potential to transform the real estate industry by introducing new techniques utilizing artificial intelligence. It demonstrates how the current approaches can be successfully enhanced with the use of state-of-the-art machine learning techniques. It explains how to incorporate various covariates into a hedonic pricing model by extracting them from satellite maps, text descriptions, and property photos. Unlike previous studies, which mainly focused on incorporating single feature types (e.g., Google Street images) into basic analyses, this work employs a more comprehensive framework combining information from multiple sources. This method aims to mimic the information-gathering process that potential buyers go through before making a purchase decision with features like a view of the city or greenery surrounding the house.

3. Attributes of the Residential Real Estate Market in Germany

3.1 Introduction

As one of the largest and most stable economies in Europe, Germany has shown a profound contrast to the real estate markets of several Eurozone countries. This analysis looks at the multi-layered intricacies of the German residential real estate market and examines the factors that have contributed to its continued stability. It also examines the evolving landscape of the market, including recent trends in real estate prices, rental markets, regulatory framework, migration and the impact of demographic change and potential imbalances that could arise.

Some economic indicators are foreseeing a turnaround to the positive real estate environment in Germany, as the days of economic boom and low interest rates have come to an end in the wake of the Covid 19 pandemic. It arises the question which risks and opportunities those new embedded market conditions will have on the German real estate market and which policies might help to adapt.

3.2 Overview

After World War II, Germany faced extensive destruction, which led to significant reconstruction efforts. During this period, cities and infrastructure were rebuilt, with a focus on affordable housing. Rent control measures were introduced to prevent excessive price increases (Droste, 2014).

West Germany lacked a single predominant city akin to Paris in France due to the division of the country into East and West. This geopolitical situation resulted in a polycentric urban structure, with a cluster of major cities known as the "Big Seven" emerging as focal points of commercial interest. These cities included Berlin, Düsseldorf, Frankfurt, Hamburg, Munich, Cologne, and Stuttgart. Each city had its own unique economic strengths and significance, contributing to the nation's recovery and development (Rohmert, 2013).

The "Wirtschaftswunder," or economic miracle, facilitated growth and prosperity, but the homeownership rate did not rise considerably (Kofner, 2013). The reunification of East and West Germany brought about new challenges because the property markets in Eastern Germany struggled to adapt to the capitalist system. This led to issues like dilapidated buildings and disparities in property values in the eastern provinces (Diefendorf, 1993).

In contrast to many other European countries, Germany's nominal prices for real estate stayed relatively flat in the early 2000s. The global financial crisis of 2008 had a limited impact on Germany's real estate market due to its stability, prudence, and resilient economy, while many other European countries experienced a strong downturn in prices due to the bursting of real estate bubbles. After the crisis of 2008, the real estate market started getting momentum again. Factors contributing to this included low interest rates, increased foreign investment, and urbanization. Property prices continued to rise, particularly in major cities, and the market started to attract more international investors (Barasinska et al., 2021).

Germany continues to have a strong culture of renting, with almost the same share of the population renting as owning homes. Rent control laws remained in place, and affordable rental housing remained a priority. Some major cities experienced a debate on housing affordability and the impact of rising property prices on residents (Dahl & Góralczyk, 2017).

3.3 Demographic Trends

The demographic situation and its prospects are integral parts of shaping the housing market. Variables like population growth, housing stock, migration, and household characteristics are affecting rents and house prices from the demand side (Belke & Keil, 2018).

At the end of 2011, the population of Germany numbered around 80.3 million. That number has risen to 84.4 million people by the end of 2022, an increase of five percent (Destatis 2023). The increase in Germany's population is primarily due to a combination of factors like intra- and extra-European migration, the attraction of skilled workers, and demographics (BiB, 2021).

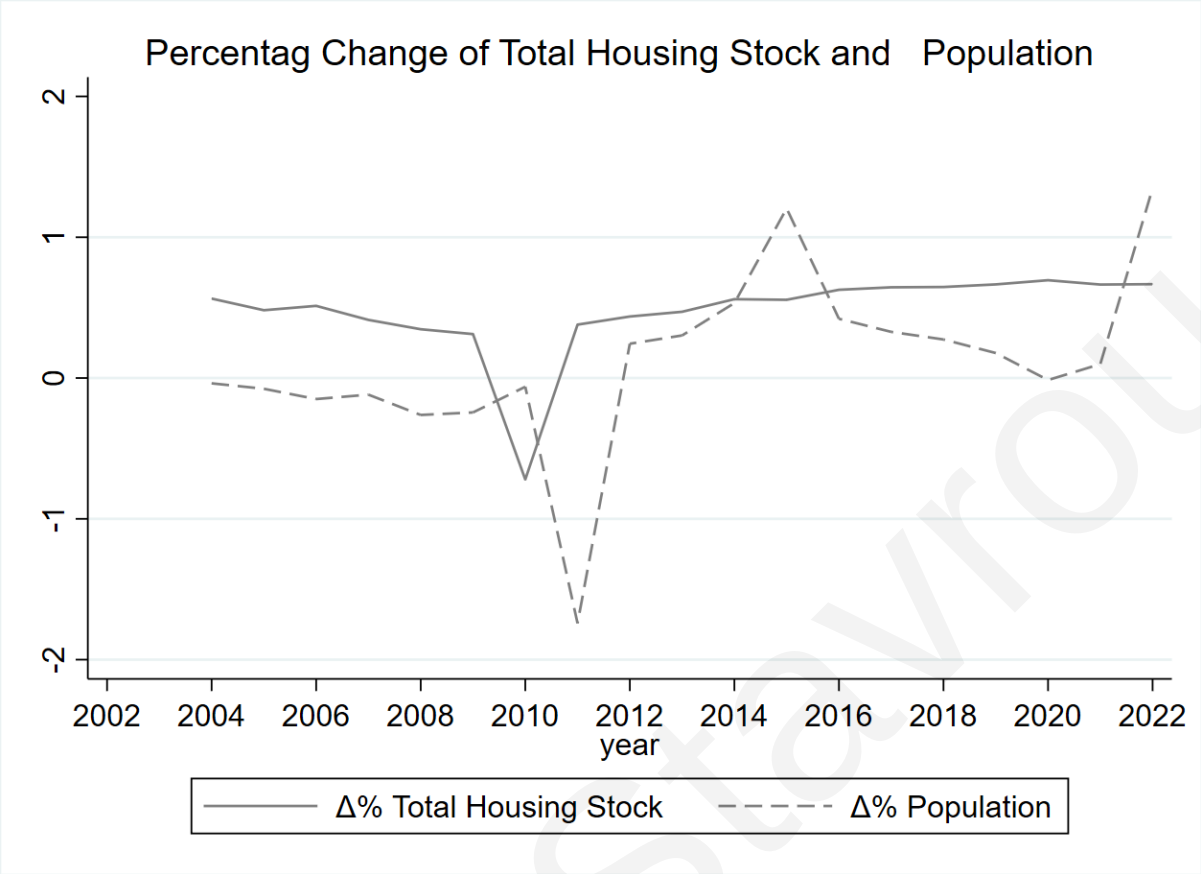

Fig. 1 *Percentage Change of Housing Stock and Population in Germany. (Source: Destatis 2023)*

To illustrate potential imbalances that may result from a discrepancy between supply and demand, Figure 1 shows the percentage change in the population and housing stock, respectively. It is noteworthy that at first, the rate of increase in the housing stock, which represents supply, remained larger than the rate of increase in the population, which represents demand. Because of the population growth peaks in 2015 and 2021, this link was abolished by 2014. Consequently, it can be concluded that demand significantly outpaced supply, particularly in the second half of the graph.

Thus, migration aids in the comprehension of population growth peaks. However, it needs to be seen differently because different kinds of migration have distinct potential effects on the housing market (Kurschner et al., 2016; Dahl & Góralczyk, 2017).

According to Kurschner et al. (2016), who investigated the effects of migration inside Germany following reunification in 1990, migration significantly affects rent appreciation, which is in line with the general theory. It is crucial to remember that this is not a case of refugees but rather of intra-European migrant patterns. The migrations, which mostly originated in Germany's former east, caused rents in the east to decrease while they increased in the west.

The European Union's enlargement in 2004 and 2007 is a more recent example of intra-European migration. It allowed citizens of Eastern European countries to freely relocate inside the EU, especially to Germany. This led in an influx of migrants from countries such as Poland, Romania, and Bulgaria, totalling 4.4 million individuals between 2006 and 2014. By the end of this era, Germany had risen to second place among OECD migrant destinations. It is crucial

to note that due to standardization efforts in education and labour standards within the EU-framework, these migrants can be incorporated more quickly into the labour market than migrants from outside of Europe (Bertoli et al. 2016).

Kürschner Rauck & Kvasnicka (2018) reached an entirely opposite outcome in another investigation. They discovered that refugee immigration has a detrimental effect on rent growth by analysing the effects of the 2015 refugee crisis. This contradicts earlier studies. This discrepancy most likely has multiple causes. The perception that refugees have among native people differs from that of other immigrants, which is one major contributing reason. Whether accurate or not, this perception implies that the local populace generally sees the presence of migrants, particularly when concentrated in certain locations, as a drawback that drives down rental prices. Also, the fact that refugees are initially housed in camps rather than in apartments suggests a gradual process of integration of these people into the housing market. The mid-term effects are yet to be observed after those newly arrived population groups start to settle in appropriate accommodation (Dahl & Góralczyk, 2017).

Additionally, Germany has implemented a wide range of policies to alleviate the scarcity of trained labour. These policies include the Job Seeker Visa for job hunters and the Blue Card system, which permits qualified people from non-EU nations to work and reside in Germany. Other crucial elements are the acknowledgment of foreign qualifications and the promotion of integration via language instruction. Family reunification is also encouraged (Kuehn 2021).

The population growth continues despite Germany experiencing a prolonged period of low birth rates and higher death rates. Overall, the total fertility rate increased by 0.15 children per woman between 2011 and 2019 to 1.49 but is still insufficient to mitigate the aging of the population (BiB, 2021).

Furthermore, as the population in Germany ages, older individuals may require specific housing demands, such as smaller or more accessible apartments. For instance, the median age increased from 35.6 to 45.9 years between 1975 and 2020. The aging population is anticipated to have a greater influence on the real estate market going forward due to increased life expectancy (BiB, 2021).

The German property market is currently in a unique state. The building industry is currently unable to meet the growing demand for houses brought on by population growth. Conversely, the aging population highlights the need for specialized housing. The primary cause of population expansion is migration, which puts strain on the rental market, particularly in urban areas. The next chapter goes into more detail on this, focusing on migrant flows and regional disparities.

3.4 Regional Analysis

In Germany, there are clear geographical differences in the RRE (Residential Real Estate) market. They result from a multitude of push and pull variables, including living standards, government regulations, economic dynamics, and climate. The prognosis and growth of real estate in particular geographic areas may be impacted by some of those varying regional variables.

Urbanization is a far-advanced phenomenon, with approximately 77% of the population living in urban areas. Economic opportunities, education, improved infrastructure, network effects, an aging rural population, and fewer language and cultural barriers for immigrants are some of the factors that contribute to urbanization. Urbanization has consequently increased demand for housing, particularly in large cities. Concerns about affordability in agglomerations and a marked mismatch between the supply and demand for housing have grown (Dahl & Góralczyk, 2017). However, between 2011 and 2023, the population density of Germany's ten largest cities increased by 7% (Destatis 2011; Destatis 2023).

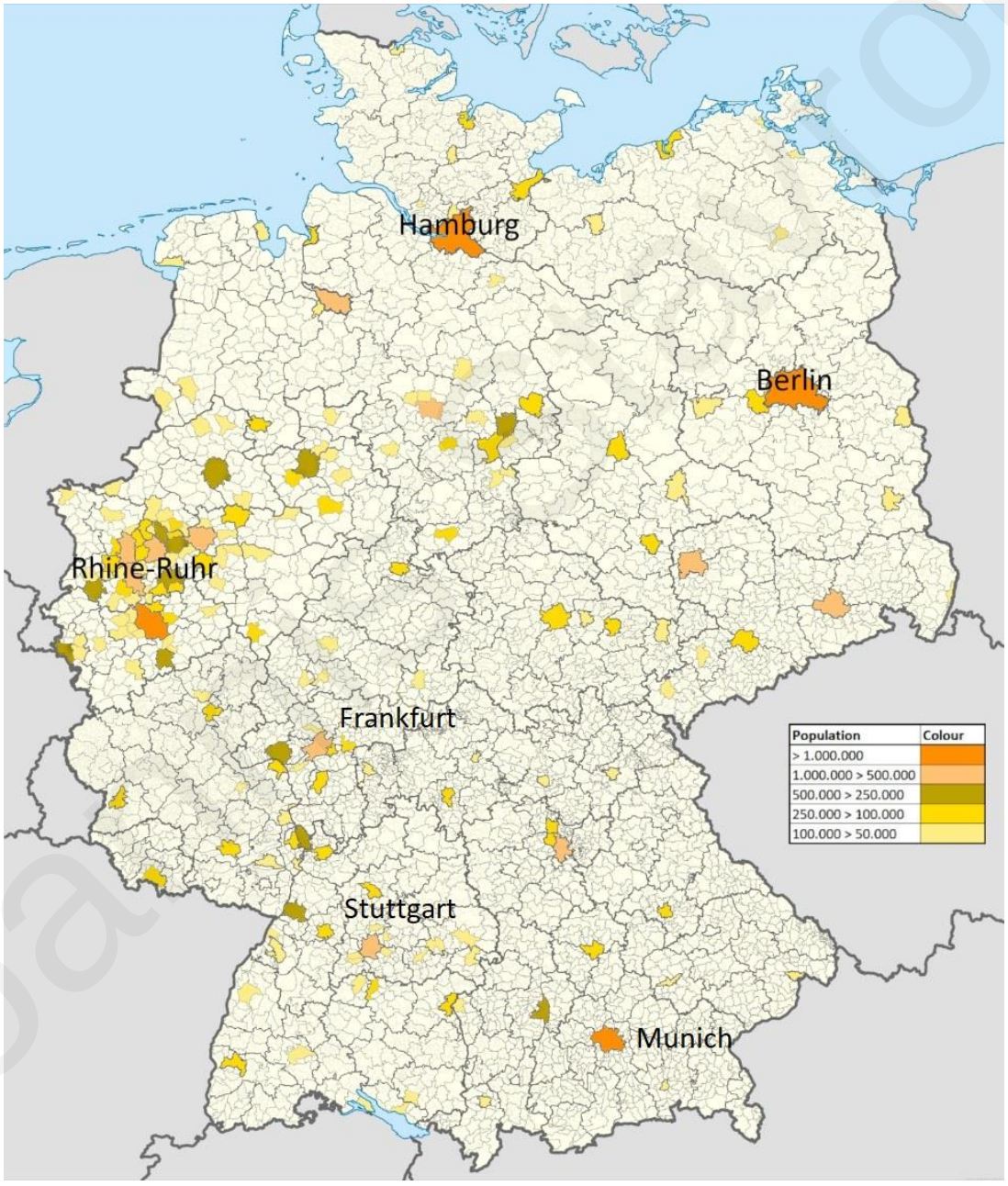

Fig. 2 *Agglomerations in Germany after municipal regions. "Gemeinde" or "Gemeindegebiete," are the smallest administrative units in the country. They are typically composed of cities, towns, and municipalities. The highlighted areas include Municipalities of at least 50.000 inhabitants. Map: Federal Office for Geography and Geodesy (2013) and Data: Federal Statistical Office (2023).*

Figure 2 depicts the agglomerations in Germany. Special attention goes to the so-called “big seven”, a cluster of major cities and agglomerations with pulling factors like commercial vitality. These include Berlin, Hamburg, Munich, Cologne, Frankfurt, and Stuttgart (Wijburg, 2017). Together, all the highlighted municipalities form a sizable demographic cohort with a total population of 35 million. This demographic concentration underscores the pronounced impact of these large urban centres on the national landscape. A considerable portion of 42 percent of the country's population resides in an area that represents only 6 percent of the total land mass, which underscores the intensification of human settlement in these urban centres.

Regional differences are also reflected in real estate investment trends. Certain regions are attracting more investment due to factors such as dynamic economic growth, demographic shifts, and the presence of favourable government policies. Consequently, this affects construction activity in areas that are more attractive for real estate investment, which can often be seen in the issuance of building permits. More building permits tend to be issued in regions with population growth and economic development, underscoring the close link between those factors and real estate market development (Belke & Keil 2018).

Fig. 3 *Investment in RRE per Capita in Federal States. They are referred to as "Bundeslaender" and independent administrative units in the country. Map: Federal Office for Geography and Geodesy (2013) and Data: Federal Statistical Office (2023).*

Figure 3 depicts the quartiles for the per capita investment in RRE for each federal state. The quartile with the largest investments is represented by Bavaria and Brandenburg. Hamburg, Baden-Wurttemberg, Schleswig-Holstein, and Rhineland-Palatinate follow. The three former east territories of Sachsen, Sachsen-Anhalt, and Thuringia, North-Rhine Westphalia, Saarland, and Bremen get the least investment per capita. Several places in the nation are now regarded as real estate hotspots. The capital city of Berlin, as well as its agglomeration, remain hotspots for large real estate investment, particularly Brandenburg, which has the second greatest RRE investment per capita. Despite rising prices, the city's flourishing economy, expanding population, and dynamic cultural scene make it an appealing residential and commercial real estate destination. Munich is another city noted for its high quality of living and solid economy. The city's residential rentals and buy prices have increased significantly, making it an appealing investment site. Both cities' populations are predicted to expand by 15% until 2035 (Dahl & Góralczyk, 2017).

The demand for housing in certain regions has created a pronounced gap in housing prices between urban centres and rural areas. But also, disparities between east and west. Urban locals tend to pay significantly higher housing prices. Rents in urban centres with a population density of at least 1.000 persons per square kilometre are on average 24.5 percent higher than in rural areas with less than 300 residents per square kilometre (Immoscout, 2022).

These regional disparities engender a diverse array of implications. Elevated housing prices in urban centres can lead to housing affordability challenges, whereas lower prices in rural areas may signal underlying economic fragility. Differences in investment and the demand for distinct types of real estate serve as indicators of varying levels of regional economic development and divergent growth prospects. Understanding these regional disparities holds importance for policymakers, urban planners, real estate stakeholders, and investors. This comprehension can inform strategic and policy decisions aimed at alleviating affordability issues, fostering equilibrium in regional development, and capitalizing on investment opportunities.

3.5 Regulatory Framework

Regulating real estate markets is crucial to prevent housing bubbles, ensure tenant protection and affordability, protect against financial instability, and ensure property rights. Supervision helps to maintain a balanced and stable housing sector, safeguarding the well-being of both homeowners and the broader economy. Also, ideas of sustainable land use and environmental protection are important factors to consider (Pfnuer & Wagner 2020).

Ownership and use of land in Germany are governed by a multi-layered set of rules that combine federal and state laws. The German Civil Code, Bürgerliches Gesetzbuch (BGB), serves as the fundamental legal document that governs property rights, transactions, and contractual obligations. A transparent land register, in which ownership and encumbrances are publicly recorded, increases legal certainty. In the area of land use, the German Building Code, Baugesetzbuch (BauGB), establishes zoning regulations and urban planning procedures, granting municipalities extensive autonomy. The Capital Investment Code serves as a regulation governing real estate funds. In addition, the Energy Saving Ordinance and the Housing Construction Premium Act deal with energy efficiency standards and housing subsidies, respectively.

Germany offers robust tenant protection laws to ensure a fair and secure environment for renters, with some regional differences. These regulations encompass various aspects of the landlord-tenant relationship, including rental agreements, rent deposits, maintenance responsibilities, termination rules, eviction protection, and rent increase regulations. Rental agreements typically feature lengthy notice periods, and landlords must follow strict procedures for eviction (Davies et al. 2017).

The legislation also provides loopholes for landlords to obtain a better position in tenancy relations and to incentivise the renewal of RRE. Under the modernisation legislation landlords are entitled to pass the cost of renovation to the tenant and increase the annual rent by 11 percent of the gross cost. Furthermore, once the renovation has been paid off, the adjusted rent can stay in place. The modernization law has therefore provided market participants with the opportunity to bypass rent controls and increase their worth (Davies et al. 2017).

Rent control and tenant protection mechanisms are integral parts of the regulatory framework in Germany. The rent brake is designed to curb excessive rent increases, especially in regions with housing shortages, by limiting permissible rent increases to a predetermined percentage above the local comparative rent index. The rental break introduced in Germany in 2015 applies only to certain real estate markets, mainly major cities. It limits rents for new leases to 10% above existing rent levels. A total of 313 municipalities are currently affected, corresponding to around 28% of Germany's population (Dahl & Góralczyk, 2017). Evidence from Deschermeier et al. (2016) found that apart from the positive effects of protecting tenants from overpriced rents, it can also contribute negatively to the supply of construction and the quality of RRE. With the prospect of lower earnings in the future, landlords and construction companies are disincentivised to invest. On a macroeconomic scale banking supervision and macroprudential rules play an important role for financial stability. Due to the immense volume of mortgages given out associated with RRE a stable market is of systemic importance. In Germany roughly a third of all outgiven loans to residential enterprises and private individuals account for housing (Dahl & Góralczyk, 2017).

One of the instruments ensuring financial stability are strict mortgage lending standards, including loan-to-value (LTV) and debt-to-income (DTI) ratios banks must consider before giving out loans. These measures ensure that borrowers have the financial capacity to repay their loans and reduce the risk of excessive lending that can inflate housing bubbles (Barasinska et al. 2019). In Germany, the loan-to-value (LTV) ratio typically ranges from 60% to 80% and is therefore among the lower values in the European comparison (Johnston et al. 2020). This is especially significant because Cerutti et al. (2017) highlighted relaxing lending requirements in relation to an increase in the LTV ratio as one of the primary causes of housing bubbles.

German banks are required to maintain capital buffers to withstand potential losses from real estate exposure. These capital requirements are designed to bolster the resilience of financial institutions during economic downturns or real estate market corrections. Regular stress tests are conducted on banks to assess their ability to weather adverse scenarios, including significant real estate market downturns. These tests help identify vulnerabilities within the financial system and guide necessary corrective actions. Barasinska et al. (2023) found that capital buffers might even have a stronger effect on default than LTVs, suggesting that mortgage default decisions appear to be driven more by liquidity than by strategic decisions.

The macroprudential framework proved its worth at the eve of the financial crisis. Some countries, such as Spain and Ireland, experienced a significant housing boom that was followed by a devastating downturn after the 2008 global financial crisis. Germany only experienced minimal movements in housing prices. This divergence underscores the crucial role of macroprudential policy as a complementary tool to monetary policy. While monetary policy is primarily aimed at macroeconomic stability, macroprudential policy plays an important role in safeguarding financial stability by addressing risks emanating from the financial system, in particular asset price bubbles. The case of the housing bubbles in Spain and Ireland illustrates the need for effective macroprudential policies to curb excessive lending and speculation to mitigate the negative consequences of housing market collapses and their broader economic effects (European Systemic Risk Board 2019).

3.6 Taxation

In Germany, taxation encompasses several property-related levies that play a crucial role in the country's fiscal system. There are mainly two types of property taxes: the property tax (Grundsteuer) and the land transfer tax (Grunderwerbststeuer). The property tax is a recurring tax levied on the ownership of land and real estate. It is calculated based on the value of the property and local tax rates. The real estate transfer tax, on the other hand, is a one-time tax levied when real estate changes hands. It grants the fiscus revenue and discourages investors from speculating (Fritzsche & Vandrei, 2019).

Real estate taxation varies considerably across Europe. For instance, Belgium distinguishes itself by imposing one of the highest tax rates in Europe, at 10 percent. Conversely, countries such as the United Kingdom and Portugal adopt progressive rate structures. Notably, almost half of the member states in the European Union maintain transfer tax rates below 5 percent, while Germany occupies an intermediate position with a median rate of 5 percent. This divergence in tax rates translates into a substantial disparity in the proportion of real estate transfer taxes relative to the overall transaction costs. By looking at Germany, it becomes evident that the real estate transfer tax constituted nearly 52% of the average transaction cost in 2011, underscoring its considerable influence on property transactions within the nation (Fritzsche & Vandrei, 2019).

Given the unobtrusive nature of property taxation for transfer and ownership in the European comparison, different explanations for the low home-ownership rate must be concluded. This is particularly of interest for Germany because it distinguishes itself by its above-average GDP per capita and average house price-to-income ratios (Braun, 2021). Since homeownership is being perceived as wealth, income and affordability proxies should therefore indicate a different outcome (Voigtlaender, 2009). Braun (2021) argues that there are mainly two factors leading to the lowest home ownership rate in Europe. Firstly, the absence of mortgage interest deductions (MID) makes it less affordable to buy property. Secondly, the absence of imputed rent taxation makes it more favourable to own property. Both policies collide with each other on the matter of homeownership. She concludes that mortgage deductibility would increase homeownership but lead to welfare losses in the long run because of overaccumulation of net worth to faster overcome the constraints towards homeownership. Taxing imputed rents would, on the other hand, enhance social welfare because it helps to distribute wealth since it considers the hypothetical price a homeowner would pay to live on his own property.

Another tax peculiarity in Germany is that privately held residential buildings are exempt from the capital gains tax if the object has been held for at least ten years. This gives private landlords an advantage over commercial landlords (Davies, 2017).

The literature also finds that under-taxation of homeowners results in significant tax losses, lowers the user cost of housing relative to a neutral tax system, and consequently leads to overconsumption of housing services (Braun, 2021). However, overtaxation can also lead to the inefficient allocation of residents to suitable housing. Retired households, who often live in housing that exceeds their current space needs once their children have moved out, may face disincentives to downsize to more suitable living arrangements because of high transaction costs (Fritzsche & Vandrei, 2019).

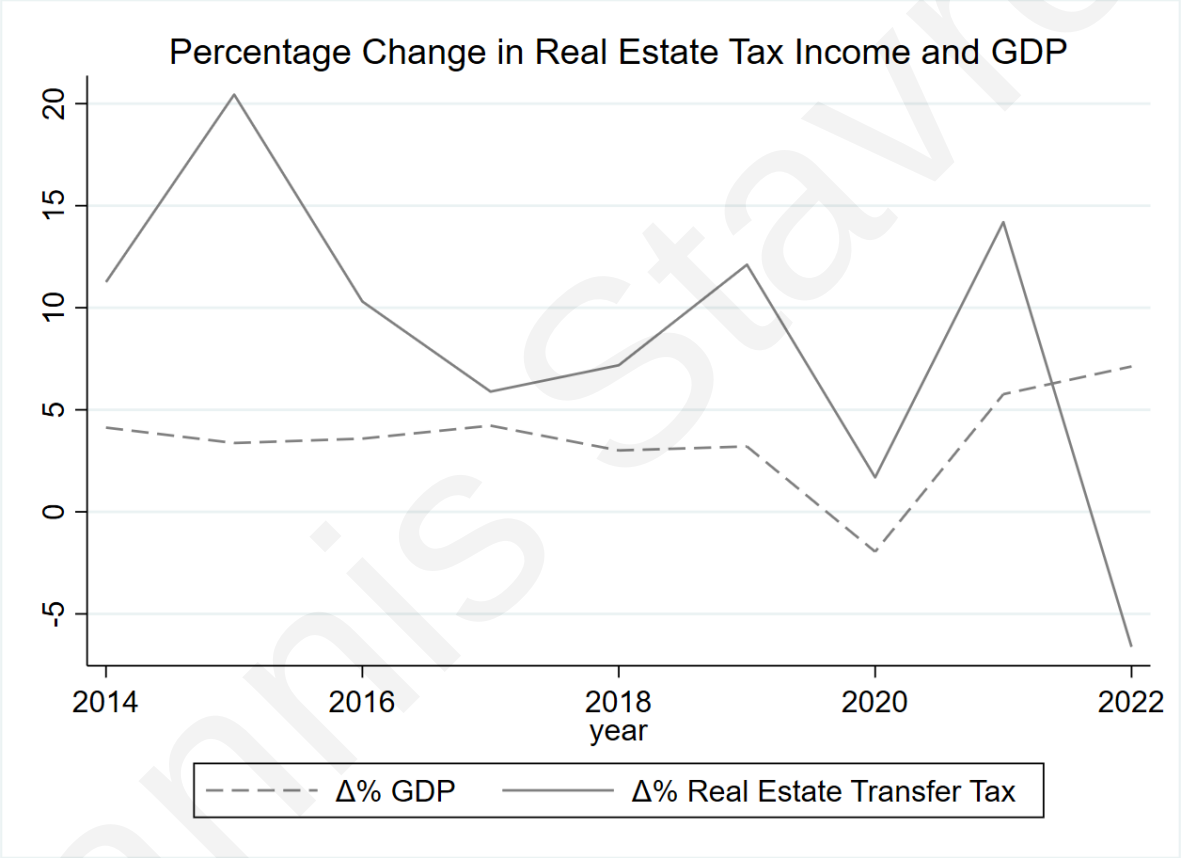

Fig. 4 *Percentage change of nominal GDP and Real Estate Transfer Tax in Germany (Source: Destatis 2023)*

The growth in tax revenue over the last few years was substantially higher than the growth of the GDP (Figure 4). With the increase in the key interest rate, a trend reversal was foreseeable. Indeed, in 2021, tax revenue dropped by more than 20 percent.

3.7 Financing

Over the course of the 20th century, mortgage lending has grown to a dominant share of banking portfolios. This has far-reaching implications because monetary conditions can spill

over more easily from one sector to another. The close link between monetary conditions, credit growth, and house price booms is of pivotal importance for the financial stability of the wider economy (Jorda et al., 2014).

There are several instruments aimed at ensuring the liability of transactions. These include LTV backing, repayment structure, interest rate fixation, maturity, creditworthiness, and taxation. Regarding mortgage market characteristics such as the average loan-to-value ratio or the share of loans with adjustable interest rates, the German market stands out as conservative (European Systemic Risk Board, 2019). Credit quality and borrower equity requirements are strict. Full financing is possible in principle, but still very limited in the German housing system. Banks will usually impose strict requirements in terms of personal creditworthiness and affordability for such loans (Kofner, 2013).

The determination of mortgage lending value for private residences in Germany is essentially based on the property's long-term sustainable features. This strategy emphasises the fundamental features and stability of the property over short-term market changes. House prices, especially the development of house price bubbles, have a limited influence on determining lending values, which do not correspond to the sometimes-erratic trajectory of home prices. As a result, this model encourages financial caution and long-term planning. For most first-time homeowners, this means being patient, saving diligently, or opting for more inexpensive housing alternatives as they negotiate the real estate market. This cautious approach demonstrates a dedication to financial stability and responsible homeownership (Kofner, 2013).

Another important instrument credit institutions use to determine the liability of their debtors is the SCHUFA register. It encompasses personal information such as birth date, timely payment of credit card bills or loan instalments, and information on abusive or fraudulent behaviour. It is noteworthy to say that there is low advancement of AI in credit scoring in the German market, whereas clear motives arise to push further development, like cost reduction and risk automatization (Schmitz, 2023).

The central role in facilitating the acquisition of real estate in Germany embodies the mortgage market. Borrowers have a variety of mortgage types available to them, including fixed-rate and variable-rate mortgages.

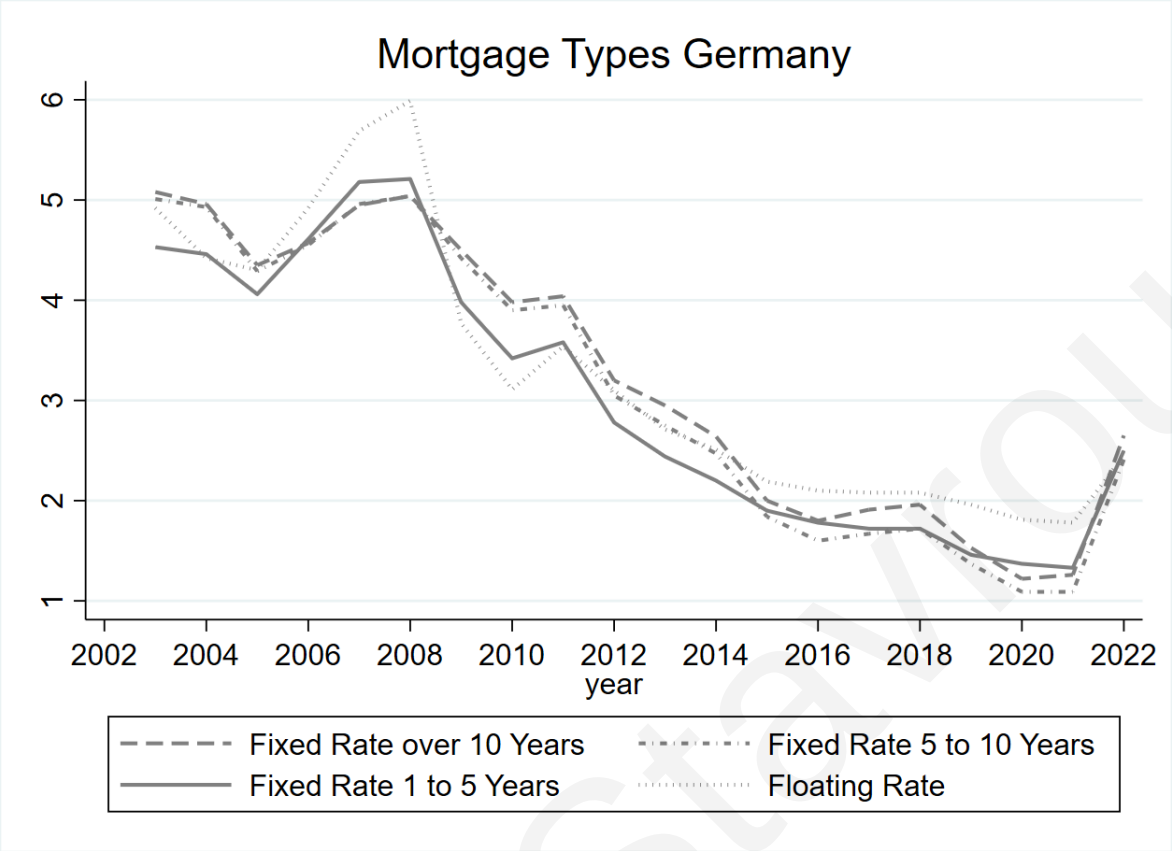

Fig. 5 *Mortgage Types in Germany (Source: Deutsche Bundesbank, 2023)*

These mortgage products are offered by banks, credit unions, and other financial institutions (Detusche Bundesbank, 2023). The primary factor influencing the cost of ownership is the mortgage interest rate, and when the housing market is balanced, agents are indifferent whether a property is owned or rented (Adelino et al. 2022). Whatever the product type, smaller loans have a higher chance of repayment. While adjustable rates offer a higher short-term risk to borrowers of both FRMs and ARMs, fixed mortgages have a gradually increasing default threat (Calhoun & Deng, 2000).

Figure 5 covers the effective rates for secured and unsecured loans for the purchase of residential property, including construction and improvement loans. As depicted in the graph, the initial movement of the rates before the financial crisis stayed within a corridor of 4 to 5 percent. It is noticeable that the movement between the different mortgage interest rates is relatively simultaneous, only with the floating rate featuring a higher variance than the other rates. The incidents of 2008 were followed by a long and steady decline in real rates until 2021. Ever since, mortgages in Germany have been on the rise again.

The varying interest rates have several implications for the German real estate market. Firstly, because interest rates are not tax-deductible for homeowners in Germany, low interest rates facilitate demand even more, and vice versa (Barasinska et al. 2019). Secondly, under a normalising inflation regime, rising interest rates generally lead to a decrease in the demand for mortgages.

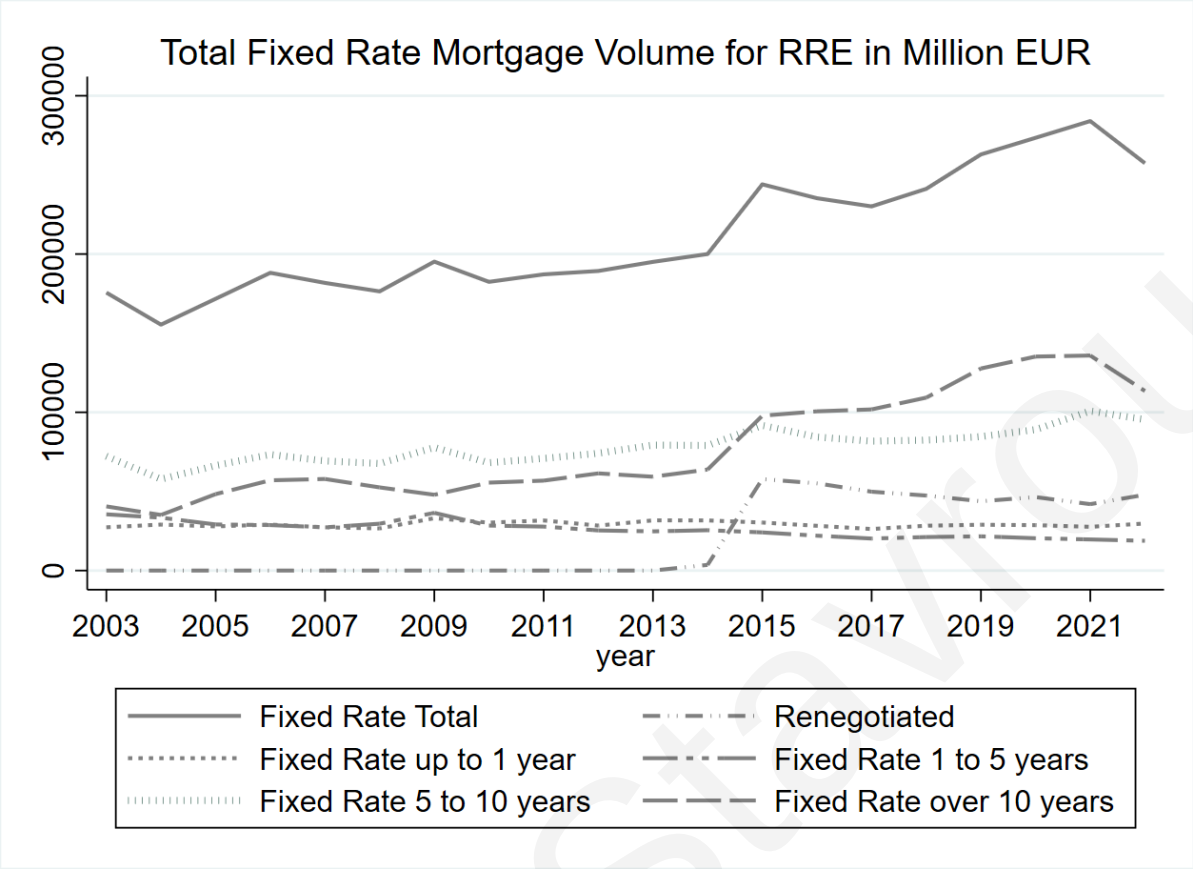

Fig. 6 *Mortgage Volume for different Rates in Germany* (Source: Deutsche Bundesbank, 2023)

This inverse relationship occurs because higher interest rates mean that borrowing money becomes more expensive for potential homebuyers. As a result, the cost of financing a home purchase increases, making homeownership less affordable. This, in turn, reduces the number of individuals who are willing and able to take on a mortgage (Zhu & Tsartsonis,2004).

In fact, a turnaround is already discernible, and this occurs at the beginning of the implementation of the interest rate hikes. Figure 6 displays the overall RRE mortgage volume according to the several types of interest rates. The line depicting the total RRE mortgages demonstrates that the downturn of overall mortgage volume after 2021 is the sharpest in the last 20 years. Considering the high inflation in 2021, numbering 7.8 percent, the real decline might even have turned out higher.

The most widespread financing for property is with around 80 percent mortgages with fixed interest rate periods of at least 5 years. Over the course of the low interest rate regime of the 2010s, the number of mortgages with an interest rate fixation of at least 10 years rose from 30 to 40 percent, mostly at the cost of the 5 to 10-year rate (Figure 6). Considering the widespread fixed interest rates of RRE, it is unlikely that interest volatility will pose an immediate threat to financial stability in the German real estate market (Barasinska et al. 2021), while the high interest rate exposure of newly issued mortgages due to no tax deductibility might explain the drop in mortgage volume further (Barasinska et al. 2019).

Germany aims to cultivate a welcoming and favourable investment environment for foreign investors. The country maintains transparency and consistency in its legal, regulatory, and accounting systems, aligning with international standards. Equally, both foreign and domestic

investors enjoy equal treatment concerning investment incentives, property establishment, and protection. Foreign investors can place their trust in Germany's efficient and sophisticated legal system, fostering a climate of confidence and security (Stompfe, 2020). The internationalisation of the German real estate market has helped facilitating the influx international investment flows. Pfnuer & Wagner (2020) argue that the financing of real estate proves to be less of a bottleneck then the operational factors of involved companies, like planning and employing competent staff. Over the course of a consistent healthy economic situation the construction industry failed to innovate itself and to provide housing for the rising demand.

3.8 Subsidies and building activity

According to a press release by the German federal government, it has set itself the target of 400,000 new apartment constructions, of which 100,000 are social housing. This objective aims at providing affordable housing, especially for the lower-income population. The federal government plans to support the housing market in 2022 by around 1 billion EUR with the latest climate and digitization standards (Mueller, 2022).

The decision by the federal government to implement new subsidy schemes was preceded by a period of substantial declines in subsidies between 2005 and 2012. Within this period, a total of 2 billion EUR was allocated to different fiscal projections. This decline can be primarily attributed to the elimination of the owner-occupied home subsidy, known as the "Eigenheimzulage" (Kofner, 2013).

The program was implemented during the period from 1997 to 2005 as a government-funded subsidy with the primary objective of stimulating exclusively homeownership. This initiative entailed the provision of subsidies for both the construction of new private housing and the acquisition of existing private housing units. At the outset of this program, homeownership rates in the nation were reported at approximately 39 percent. This ownership rate was notably lower than that observed in most industrialised states. However, as the program ended in 2005, there was a discernible increase in homeownership, with the rate climbing to 42 percent (Bischoff & Maening, 2012).

After abolishing the “Eigenheimzulage” financial aid was strategically directed towards specific areas, including energy modernization, senior-friendly reconstruction, preservation of architectural structures, and urban redevelopment. Notably, the scope of subsidies no longer encompasses general tax incentives. (Kofner, 2013). Yet the market failed to provide affordable housing for lower-income individuals, even under positive market conditions. Germany used to have a considerable social housing sector, which was limited to lower-income groups. It accounted for almost a quarter of all post-war-constructed homes in the 1970s. Totally, there were 3.9 million social homes in 1987; the number declined to 1.5 million in 2014 (Droste, 2014).

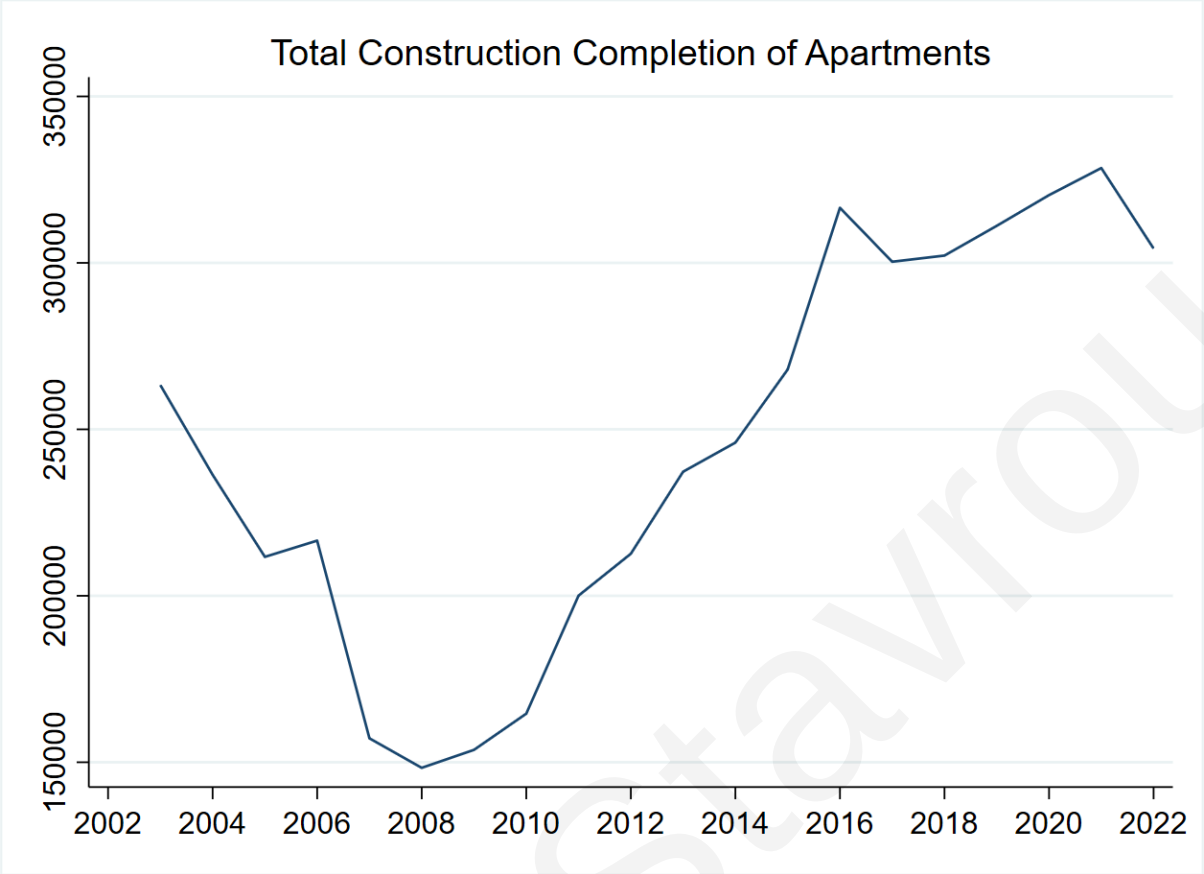

Fig.7 *Total Construction Completion of Apartments in Germany* (Source: Federal Statistical Office, 2023)

Figure 7 illustrates the boom of the housing sector in Germany under favourable construction conditions. Since 2008, the total completion of apartments has more than doubled within six years. The pivotal point seems to have been reached by 2021, with a downward trend. The prospect of reaching 400,000 yearly apartment completions to take some pressure from the rental market could not yet be achieved.

Generally, the housing stock in Germany is divided between professional-entrepreneurial landlords with a share of 23 percent, small private and amateur landlords with 37 percent, and owner-occupiers with 40 percent (Droste & Knorr-Siedow, 2014). The tax regime governing capital gains demonstrates a preference for individual private property ownership. Under this system, capital gains generated from the sale of a residential property held privately for a period exceeding ten years are exempt from taxation, unless the seller falls under the classification of a "commercial real estate dealer," indicating regular engagement in real estate trading activities (Kofner, 2013).

In 2019, the federal government approved a funding scheme for the construction and renovation of buildings to meet certain energy standards. It aims to incentivize owners to modernise dilapidated buildings to meet carbon neutrality by 2050. Yet the subsidy failed to benefit their receiver strong enough to push the reconstruction efforts of the buildings with the lowest energy standards. Taruttis & Weber (2021) found that only vendors benefit from upgrading and selling. Those who rent out must cover the substantial cost of the renovation themselves, while renters must meet increased rents, making it a loss for both parties.

Further, Krolage (2022) found that subsidy recipients were not necessarily benefiting from the subsidy schemes. In some bordering regions of federal states with extensive remedies, the subsidies even had spillover effects in the form of house price appreciations, thereby rewarding ownership of property over construction in those regions.

3.9 Risks

In recent years, the German housing market has visibly gained momentum. Especially the low interest rate policy of the ECB helped market participants in Germany obtain loans at favourable conditions, facilitating demand. Although construction expanded considerably, the newly provided housing failed to provide enough living space. Housing prices grew over this period proportionately stronger than inflation and rents (Dahl & Goralczyk, 2017). The rent-price ratio for housing is often used as an economic efficiency indicator. This indicator is similar to the dividend-price ratio in stock trading and measures how fairly an object is valued in relation to its true long-term value. Low price-to-rent ratios usually imply overvaluation (Gallin 2004).

Figure 8 illustrates how the house price growth outstripped the rent growth and even continued to rise until 2021. The divergence of house prices and rents indicates an overvaluation of house prices. According to the European Systemic Risk Board (2019), house price overvaluation might even amount to 15–30 percent in urban areas.

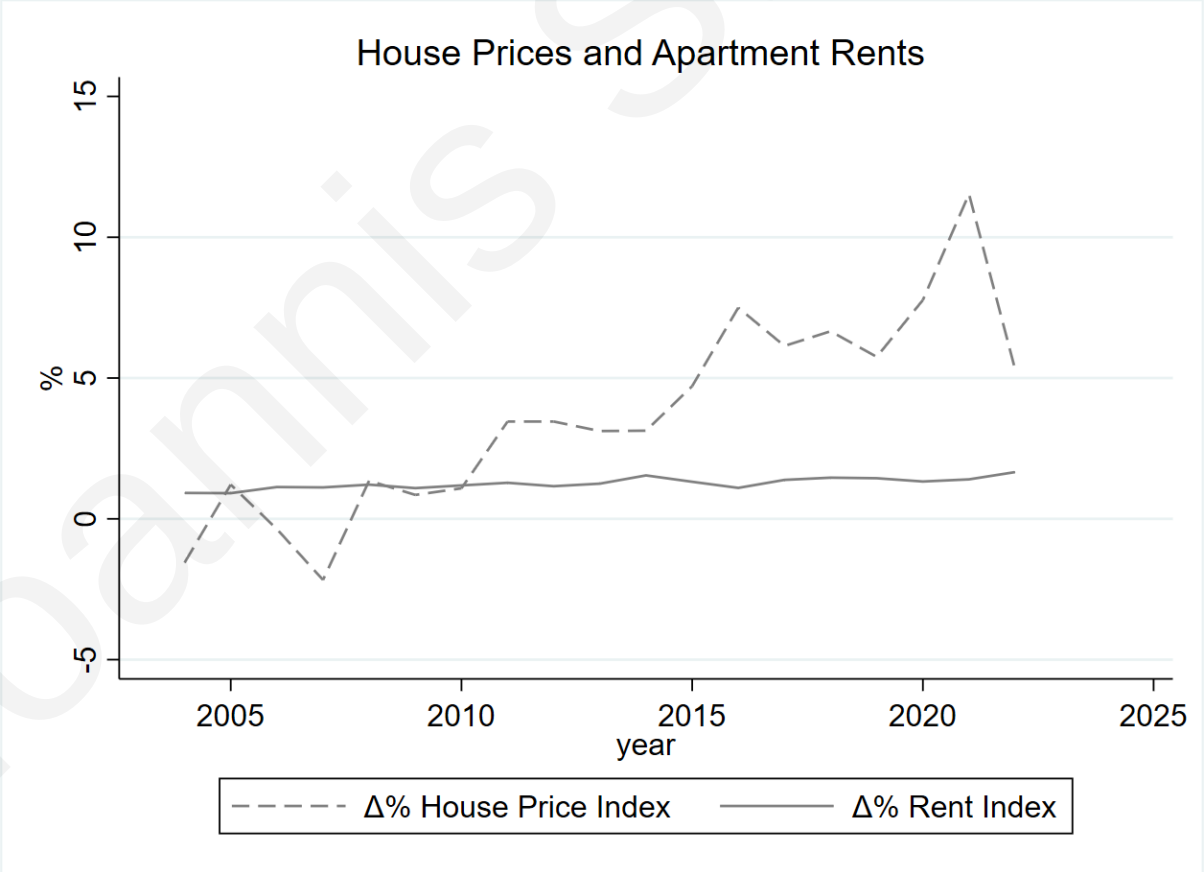

Fig 8 *Percentage Change in House Price Index and Rent Price Index* in Germany (Source: Federal Statistical Office, 2023)

The current situation in the social housing sector is likely exacerbating the situation as more dwellings are leaving in comparison to entering the market as rising construction costs evaporate the already low profitability of low-cost housing. Especially social housing can be seen as a chance to provide housing for the changing demographic situation, as the majority of immigrants in Germany have limited financial capacities (Droste & Knorr-Siedow, 2014).

Figure 9 illustrates the co-movement of the percentage change in construction costs and construction approvals. Over the span of 15 years, construction costs grew at a positive rate comparable to the inflation rate. Construction approvals on the other side grew considerably faster between 2010 and 2016, with rates of 5 to 20 percent. Until 2020, both growth rates converged to each other close to zero before diverging with a construction cost appreciation of almost 15 percent and a drop in approvals of almost 10 percent.

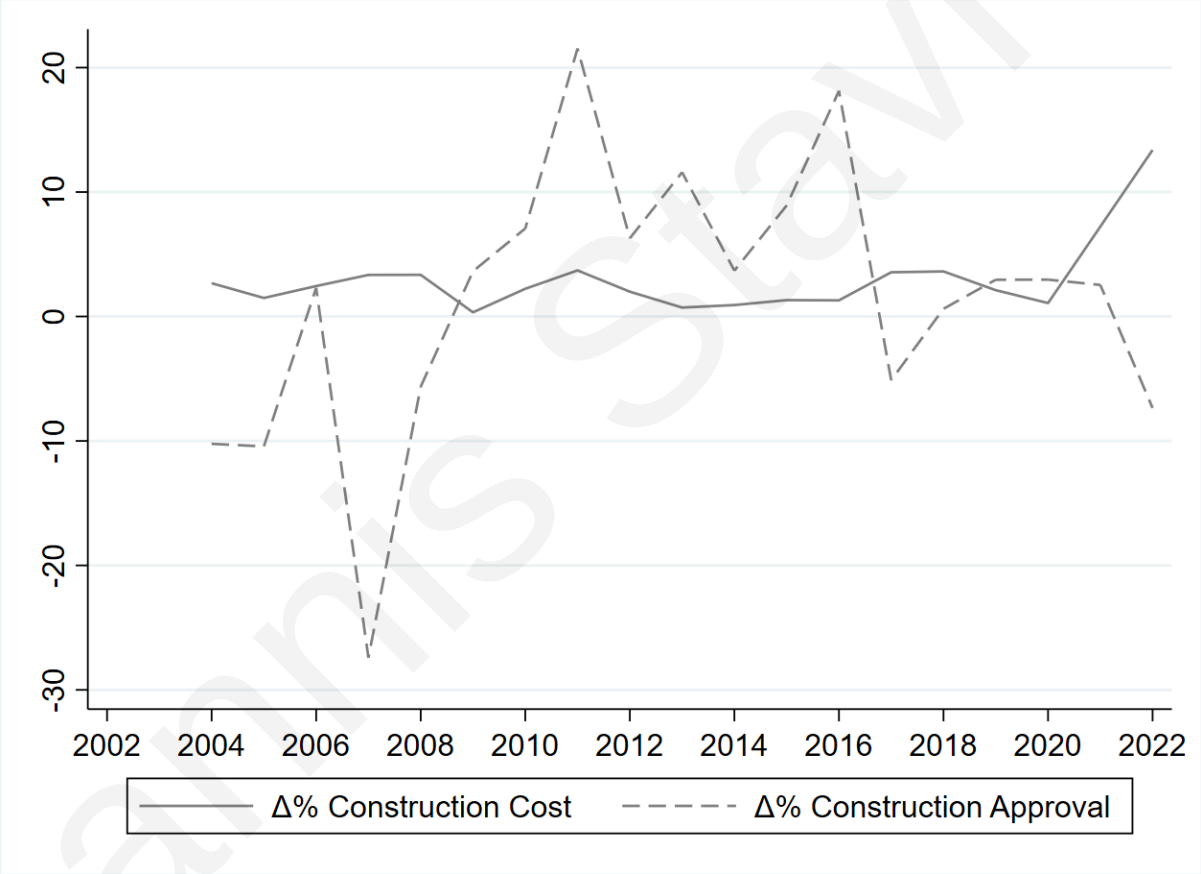

Fig 9 *Percentage Change of Construction Cost and Approvals in Germany* (Source: Federal Statistical Office, 2023)

In this macroeconomic context, it can be concluded that the general conditions in the construction industry seem depressing. Construction activity increased only for a short period of time, while macroeconomic conditions were favourable. Still, it could not meet the proportionally higher demand due to population growth, especially for low-priced housing. This disequilibrium was initially reflected in higher prices for houses and rents (Dahl & Goralczyk, 2017). In exactly this situation, the rental-break policy of 2015 was reintroduced, limiting the scope of action for renters, and virtually relocating the problem from tenants away (Davies, 2017). This kept rental growth relatively stable but left a considerable demand

overhang in urban areas as the main hurdle became finding a flat to rent instead of being able to afford it (Cornelius 2014). Meanwhile, property prices continued to climb to new all-time highs until reaching a pivotal point in 2021 with the change in the low interest rate policy. A cooling of the house market is already evident. It is now of upmost importance for policymakers to create the right incentives for investments in the housing market to facilitate a steady supply in the current situation. Especially social housing might be the right solution for the difficulties renters have to face.

4. Empirical Strategy

4.1 Introduction

In this chapter, a comprehensive overview of the methodological approach employed for the cross-sectional data analysis conducted in this study is provided. The research objectives, data sources, data collection process, data cleaning procedures, and statistical techniques used in the analysis with Stata are outlined. Three distinct models aimed at analysing housing prices were developed based on the dataset provided.

4.2 Research Objectives

This empirical approach has the key research objective constructing a comprehensive cross-sectional regression model that incorporates hedonic aspects while analysing house prices. In particular, the research aims to achieve several specific goals.

Firstly, it seeks to investigate the relationship between various property characteristics, such as size, location, amenities, and architectural features, and their impact on housing prices using a cross-sectional dataset.

Secondly, the research aims to quantify the individual and combined effects of these hedonic characteristics on home values. It intends to discern how each of these aspects contributes to the overall value of a property.

Additionally, the study plans to explore potential spatial patterns and variations within the hedonic pricing model. This exploration includes considering regional disparities in the housing market and understanding how they influence pricing dynamics.

Furthermore, the research will examine differences in the predictive accuracy and significance of certain variables across various models, specifically those related to house purchases, apartment purchases, and apartment rentals.

By accomplishing these research objectives, this study intends to contribute to a deeper understanding of the microeconomic factors that shape house prices. Ultimately, it seeks to empower better-informed decision-making in the German real estate market.

4.3Data Sources

The dataset was provided by the research data centre (FDZ) Ruhr, a department of the RWI-Leibniz Institute for Economic Research. It offers a unique collection of information on

German real estate prices, sourced from ImmobilienScout24. This dataset includes details about property listings, encompassing both price information and various observable attributes that influence property values. The Cross-Sectional Campus File is a sample drawn from one recent year (2020) for all of Germany. All variables included in the subsequent analyses are described in Table 1. The sample is drawn from all advertisements that were in the database for at least one day within the respective year.

Table 1 Variable description

Variable name	Description	Source
Price	*Price for a property in EUR. Relevant for house and apartment purchases*	RWI-GEO-RED Cross-Section
Rent	*Rent for a property in EUR/month. Relevant for apartments only*	RWI-GEO-RED Cross-Section
Age	*Age of a property*	RWI-GEO-RED Cross-Section
Population Density	*Number of people per km2 of the municipality the property is located in*	Federal Statistical Office
Living Space	*Number of square meters of living space available for the property*	RWI-GEO-RED Cross-Section
Benefit	*Common charge for community association in EUR/month*	RWI-GEO-RED Cross-Section
Elevator	*Elevator in object*	RWI-GEO-RED Cross-Section
Kitchenette	*Kitchenette in object*	RWI-GEO-RED Cross-Section
Bathroom	*Number of bathrooms in object*	RWI-GEO-RED Cross-Section
Balcony	*Balcony in object*	RWI-GEO-RED Cross-Section
Condition 1	*Condition of object: First occupancy*	RWI-GEO-RED Cross-Section
Condition 2	*Condition of object: First occupancy after reconstruction*	RWI-GEO-RED Cross-Section
Condition 3	*Condition of object: Like new*	RWI-GEO-RED Cross-Section
Condition 4	*Condition of object: Reconstructed*	RWI-GEO-RED Cross-Section
Condition 5	*Condition of object: Modernised*	RWI-GEO-RED Cross-Section
Condition 6	*Condition of object: Completely renovated*	RWI-GEO-RED Cross-Section
Condition 7	*Condition of object: Well kempt*	RWI-GEO-RED Cross-Section
Condition 8	*Condition of object: Needs renovation*	RWI-GEO-RED Cross-Section
Condition 9	*Condition of object: Dilapidated*	RWI-GEO-RED Cross-Section
Furnishing 1	*Facilities of object: Normal*	RWI-GEO-RED Cross-Section
Furnishing 2	*Facilities of object: Sophisticated*	RWI-GEO-RED Cross-Section
Furnishing 3	*Facilities of object: Deluxe*	RWI-GEO-RED Cross-Section
Heating 1	*Type of Heating: Gas Heating*	RWI-GEO-RED Cross-Section
Heating 2	*Type of Heating: District heating*	RWI-GEO-RED Cross-Section
Heating 3	*Type of Heating: Floor heating*	RWI-GEO-RED Cross-Section
Heating 4	*Type of Heating: Oil heating*	RWI-GEO-RED Cross-Section
Heating 5	*Type of Heating: Thermal heat pump*	RWI-GEO-RED Cross-Section
Heating 6	*Type of Heating: Central heating*	RWI-GEO-RED Cross-Section
Heating 7	*Type of Heating: Self-contained heating*	RWI-GEO-RED Cross-Section
Heating 8	*Type of Heating: Wood pellet heating*	RWI-GEO-RED Cross-Section
Offer 1	*Type of provider: Private offer*	RWI-GEO-RED Cross-Section
Offer 2	*Type of provider: Housing industry*	RWI-GEO-RED Cross-Section
Offer 3	*Type of provider: Real estate agent*	RWI-GEO-RED Cross-Section
Offer 4	*Type of provider: Builder*	RWI-GEO-RED Cross-Section
Category 1	*Flat/House type: Flat/semi-detached house*	RWI-GEO-RED Cross-Section
Category 2	*Flat/House type: Raised ground/terraced house middle unit*	RWI-GEO-RED Cross-Section
Category 3	*Flat/House type: Maisonette/terraced house end unit*	RWI-GEO-RED Cross-Section
Category 4	*Flat/House type: Penthouse/bungalow*	RWI-GEO-RED Cross-Section
Category 5	*Flat/House type: Souterrain/farmhouse*	RWI-GEO-RED Cross-Section
Category 6	*Flat/House type: Flat with terrace/mansion*	RWI-GEO-RED Cross-Section

The dataset is divided into three distinct sets: one for houses for sale, another for apartments for sale, and a third for apartments available for rent. ImmobilienScout24 is the largest online platform for real estate in Germany, facilitating property owners, both private and commercial, to advertise their properties for a fee. However, it is important to note that this dataset exclusively comprises residential real estate listings. It distinguishes between houses and apartments and encompasses properties available for both sale and rent. ImmobilienScout24 holds a significant market presence, with a self-reported market share of approximately 50% of all real estate listings offered for sale or rent in Germany (Georgi and Barkow 2010). Consequently, this dataset comprises a substantial volume of observations. Notably, property owners are required to complete a questionnaire when advertising their properties on the platform, which includes specifying the property's price. It is essential to understand that this advertised price is non-binding, representing an offering price rather than transaction prices. Almost all listings include price information. In addition, advertisers can include additional property-specific characteristics in their listings, enhancing the presentation of their property and possibly increasing their chances of securing a favourable rental or sale price.

The dataset includes observations from German municipalities, albeit it should be noted that not all municipalities are included in the set.

Furthermore, data from the German Federal Statistical Office is added to the study to enhance its geographical characteristics, such as population density within a certain region. This was accomplished by linking the corresponding features of the area with the municipal identity that was appended to every observation.

4.4 Data Cleaning and Preprocessing

The three experimental models' data sets must be processed differently from one another since, despite having comparable setups, they differ in a few key areas. The possibility of lowering the number of observations is highly constrained, particularly in the smaller sets, mostly because of the wide variations in dataset sizes. The appendix's descriptive statistics section contains the datasets' original sizes (Table 4, 5 and 6). Working with the three datasets created various trade-off issues between incorporating variables that have informative value and maintaining the highest possible number of observations. The incomplete inclusion of several binary variables in the dataset causes this issue. The property's parking space and the floor on which it is located were two of the factors that were left out of the regression to prevent bias. Complete advertisements may influence the perceived price of a home or the amount of rent a seller may ask for, which gives rise to the biasedness assumption. It is noteworthy that the data set is only marginally affected by the omission of these variables' observations. The treatment of outliers is extremely important in this work because the dataset only represents suggested prices by the seller on the online-platform for real estate. Along with the basic OLS regression, an additional quantile regression analysis is being performed to ensure that no data are lost by eliminating them from the analysis. It is significant to note that the data was not subjected to any variable modifications, such as square root or log transformations. To preserve the original scale of measurement, raw data was chosen.

5. Methodology

As previously stated, the hedonic analysis of house prices is constructed utilising the cross-section data. The following could be used to formulate the OLS regression model:

Eq.1:

$$Y_{id} = \beta_0 + \beta_1 x_1 + ... + \beta_i x_i + \beta_1 D_1 + \ldots + \beta_d D_d + \varepsilon_i$$

Here, i stands for a single house, Y for the real selling price coefficient, and X for each home's attributes. The dependent variable's variance in these data is explained by the variability among all observations. It does not matter if the fluctuation is connected to the same house being sold again or not. The computed coefficients—the slopes and the intercept—are thought to remain consistent throughout time and across residences. The continuous variables are represented by the parameters β, which are regarded as elasticities. When the value of the dummy variable varies, the parameters associated with it are understood to represent the proportionate change in the average real price of a home. If the OLS estimator is to be BLUE, the following assumptions must be met:

$$E\,(x'_i\,\varepsilon_i) = 0$$

$$E\,(\varepsilon_i) = \sigma^2_\varepsilon$$

$$E\,(\varepsilon_{i,}\ \varepsilon_i) = 0$$

$$E \sim N\,(0, \sigma^2_\varepsilon)$$

This publication includes estimates for the quantile regression studies in addition to the OLS regression. The reasoning behind this is that misleading regression results could occur because there are multiple signs that the OLS estimates are not BLUE. An expansion of linear regression is quantile regression. The quantile regression model is expressed as follows, in contrast to linear OLS regression, which models the conditional mean of the dependent variable as a function of the independent variables as shown in Eq. 1.:

Eq.2:

$$Q_\tau\,(Y_{id}|X_i) = \beta_{0\tau} + \beta_{1\tau} x_1 + ... + \beta_{i\tau} x_i + \beta_{1\tau} D_1 + \ldots + \beta_{d\tau} D_d + \varepsilon_{i\tau}$$

In this case, β0τ is the intercept, βiτ is the coefficient for the independent variable Xi, and εiτ is the error term for the τ-th quantile. Qτ (Yid∗Xi) is the τ-th quantile of Yi given Xi. Like before, D stands for the dummy variable once more, which can have a value of 0 or 1. This paper focuses just on the 50th quantile for simplicity's sake, thereby dividing the data into two even halves below and above the median. Understanding the relationship between independent factors and the middle value of the dependent variable's distribution can be gained by doing a quantile regression at the 50th quantile, sometimes referred to as the median. This is useful because it takes into consideration possible variations in the relationships within the core region of the distribution that conventional mean-based regression would overlook.

6. Modelling and results for housing prices

Within the framework of the methodological procedures outlined in Sect. 5, this chapter addresses the modelling of the data presented in Sect. 4.

The first of three hedonic pricing models, which addresses flat rentals, is represented by Table 2. The estimated coefficients for the OLS and QR are shown. The regressions for specifications (1) through (3) are presented from left to right in ascending order of the number of independent variables included. This is necessary to evaluate each independent variable's impact when the total number of variables is altered.

Table 2 Apartment Rents

	OLS-regression			Quantile-regression		
Rent	(1)	(2)	(3)	(1)	(2)	(3)
Age	-0.340***	-0.337***	-0.315***	-0.462***	-0.428***	-0.392***
	(0.0125)	(0.0118)	(0.0115)	(0.0120)	(0.0117)	(0.0112)
Population Density	0.0875***	0.0893***	0.0895***	0.0770***	0.0787***	0.0776***
	(0.000510)	(0.000474)	(0.000470)	(0.000472)	(0.000441)	(0.000422)
Living Space	9.534***	8.842***	8.636***	9.132***	8.420***	8.174***
	(0.0219)	(0.0206)	(0.0207)	(0.0210)	(0.0199)	(0.0193)
Benefit	-192.1***	-163.4***	-142.3***	-184.2***	-152.0***	-132.9***
	(2.933)	(2.634)	(2.581)	(3.620)	(3.348)	(3.205)
Elevator	117.8***	45.98***	47.83***	114.3***	40.52***	42.24***
	(1.031)	(1.006)	(1.006)	(1.085)	(1.100)	(1.070)
Kitchenette	131.1***	112.9***	98.05***	135.8***	114.5***	94.11***
	(0.834)	(0.780)	(0.808)	(0.930)	(0.883)	(0.871)
Bathrooms	80.12***	61.09***	60.99***	89.64***	67.12***	66.69***
	(2.465)	(2.235)	(2.233)	(1.950)	(1.804)	(1.734)
Balcony	47.50***	31.31***	32.48***	39.71***	25.36***	26.63***
	(0.920)	(0.844)	(0.835)	(1.078)	(1.004)	(0.964)
Condition 1		166.5***	160.4***		171.3***	163.1***
		(2.122)	(2.110)		(2.211)	(2.124)
Condition 2		64.67***	62.43***		65.55***	61.19***
		(2.019)	(1.985)		(2.165)	(2.067)
Condition 3		77.08***	73.51***		75.90***	72.62***
		(1.813)	(1.791)		(1.925)	(1.837)
Condition 4		-4.916**	-0.855		-6.403**	-3.973*
		(1.715)	(1.674)		(2.026)	(1.933)
Condition 5		7.956***	4.667**		14.01***	10.03***
		(1.690)	(1.667)		(1.977)	(1.892)
Condition 6		6.853***	2.808		8.271***	2.386
		(1.557)	(1.533)		(1.803)	(1.725)
Condition 7		-5.118***	-5.555***		0.923	-0.359
		(1.287)	(1.264)		(1.523)	(1.454)
Condition 8		-60.95***	-64.17***		-44.23***	-48.93***
		(5.171)	(5.087)		(6.599)	(6.293)
Condition 9		-38.33***	-37.98***		-28.65***	-31.75***
		(4.236)	(4.139)		(5.237)	(4.995)
Furnishing 1		-26.73***	-24.63***		-19.63***	-18.93***
		(0.918)	(0.912)		(1.133)	(1.102)
Furnishing 2		47.81***	42.78***		50.75***	42.11***
		(1.152)	(1.163)		(1.240)	(1.220)
Furnishing 3		170.6***	162.6***		171.7***	162.2***
		(3.412)	(3.395)		(2.850)	(2.741)
Heating 1		-6.988***	-15.51***		-2.522	-12.93***
		(1.687)	(1.665)		(1.920)	(1.841)
Heating 2		-36.06***	-24.92***		-37.66***	-25.30***
		(1.738)	(1.700)		(1.968)	(1.883)
Heating 3		52.67***	46.01***		52.48***	46.02***
		(1.913)	(1.890)		(1.975)	(1.887)
Heating 4		6.500*	-4.825		12.82***	-0.630
		(2.542)	(2.519)		(2.949)	(2.825)

Heating 5		34.38***	25.16***		33.96***	24.18***
		(3.100)	(3.067)		(3.335)	(3.185)
Heating 6		-12.39***	-12.52***		-9.083***	-8.107***
		(1.351)	(1.320)		(1.498)	(1.432)
Heating 7		-27.49***	-28.90***		-19.37***	-20.90***
		(1.736)	(1.709)		(2.001)	(1.910)
Heating 8		41.30***	36.29***		44.31***	39.79***
		(5.629)	(5.493)		(6.011)	(5.732)
Offer 1			14.01***			25.63***
			(3.166)			(3.297)
Offer 2			-53.31***			-44.84***
			(3.149)			(3.307)
Offer 3			17.90***			22.05***
			(3.167)			(3.294)
Offer 4			34.29***			41.28***
			(3.920)			(4.114)
Category 1			-9.442***			-8.275***
			(0.784)			(0.892)
Category 2			-1.997			-0.824
			(2.250)			(2.585)
Category 3			35.50***			33.39***
			(10.26)			(8.492)
Category 4			13.35***			19.52***
			(2.460)			(2.268)
Category 5			79.32***			82.73***
			(4.156)			(3.510)
Category 6			7.714***			4.797*
			(2.006)			(2.204)
_cons	-298.1***	-226.1***	-197.6***	-275.8***	-207.2***	-178.2***
	(2.788)	(2.933)	(4.187)	(2.369)	(2.795)	(4.151)
N	228236	228236	228236	228236	228236	228236
R-sq	0.679	0.736	0.744			

Point estimates with standard errors in parentheses and the associated p-value: $***p < 0.01$; $**p < 0.05$; $*p < 0.1$

Most covariates behave in a predictable way. Particularly those in specification (1) are highly significant and align with the expected sign in both the OLS and quantile regression. There is a discrepancy between the quantile regression and the OLS. This can be stated as follows: in the OLS regression, the variables "population density," "living space," "benefit," "elevator, balcony," and "age" have a greater impact on rent; in the quantile regression, the variables "kitchenette," "bathrooms," and "living space" have a higher impact.

The following specifications show more variations in these values. As a result, observations are made showing that the OLS and QR have nearly twice as high coefficients of the same variable and same specification. For instance, the influence of a modernised object on rentals is represented by the variable "condition 5," which is significant for both specifications (2) but nearly twice as high for the quantile regression. Along with the variable coefficients to both sides between the OLS and QR estimators that were already noted in specification (1), another notable observation in specification (2) is the variation in the significance level of individual variables. A situation where there is a noticeable difference in significance levels between the OLS and quantile regression can be explained by the variables "condition 7, heating 1 and heating 4".

Finally, at the final and longest specification (3), the same pattern emerges as it did in the earlier specifications. Interestingly, adding nine highly significant factors does not considerably raise the R-sq (0.744) compared to the specification, where the R-sq (0.736) is marginally smaller.

Table 3 House Price

	OLS-regression			Quantile-regression		
Price	(1)	(2)	(3)	(1)	(2)	(3)
	price	price	price	price	price	price
Age	-786.7***	-620.4***	-545.5***	-593.2***	-540.8***	-428.1***
	(20.36)	(20.38)	(20.18)	(14.97)	(16.53)	(16.57)
Population Density	136.9***	134.6***	129.7***	121.2***	121.7***	116.4***
	(1.063)	(1.077)	(1.097)	(0.726)	(0.751)	(0.764)
Living Space	2224.3***	2008.4***	1953.5***	1813.4***	1597.6***	1625.7***
	(24.14)	(22.60)	(22.98)	(12.21)	(12.53)	(12.97)
Bathrooms	-10635.8***	4403.7**	2789.4*	-6898.3***	10723.5***	8546.9***
	(1343.8)	(1352.0)	(1350.0)	(779.5)	(823.4)	(819.5)
condition_1		28191.4*	-9969.6		43201.1***	265.0
		(14183.0)	(14103.7)		(9505.9)	(9462.1)
condition_2		136690.8***	102193.6***		133624.4***	108126.8***
		(4638.8)	(4782.7)		(3395.6)	(3514.8)
condition_3		79892.5***	43297.6***		71344.5***	34542.6***
		(6288.3)	(6371.3)		(4480.2)	(4556.9)
condition_4		56234.9***	22592.5***		62016.3***	26744.2***
		(4232.0)	(4456.5)		(3442.9)	(3565.4)
condition_5		63973.7***	30184.5***		55038.3***	25185.1***
		(7078.9)	(7064.3)		(5412.2)	(5453.0)
condition_6		38815.0***	9997.9***		39985.8***	14066.3***
		(2559.3)	(2822.6)		(2099.1)	(2252.0)
condition_7		-43567.4***	-72768.3***		-45249.2***	-72372.5***
		(3216.9)	(3443.7)		(2926.4)	(3024.5)
condition_8		-23423.8	-47656.2**		-7957.2	-36639.1**
		(16044.3)	(15897.1)		(14030.2)	(13881.3)
condition_9		-65907.0*	-104202.8***		-99405.0**	-132650.3***
		(27482.9)	(27030.5)		(33044.7)	(32655.5)
furnishing_1		-47258.4***	-42401.0***		-30340.3***	-30680.4***
		(2201.5)	(2182.7)		(2026.8)	(2019.6)
furnishing_2		24964.3***	46741.6***		21116.1***	33935.9***
		(1827.3)	(1938.5)		(1652.2)	(1783.6)
furnishing_3		284026.2***	269864.0***		225745.0***	219844.4***
		(9545.0)	(9491.6)		(5063.3)	(5064.5)
heating_1		11325.0***	-1370.1		-11087.2***	-21286.3***
		(1909.6)	(1904.9)		(2117.2)	(2123.5)
heating_2		40773.4***	22821.1**		28197.0***	12642.2
		(8668.5)	(8587.4)		(7270.1)	(7237.9)
heating_3		101909.5***	82089.2***		69435.9***	51610.5***
		(2559.0)	(2538.3)		(2416.7)	(2427.5)
heating_4		40279.0***	11645.3*		19886.6***	-6108.6
		(4819.2)	(4881.4)		(4034.1)	(4067.1)
heating_5		143010.8***	144598.9***		113178.4***	110901.0***
		(1489.8)	(1480.4)		(1767.9)	(1752.4)
heating_6		36174.9***	17565.3***		14097.5***	623.6
		(2219.8)	(2348.1)		(1990.0)	(2062.1)
heating_7		-19969.2**	-32048.5***		-25835.8***	-38802.7***
		(6849.1)	(6868.9)		(5025.8)	(4983.0)
heating_8		97046.7***	59329.8***		73365.9***	21929.0
		(17888.3)	(17615.3)		(13716.4)	(13572.0)
offer_1			99906.1***			87284.8***
			(3765.7)			(3223.2)
offer_2			40555.1***			32537.2***
			(7791.0)			(7041.4)
offer_3			79982.0***			54663.0***
			(2615.4)			(2269.4)
offer_4			156040.8***			157280.5***
			(5315.4)			(4850.6)
category_1			14632.2***			21531.2***
			(2127.2)			(2188.2)
category_2			-46366.0***			-25192.1***
			(2685.2)			(3116.1)

category_3			-4101.2			7473.4
			(3657.2)			(3894.4)
category_4			15091.1***			9841.9***
			(1887.3)			(2562.8)
category_5			1189.9			-18470.8*
			(12894.4)			(9136.9)
category_6			97170.5***			-563.0
			(6493.2)			(3782.2)
_cons	92819.6***	15331.5***	-11144.4**	116802.2***	61587.0***	36093.3***
	(3474.7)	(3586.1)	(3811.2)	(2040.3)	(2609.9)	(2790.1)
N	118817	118817	118817	118817	118817	118817
R-sq	0.427	0.504	0.516			

Point estimates with standard errors in parentheses and the associated p-value: $***p < 0.01$; $**p < 0.05$; $*p < 0.1$

In theory, the models for the rental market and home purchases should be different. The reasons for this were previously covered in Chapter 4.4. As a result, in specification (1), the base model for house purchases has fewer variables, namely "age, population density, living space, and bathrooms." The number of observation as well as the R-sq are in this model significantly lower than in the on for apartment rents. All the variables are highly significant, but the projected influence of the number of bathrooms should be positively connected with the house price, because a higher number of rooms, particularly bathrooms, signifies a higher number of possible residents of the property. A model misspecification is possible, given that the base model lacks some variables from the preceding model for flat rents, where this misspecification did not appear. Comparing the OLS with the quantile estimates, it is noticeable that all covariates are closer to 0 in the quantile regression.

Specification (2) expands the model with the same variables as in the previous flat rent model. By expanding the covariate set, R-sq increases by 0.077, whereas the previous model for flat rents had a lesser rise of 0.057. This is most likely explained by the fact that the mean deviation of the residuals in the house price model is already substantially less explained by the base model (R-sq: 0.427). The probable misspecification of the bathroom variable in the first column no longer occurs in the second row, as the sign has now changed to positive. It is noteworthy to mention that the significance of the variable also dropped to a 5 percent level. With decreasing housing quality, the coefficients of the condition in which the property to be sold is in can be observed in an approximately linearly decreasing sequence. The same applies to the quality of the furnishings of a property at the time of the offer. This does not apply to the heating types of the houses, because this would bring classification issues to interpret them in a meaningful sequence. Like in the previous model, the OLS and quantile estimators vary at different intensities across the covariates. The variable “furnishing 1”, which represents the gas heating type, stands out. The coefficient prefix is reversed in this case for OLS and the quantile regression under both estimates is significant at the 1 percent level. Furthermore, for both, the OLS and quantile regressions, “condition 8”, which represents houses which are in need for renovations, do not seem to significantly impact the purchasing price. In conclusion, it can be said that specification 2 assumes the expected values of the covariates. the slope coefficient also assumes a high positive value here, which is a logical conclusion when buying a house, as the property already has a certain value.

The last specification (3) expands the model by some covariates describing the category of the house (“category”) and the type of vendor through which the house is sold (“offer”). There is no significant difference in the previous covariates, neither in the significance level nor in the coefficients, except for “condition 1” and “heating 1”. In “condition 1” the prefix reverses and

the significance level drops below the 10 percent level in OLS. In the quantile regression, the coefficient stays positive, but drops by almost 40,000. This also might be negligible since the significance is well below the 10 percent level. A similar observation can be made with "heating 1".

In summary, both models differ in the accuracy of the mean deviation from the residuals. Even the first specification for the apartment rent does contain a higher R-sq (0.679) than the third specification (R-sq: 0.516) of the house price model. This must be taken into account as the first two specifications of the two models cannot be directly compared with each other as the variables differ due to the different set ups.

7. Robustness

This chapter deals with the methods used to test the validity of the models already mentioned. As generally known, there are several options available. These include points such as the graphical analysis of the distribution functions of the respective variables, statistical tests or the removal and addition of variables and subsequent evaluation of the changed outcome.

The variable inclusion method involves adding or removing variables to assess the model's robustness. As previously mentioned in chapter 6, the various specifications are used to look at the covariate features and, if needed, identify misspecifications. Variables are added with each new specification in an ascending order. This subject was covered in the evaluation of the models in chapter 6, so no more information is provided here.

The model must also be evaluated using the BLUE criterion to determine the accuracy of the outcomes. To test for heteroscedasticity, both the White test and the Breusch-Pagan test were used. Both test procedures assume that in the null hypothesis, the variables have a constant variance over the course of the data set.

The first test is carried out with the apartment rent of the third specification as this already includes all variables that have been used.

- The Breusch-Pagan test for heteroscedasticity was conducted, resulting in a chi-square statistic of $X^2 = 43535.42$ with degrees of freedom (df) = 1, $p < 0.01$. Therefore, the null hypothesis must be rejected and heteroscedasticity cannot be ruled out.
- By conducting the White test, the test statistics come to the same conclusion. The results are a chi-square of $X^2 = 39700.09$ with degrees of freedom (df) = 653, $p < 0.01$. Again, the null hypothesis must be rejected pointing out the presence of heteroscedasticity.

To extend the robustness determination to the house price model, the same tests were also carried out in this model for the third specification.

- The Breusch-Pagan test for heteroscedasticity was conducted, resulting in a chi-square statistic of $X^2 = 78850.90$ with degrees of freedom (df) = 1, $p < 0.01$. Therefore, the null hypothesis must be rejected and heteroscedasticity cannot be ruled out.
- By conducting the White test, the test statistics come to the same conclusion. The results are a chi-square of $X^2 = 24197.63$with degrees of freedom (df) = 534, $p < 0.01$. Again, the null hypothesis must be rejected pointing out the presence of heteroscedasticity.

Both the flat rent and house pricing models exhibit heteroscedasticity, according to the test protocols. To safeguard the models from miscalculation, robust standard errors were constructed in the simple OLS regression.

When applied to cross-sectional data in a hedonic pricing framework, quantile regression is more resilient to outliers than ordinary least squares (OLS) regression. Quantile regression is less susceptible to extreme values since it directly estimates conditional quantiles, which provides resistance to outliers and eliminates susceptibility to distributional assumptions. It is ideally suited for applications such as hedonic pricing because of its capacity to manage heteroskedasticity and offer insights into the impact of factors at different locations in the distribution. Furthermore, robust standard errors are provided via quantile regression, increasing the reliability of conclusions even in the presence of outliers. To summarise, quantile regression's increased robustness can be attributed to its focus on individual quantiles and its distribution-free character. This makes it useful for analysing real estate prices, where outliers may be common.

The distribution function of the non-binary variables, which also reflect the fundamental variables and are thus already included in the first specification, is the final criterion considered to assess the robustness of the model. These include the number of bathrooms, square metres, age, and population density. To find a normal distribution for these variables, the graphical analysis of the distribution functions was the focus here. In the context of the BLUE assumptions, this criterion is essential to prevent spurious regression results. As can be seen from the graphical examination of the distribution functions under Figs. 10 and 11 in the appendix, the variable "living space" most closely resembles a normal distribution. The remaining variables exhibit significant skewness. This could explain some regression errors that have already been pointed out in chapter 6.

8. Conclusion

Numerous relevant subjects are covered by the literature on the housing market, digging into the diverse dynamics related to financial stability, general market characteristics, hedonic pricing modelling, and micro- as well as macroeconomic fundamentals. This work now aims to combine the various disciplines of real estate research in order to provide a more complete picture on how different determinants might affect housing prices.

The first section of the paper, which deals with broad market analysis of the German housing market, provides a deeper knowledge of the market dynamics by examining the economic policy framework circumstances. This includes unique characteristics that have manifested themselves in Germany over the years and must also be constantly re-evaluated due to the constantly changing economic interplay of factors. Rising rents and declining purchase prices in a challenging market phase with high interest rates are the results of recent demographic shifts that have not been proactively handled to make up for the supply gap by the policymakers. The stable pre COVID-19 renting market, which justified the low owner-occupier rate, does not seem to be able to attract urgent investments on a broad scale. According to the Pestel Institute (2023) up to 700,000 flats are missing in the German housing market. Whether the private sector can supply as many residential units in a short period of time is debatable. This looks less plausible now that construction prices and loan rates have increased.

It appears that the creation of affordable homes would be best served by a focused governmental subsidy strategy.

However, there are already indications that demand and, consequently, prices for single-family homes, are plummeting. When combined with growing rents, this may cause the price-to-rent ratio to level out and increase the appeal of investing in the building industry for rental purposes. Opportunities may be found mostly in the eastern federal states of Germany, where there is an abundance of free land for construction.

Two results were reached in the second section of the investigation, when two hedonic approaches reflecting rentals and housing prices were built. The first realisation comes from the intuition of the accuracy of rent and home price estimations rather than the various modelling techniques, OLS, and quantile estimators. In terms of prediction accuracy across the board, the rental price model appears to perform better than the home price model. Although the exact nature of this situation is unknown, indications point to apartments being more homogeneous, which improves hedonic rent prediction. Because the value of the land must be considered in relation to what possible development activities could add value to it, estimating the intrinsic worth of a house may also be more difficult. This also makes sense because the apartment price model's r-sq forms a transition between the apartment rent and house price model. nevertheless, it must be considered that the data situation in the rental model is the most detailed. Furthermore, there are significant indicators that the distribution functions lack normality, suggesting that the quantile model would be a better fit for describing the data hedonistically.

An improvement in the data situation in the upcoming years may combine both approaches to enable future investigation into this work. The goal of this is to create a panel data collection that include macroeconomic and hedonic variables like unemployment and interest rates. Implementing AI in the hedonic pricing method, which, for instance, enables criminal data or newspaper stories to be automatically integrated in the pricing of goods, would be another intriguing option to support this effort.

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Figures and Tables

Figure 1:

- Statistisches Bundesamt (Destatis), Population Germany, 2022

Figure 2:

- All data for inside Germany incl. german national borders: *Bundesamt für Kartographie und Geodäsie (BKG): Municipalities 1:250.000 - 01.01.2013
- RWI – Leibniz Institute of Economic Research, RWI Real Estate Data - Campus File Cross-Section, 03.11.2022, Essen

Figure 3:

- Map of Germany with the boundaries of the Bundesländer, Ahoerstemeier, 09.02.2004
- Statistisches Bundesamt (Destatis), Construction Investment,24.08.23, https://www-genesis.destatis.de/genesis/online?sequenz=tabelleErgebnis&selectionname=81000-0019

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- Statistisches Bundesamt (Destatis), National Account, 2023
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- Statistisches Bundesamt (Destatis), House Price Index, 2023
- Statistisches Bundesamt (Destatis), Rent Index, 2023

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- Statistisches Bundesamt (Destatis), Construction Approvals, 2023

Table 1:

- RWI – Leibniz Institute of Economic Research, RWI Real Estate Data - Campus File Cross-Section, 03.11.2022, Essen

Table 2 and 3:

- RWI – Leibniz Institute of Economic Research, RWI Real Estate Data - Campus File Cross-Section, 03.11.2022, Essen

Appendix

Table 4 Summary Statistics Apartment Rent

Variable	Obs	Mean	Std. Dev.	Min	Max
Rent	397574	638.851	330.467	174.09	2300
Age	300052	53.685	38.654	0	520
Population Density	397230	1380.852	984.018	14	4868
Living Space	397574	67.337	23.86	20.02	150
Benefit	397573	.021	.144	0	1
Elevator	397574	.237	.425	0	1
Kitchenette	397574	.437	.496	0	1
Bathrooms	309143	1.062	.251	0	5
Balcony	397574	.644	.479	0	1
condition 1	397574	.058	.234	0	1
condition 2	397574	.056	.229	0	1
condition 3	397574	.094	.291	0	1
condition 4	397574	.069	.253	0	1
condition 5	397574	.077	.266	0	1
condition 6	397574	.104	.305	0	1
condition 7	397574	.259	.438	0	1
condition 8	397574	.004	.063	0	1
condition 9	397574	.006	.075	0	1
furnishing 1	397574	.305	.461	0	1
furnishing 2	397574	.258	.438	0	1
furnishing 3	397574	.019	.136	0	1
heating 1	397574	.096	.295	0	1
heating 2	397574	.084	.278	0	1
heating 3	397574	.076	.266	0	1
heating 4	397574	.023	.149	0	1
heating 5	397574	.014	.117	0	1
heating 6	397574	.427	.495	0	1
heating 7	397574	.08	.271	0	1
heating 8	397574	.004	.064	0	1
offer 1	397574	.371	.483	0	1
offer 2	397574	.345	.475	0	1
offer 3	397574	.249	.432	0	1
offer 4	397574	.02	.139	0	1
category 1	397574	.51	.5	0	1
category 2	397574	.023	.15	0	1
category 3	397574	.002	.048	0	1
category 4	397574	.03	.172	0	1
category 5	397574	.01	.1	0	1
category 6	397574	.045	.206	0	1

Table 5 Summary Statistics House Purchase

Variable	Obs	Mean	Std. Dev.	Min	Max
Price	192651	453220.04	302746.67	37500	2700000
Age	153335	76.091	41.654	0	520
Population Density	191930	629.226	861.805	13	4868
Living Space	192651	169.806	74.502	70.05	633
Bathrooms	144053	1.711	1.019	0	15
condition 1	192651	.004	.061	0	1
condition 2	192651	.032	.177	0	1
condition 3	192651	.017	.128	0	1
condition 4	192651	.029	.167	0	1
condition 5	192651	.01	.101	0	1
condition 6	192651	.137	.344	0	1
condition 7	192651	.046	.21	0	1

condition 8	192651	.002	.048	0	1
condition 9	192651	0	.02	0	1
furnishing 1	192651	.12	.325	0	1
furnishing 2	192651	.471	.499	0	1
furnishing 3	192651	.015	.121	0	1
heating 1	192651	.101	.301	0	1
heating 2	192651	.006	.075	0	1
heating 3	192651	.085	.279	0	1
heating 4	192651	.021	.145	0	1
heating 5	192651	.165	.371	0	1
heating 6	192651	.199	.399	0	1
heating 7	192651	.015	.12	0	1
heating 8	192651	.002	.039	0	1
offer 1	192651	.047	.212	0	1
offer 2	192651	.007	.085	0	1
offer 3	192651	.416	.493	0	1
offer 4	192651	.016	.125	0	1
category 1	192651	.08	.272	0	1
category 2	192651	.035	.183	0	1
category 3	192651	.02	.14	0	1
category 4	192651	.05	.219	0	1
category 5	192651	.004	.065	0	1
category 6	192651	.022	.147	0	1

Table 6 Summary Statistics Apartment Purchase

Variable	Obs	Mean	Std. Dev.	Min	Max
Price	109869	349334.84	250802.72	22500	1990000
Age	99985	57.794	38.271	0	520
Population Density	99500	1752.447	1267.236	30	4868
Living Space	109869	81.404	30.804	25.9	210
Elevator	109869	.37	.483	0	1
kitchenette	109869	.353	.478	0	1
Bathrooms	82192	1.162	.4	-5	5
Balcony	109869	.752	.432	0	1
condition 1	109869	.173	.378	0	1
condition 2	109869	.027	.163	0	1
condition 3	109869	.067	.25	0	1
condition 4	109869	.032	.175	0	1
condition 5	109869	.054	.227	0	1
condition 6	109869	.034	.182	0	1
condition 7	109869	.282	.45	0	1
condition 8	109869	.031	.174	0	1
condition 9	109869	.002	.047	0	1
furnishing 1	109869	.216	.411	0	1
furnishing 2	109869	.283	.45	0	1
furnishing 3	109869	.033	.18	0	1
heating 1	109869	.06	.238	0	1
heating 2	109869	.064	.245	0	1
heating 3	109869	.128	.334	0	1
heating 4	109869	.015	.123	0	1
heating 5	109869	.03	.17	0	1
heating 6	109869	.383	.486	0	1
heating 7	109869	.055	.227	0	1
heating 8	109869	.006	.076	0	1
offer 1	109869	.104	.305	0	1
offer 2	109869	.037	.189	0	1
offer 3	109869	.718	.45	0	1
offer 4	109869	.112	.316	0	1
category 1	109869	.463	.499	0	1
category 2	109869	.02	.14	0	1
category 3	109869	.003	.055	0	1
category 4	109869	.05	.219	0	1
category 5	109869	.027	.163	0	1
category 6	109869	.013	.113	0	1

Table 7 Summary Statistics Apartment Purchase

	OLS-regression			Quantile-regression		
Price	(1)	(2)	(3)	(1)	(2)	(3)
Age	55.02**	-76.14***	-76.43***	60.65**	-185.3***	-181.5***
	(18.98)	(19.54)	(19.56)	(18.52)	(16.67)	(16.71)
Population Density	76.35***	77.19***	77.27***	62.37***	65.38***	65.28***
	(0.555)	(0.537)	(0.538)	(0.539)	(0.464)	(0.466)
Living Space	4970.2***	4612.6***	4553.8***	4401.6***	4070.5***	3986.3***
	(34.62)	(33.33)	(34.22)	(26.10)	(22.57)	(23.31)
Elevator	87769.4***	34525.4***	32554.4***	80608.0***	24432.3***	22617.6***
	(1299.8)	(1370.4)	(1395.8)	(1417.3)	(1346.2)	(1373.1)
Kitchenette	10015.8***	33095.2***	33960.5***	7001.7***	31364.7***	31772.9***
	(1314.4)	(1305.2)	(1317.9)	(1428.3)	(1323.4)	(1338.4)
Bathrooms	57052.0***	42640.6***	42511.0***	58001.4***	37113.8***	36505.0***
	(2727.7)	(2526.0)	(2532.8)	(1995.6)	(1699.7)	(1707.5)
Balcony	28050.1***	15406.4***	16241.6***	27152.8***	16083.4***	16243.9***
	(1557.6)	(1470.0)	(1467.4)	(1752.3)	(1506.1)	(1509.6)
Condition 1		79268.3***	67562.1***		77870.1***	66928.9***
		(3148.7)	(3166.7)		(3174.6)	(3195.1)
Condition 2		13012.1**	14236.8***		7683.6*	7496.8*
		(4287.3)	(4273.6)		(3811.3)	(3812.2)
Condition 3		63098.9***	61371.1***		53031.1***	51809.1***
		(3150.3)	(3130.0)		(2620.9)	(2621.9)
Condition 4		-9184.7**	-5871.3		-15835.3***	-12938.5***
		(3429.6)	(3432.1)		(3344.5)	(3357.1)
Condition 5		-22766.1***	-19490.7***		-21029.4***	-18956.3***
		(2559.1)	(2568.1)		(2708.1)	(2727.2)
Condition 6		-5977.0	-3619.3		-12092.0***	-12826.4***
		(3148.7)	(3166.7)		(3174.6)	(3195.1)
Condition 7		-17775.3***	-16004.5***		-19728.2***	-16004.5***
		(1790.5)	(1779.4)		(1836.5)	(1836.4)
Condition 8		-47032.7***	-44655.0***		-44856.2***	-42150.3***
		(3210.0)	(3199.3)		(3324.2)	(3325.2)
Condition 9		-26276.9***	-26891.8***		-18205.1***	-17915.6***
		(12655.6)	(12827.2)		(11488.7)	(11482.4)
Furnishing 1		-26276.9***	-26891.8***		-18205.1***	-17915.6***
		(1402.4)	(1409.9)		(1582.0)	(1595.3)
Furnishing 2		19083.3***	17629.6***		23798.8***	21990.5***
		(1740.8)	(1754.8)		(1633.4)	(1660.3)
Furnishing 3		106635.6***	104987.4***		75201.3***	75555.3***
		(5138.3)	(5148.9)		(3381.4)	(3396.6)
Heating 1		-7254.5**	-5085.2		-8647.2**	-7207.2**
		(2716.6)	(2708.4)		(2755.4)	(2761.6)
Heating 2		-18348.5***	-16402.7***		-25203.1***	-24389.0***

		(2713.6)	(2701.7)		(2642.8)	(2644.7)
Heating 3		34142.7***	31987.0***		28379.5***	26189.9***
		(2713.6)	(2701.7)		(2642.8)	(2644.7)
Heating 4		-27187.9***	-25075.4***		-21890.7***	-20012.3***
		(4338.5)	(4333.7)		(4652.4)	(4655.8)
Heating 5		17274.1***	15608.9***		24808.5***	22086.9***
		(3745.6)	(3728.9)		(3710.4)	(3714.2)
Heating 6		-8577.9***	-7201.3***		-7429.8***	-6010.1**
		(1887.4)	(1874.6)		(1879.3)	(1883.1)
Heating 7		-29407.9***	-27401.2***		-24799.9***	-21432.9***
		(2870.7)	(2850.3)		(2864.7)	(2864.4)
Heating 8		26692.4***	20010.7**		48447.0***	41455.1***
		(6391.4)	(6393.3)		(7625.6)	(7629.5)
Offer 1			8457.2*			19561.3***
			(3931.0)			(3866.4)
Offer 2			-10848.0*			-9830.8*
			(4389.0)			(4556.4)
Offer 3			12137.1***			16143.4***
			(3650.9)			(3528.8)
Offer 4			41458.4***			47810.2***
			(4130.3)			(3987.7)
Category 1			-12721.5***			10256.4***
			(1248.7)			(1287.5)
Category 2			-1323.9			-1425.8
			(1248.7)			(1287.5)
Category 3			10007.4			32422.7***
			(13085.4)			(9692.4)
Category 4			-17259.3***			-3189.8
			(3215.9)			(2642.6)
Category 5			54128.6***			63506.9***
			(4859.5)			(3529.4)
Category 6			-10084.1			-5965.6
			(5351.9)			(5343.5)
_cons	-296770.4***	-233193.3***	-235373.8***	-236815.4***	-233193.3***	-175657.6***
	(3641.9)	(3965.2)	(5268.0)	(3044.1)	(3212.6)	(4720.3)
N	69111	69111	69111	69111	69111	69111
R-sq	0.608	0.658	0.662			

Point estimates with standard errors in parentheses and the associated p-value: $***p < 0.01$; $**p < 0.05$; $*p < 0.1$

Figure 10 Density Functions Apartment Rents

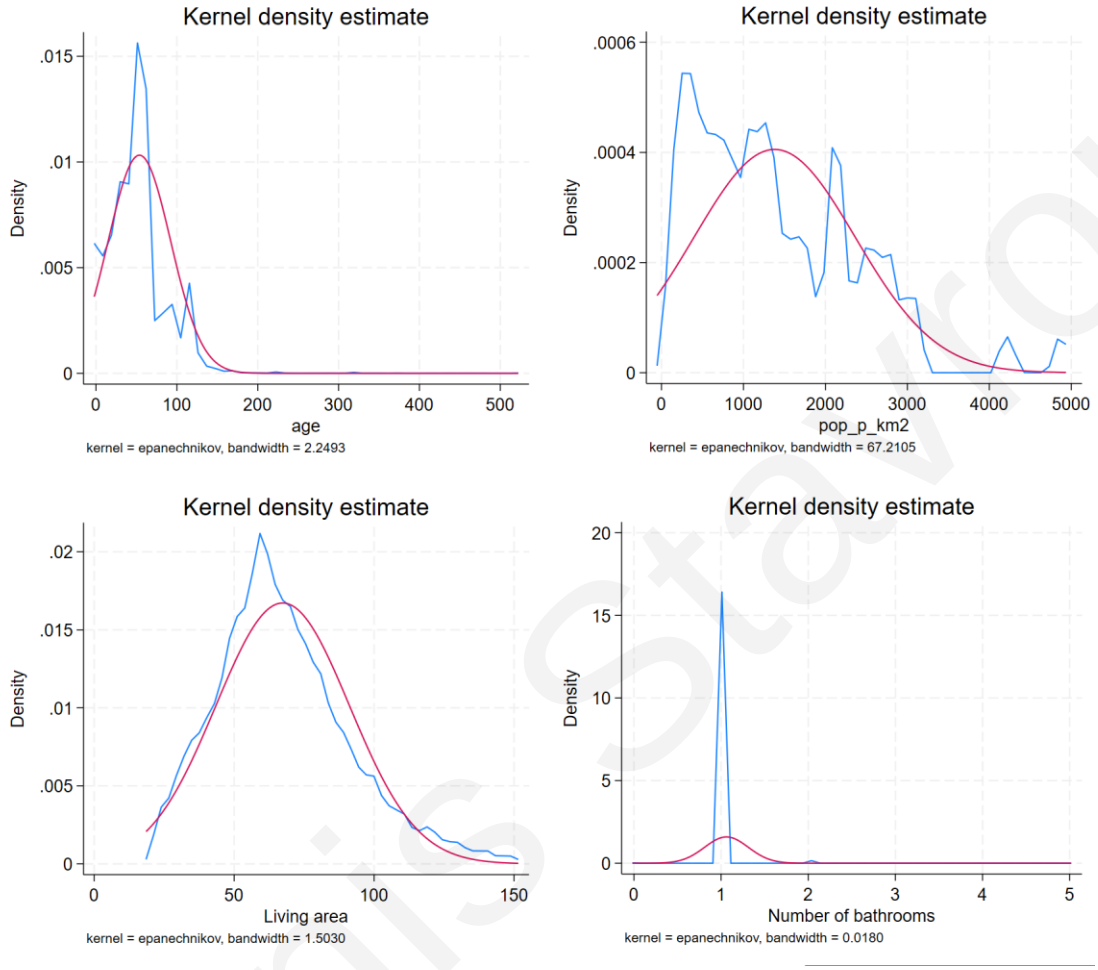

Figure 11 Density Functions House Price