ESSAYS IN THE ECONOMICS OF HOUSING POLICY AND MARKET DYNAMICS

by

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I dedicate this thesis to my family: my wife Miriam and my daughter Nala, my parents, my sisters, and my brother.

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ABSTRACT

This dissertation explores the effects of exogenous shocks on German housing market dynamics in three studies, focusing on the Berlin rent freeze, a real estate agent fee reform, and the energy price shock associated with the war in Ukraine in 2022. The dissertation empirically investigates how these policy changes and external shocks influence housing prices, housing supply, and broader market dynamics. The first study examines the effects of the Berlin rent freeze; a significant policy intervention introduced in 2020 to address housing affordability in one of Germany's most dynamic rental markets. Using a triple-difference methodology, the analysis reveals that while the rent freeze successfully reduced advertised rents, it also caused a significant contraction in the supply of rental dwellings. The effects were most pronounced in central districts with higher initial rent levels, highlighting the trade-offs inherent in rent control policies. The second study investigates the effects of a 2020 reform in Germany that restructured the payment of real estate agent fees (REAF). The law aimed to reduce transaction costs for homebuyers by implicitly mandating an equal split of fees between buyers and sellers. Employing a difference-in-differences framework, the findings indicate that while REAF reductions benefitted buyers of single-family houses in less competitive markets, they led to increased housing prices in high-demand areas, offsetting the intended cost savings. This highlights the nuanced implications of transaction cost reforms, particularly in tight housing markets. The third study explores the impact of the 2022 energy price shock, triggered by the geopolitical crisis in Ukraine involving Russia, on housing market valuations in Germany. The analysis demonstrates that less energy-efficient dwellings experienced a relative price discount in both rental and purchase markets. The findings underscore the growing importance of energy efficiency as a determinant of housing value and the need for targeted retrofitting policies to mitigate disparities. Across these three studies, the dissertation employs robust and quasi-experimental designs, including hedonic regressions and difference-in-differences methods, leveraging a comprehensive dataset covering the German housing market. The findings contribute to the literature on housing economics by illustrating how policy and external shocks shape market outcomes, with significant implications for affordability, supply, and energy sustainability. Policy makers are urged to consider the trade-offs highlighted in this research. For rent control, immediate affordability gains must be weighed against potential long-term supply constraints. In transaction cost reforms, the distributional effects across different market segments demand attention. Lastly, the energy efficiency analysis emphasises the need for measures to enhance housing stock sustainability while ensuring affordability for vulnerable groups.

Chapter 1 – INTRODUCTION

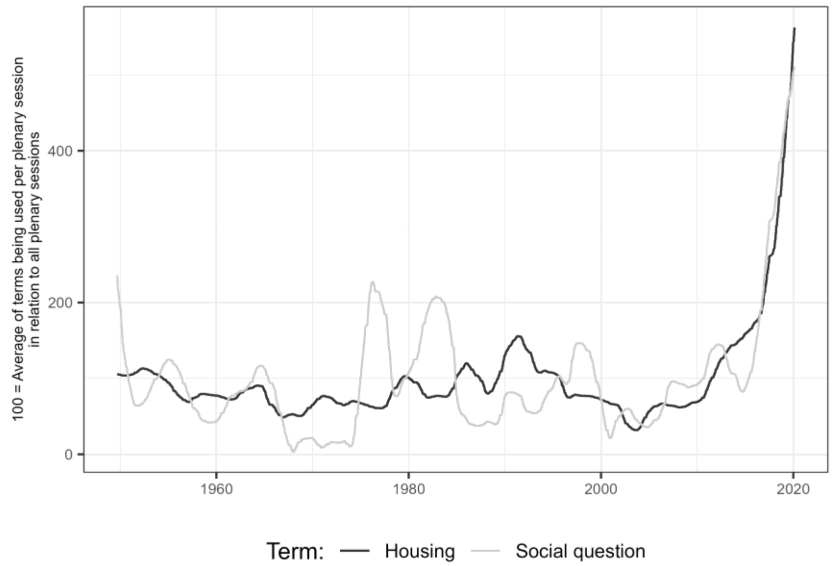
1.1 Motivation

This dissertation explores aspects of what policy makers in Germany have dubbed as "the social question of our time": housing (BMI, 2018). The quote is filled with preconceived notions. Housing is inherently social, as it pertains to society and the way we live or can live together. The ability to afford housing is considered a basic need, making it a socially important topic for debate and discussion (Mulroy & Ewalt, 1996). Beyond that, housing is also a "question", implying that there are yet unanswered issues to be addressed by society and policy makers. The former minister of the Interior, Building and Homeland, Horst Seehofer, put it in the following terms in a speech in the German parliament:

> "[…] We are providing the right answers to the key social question of our time: more rental housing, more home ownership, and affordable housing are the right answers to creating secure and appropriate living spaces." (Deutscher Bundestag, 2018, p. 5359)

Hence, there seem to be concrete answers to the housing "question": more rental housing, more home ownership, and affordable housing. These are the core challenges and objectives of housing policy. This dissertation addresses these through empirical research. In this motivational section, I want to highlight the key aspects of what it is that makes policy makers say, "Neither work nor pensions, no, housing is the social challenge of our time" (Deutscher Bundestag, 2018, p. 5373), and why the words "housing" and "social question" have been intertwined heavily in recent German political debates, as illustrated in Figure 1.1. What is more, this chapter serves to place the contributions of this dissertation within the broader scope of this socially highly relevant topic, recognising that research on housing, like any research field, is inherently multi-faceted.

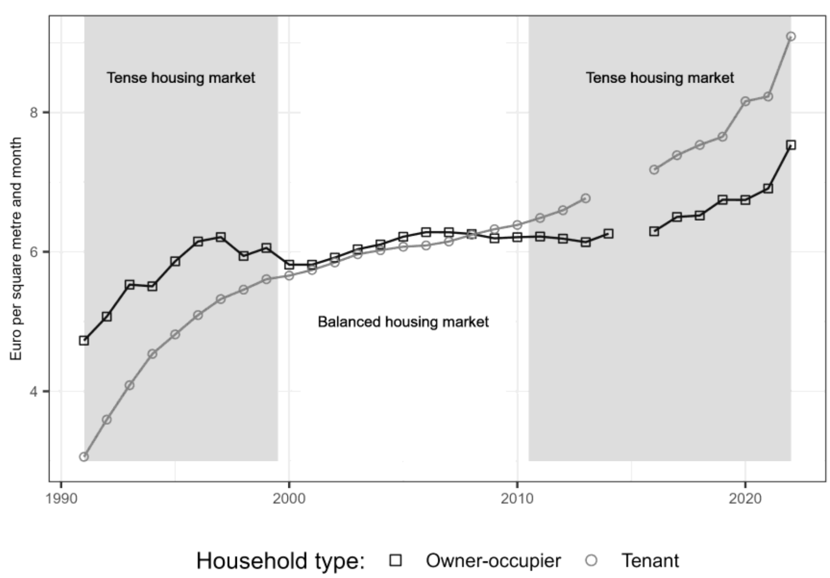
Figure 1.1: Frequency of "housing" and "social question" references in German parliamentary plenary debates



Notes: Fitted values from a LOESS regression with a smoothing span of 0.1. The timeframe depicted extends from 1949 to 2020. All plenary debates conducted in the German parliament during this period are considered. The values represent the frequency of term occurrences relative to the average across all plenary days. Higher values indicate that the terms were mentioned more frequently compared to all terms on the respective plenary day and relative to the overall average. A value of 100 means that the term was mentioned at an average frequency over the period considered. The German term analysed for "housing" is "Wohnen" and for "social question" it is "Soziale Frage".
Source: Author's illustration based on Sagner et al. (2020).

41.8 percent of German households, which is equivalent to approximately half of the population, are owner-occupiers, the other half are tenants (Federal Statistical Office, 2024a). Therefore, housing issues concerning either of the two groups are equally relevant for society, at least from a quantitative perspective. The housing market, during the time frame analysed in the three main chapters of this dissertation, which is the late 2010s to the early 2020s, can be considered as tense, as illustrated in Figure 1.2. Average housing expenditures for both, owner-occupiers as well as for tenants, increased strongly when compared to the 2000s. Brausewetter et al. (2024) highlighted that price increases in the 2010s were mainly driven by changes in the population density, i.e. purely quantitative increases in demand, changes in the local skill level, i.e. affordability-driven price increases, for the purchase market exacerbated by decreasing mortgage rates, as well as an increased interest by investors in the housing market. Kohl et al. (2019), Baldenius et al. (2020), as well as Holm et al. (2021) point out that while the German housing market has seen strong price increases, the average share of income spent on housing remained stable in the 2010s. These studies point out that the market price increases have not led to an increase in the share of income spent on housing, it even decreased moderately for sitting households, i.e. those households that have not moved recently. However, the households that have moved more recently spend an increasingly larger share of their income on housing as they face market conditions. The rise in market prices, both in the rental and purchase market, translates into increased entry barriers, effectively making it more financially challenging for those looking to move. As several vulnerable socio-economic groups, e.g. single-person households, pensioners, and the irregularly or marginally employed already spend a large share of their income on housing, and the gap between sitting households' housing cost burden and the one of the movers widened, policy makers intervened to make housing more accessible and affordable (Sagner et al., 2020).

Figure 1.2: Classification of the German housing market over time based on expenditures



Notes: This figure shows the nominal average monthly gross cold living expenditures for owner-occupier households and tenants. For owner-occupiers the total mortgage payments in addition to the cold ancillary costs (utilities) per month are considered. For tenants the gross cold rent, i.e. the net cold rent plus the cold ancillary costs, are considered. The period depicted extends from 1991 to 2022.
Source: Author's illustration based on Sagner (2021) and updated with SOEP v39 (2024) data.

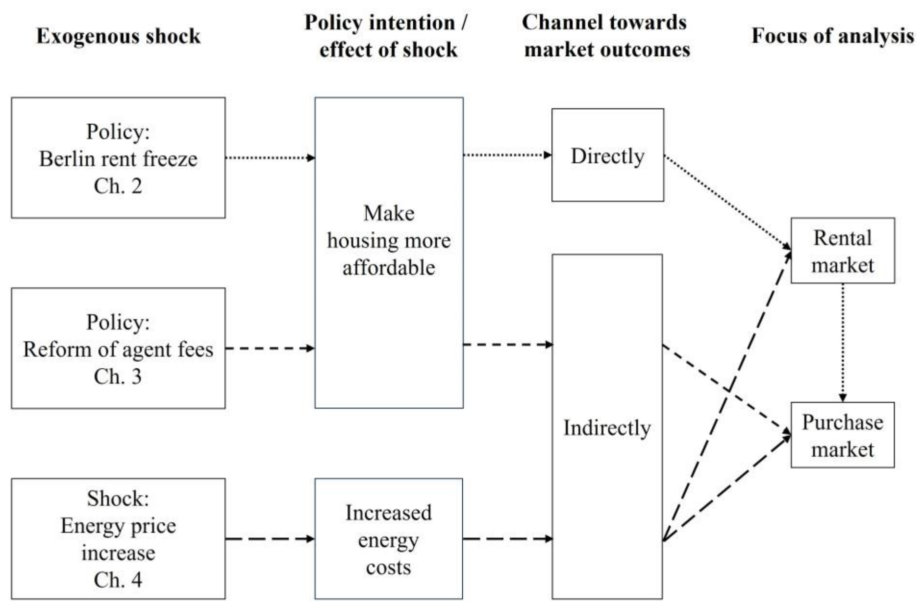
1.2 Aims and contribution

Building on the above motivation, the central aim of this thesis is to enhance understanding of how the German housing market reacts to policy interventions and external shocks. This dissertation explores two policy interventions that are targeted at making housing more affordable and an external shock that indirectly impacts the housing market and is closely related to recent trends in German housing policy. This thesis seeks to offer insights that inform policymaking in the context of the economic outcomes of housing policy and housing market dynamics, contributing to solutions for "the social question of our time" (BMI, 2018).

The conceptual framework of this thesis is illustrated in Figure 1.3. The three independent chapters of this dissertation are conceptually linked by several shared themes. Each chapter focuses on housing market dynamics, i.e. prices, quantities or both, following some sort of exogenous shock. The two policy interventions analysed are aimed at the housing market, with one directly targeting market outcomes and the other indirectly. Both policy interventions have the shared intention of making housing more affordable. The external shock analysed is a sudden and stark energy price increase which might affect market outcomes indirectly.

The research in the three chapters is aligned with assessing the effectiveness, meaning the intended consequences if there are any, i.e. only in the case of the policy interventions, and the unintended consequences of these external influences, on housing market dynamics. All three chapters examine and discuss the implications for key stakeholders in the housing market including tenants and landlords, homebuyers and sellers. Each chapter aims to establish causality between the respective exogenous shock and housing market outcomes. Each chapter will illustrate that the analysed policy interventions and external shocks directly affect only certain subgroups of the housing market, while other dwellings are either not affected at all or are significantly less affected. Hence, the three separate settings lend itself to apply variants of the difference-in-differences (DiD, diff-in-diff) design. This quasi-experimental approach to establish causality is widely adopted in analysing the effect of external shocks on housing market outcomes (Glaeser & Luttmer, 2003; Sims, 2007; Autor et al., 2014; Diamond et al., 2019). For the German housing market, it has been used extensively to analyse the effects of the rent brake (Deschermeier et al., 2016; Thomschke, 2019; Breidenbach et al., 2022).

Figure 1.3: Conceptual framework of the thesis



Notes: This figure shows the conceptual framework of the thesis. Dash types indicate the individual chapters and how the exogenous shocks affect market outcomes respectively.
Source: Author's illustration.

Finally, all three chapters make use of the same data source by Value Marktdaten. The Value Marktdaten database is among the largest and most established real estate market databases in Germany, serving as a key data source for the real estate industry as well as researchers. It is built on a comprehensive compilation of curated real estate market data from over 100 sources. The database offers nationwide real estate listing price data for residential and commercial properties, with updates daily. Each property entry includes comprehensive features for market analysis. The database includes detailed information for each property, such as location, dwelling type, area, price, quality, and age. Access to the data was obtained through a licensing agreement between the German Economic Institute (Institut der deutschen Wirtschaft, IW) and Value Marktdaten, under which the German Economic Institute pays a fee for data access. The data is not publicly available.

Next, the three chapters which make up the main body of this dissertation are summarised individually, their respective key findings are highlighted, then the methodological approach, the contribution to the literature, and the policy implications are outlined.

Overview of chapter 2: Supply Side Effects of the Berlin Rent Freeze

The chapter "Supply Side Effects of the Berlin Rent Freeze" is joint work with Michael Voigtländer and published in the *International Journal of Housing Policy* (Sagner & Voigtländer, 2022). The work in this chapter was awarded with the "Paper of the Year Award 2022/23" by the German Economic Institute, as selected by an external committee comprising Prof. Dr. Lothar Funk, Prof. Dr. Dr. h.c. Karl-Heinz Paqué, and Prof. Dr. Jens Südekum. The chapter provides an empirical analysis of one of the most significant housing policy interventions in recent German history: the Berlin rent freeze. Implemented in February 2020, the rent freeze (in German: "Mietendeckel") aimed to address affordability challenges by capping rents for existing leases and regulating permissible rent levels for new rentals. However, the policy was short-lived, as it was ruled unconstitutional in March 2021. This study examines the short-term impacts of the rent freeze on housing prices, supply, and market dynamics, offering valuable insights into the unintended consequences of rent control measures. This work was further explored in a research project funded by the Friedrich-Naumann Foundation (Sagner & Voigtländer, 2024). In this research the methodology is extended to an event study design and long-run effects after the abolishment of the Berlin rent freeze are analysed and discussed in a broader Germany-wide setting.

Key findings

The study finds that while the rent freeze successfully reduced advertised rental prices in Berlin, it also triggered significant reductions in the supply of rental housing. Public rental listings in Berlin dropped by up to 60 percent in some areas, as many landlords either withdrew properties from the rental market or likely delayed letting decisions in response to the policy. The analysis reveals that the rent freeze had the largest impact on rents and rental supply in central districts with higher rent levels and price increases before the introduction of the law, with a positive correlation between rent reductions and supply decreases, supporting the textbook principle that stricter rent ceilings in relation to market prices lead to stronger adverse quantity effects.

Methodology

The study analyses the effects of the Berlin rent freeze on rental and purchase prices as well as supply making use of a comprehensive real estate dataset. To identify the causal effect of the policy on housing market dynamics, three different approaches are discussed and adopted. As the policy only applied to a subset of the total housing stock in Berlin, two different difference-in-differences approaches are applied: one approach compares dwellings that are subjected to the rent freeze in Berlin with dwellings that would be subjected to the rent freeze if they were in Berlin but are located in the six other largest German cities, namely Cologne, Düsseldorf, Frankfurt am Main, Hamburg, Munich, Stuttgart. The second difference-in-differences approach compares dwellings within Berlin only: those that are subjected to the rent freeze and those that are exempt. As both approaches come with their respective endogeneity concerns, a triple-difference approach is used to enhance robustness of the findings by using both, within-Berlin comparisons and across-city comparisons. The study incorporates dwelling-specific characteristics such as size, location, and age within a hedonic regression framework, aiming to effectively control for variations in market dynamics unrelated to the rent freeze.

Contribution to the literature

This paper contributes to the literature and ongoing debate regarding rent control policies (Kholodilin, 2024; SVR, 2024, pp. 270). It provides evidence that rent freezes combined with a rent cap, while, per construction, effective in lowering rental prices in the short-term, can have severe unintended consequences for housing supply. The study highlights the trade-off inherent in such policies: achieving affordability at the expense of market availability.

Policy implications

The findings of this research are particularly relevant for policy makers navigating the delicate balance between affordability and housing market stability. The Berlin case illustrates that while rent control may seemingly offer immediate relief for tenants in the form of lower rents, it risks exacerbating supply shortages in already constrained markets. This insight is critical for cities considering similar interventions, as it emphasises the need for policies that address affordability without undermining supply, such as incentivising new construction or targeted subsidies.

Overview of chapter 3: Housing Price Spillovers After Real Estate Agent Fee Reduction: Evidence from the German Housing Market

The chapter "Housing Price Spillovers After Real Estate Agent Fee Reduction: Evidence from the German Housing Market" is single-author work. A condensed version of this chapter is undergoing a second round of revisions for publication in *Housing Studies* at the time of this dissertation. The paper investigates the effects of a significant policy change in Germany: the introduction of the "Law on the distribution of real estate agent fees when brokering purchase contracts for apartments and single-family houses" in December 2020. This legislation aimed to reduce transaction costs for homebuyers. The law prohibits real estate agents from charging fees to non-hiring parties when the hiring party does not pay a fee. If both the buyer and seller hire an agent, the law mandates an equal split of the fee between them. The study explores how this policy affected housing market dynamics and discusses who benefitted from the reform: buyers, sellers, or real estate agents.

Key findings

The findings reveal that the law led to a significant reduction in the REAF for buyers. However, this reduction translated into increased housing prices, particularly for apartments in high-demand markets, effectively offsetting the benefits for buyers. Single-family houses and dwellings in less sought-after housing markets experienced smaller or no price increases. In these markets, buyers are likely better off after the introduction of the law, as their overall cost of purchase decreased. Sellers of apartments, especially in tense housing markets, on the other hand, profited from higher sales prices which offset the REAF they likely had to pay after the reform, while real estate agents may have indirectly benefitted due to higher overall transaction values.

Methodology

The study evaluates the effects of a real estate agent fee reform on housing prices and market dynamics. Using a hedonic difference-in-differences regression framework, the analysis aims to capture the causal impact of the reform by comparing changes in housing prices before and after the reform between treated and control groups. Two distinct approaches to the diff-in-diff framework are applied to enhance robustness and provide a nuanced understanding. The first approach uses a binary treatment assignment, dividing the data into treated and untreated dwellings based on whether a property is offered with a REAF for the buyer or not. This method aims to capture the overall effect of the reform on the targeted segment of the housing market. The second approach supplements the first and introduces a continuous treatment assignment, which incorporates variations in the intensity of the reform's impact on the REAF for the buyer. The two approaches are complemented by an event study design to investigate intertemporal dynamics. By leveraging a comprehensive dataset of real estate listings, the study incorporates dwelling-specific characteristics, such as size, location, and type, to control for confounding factors.

Contribution to the literature

This paper contributes to the body of research on transaction costs, housing market regulation, and capitalisation of housing subsidies into market prices. The paper demonstrates how a reduction in buyer-side transaction costs can result in upward pressure on housing prices, especially in high-demand housing markets. By differentiating between housing types and market conditions, the study uncovers nuanced impacts of transaction cost reforms on stakeholders.

Policy implications

The study highlights the risk of unintended consequences in transaction cost reforms, such as price pass-through, and emphasises the need for complementary measures to address affordability challenges, for example in the form of supply-side incentives. The differentiated impacts on buyers and sellers suggest that market dynamics, bargaining power, and demand elasticity play a critical role in shaping policy outcomes.

Overview of chapter 4: Energy Price Shock and Housing Market Dynamics: Evidence from Germany

The chapter "Energy Price Shock and Housing Market Dynamics: Evidence from Germany" is single-author work and is undergoing review for publication in *Journal of Housing Economics* at the time of this dissertation. The chapter investigates the effects of the 2022 energy price shock, triggered by Russia's invasion of Ukraine, on housing market dynamics in Germany. The study specifically examines how rising energy costs influenced the valuation of energy-efficient versus less energy-efficient dwellings. The paper provides insights into the growing importance of energy efficiency in the housing market.

Key findings

The analysis finds that less energy-efficient dwellings (LEED, rated below A on Energy Performance Certificates) experienced relative price declines in the purchase and rental market compared to more energy-efficient dwellings (MEED, rated as A and A+) after the energy price shock associated with Russia's invasion of Ukraine. LEED saw a relative price decline of up to 8.9 percent in the purchase market within two years of the energy price shock. In the rental market, the relative price gap between MEED and LEED widened also, with energy-efficient dwellings commanding an additional rental price premium of 3.3

percent. An analysis on a more granular energy efficiency level highlights that the green premium, i.e. the premium relative to the median energy efficiency, has increased strongly.

Methodology

In the main identification strategy, the study employs a difference-in-differences regression framework within an event study design, using a comprehensive housing market dataset where two distinct groups are analysed. The treated group (LEED) are dwellings with lower energy efficiency while the control group (MEED) are highly energy-efficient dwellings. This approach aims to isolate the causal effects of the energy price shock by comparing price trends for these groups before and after the shock. The methodology controls for time-invariant differences and common time trends, incorporating fixed effects for postal codes, region types, and housing characteristics such as dwelling size, type, and construction year. Additionally, several extensions to analyse treatment heterogeneity are considered.

Contribution to the literature

This paper contributes to understanding how energy costs shape housing market dynamics. The study provides empirical evidence of rising price advantages for energy-efficient dwellings following an energy price shock. Regional and property-specific variations underscore the complex interplay between energy efficiency and market outcomes.

Policy implications

The findings emphasise the need to support energy-efficient renovations to mitigate the growing market penalty for less efficient dwellings. Policies such as subsidies, low-interest loans, and expanded Energy Performance Certificates can enhance energy efficiency across the housing stock. Additionally, measures to ensure affordable access to energy-efficient rental dwellings are essential, particularly for low-income households facing rising rental premiums for more energy-efficient dwellings.

1.3 Outline

The rest of the thesis is structured as follows. The main body of the dissertation is made up of three self-contained chapters. While the appendices for each chapter are placed directly after each chapter, the dissertation includes a unified bibliography at the end of the main body.

Chapter 2 investigates the supply side effects of the Berlin rent freeze in the short-term. The chapter begins with the abstract and an introduction. After that, in chapter 2.3 the institutional background regarding recent regulatory policy interventions in the German rental market is outlined and the rental price development in Germany and specifically Berlin is highlighted, then the basic structure of the Berlin rent freeze is introduced. In chapter 2.4, the data and methodology for the analysis are illustrated, and the main hypotheses to be explored are motivated. The identification strategy is discussed, and based on possible endogeneity concerns, the set of chosen strategies is explained. Chapter 2.5 includes the main results of the difference-in-differences and triple-difference regressions, additionally, results from heterogeneity analyses are illustrated. The last chapter discusses the findings in the light of the main hypotheses and concludes with policy implications.

Chapter 3 investigates housing price spillovers after the introduction of a new law targeting real estate agent fees. After the abstract and an introduction, the institutional background on real estate transaction costs in Germany and the change in the legislation are outlined in chapter 3.3. Thereafter, the data setup and descriptive findings on the effectiveness of the law are illustrated in chapters 3.4 and 3.5. In the empirical analysis in chapter 3.6, first, the main hypothesis and its corollaries are introduced, and then the identification strategy is outlined. Chapter 3.7 places this work within the related literature. The main results as well as heterogeneity analyses and robustness checks are presented in chapter 3.8. The implications for the key affected parties of the reform are presented in chapter 3.9, and conclusions are drawn in chapter 3.10.

Chapter 4 examines the impact of the energy price shock triggered by the Russian invasion of Ukraine in 2022 on German housing market dynamics. After the abstract and introduction, the analysis is further motivated, and background information on the German housing market's dependence on fossil fuels is presented in chapter 4.3. The paper's contribution to the literature is discussed in chapter 4.4. Chapter 4.5 introduces the data analysed and contains descriptive evidence on energy consumption in the German housing market and its relation to a dwelling's price. After the outline of the identification strategy, the results are presented in chapter 4.7. The main effects are highlighted, along with the presentation of model extensions and results of heterogeneity analyses, lastly volume effects are presented. The chapter concludes with a discussion of the findings and policy implications in chapter 4.8.

Chapter 2 – Supply Side Effects of the Berlin Rent Freeze

Notes: This chapter is joint work with Michael Voigtländer and published as: Sagner, P., & Voigtländer, M. (2022). Supply side effects of the Berlin rent freeze. *International Journal of Housing Policy*, 23(4), 692–711. This work was awarded with the "Paper of the Year Award 2022/23" by the German Economic Institute, as selected by an external committee comprising Prof. Dr. Lothar Funk, Prof. Dr. Dr. h.c. Karl-Heinz Paqué, and Prof. Dr. Jens Südekum. This work was further explored in a research project funded by the Friedrich-Naumann Foundation (Sagner & Voigtländer, 2024). In this research the methodology is extended to an event study design and long-run effects after the abolishment of the Berlin rent freeze are analysed and discussed in a broader Germany-wide setting.

2.1 Abstract

On 23 February 2020, the Berlin Senate introduced the Berlin rent freeze ("Mietendeckel"). The law was repealed on 25 March 2021. The Berlin rent freeze was an unprecedented market intervention in the German housing market. We analyse how the rent cap part of the legislation which fixed rents at below market levels affected the supply side in the short-term. We find rent decreases accompanied by decreases in supply five times as large. We further investigate spillover effects on the purchase market, regionally heterogeneous effects as well as different effects by dwelling characteristics. We find the rent freeze did not have spillover effects on dwellings for sale which points to a "wait-and-see-attitude" on the investors' side. We make use of a rich dataset of real estate advertisements and employ hedonic difference-in-differences and triple-difference estimation strategies.

2.2 Introduction

Germany has experienced a remarkable boom in housing prices in the 2010s. Rental prices in the seven biggest cities increased by more than 55 percent between 2010 and 2020 (Deutsche Bundesbank, 2021). In the noughties, by contrast, rental increases were stagnant in real terms. The development since then can be explained by two reasons. First, housing demand increased as labour markets in Germany boomed. Specifically, in the big cities more high-qualified jobs were created, similar to other countries like the United States (Moretti, 2012). The job creation increased migration to the big cities, attracting highly qualified workers from abroad as well as from more rural parts of Germany. Second, the increased demand was not met with appropriate construction activities. Although construction increased throughout the late 2010s, Henger and Voigtländer (2019) estimate that in the big cities only between 50 and 86 percent of dwellings needed were built.

The situation in Berlin is especially tense and unique. Due to the Berlin Wall, which had split the city into two parts, central locations in Berlin have developed differently from other metropolitan cities around the world. After re-unification in 1989/90, economic growth in Berlin was only moderate, so that rents even in these central locations like Mitte, Friedrichshain or Kreuzberg developed just slowly. After the global financial crisis in 2007/08 the situation changed. Berlin attracted more and more start-ups and highly qualified workers (OECD, 2018). During the 2010s, the population in Berlin grew by more than 10 percent and demand for centrally located apartments surged, hence rents increased considerably. This, however, led to social tensions between parts of the population that benefitted only marginally from the booming economy – despite the economic growth, the unemployment rate in Berlin is still considerably above the national average – and the often highly qualified and well-paid workers who came from other national regions or countries.

Consequently, public demand for new regulations in the Berlin housing market is high. The Berlin senate responded by introducing a new rental regulation, the so-called "Mietendeckel" or Berlin rent freeze. The rent freeze is a rental price cap, not only including a rental increase stop for five years, but also forcing landlords to lower rents if they exceed the reference rents which are based on the rent tables of 2013. If current rents exceed these reference rents by more than 20 percent, the rent must be lowered for the sitting tenant. In addition, in case of a new contract, the reference rent shall not be exceeded.

In this paper, we analyse how the supply of rental offers and rental prices for new rental contracts were affected by the Berlin rent freeze in the first months after the introduction until October 2020. Additionally, we investigate spillover effects on the ownership market. As the analysis makes use of asking data, we cannot comment on the rent freeze's effect on the rents of sitting tenants. Long-term effects, for instance on the quality of the housing stock, which should be expected as a consequence of such a policy (Turner & Malpezzi, 2003), cannot be analysed as the period under question is too short. What is more, the rent freeze legislation was overturned by the German constitutional court on 25 March 2021. During the time frame analysed in this paper there was considerable uncertainty about the consistency of the legislation with the constitution. This uncertain legal situation might explain some of our findings regarding the spillover effects on the ownership market or rather the lack of expected spillover effects. Thus, supply side reactions analysed in this paper are based on an uncertainty about the regulatory framework, therefore the study can be regarded as a first (short-term) analysis on the impact of the rent freeze on the supply side.

The paper is structured as follows: First, the institutional background and the regulation are explained, then the data and methodology are discussed. We use a sophisticated hedonic triple-difference approach to analyse the effects of the rent freeze. After that, the findings are presented. Finally, the results are summarised and discussed.

2.3 Institutional background

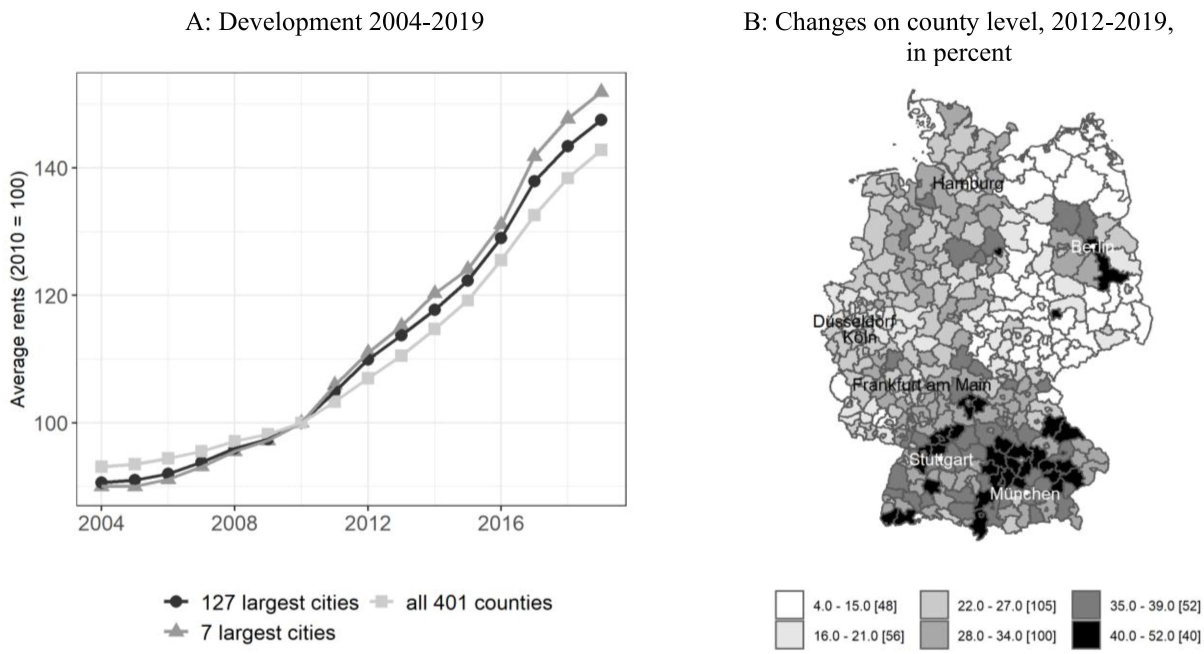
A total of 53.5 percent of households in Germany live in rented apartments making it a country with one of the highest shares of renters in Europe (Voigtländer, 2009; Kohl, 2017; Kaas et al., 2021). In Germany's big cities, the share of renters is even larger; in Berlin, 83 percent of its 2 million households rent their dwelling (Federal Statistical Office, 2019).

A high demand for housing has led to strong rental price increases in Germany during the last decade (Egner & Grabietz, 2018). These rent increases were not exclusively concentrated on larger cities and their surrounding suburban regions (see Figure 2.1). Economic hotspot areas mainly located in Southern Germany saw the largest rent increases. However, Germany's largest cities, especially the seven biggest cities, sometimes called A-cities, Berlin, Cologne, Dusseldorf, Frankfurt am Main, Hamburg, Munich, and Stuttgart, are of special interest to policy makers in terms of rental price regulation due to their large populations and high share of renters.

2.3.1 Regulatory policy interventions in Germany: Rent brake

The nationwide rent increases have led to the adoption of the so-called rent brake across many German municipalities (Deschermeier et al., 2016). The rent brake is aimed at newly agreed rents in tight housing markets. A municipality can be declared to have a tight housing market by its respective state government since 1 June 2015, if one of four conditions is met: (a) rents increase more than the national average, (b) rent burden is higher than the national average, (c) residential population is growing without the necessary living space being created through new construction activity, (d) low vacancy rate with high demand for housing (German Civil Code (BGB), 2021, § 556d). As these conditions are very broad, many municipalities have been declared to have tight housing markets covering a large share of the German population. Under the rent brake, newly agreed rents are not allowed to be higher than 10 percent above the local rent index. This does not apply to dwellings built after 1 October 2014 or dwellings that were modernised comprehensively.

Figure 2.1: Average rental prices in Germany



Notes: B: number of counties in respective groups in parentheses.
Source: Authors' calculations based on Deutsche Bundesbank (2021), Value Marktdaten.

According to a meta-study by Michelsen and Mense (2019) most studies on the German rent brake find a moderate slowdown in rent increases caused by the rent brake. Deschermeier et al. (2017) find that the rent brake has decreased rents in Berlin for the subjected dwellings by 2.7 percent. A more recent study by Thomschke (2019) assesses the effects of the rent brake on rents in some of the largest cities. According to his study, the price-dampening effect can be as high as 5 percent in Berlin, Hamburg, and Munich, while no effects were found in Cologne and Dusseldorf. He adds that the price effects fall short of the expected effects almost everywhere. Before the introduction of the rent freeze, Berlin, as well as the reference cities included in the following empirical analysis, were subjected to the rent brake.

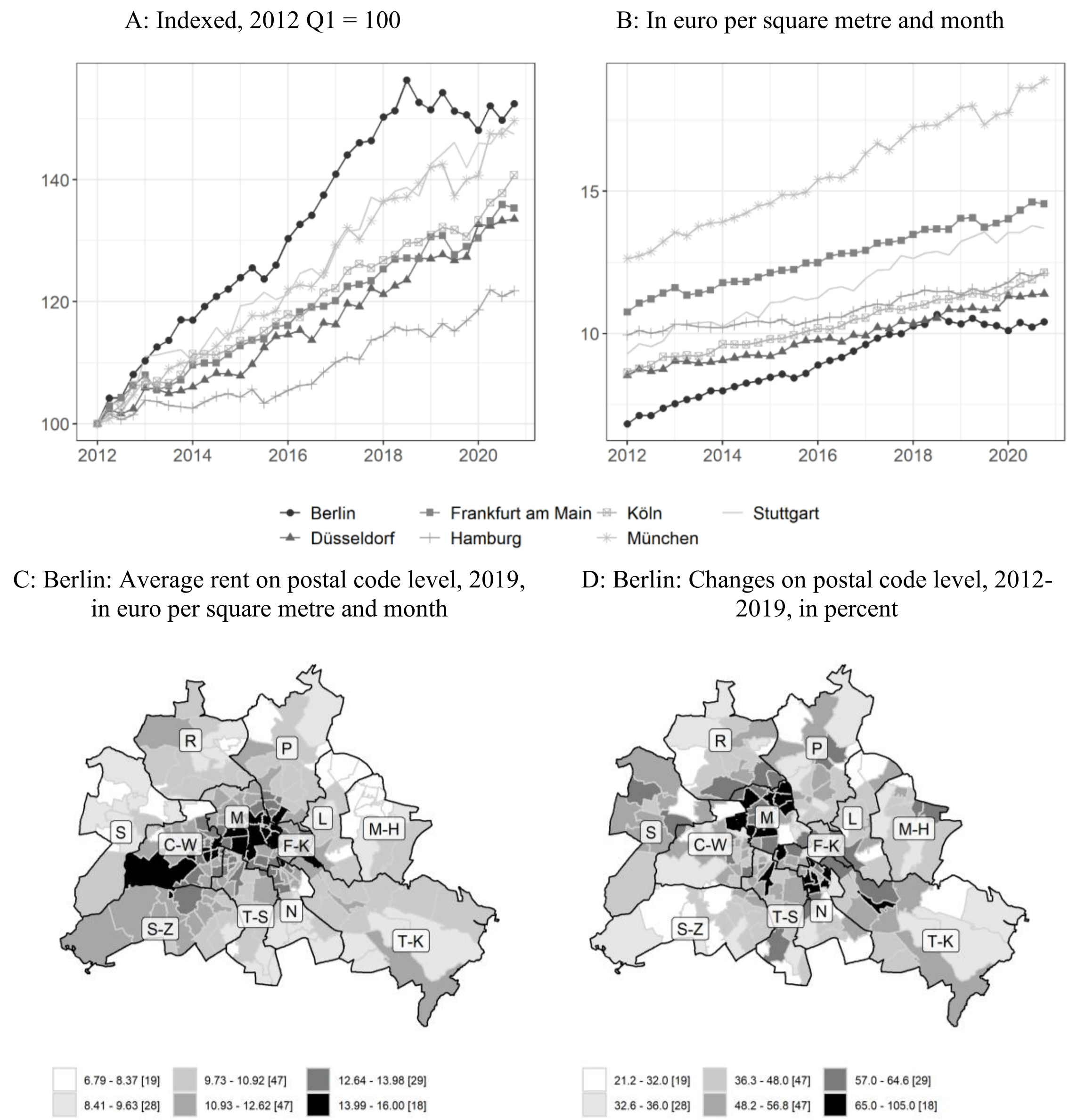
2.3.2 Rental price development in Berlin

The rental increases in Berlin during the 2010s were among the largest in Germany. Between 2012 and the beginning of 2018 average asking rents increased by more than 50 percent (see Figure 2.2.A). In Berlin, newly agreed rents affect 6 percent of households per year (Techem, 2018). Even though rental price increases in Berlin were large, the rent level remains relatively low when compared to the six others among the seven largest cities in Germany (see Figure 2.2.B). Average new rents in Munich, the most expensive city of the seven and one of the most expensive regions in all of Germany, are roughly 80 percent higher than in Berlin. Rent levels as well as rental price increases are heterogeneous within the city (see Figure 2.2.C and Figure 2.2.D). Rent levels are highest in the central districts Mitte and Charlottenburg-Wilmersdorf. Price increases are also highest in the more central areas of the city but affect formerly less expensive districts in Neukölln and Friedrichshain-Kreuzberg also. The increases in rents drove public unease and demand for political action. The Berlin Senate has adopted regulatory policies aimed at slowing down the increase in rents, with the most drastic measure being the rent freeze.

2.3.3 Regulatory policy intervention in Berlin: Rent freeze (and cap)

The “Law on the Revision of Legal Provisions regarding Rent Limitation” came into effect on 23 February 2020 (Schirmer & Städele, 2020). Informally the law is called the Berlin rent freeze (“Mietendeckel” in German). In addition to freezing the rents for existing leases at a reference date, i.e. 18 June 2019 when the law was announced, the legislation included rent ceilings for both new and existing rents. The law was repealed on 25 March 2021 as the German constitutional court ruled the rent freeze violated the German constitution because the federal government had already passed a rent-regulating law, the rent brake, and Berlin’s senate was not to infringe on that (Bundesverfassungsgericht, 2021).

Figure 2.2: Average net rent in Berlin compared to other large cities and within-city variation of levels and changes (nominal)



Notes: The twelve Berlin districts are outlined in black, and the abbreviations correspond to the following names: C-W: Charlottenburg-Wilmersdorf, F-K: Friedrichshain-Kreuzberg, L: Lichtenberg, M-H: Marzahn-Hellersdorf, M: Mitte, N: Neukölln, P: Pankow, R: Reinickendorf, S: Spandau, S-Z: Steglitz-Zehlendorf, T-S: Tempelhof-Schöneberg, T-K: Treptow-Köpenick. All rents and changes in nominal terms. Source: Authors' calculations based on Value Marktdaten.

The law applied to dwellings in Berlin only, including but not limited to single-family or semi-detached houses as well as furnished apartments or short-term rentals. The law did not apply to dwellings that first became ready for occupancy after 2013, publicly subsidised housing, apartments that were modernised through public funds, or student housing, such as dormitories, and apartments that were rented out by welfare organisations.

The rent ceiling part of the legislation had two functions: it was an upper rent limit and a reference point for rent reductions for sitting renters. The legal rent level depended on the dwelling's year of construction and fit-out standard. Legal rent levels ranged from 3.92 euro per square metre and month for an apartment without central heating and own bath built before 1918 to 9.80 for an apartment built from 2003 to 2013. These rents were based on the 2013 Berlin rent index adjusted to reflect changes in real wages since then. Exemptions allowed for a higher rent than the base level. E.g. if the apartment qualified as having a "modern fit-out", an additional 1 euro per square metre and month could be charged. After 23 February 2020 new rents were not to exceed the respective rent cap levels.

While the rent brake regulation is in place in several German municipalities and represents a modern form of rental regulation as it limits rent increases (also called second-generation rent control), the rent freeze applied to Berlin only. As it set strict upper limits on rents it can be labelled a first-generation rent control policy (Turner & Malpezzi, 2003; Arnott, 1995).

2.4 Data and methodology

2.4.1 Data

In the following empirical analysis, we make use of rental and purchase asking price data on a dwelling level provided by Value Marktdaten (formerly Empirica Systeme), a consolidator of online real estate offers. Value Marktdaten collects data from real estate advertisements in more than 100 sources. Data from all major online platforms is included. Using asking price data means that we cannot comment on actual transaction prices. However, making use of asking prices is common practice in research on the German housing market (Deschermeier et al., 2016; Thomschke, 2019; Breidenbach et al., 2022). It also means that we cannot comment on possible decreases in sitting renters' rents. Our data covers the seven largest cities in Germany: Berlin, Cologne, Dusseldorf, Frankfurt am Main, Hamburg, Munich, and Stuttgart. The choice of the six cities beyond Berlin is due to the similarities these cities share with Berlin regarding their market size, price levels and dynamics, as well as socio-economic and demographic indicators (Wiersma et al., 2022). The data in our analysis includes offers from January 2016 until October 2020. The data is summarised in Table 2.A.1 in the appendix.

For us to identify the causal effect of the introduction of the rent freeze on quantity and prices of advertised dwellings, we need to split our dataset into those dwellings subject to the rent freeze and those that are exempt. As outlined above, apartments that were ready for first occupancy after 2013 are generally not subjected to the legislation. Dwellings built prior to 2014 but remodelled and renovated extensively to an as-new level are also not subjected to the rent freeze. We make use of an identifier variable supplied by the data provider to identify those dwellings.

2.4.2 Hypotheses

Our four main hypotheses can be linked directly to Arnott (1995) and his textbook example of the effects of first-generation rent control on market supply. The first hypothesis is the most obvious to expect. If rents are fixed below the market price the quoted rents under the rent freeze legislation should be lower than before the introduction of the rent freeze. Hence, we expect to find a negative effect of the rent freeze on quoted rents (H1). Secondly, we might observe effects on the purchase prices of affected dwellings (H2). Regarding hypothesis (H2), our a priori assumptions are unclear. In the short-term, sellers might try to realise higher market prices, based on rental prices before the introduction of the rent freeze. In the medium term, prices could decrease as the dwellings' value based on discounted future rents decreases. Additionally, potential effects on purchase prices as well as the number of dwellings offered for sale depend on whether investors and owners expect the rent freeze to be legally binding in the long run. We test whether the rent freeze influenced the number of affected dwellings offered for rent (H3). We expect to find a negative effect. There are at least two reasons why:

first, the uncertain legal status of the rent freeze might lead landlords to hold vacant properties off the market until the legal status is clear, second, sitting tenants have an incentive to stay in their current flats, as their rent is likely to decrease under the rent freeze. We expect a positive effect on the number of apartments offered for sale (H4). This hypothesis is motivated by Diamond et al. (2019) who find that rent regulation in San Francisco led to an expansion of the owner-occupier market over time. As we analyse asking data, our hypotheses are focusing on supply-side effects only and are summarised below:

(H1) Negative effect on the quoted rents for affected dwellings.
(H2) Positive or negative effect on the price of affected dwellings offered for sale.
(H3) Negative effect on the number of affected dwellings offered for rent.
(H4) Positive effect on the number of affected dwellings offered for sale.

2.4.3 Identification strategy

To evaluate the effects of the rent freeze on the dwellings in question, a difference-in-differences (diff-in-diff) approach can be adopted. Regarding the effect of implementing a rent freeze on rents, for example, the basic idea of a diff-in-diff approach is that the rents in the regulated market would have developed the same as in the unregulated market, had the rent freeze not been implemented. Hence, the effect of the policy intervention is the difference in the rents of the dwellings in question after the implementation of the rent freeze and before, minus the same difference for the properties that were not subjected to the rent freeze. In its simplest form, this diff-in-diff approach can be summarised formally as

$$did = \left(\bar{y}_{tr,post} - \bar{y}_{tr,pre}\right) - \left(\bar{y}_{cntr,post} - \bar{y}_{cntr,pre}\right), \quad (2.1)$$

where $\bar{y}$ is the respective group mean, tr indicates the treated group, $cntr$ indicates the control group, pre and $post$ stand for the time before and after the policy intervention, i.e. the introduction of the rent freeze. The diff-in-diff approach is widely applied in estimating the causal effects of rent regulation on supply and demand (Glaeser & Luttmer, 2003; Sims, 2007; Autor et al., 2014; Diamond et al., 2019) and is one of the principal identification strategies in applied economics (Bertrand et al., 2004; Angrist & Krueger, 1999; Athey & Imbens, 2006). As policy interventions aimed at the rental market have become more frequent in Germany and other European countries in recent years (Kettunen & Ruonavaara, 2020), so have studies evaluating their causal effects (Deschermeier et al., 2016; Thomschke, 2019; Breidenbach et al., 2022).

The Berlin rent freeze legislation applies only to specific dwellings in Berlin, which gives us two possible ways to set up our treatment and control groups in a diff-in-diff setting. One option would be to restrict our data to (theoretically) treated dwellings only. In our case the control group would then be comprised of dwellings in the other six of the seven largest cities that would be subject to the rent freeze were they in Berlin and the treatment group is made up of dwellings subjected to the legislation in Berlin.

A second identification approach would be to restrict data to dwellings within Berlin only. The treatment group would then be made up off dwellings subjected to the new legislation, and dwellings not subjected would constitute the control group; all dwellings would be in Berlin.

Extending Equation 2.1 to a hedonic regression framework (Sheppard, 1999), we can write this as

$$y = \beta_0 + \beta_1 D_{post} + \beta_2 D_{tr} + \beta_3 D_{post} D_{tr} + \beta_4 X + \varepsilon, \tag{2.2}$$

with y as the dependent variable, e.g. rental or sales price per square metre, or the number of offers. β_0 captures the estimated population mean in case of no treatment (i.e. $D_{tr} = 0$) before the rent freeze was introduced (i.e. $D_{post} = 0$); β_1 captures the change over time for the control group (i.e. $D_{tr} = 0$); β_2 is simply the expected difference in the levels between the treatment and control group prior to the treatment. The diff-in-diff effect is then captured by β_3 as this is the difference in the change over time between treated and untreated while considering the ex-ante differences in levels between the treated and untreated. The regression setup allows us to include a set of hedonic covariates describing the dwelling's characteristics as indicated by the vector X. ε captures the error-term.

2.4.4 Possible concerns regarding assumptions

Both identification strategies discussed above come with concerns regarding endogeneity. An unbiased estimate of β_3 hinges on the assumption that the dependent variable in the unfrozen market segment would have developed the same as in the frozen segment, had the rent freeze not been introduced.

If we were to restrict our sample to dwellings that are subjected to the rent freeze in Berlin and our control cities, a possible endogeneity concern might be that rental price development in Berlin has been substantially different from changes in the other cities. If this "parallel path assumption", as it is sometimes called, was violated, our diff-in-diff estimate would be biased.

If we were to restrict our sample to observations within Berlin only, we would have to assume that our dependent variable was to develop the same for the subjected dwellings had they not been subjected as for the subjected. In case of prices, this assumption might be challenged as the dwellings that are exempt from the rent freeze are also exempt from the rent brake, making it less likely that they would follow a parallel time trend. Hence, both identification strategies suffer from potential endogeneity concerns. To overcome these concerns, we, in addition to estimating both possible diff-in-diff strategies, follow Breidenbach et al. (2022) and apply a triple-difference estimator (Berck & Villas-Boas, 2016) by combining both diff-in-diff approaches described above. Formally,

$$\begin{aligned} y = \beta_0 + \beta_1 D_{berlin} + \beta_2 D_{subj} + \beta_3 D_{berlin} D_{subj} \\ + \beta_4 D_{post} + \beta_5 D_{post} D_{berlin} + \beta_6 D_{post} D_{subj} \\ + \beta_7 D_{post} D_{berlin} D_{subj} + \beta_8 X + \varepsilon. \end{aligned} \tag{2.3}$$

The OLS-regression to be estimated includes three indicator variables: D_{berlin} is equal to one if the apartment offered is in Berlin and zero otherwise, D_{subj} indicates whether the dwelling is subjected to the rent freeze, i.e. equal to one, or not. D_{post} is the treatment time indicator, which equals zero before the implementation of the rent freeze and one after the implementation. The main coefficient of interest is β_7 which captures the effect of the rent freeze on the outcome variable of interest for dwellings in Berlin subjected to the rent freeze.

The triple-difference estimator for this coefficient is then nothing more than a difference of two difference-in-differences and can be written as

$$\widehat{\beta_7} = [(\bar{y}_{berlin,subj,post} - \bar{y}_{berlin,subj,pre}) - (\bar{y}_{berlin,not\ subj,post} - \bar{y}_{berlin,not\ subj,pre})] - [(\bar{y}_{other\ cities,subj,post} - \bar{y}_{other\ cities,subj,pre}) - (\bar{y}_{other\ cities,not\ subj,post} - \bar{y}_{other\ cities,not\ subj,pre})]. \quad (2.4)$$

2.5 Results

2.5.1 Main

We present our findings for each of our four hypotheses in Figure 2.3. The full regression tables can be found in the appendix (Table 2.A.2 to Table 2.A.5). A priori we expected to find a negative effect on rents (H1). Indeed, we find that the introduction of the rent freeze had a negative effect on the nominal monthly net rent per square metre between -6.9 and -12.4 percent in the case of the diff-in-diff approach for affected dwellings only and for dwellings in Berlin only, respectively (see top-left of Figure 2.3). Employing the triple-difference estimator, we find that the rent freeze had a negative effect on rents of -10.3 percent. One possible reason as to why the diff-in-diff estimate for within Berlin only is larger might be demand spillovers within Berlin after the introduction of the rent freeze (Dolls et al., 2021). This theory is supported by our estimation results for the effects on the number of rental offers (H3). We expected the rent freeze to have a negative effect on the number of affected dwellings offered for rent. For the triple-difference estimate, we find that the introduction of the rent freeze led to a decrease in the number of offered rental apartments of -51.8 percent. The other two estimation strategies result in estimates of similar magnitude. This stark decrease in the number of affected dwellings offered for rent makes spillover effects on prices likely. A decrease in the number of affected dwellings offered for rent might result in the other non-affected dwellings becoming more sought after due to a lack of alternative options.

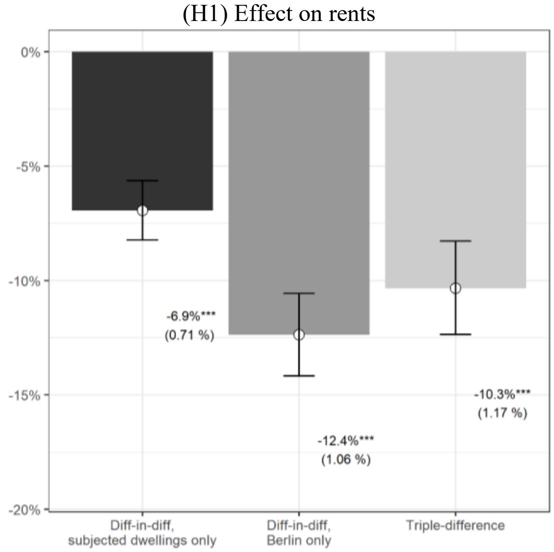
While we do find strong effects on rents and the number of dwellings offered for rent, both with the expected sign, we do not find such a clear-cut picture for offers regarding purchase prices and the number of dwellings offered for purchase. A priori we expected the number of affected dwellings offered for sale to increase (H4) because the owners of the respective dwellings have a higher incentive to sell their apartments than before the introduction of the rent freeze. One possible reasoning behind this hypothesis is that some owners would be forced to sell their dwellings because they are no longer able to sustain the expenses connected with renting out these dwellings, as the second stage of the rent freeze includes the possible reduction of sitting renters' rent. These lower rents might not be high enough to cover landlords' expenses. However, we find that the introduction of the rent freeze did not result in an increase in the number of affected dwellings offered for sale.

Regarding purchase price effects, our a priori assumption was unclear (H2). We do not find any price effects when employing the triple-difference estimator. If we restrict our sample only to affected dwellings, we find a small but statistically significant effect on purchase prices. We can interpret this effect as prices for affected dwellings in Berlin increasing more strongly after the introduction of the rent freeze when compared with other cities. However, if we employ the diff-in-diff estimate to observations within Berlin only, we do not find that prices for affected dwellings increased more strongly than prices for unaffected dwellings. The triple-difference estimate catches this distinction, giving us confidence that adopting all three estimation strategies was a good approach. The lack of spillover effects might point to a wait-and-see attitude on the investors' side. During the period analysed market analysts and investors alike were still expecting the verdict of the constitutional court on whether the rent freeze was indeed going to be in place for a longer period, many expecting the law to be overturned. For owner-occupiers on the other hand the rent freeze might not have been hindering the decision to sell their dwelling, as this decision is not solely dictated by the market and political uncertainty but based on personal reasons, also. The above findings are in line with and expand on studies by Hahn et al. (2023) and Dolls et al. (2021).

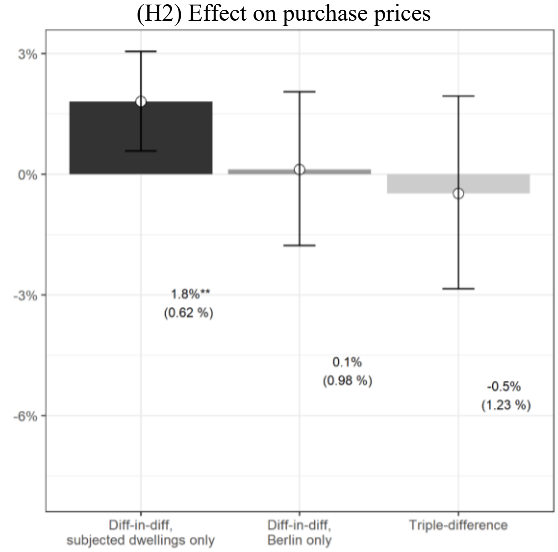
Figure 2.3: Main price and quantity effects

Price effects:

(H1) Effect on rents



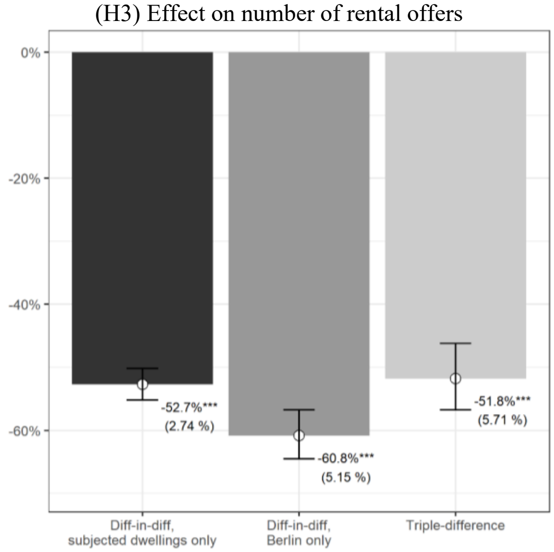
(H2) Effect on purchase prices



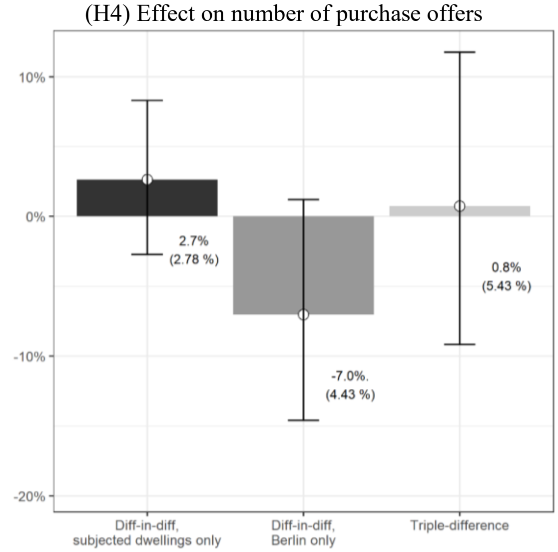
Obs.:	355,481	144,679	428,794	146,185	78,198	176,589
Adj. R^2:	0.657	0.573	0.689	0.719	0.642	0.736

Quantity effects:

(H3) Effect on number of rental offers



(H4) Effect on number of purchase offers



Obs.:	31,933	17,662	53,154	28,944	15,110	41,720
Adj. R^2:	0.656	0.659	0.641	0.434	0.463	0.418

Notes: The graph shows results of difference-in-differences regressions and triple-difference regressions. If the dependent variable is the price, i.e. for (H1) and (H2) the regressions include a set of hedonic control variables describing the dwellings' characteristics. For quantity effects, i.e. for (H3) and (H4), the dependent variable is the number of offers per month. All regressions are estimated in a log-linear setup. Coefficients and standard errors are transformed and represent percentage changes. All regressions include time and postal code fixed effects. Standard errors are presented in parentheses and clustered at the postal code level. Error bars represent 95-percent confidence intervals.

***, **, *, and . indicate significance at the 0.1, 1, 5, and 10 percent levels.

Source: Authors' calculations based on Value Marktdaten.

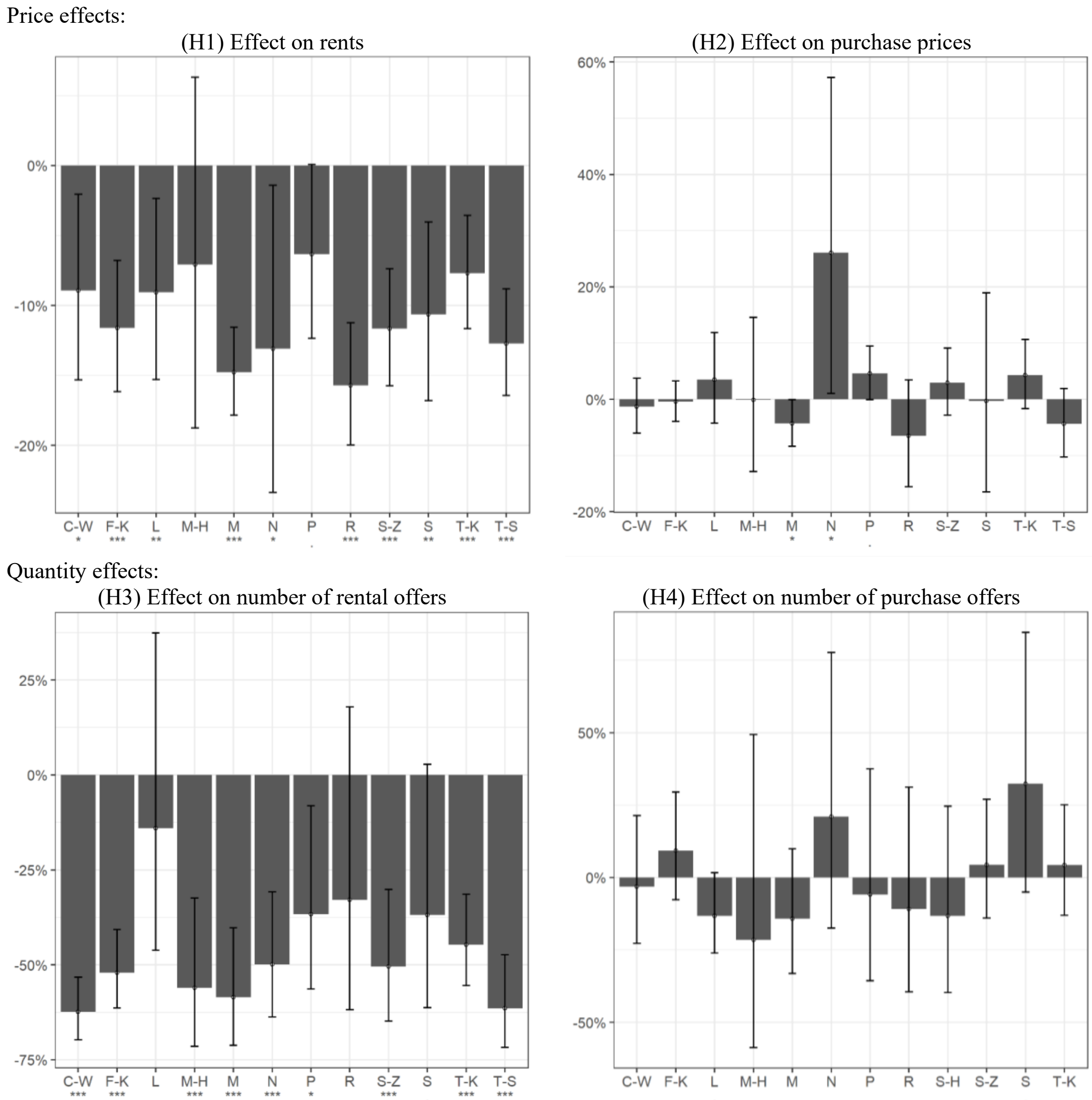
2.5.2 Regional heterogeneity

In the following, we extend our analysis to a more localised level to gauge potential regionally heterogeneous effects of the rent freeze. We start by applying the triple-difference estimator to Berlin's 12 districts for each of our four hypotheses. This means that instead of including all the observations in Berlin, we restrict data in the treatment group to be within the respective district analysed only. The control group remains unchanged. In doing so, we effectively run 12 regressions per hypothesis, thereby assuming prices and quantities offered would have developed the same in each district – instead of the whole city as before – compared to the control group. The resulting estimates are presented in Figure 2.4.

We find that in seven of the twelve districts the rent freeze had a stronger than average effect ranging from -13 percent or less in Tempelhof-Schöneberg, Neukölln, Mitte, and Reinickendorf to below average effects in Treptow-Köpenick, Marzahn-Hellersdorf, and Pankow with effects greater than -8 percent. Except for Marzahn-Hellersdorf, all estimates are statistically significant at the common thresholds. We can conclude that while the rent freeze had a regionally heterogeneous effect on rents, we find the expected negative effect in all districts, and no single district solely drives the overall effects on rents.

We find the largest decreases in the number of apartments offered for rent in the districts Mitte (-61.4), Tempelhof-Schöneberg (-61.2), and Charlottenburg-Wilmersdorf (-59.6). The districts Lichtenberg (-18.2), Reinickendorf (-32.8) and Spandau (-35.1) saw the smallest decreases in the number of rental apartments offered while these effects were not statistically significant at common thresholds. Hence, the districts affected by the largest decreases in rents and the quantities offered are those in central locations with relatively high rent levels and strong rent increases in recent years which could already be classified as having the tensest market situation before the rent freeze. These districts are those closest to the central business district and public infrastructure. We could not identify any overall effect on purchase prices and the number of apartments offered for sale on a district level which underlines our main findings.

Figure 2.4: Price and quantity effects by district



Notes: The graph shows results of triple-difference regressions. If the dependent variable is the price, i.e. for (H1) and (H2), the regressions include a set of hedonic control variables describing the dwellings' characteristics. For quantity effects, i.e. for (H3) and (H4), the dependent variable is the number of offers per month. All regressions are estimated in a log-linear setup. Coefficients are transformed and represent percentage changes. All regressions include time and postal code fixed effects. Standard errors are clustered at the postal code level. Error bars represent 95-percent confidence intervals. C-W: Charlottenburg-Wilmersdorf, F-K: Friedrichshain-Kreuzberg, L: Lichtenberg, M-H: Marzahn-Hellersdorf, M: Mitte, N: Neukölln, P: Pankow, R: Reinickendorf, S: Spandau, S-Z: Steglitz-Zehlendorf, T-S: Tempelhof-Schöneberg, T-K: Treptow-Köpenick.

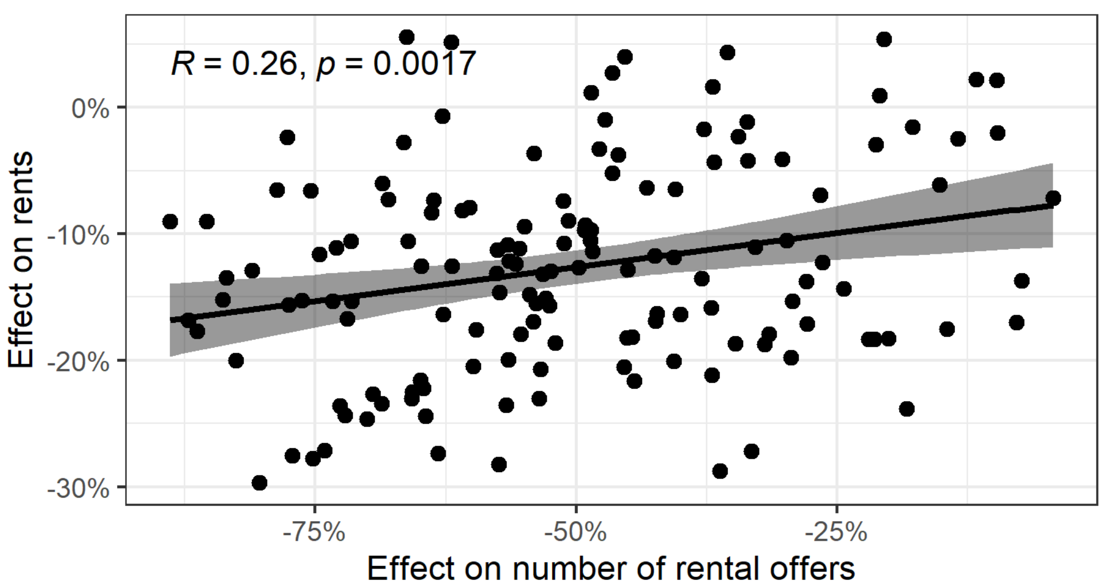
***, **, *, and . indicate significance at the 0.1, 1, 5, and 10 percent levels.

Source: Authors' calculations based on Value Marktdaten.

2.5.3 Relationship between rent and quantity effects

To further investigate the relationship between the rent and quantity effects the rent freeze had, we localise our analysis to a postal code level. We run one regression per postal code area within Berlin per dependent variable of interest, i.e. the number of rental offers, and the nominal net rent per square metre and month. There are 191 postal code areas in Berlin. After excluding statistically insignificant estimates for price and quantity effects as well as outliers we are left with 144 postal code areas for which we estimated rent and quantity effects using triple-difference regressions. The effect pairs are depicted in Figure 2.5.

Figure 2.5: Relationship of rent and quantity effects



Notes: The graph shows the relationship between the rent effect the rent freeze had on a postal code level and the effect on the number of dwellings offered. The graph includes results of a Pearson correlation test and a linear regression line with a 95-percent confidence interval. Effects are results from (hedonic) triple-difference regressions. Source: Authors' calculations based on Value Marktdaten.

The graph shows the relationship between the estimated effect the rent freeze had on rents and the effect on the number of dwellings offered for rent. The Pearson correlation between the two is equal to $R = 0.26$ and statistically significant with a p-value of 0.0017. We also tested for rank-based correlation. The Spearman rank correlation coefficient between the rent and quantity effect is $\rho = 0.2246$ with a p-value of 0.0069, and Kendall's rank correlation is $\tau =$

0.1581 with a p-value of 0.0049. We conclude that there is a positive relationship between the effect on rents and the effects on quantities offered. This means locally, on average, a stronger decrease in rents due to the rent freeze is associated with a stronger reduction in the number of dwellings offered for rent. This, of course, does not mean that this is a causal relationship. From theory however, it is the relationship we expected to find. The further the new rent ceiling is from a market rent, the larger is the effect on quantities offered.

2.5.4 Dwelling heterogeneity

As illustrated by Breidenbach et al. (2022) and Thomschke (2019), the rent brake had heterogeneous effects depending on dwelling characteristics and location. To assess whether different dwelling types are affected differently by the rent freeze as well, we split our data by different characteristics: the number of rooms, the size of the dwelling in square metres, and whether it is offered as renovated or not.

The two size characteristics are important because they might give us some indication of which types of households are affected most by the rent freeze. Dwellings with one room are typically occupied by singles, dwellings with two to three rooms by couples and small families, dwellings with four or more rooms by larger families. Small dwellings saw a larger decrease in rents per square metre due to the rent freeze than large dwellings. In dwellings with one room only, the rent freeze had a negative effect on rents of -10.2 percent. For dwellings with four or more rooms, the estimated effect is -9.1 percent. For apartments smaller than 50 square metres, we find a rent effect of -10.9 percent; for larger apartments above 80 square metres, rents decreased by only -7.9 percent. This result seems plausible, as the rent freeze, different from the rent brake, does not differentiate the legal rent levels by dwelling size. Typically, smaller dwellings are more expensive per square metre than larger ones because costs related to the dwelling's amenities, i.e. the construction and maintenance costs related to the kitchen or bathroom, are divided across a smaller space. The rent per square metre in smaller dwellings decreased slightly more than in larger dwellings to meet the new legislation's thresholds.

Furthermore, we find that dwellings with two to three rooms and a size of 50 to below 80 square metres saw the largest decreases in offers after the introduction of the rent freeze. Very large apartments seem to be affected the least. If we were to declare a household type with the smallest chance of finding a dwelling for rent after the introduction of the rent freeze, it would be couples and small families. However, the two to three rooms, 50 to below 80 square metre apartments are the most versatile ones in terms of the household type since they also represent a valid choice for single households. We do not find any significant effect on the purchase market for either of the size classifications.

We further explored whether renovated dwellings are affected differently than non-renovated dwellings motivated by findings by Breidenbach et al. (2022) that the quality of dwellings under the rent brake decreased after its introduction. The rent freeze itself allows for different rent levels depending on the dwelling's amenities as discussed above. However, the reason as to why there might be observable differences depending on whether an apartment is renovated or not is that landlords, after the introduction of the rent freeze, have less incentive to invest in their dwellings, as overall rent income is lower after the introduction. This might lead some landlords to forego smaller renovations, like a fresh coat of paint or new floors. In support of this reasoning, we find that the number of dwellings offered for rent and indicated as renovated decreased more than for those dwellings which were explicitly indicated as not renovated. Regarding rent effects by renovation status, we do not find any statistically significant effect on the rental price if the dwelling was offered as renovated, but a strong negative effect if the dwelling was offered as not renovated. For those dwellings for which we do not know their renovation status, the effects are closest to the overall effects described above as they represent the bulk of the observations. It should be noted, however, that the short timespan analysed in our study does not allow us to cover this research question fully, but it can merely serve as a first indication of what might happen to the Berlin housing stock in the long term. The results are summarised in Table 2.1.

Table 2.1: Price and quantity effects of the Berlin rent freeze by dwelling characteristics

Number of rooms	**1 room**	**2-3 rooms**	**4 and more rooms**	
(H1) Effect on rents	−10.2 %***	−9.8 %***	−9.1 %***	
	(2.94 %)	(1.27 %)	(1.59 %)	
Obs.:	56,092	280,288	50,272	
Adj. R^2:	0.665	0.706	0.729	
(H2) Effect on purchase prices	−2.8 %	−0.6 %	0.8 %	
	(4.56 %)	(1.51 %)	(1.91 %)	
Obs.:	17,604	106,042	37,768	
Adj. R^2:	0.776	0.747	0.688	
(H3) Effect on number of rental offers	−28.1 %***	−48.1 %***	−18.8 %***	
	(7.25 %)	(7.17 %)	(5.38 %)	
Obs.:	25,159	49,057	27,384	
Adj. R^2:	0.299	0.557	0.138	
(H4) Effect on number of purchase offers	−11.5 %	−2.4 %	−1.0 %	
	(9.34 %)	(5.81 %)	(5.98 %)	
Obs.:	11,967	34,961	20,485	
Adj. R^2:	0.135	0.314	0.115	
Size of dwelling	**< 50 sqm.**	**50-79 sqm.**	**80-119 sqm.**	**>= 120 sqm.**
(H1) Effect on rents	−10.9 %***	−10.1 %***	−7.9 %***	−7.9 %***
	(2.94 %)	(1.55 %)	(1.22 %)	(2.00 %)
Obs.:	93,222	201,416	102,956	28,591
Adj. R^2:	0.673	0.712	0.727	0.678
(H2) Effect on purchase prices	−3.0 %	−1.1 %	−0.3 %	1.2 %
	(3.45 %)	(1.84 %)	(1.76 %)	(2.43 %)
Obs.:	28,472	71,839	51,327	23,936
Adj. R^2:	0.785	0.775	0.731	0.603
(H3) Effect on number of rental offers	−34.3 %***	−45.2 %***	−31.9 %***	−17.0 %***
	(6.14 %)	(6.42 %)	(6.28 %)	(5.74 %)
Obs.:	30,888	43,621	39,117	17,905
Adj. R^2:	0.433	0.531	0.244	0.151
(H4) Effect on number of purchase offers	−7.6 %	−5.8 %	−4.2 %	−5.4 %
	(10.72 %)	(6.38 %)	(5.80 %)	(6.16 %)
Obs.:	16,734	28,513	25,412	14,273
Adj. R^2:	0.167	0.267	0.129	0.157
Renovated	**Yes**	**Do not know**	**No**	
(H1) Effect on rents	−2.2 %	−10.5 %***	−29.7 %*	
	(3.72 %)	(1.29 %)	(16.78 %)	
Obs.:	90,559	331,350	6,885	
Adj. R^2:	0.682	0.691	0.633	
(H2) Effect on purchase prices	1.4 %	−0.5 %	2.2 %	
	(3.37 %)	(1.35 %)	(1.44 %)	
Obs.:	24,789	140,084	11,716	
Adj. R^2:	0.751	0.733	0.748	
(H3) Effect on number of rental offers	−45.8 %***	−48.1 %***	−34.0 %***	
	(7.28 %)	(5.94 %)	(10.97 %)	
Obs.:	30,308	51,794	5,211	
Adj. R^2:	0.389	0.548	0.094	
(H4) Effect on number of purchase offers	6.2 %	−2.6 %	−3.3 %	
	(6.56 %)	(5.68 %)	(3.19 %)	
Obs.:	15,728	39,536	8,212	
Adj. R^2:	0.131	0.331	0.051	

Notes: The table shows results of triple-difference regressions. If the dependent variable is the price, i.e. for (H1) and (H2), the regressions include a set of hedonic control variables describing the dwellings' characteristics. For quantity effects, i.e. for (H3) and (H4), the dependent variable is the number of offers per month. All regressions are estimated in a log-linear setup. Coefficients are transformed and represent percentage changes. All regressions include time and postal code fixed effects. Standard errors are clustered at the postal code level.
***, **, *, and . indicate significance at the 0.1, 1, 5, and 10 percent levels.
Source: Authors' calculations based on Value Marktdaten.

2.6 Discussion

The Berlin rent freeze was implemented to give renters “breathing space” as Berlin’s mayor put it (Süddeutsche Zeitung, 2021). The basic idea was clear and simple: stop rent increases – even lower existing rents – and hope for new construction to catch up to demand in the meantime. Alston et al. (1992) found that there is no greater degree of consensus among economists regarding first-generation rent controls. In their study, 92.9 percent of economists agreed with the statement that “a ceiling on rents reduces the quantity and quality of housing available” (Alston et al., 1992, p. 204). Arnott (1995) points out that this finding is linked to traditional models of rent control. He continues to describe the three effects of what he calls a “textbook analysis of a rent freeze” that result from fixing rents below market rents. Before summarising our findings on the Berlin rent freeze, we find it worthwhile to recite these three effects. First, renters who manage to find a dwelling subjected to the rent freeze benefit as they pay lower rents. These renters are generally market insiders who have lived in the city for a long time. This first effect comes at the cost of new residents as they will most likely not find a dwelling subjected to the rent freeze. The second effect describes the reactions on the supply side: landlords decrease maintenance expenses to make up for less rental income and try to convert their dwellings to owner-occupied housing. Third, the low rents induced by the rent freeze lead to excess demand for housing. This in turn intensifies typical characteristics of a tight housing market: housing mismatch, reduced housing mobility, increases in discrimination of new renters, and “black-market-phenomena” such as one-off payments prior to renting the dwelling (Arnott, 1995, p. 103).

The findings of our supply side analysis of the Berlin rent freeze match many of the findings in the textbook analysis of a rent freeze. The rent cap or rent ceiling part of the legislation lead to a decrease in rents of -10.3 percent, i.e. well below market rents. At the same time, the effect on the number of dwellings offered for rent was five times as large (-51.8 percent). However, we do not find any spillover effects on the purchase market, neither on the quantity of affected dwellings offered for sale, nor on their price.

We investigate the regional heterogeneity the rent freeze had on a district level and find that the decreases in rents and decreases in the number of apartments offered for rent were largest in the central, highly sought after districts Tempelhof-Schöneberg, Neukölln, Mitte, and Charlottenburg-Wilmersdorf, while they were smallest in Treptow-Köpenick, Marzahn-Hellersdorf, and Pankow, districts in the outskirts of the city. By extending our analysis to a postal code level, we find a statistically significant positive correlation between the rent effect and the quantity effect on a regional level. This means that in parts of the city where rents decreased the most after the introduction of the rent freeze, so did the number of dwellings offered for rent. This finding supports the textbook finding that the lower the rent ceiling compared to market rents, the stronger the effect on quantities.

In smaller dwellings, rents decreased by slightly more, while quantity effects were largest for dwellings with two to three rooms and between 50 and 80 square metres in size. This type of dwelling is the most versatile regarding potential renters, as it is a feasible option for singles, couples, and small families. However, if we were to assign a group likely to be affected the most by the decreases in rental offers, it is two to three person households, i.e. couples and small families.

For landlords, a rent ceiling below market rents means less rental income, thereby increasing incentives to save. Over a longer period, this can lead to dilapidation. Even in our short-run analysis, we find a first indication: the number of dwellings offered for rent as explicitly renovated decreased more strongly than the number of dwellings which were explicitly reported as unrenovated.

The rent freeze was an unprecedented disruption to Berlin's housing market. The supply side effects were immense. By implementing this policy, the Berlin senate had chosen to renounce the notion of a free housing market. Sitting renters profited immensely as they not only had already found a dwelling but were also likely to see their rents lowered after the implementation of the second stage of the rent freeze. For them, the incentives to move were basically zero. In the longer run this would likely have exacerbated housing mismatches. For renters in need of a new apartment the situation was dire. As the most mobile group in society are the young, they were likely to be affected the greatest by the decreases in the number of dwellings offered. The question remaining to be answered is whether the protection of sitting renters was worth harming those looking for a new dwelling. If the match between our empirical findings and the textbook example is any indication, this is highly unlikely.

Appendix

A.2.1 Tables

Table 2.A.1: Summary statistics

	Purchase, N = 176,589±	Rent, N = 428,794±
Price (either rent or purchase price in euro per square metre) (log)	8.35 (0.41)	2.43 (0.28)
Number of rooms	2.79 (1.15)	2.47 (0.96)
Dwelling size in sqm.	82 (39)	71 (31)
Construction year	1,962 (39)	1,963 (38)
City		
Berlin	78,198 (44%)	144,679 (34%)
Dusseldorf	9,518 (5.4%)	39,254 (9.2%)
Frankfurt am Main	10,653 (6.0%)	36,374 (8.5%)
Hamburg	25,394 (14%)	102,517 (24%)
Cologne	13,311 (7.5%)	37,497 (8.7%)
Munich	29,302 (17%)	50,725 (12%)
Stuttgart	10,213 (5.8%)	17,748 (4.1%)
After introduction of rent freeze		
No	154,609 (88%)	380,980 (89%)
Yes	21,980 (12%)	47,814 (11%)
Potentially subjected to rent freeze		
No	30,404 (17%)	73,313 (17%)
Yes	146,185 (83%)	355,481 (83%)
State of dwelling fit-out		
High-quality	19,411 (11%)	27,116 (6.3%)
Good	75,750 (43%)	176,505 (41%)
Normal	74,950 (42%)	211,927 (49%)
Simple	6,478 (3.7%)	13,246 (3.1%)
State of dwelling overall		
Good	85,822 (49%)	215,329 (50%)
Normal	79,746 (45%)	207,358 (48%)
Bad	11,021 (6.2%)	6,107 (1.4%)
Heating system		
Central	128,589 (73%)	311,200 (73%)
Floor	18,015 (10%)	47,209 (11%)
Room	1,402 (0.8%)	4,235 (1.0%)
Unknown	28,583 (16%)	66,150 (15%)
Heating source		
Gas	82,987 (47%)	192,015 (45%)
Oil	19,761 (11%)	34,309 (8.0%)
Electric	2,767 (1.6%)	9,105 (2.1%)
Alternative	3,530 (2.0%)	6,311 (1.5%)
Coal	46 (<0.1%)	109 (<0.1%)
Unknown	67,498 (38%)	186,945 (44%)
Storage room		
No	129,743 (73%)	328,872 (77%)
Yes	46,846 (27%)	99,922 (23%)
Alarm system		
No	175,369 (99%)	427,710 (100%)
Yes	1,220 (0.7%)	1,084 (0.3%)

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...Table 2.A.1 continued

Shower in bathroom		
No	109,343 (62%)	267,298 (62%)
Yes	67,246 (38%)	161,496 (38%)
Guest bathroom		
No	132,151 (75%)	351,393 (82%)
Yes	44,438 (25%)	77,401 (18%)
Window in bathroom		
No	131,376 (74%)	326,346 (76%)
Yes	45,213 (26%)	102,448 (24%)
Bathroom with bathtub		
No	84,356 (48%)	190,816 (45%)
Yes	92,233 (52%)	237,978 (55%)
Terrace or balcony		
No	38,394 (22%)	113,238 (26%)
Yes	138,195 (78%)	315,556 (74%)
Barrier-free		
No	161,279 (91%)	403,966 (94%)
Yes	15,310 (8.7%)	24,828 (5.8%)
Screed flooring		
No	175,601 (99%)	426,838 (100%)
Yes	988 (0.6%)	1,956 (0.5%)
Tile flooring		
No	100,632 (57%)	232,263 (54%)
Yes	75,957 (43%)	196,531 (46%)
PVC flooring		
No	173,038 (98%)	398,858 (93%)
Yes	3,551 (2.0%)	29,936 (7.0%)
Laminate flooring		
No	142,535 (81%)	316,687 (74%)
Yes	34,054 (19%)	112,107 (26%)
Linoleum flooring		
No	174,429 (99%)	418,929 (98%)
Yes	2,160 (1.2%)	9,865 (2.3%)
Marble flooring		
No	174,516 (99%)	425,765 (99%)
Yes	2,073 (1.2%)	3,029 (0.7%)
Parquet flooring		
No	111,960 (63%)	289,204 (67%)
Yes	64,629 (37%)	139,590 (33%)
Carpet flooring		
No	164,779 (93%)	418,367 (98%)
Yes	11,810 (6.7%)	10,427 (2.4%)
Terracotta flooring		
No	176,092 (100%)	427,721 (100%)
Yes	497 (0.3%)	1,073 (0.3%)
Utility room		
No	141,824 (80%)	363,885 (85%)
Yes	34,765 (20%)	64,909 (15%)
Garden		
No	123,666 (70%)	345,708 (81%)
Yes	52,923 (30%)	83,086 (19%)
Own garden		
Explicitly No	15,789 (8.9%)	21,584 (5.0%)
Unknown	151,559 (86%)	396,202 (92%)
Yes	9,241 (5.2%)	11,008 (2.6%)

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…Table 2.A.1 continued

Geothermal heating		
No	175,073 (99%)	425,951 (99%)
Yes	1,516 (0.9%)	2,843 (0.7%)
Pellet heating		
No	175,412 (99%)	426,233 (99%)
Yes	1,177 (0.7%)	2,561 (0.6%)
Air-to-water heat pump		
No	173,162 (98%)	423,650 (99%)
Yes	3,427 (1.9%)	5,144 (1.2%)
Solar heating		
No	174,758 (99%)	425,710 (99%)
Yes	1,831 (1.0%)	3,084 (0.7%)
Block-unit power station heating		
No	176,475 (100%)	428,563 (100%)
Yes	114 (<0.1%)	231 (<0.1%)
District heating		
No	130,642 (74%)	300,711 (70%)
Yes	45,947 (26%)	128,083 (30%)
Underfloor heating		
No	143,460 (81%)	360,905 (84%)
Yes	33,129 (19%)	67,889 (16%)
Fireplace		
No	168,528 (95%)	420,039 (98%)
Yes	8,061 (4.6%)	8,755 (2.0%)
Built-in kitchen		
No	87,980 (50%)	183,851 (43%)
Yes	88,609 (50%)	244,943 (57%)
Elevator		
No	96,662 (55%)	255,999 (60%)
Yes	79,927 (45%)	172,795 (40%)
Swimming pool		
No	173,595 (98%)	423,994 (99%)
Yes	2,994 (1.7%)	4,800 (1.1%)
Sauna		
No	172,960 (98%)	426,094 (99%)
Yes	3,629 (2.1%)	2,700 (0.6%)
Attic		
No	170,833 (97%)	415,104 (97%)
Yes	5,756 (3.3%)	13,690 (3.2%)
Top floor		
Explicitly No	56,828 (32%)	122,899 (29%)
Unknown	71,509 (40%)	195,218 (46%)
Yes	48,252 (27%)	110,677 (26%)
Landmarked		
Explicitly No	44,031 (25%)	101,004 (24%)
Unknown	122,339 (69%)	314,321 (73%)
Yes	10,219 (5.8%)	13,469 (3.1%)
Maisonette		
No	161,732 (92%)	408,813 (95%)
Yes	14,857 (8.4%)	19,981 (4.7%)
Basement		
Explicitly No	614 (0.3%)	2,399 (0.6%)
Unknown	32,867 (19%)	114,837 (27%)
Yes	143,108 (81%)	311,558 (73%)

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...Table 2.A.1 continued

Loggia		
No	153,634 (87%)	391,783 (91%)
Yes	22,955 (13%)	37,011 (8.6%)
New construction		
No	157,259 (89%)	385,591 (90%)
Yes	19,330 (11%)	43,203 (10%)
Carport		
No	174,933 (99%)	426,156 (99%)
Yes	1,656 (0.9%)	2,638 (0.6%)
Garage		
No	155,609 (88%)	396,899 (93%)
Yes	20,980 (12%)	31,895 (7.4%)
Outside parking space		
No	141,215 (80%)	379,456 (88%)
Yes	35,374 (20%)	49,338 (12%)
Underground parking space		
No	125,769 (71%)	336,630 (79%)
Yes	50,820 (29%)	92,164 (21%)
First-time occupancy		
No	151,771 (86%)	359,570 (84%)
Yes	24,818 (14%)	69,224 (16%)
State: well-kept		
No	81,560 (46%)	253,996 (59%)
Yes	95,029 (54%)	174,798 (41%)
State: as new		
No	163,829 (93%)	394,276 (92%)
Yes	12,760 (7.2%)	34,518 (8.1%)
State: refurbished		
Explicitly No	2,298 (1.3%)	216 (<0.1%)
Unknown	114,900 (65%)	275,051 (64%)
Yes	59,391 (34%)	153,527 (36%)
Refurbishment needed		
Explicitly No	0 (0%)	2 (<0.1%)
Unknown	173,370 (98%)	428,341 (100%)
Yes	3,219 (1.8%)	451 (0.1%)
Commercial landlord		
No	19,789 (11%)	115,271 (27%)
Yes	156,800 (89%)	313,523 (73%)
Housing association		
No	0	422,502 (99%)
Yes	0	6,292 (1.5%)
Unknown	176,589	0
Parking		
No	92,131 (52%)	273,089 (64%)
Yes	84,458 (48%)	155,705 (36%)
Renovated		
Explicitly No	11,716 (6.6%)	6,885 (1.6%)
Unknown	140,084 (79%)	331,350 (77%)
Yes	24,789 (14%)	90,559 (21%)
Renovation needed		
No	163,202 (92%)	421,288 (98%)
Yes	13,387 (7.6%)	7,506 (1.8%)

Notes: $^{\pm}$Mean (SD); n (%).
Source: Authors' calculations based on Value Marktdaten.

Table 2.A.2: Main regression results – Rents

Dependent variable: Net rent per square metre (log)	(1) Diff-in-diff, Subjected dwellings only	(2) Diff-in-diff, Berlin only	(3) Triple-difference
Construction year	-0.001	-0.001	-0.001
	(0.001)	(0.002)	(0.001)
Construction year squared	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Dwelling size in sqm.	-0.001 ***	-0.001 ***	-0.001 ***
	(0.000)	(0.000)	(0.000)
Number of rooms	-0.004 *	-0.003	-0.004 *
	(0.002)	(0.004)	(0.002)
State of dwelling fit-out (ref.: simple)			
Good	0.053 ***	0.057 ***	0.044 ***
	(0.004)	(0.007)	(0.004)
High-quality	0.042 ***	0.036 ***	0.033 ***
	(0.005)	(0.010)	(0.005)
Normal	0.033 ***	0.040 ***	0.028 ***
	(0.004)	(0.007)	(0.004)
State of dwelling overall (ref.: good)			
Normal	-0.064 ***	-0.074 ***	-0.061 ***
	(0.002)	(0.003)	(0.002)
Bad	-0.132 ***	-0.154 ***	-0.132 ***
	(0.005)	(0.008)	(0.005)
Heating source (ref.: alternative)			
Electric	0.040 **	0.004	0.020 *
	(0.015)	(0.021)	(0.008)
Gas	0.005	-0.024	-0.007
	(0.014)	(0.020)	(0.007)
Unknown	0.008	-0.025	-0.006
	(0.014)	(0.021)	(0.007)
Coal	-0.159 ***	-0.190 ***	-0.159 ***
	(0.040)	(0.042)	(0.034)
Oil	0.000	-0.033	-0.012
	(0.014)	(0.021)	(0.007)
Heating system (ref.: floor)			
Unknown	0.021 ***	0.015 ***	0.018 ***
	(0.002)	(0.004)	(0.002)
Central	0.004	0.004	0.005 *
	(0.002)	(0.003)	(0.002)
Room	-0.049 ***	-0.083 ***	-0.044 ***
	(0.006)	(0.017)	(0.006)
Storage room	0.003 *	0.002	0.002
	(0.002)	(0.003)	(0.001)
Alarm system	0.051 ***	0.035 **	0.041 ***
	(0.008)	(0.013)	(0.007)
Shower in bathroom	0.029 ***	0.030 ***	0.026 ***
	(0.001)	(0.002)	(0.001)
Guest bathroom	0.026 ***	0.033 ***	0.022 ***
	(0.002)	(0.004)	(0.002)
Window in bathroom	-0.005 ***	-0.005 *	-0.003 *
	(0.001)	(0.002)	(0.001)
Bathroom with bathtub	0.001	0.015 ***	-0.003
	(0.002)	(0.002)	(0.002)
Terrace or balcony	0.016 ***	0.007 *	0.015 ***
	(0.002)	(0.003)	(0.002)

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…Table 2.A.2 continued

Barrier-free	0.009 **	0.002	0.001
	(0.003)	(0.004)	(0.003)
Screed flooring	-0.043 ***	-0.031 **	-0.040 ***
	(0.013)	(0.011)	(0.011)
Tile flooring	0.003 *	0.001	0.003
	(0.002)	(0.003)	(0.001)
PVC flooring	0.000	0.009	-0.002
	(0.003)	(0.005)	(0.003)
Laminate flooring	-0.003	-0.006	-0.004 *
	(0.002)	(0.003)	(0.002)
Linoleum flooring	-0.002	0.010	-0.001
	(0.011)	(0.016)	(0.010)
Marble flooring	0.030 ***	0.017	0.030 ***
	(0.007)	(0.014)	(0.006)
Parquet flooring	0.046 ***	0.071 ***	0.044 ***
	(0.002)	(0.005)	(0.002)
Carpet flooring	-0.017 ***	-0.033 ***	-0.019 ***
	(0.003)	(0.005)	(0.003)
Terracotta flooring	-0.012 *	-0.005	-0.016 **
	(0.006)	(0.017)	(0.006)
Utility room	0.014 ***	0.025 ***	0.015 ***
	(0.002)	(0.004)	(0.002)
Garden	0.011 ***	0.018 ***	0.011 ***
	(0.003)	(0.004)	(0.002)
Own Garden (ref.: explicitly no)			
Unknown	-0.011 ***	-0.006	-0.010 ***
	(0.003)	(0.004)	(0.002)
Yes	0.015 *	0.023 ***	0.011 *
	(0.006)	(0.006)	(0.005)
Geothermal heating	-0.025	-0.040	-0.021 *
	(0.018)	(0.026)	(0.008)
Pellet heating	0.011	-0.030	-0.004
	(0.023)	(0.037)	(0.011)
Air-to-water heat pump	0.038 *	0.031	0.024 **
	(0.016)	(0.025)	(0.008)
Solar heating	0.028 ***	0.028 *	0.022 ***
	(0.008)	(0.011)	(0.005)
Block-unit power station heating	0.068	-0.051 *	0.013
	(0.080)	(0.022)	(0.035)
District heating	-0.016 ***	-0.023 ***	-0.012 ***
	(0.003)	(0.004)	(0.003)
Underfloor heating	0.056 ***	0.057 ***	0.054 ***
	(0.003)	(0.006)	(0.003)
Fireplace	0.038 ***	0.038 ***	0.039 ***
	(0.003)	(0.006)	(0.003)
Built-in kitchen	0.057 ***	0.059 ***	0.058 ***
	(0.002)	(0.003)	(0.002)
Elevator	0.016 ***	0.017 ***	0.016 ***
	(0.002)	(0.004)	(0.002)
Swimming pool	-0.006	0.004	-0.000
	(0.009)	(0.018)	(0.008)
Sauna	0.023 ***	0.029	0.022 ***
	(0.006)	(0.017)	(0.006)
Attic	-0.014 ***	-0.011	-0.015 ***
	(0.004)	(0.009)	(0.004)

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...Table 2.A.2 continued

Top floor (ref.: explicitly no)			
Unknown	-0.002	-0.003	-0.001
	(0.002)	(0.002)	(0.002)
Yes	0.010 ***	0.014 ***	0.011 ***
	(0.002)	(0.003)	(0.002)
Landmarked (ref.: explicitly no)			
Unknown	-0.053 ***	-0.062 ***	-0.055 ***
	(0.003)	(0.006)	(0.003)
Yes	-0.037 ***	-0.055 ***	-0.037 ***
	(0.006)	(0.010)	(0.006)
Maisonette	0.025 ***	0.026 ***	0.022 ***
	(0.002)	(0.004)	(0.002)
Basement (ref.: explicitly no)			
Unknown	0.023 ***	0.046 **	0.020 ***
	(0.006)	(0.015)	(0.006)
Yes	0.004	0.023	0.004
	(0.006)	(0.016)	(0.006)
Loggia	-0.026 ***	-0.026 ***	-0.024 ***
	(0.004)	(0.006)	(0.003)
New construction	0.027 *	0.060 ***	0.061 ***
	(0.011)	(0.008)	(0.004)
Carport	0.009	-0.017	0.013 **
	(0.006)	(0.015)	(0.005)
Garage	0.009 ***	-0.001	0.009 ***
	(0.002)	(0.007)	(0.002)
Outside parking space	0.013 ***	-0.000	0.012 ***
	(0.002)	(0.004)	(0.002)
Underground parking space	0.023 ***	0.020 ***	0.021 ***
	(0.003)	(0.005)	(0.002)
Dwelling in Berlin, post introduction of rent-freeze	-0.072 ***		0.037 ***
	(0.007)		(0.009)
Dwelling subjected to rent freeze, post introduction of rent freeze		-0.132 ***	-0.022 ***
		(0.010)	(0.003)
Dwelling subjected to rent freeze		-0.021 ***	-0.005 *
		(0.005)	(0.003)
Dwelling subjected to rent freeze, in Berlin			-0.036 ***
			(0.006)
Dwelling in Berlin, subjected to rent freeze, post introduction of rent freeze			-0.109 ***
			(0.012)
Indicator apartment floor	YES	YES	YES
Indicator total number of floors	YES	YES	YES
Postal code fixed effects	YES	YES	YES
Indicator time relative to introduction of rent freeze	YES	YES	YES
N	355,481	144,679	428,794
R^2	0.658	0.575	0.690
logLik	148753.887	53467.710	188018.863
AIC	-296005.775	-106155.419	-374519.727

Notes: Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and . indicate significance at the 0.1, 1, 5, and 10 percent levels.
Source: Authors' calculations based on Value Marktdaten.

Table 2.A.3: Main regression results – Purchase prices

Dependent variable: Purchase price per square metre (log)	**(1) Diff-in-diff, Subjected dwellings only**	**(2) Diff-in-diff, Berlin only**	**(3) Triple-difference**
Construction year	-0.007	0.004	0.000
	(0.005)	(0.008)	(0.006)
Construction year squared	0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
Dwelling size in sqm.	-0.000 ***	-0.000 **	-0.000 ***
	(0.000)	(0.000)	(0.000)
Number of rooms	0.012 ***	0.017 ***	0.009 ***
	(0.002)	(0.003)	(0.002)
State of dwelling fit-out (ref.: simple)			
Good	0.109 ***	0.113 ***	0.107 ***
	(0.005)	(0.007)	(0.005)
High-quality	0.092 ***	0.096 ***	0.091 ***
	(0.006)	(0.011)	(0.006)
Normal	0.070 ***	0.069 ***	0.070 ***
	(0.005)	(0.007)	(0.005)
State of dwelling overall (ref.: good)			
Normal	-0.044 ***	-0.051 ***	-0.044 ***
	(0.002)	(0.004)	(0.002)
Bad	-0.077 ***	-0.061 ***	-0.081 ***
	(0.004)	(0.007)	(0.004)
Heating source (ref.: alternative)			
Electric	0.026	0.053 *	0.042 ***
	(0.018)	(0.025)	(0.011)
Gas	-0.023	-0.043 *	-0.011
	(0.017)	(0.021)	(0.009)
Unknown	-0.020	-0.025	-0.006
	(0.017)	(0.021)	(0.009)
Coal	0.039	0.030	0.052
	(0.058)	(0.069)	(0.056)
Oil	-0.050 **	-0.057 **	-0.039 ***
	(0.017)	(0.021)	(0.010)
Heating system (ref.: floor)			
Unknown	0.027 ***	0.029 ***	0.022 ***
	(0.005)	(0.008)	(0.004)
Central	0.004	0.001	0.003
	(0.004)	(0.006)	(0.004)
Room	-0.025 **	-0.060 **	-0.028 **
	(0.009)	(0.021)	(0.009)
Storage room	-0.005 *	0.000	-0.006 **
	(0.002)	(0.003)	(0.002)
Alarm system	0.065 ***	0.059 ***	0.048 ***
	(0.013)	(0.012)	(0.010)
Shower in bathroom	0.028 ***	0.034 ***	0.024 ***
	(0.002)	(0.003)	(0.002)
Guest bathroom	0.021 ***	0.026 ***	0.017 ***
	(0.003)	(0.004)	(0.002)
Window in bathroom	-0.001	-0.006	-0.000
	(0.002)	(0.004)	(0.002)
Bathroom with bathtub	-0.010 ***	-0.008 **	-0.013 ***
	(0.002)	(0.003)	(0.002)

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…Table 2.A.3 continued

Terrace or balcony	0.027 ***	0.027 ***	0.026 ***
	(0.003)	(0.004)	(0.003)
Barrier-free	0.005	0.008	0.003
	(0.004)	(0.006)	(0.003)
Screed flooring	-0.003	-0.015	-0.009
	(0.013)	(0.019)	(0.011)
Tile flooring	0.001	-0.003	-0.000
	(0.002)	(0.004)	(0.002)
PVC flooring	-0.028 ***	-0.011	-0.028 ***
	(0.005)	(0.009)	(0.005)
Laminate flooring	-0.025 ***	-0.032 ***	-0.030 ***
	(0.002)	(0.005)	(0.003)
Linoleum flooring	-0.039 ***	-0.040 **	-0.042 ***
	(0.008)	(0.014)	(0.009)
Marble flooring	0.008	-0.009	0.003
	(0.009)	(0.019)	(0.008)
Parquet flooring	0.055 ***	0.072 ***	0.051 ***
	(0.003)	(0.004)	(0.003)
Carpet flooring	-0.042 ***	-0.055 ***	-0.044 ***
	(0.003)	(0.006)	(0.003)
Terracotta flooring	-0.002	0.005	-0.009
	(0.012)	(0.028)	(0.012)
Utility room	0.011 ***	0.014 *	0.012 ***
	(0.003)	(0.006)	(0.003)
Garden	0.026 ***	0.026 ***	0.023 ***
	(0.003)	(0.005)	(0.003)
Own Garden (ref.: explicitly no)			
Unknown	-0.002	-0.001	0.005
	(0.004)	(0.006)	(0.004)
Yes	0.018 ***	0.014	0.016 ***
	(0.005)	(0.008)	(0.004)
Geothermal heating	0.019	0.028	0.010
	(0.027)	(0.021)	(0.012)
Pellet heating	0.030	0.058	0.018
	(0.025)	(0.034)	(0.015)
Air-to-water heat pump	-0.018	-0.029	-0.011
	(0.027)	(0.023)	(0.010)
Solar heating	0.035 *	0.014	0.017
	(0.015)	(0.021)	(0.009)
Block-unit power station heating	0.028	0.060 *	0.035
	(0.022)	(0.027)	(0.019)
District heating	-0.015 **	-0.020 **	-0.013 **
	(0.005)	(0.006)	(0.005)
Underfloor heating	0.081 ***	0.075 ***	0.069 ***
	(0.005)	(0.008)	(0.004)
Fireplace	-0.377 ***		
	(0.011)		
Built-in kitchen	0.040 ***	0.033 ***	0.043 ***
	(0.005)	(0.008)	(0.005)
Elevator	0.023 ***	0.025 ***	0.022 ***
	(0.002)	(0.003)	(0.002)
Swimming pool	0.008 *	0.032 ***	0.011 **
	(0.004)	(0.005)	(0.004)
Sauna	0.004	0.000	0.001
	(0.009)	(0.020)	(0.009)

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…Table 2.A.3 continued

Attic	0.010	-0.016	-0.005
	(0.009)	(0.009)	(0.008)
Geothermal heating	0.004	-0.026 *	0.001
	(0.005)	(0.012)	(0.005)
Top floor (ref.: explicitly no)			
Unknown	0.009 **	0.001	0.008 **
	(0.003)	(0.003)	(0.003)
Yes	0.029 ***	0.018 ***	0.030 ***
	(0.004)	(0.004)	(0.003)
Landmarked (ref.: explicitly no)			
Unknown	-0.051 ***	-0.055 ***	-0.061 ***
	(0.005)	(0.007)	(0.005)
Yes	-0.029 ***	-0.040 ***	-0.037 ***
	(0.008)	(0.011)	(0.008)
Maisonette	0.031 ***	0.027 ***	0.021 ***
	(0.005)	(0.007)	(0.004)
Basement (ref.: explicitly no)			
Unknown	0.039 **	0.040	0.040 **
	(0.014)	(0.022)	(0.013)
Yes	0.034 *	0.027	0.038 **
	(0.014)	(0.022)	(0.013)
Loggia	-0.013 ***	-0.005	-0.012 ***
	(0.003)	(0.006)	(0.003)
New construction	0.007	0.095 ***	0.093 ***
	(0.040)	(0.012)	(0.006)
Carport	0.033 ***	0.029	0.031 ***
	(0.009)	(0.015)	(0.008)
Garage	0.012 ***	0.016 **	0.011 ***
	(0.003)	(0.006)	(0.003)
Outside parking space	0.001	0.002	0.000
	(0.003)	(0.005)	(0.002)
Underground parking space	0.022 ***	0.034 ***	0.028 ***
	(0.004)	(0.007)	(0.004)
Dwelling in Berlin, post introduction of rent-freeze	0.018 ** (0.006)		0.023 * (0.012)
Dwelling subjected to rent freeze, post introduction of rent freeze		0.001 (0.010)	0.007 (0.007)
Dwelling subjected to rent freeze		-0.069 ***	-0.044 ***
		(0.006)	(0.005)
Dwelling subjected to rent freeze, in Berlin			-0.044 ***
			(0.009)
Dwelling in Berlin, subjected to rent freeze, post introduction of rent freeze			-0.005 (0.012)
Indicator apartment floor	YES	YES	YES
Indicator total number of floors	YES	YES	YES
Postal code fixed effects	YES	YES	YES
Indicator time relative to introduction of rent freeze	YES	YES	YES
N	146,185	78,198	176,589
R^2	0.721	0.644	0.737
logLik	19761.968	10100.701	26801.523
AIC	-38013.935	-19411.402	-52081.045

Notes: Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and . indicate significance at the 0.1, 1, 5, and 10 percent levels.
Source: Authors' calculations based on Value Marktdaten.

Table 2.A.4: Main regression results – Number of rental offers

Dependent variable: Number of rental offers per month and postal code area (log)	**(1) Diff-in-diff, Subjected dwellings only**	**(2) Diff-in-diff, Berlin only**	**(3) Triple-difference**
Dwelling in Berlin, post introduction of rent-freeze	-0.749 ***		-0.012
	(0.043)		(0.032)
Dwelling subjected to rent freeze, post introduction of rent freeze		-0.937 ***	0.520 ***
		(0.040)	(0.073)
Dwelling subjected to rent freeze		2.545 ***	2.142 ***
		(0.058)	(0.055)
Dwelling subjected to rent freeze, in Berlin			0.926 ***
			(0.059)
Dwelling in Berlin, subjected to rent freeze, post introduction of rent freeze			-0.729 ***
			(0.052)
Postal code fixed effects	YES	YES	YES
Indicator time relative to introduction of rent freeze	YES	YES	YES
N	31,933	17,662	53,154
R^2	0.662	0.664	0.645
logLik	-18543.499	-15927.009	-47852.988
AIC	38250.999	32362.018	96879.976

Notes: Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and . indicate significance at the 0.1, 1, 5, and 10 percent levels.
Source: Authors' calculations based on Value Marktdaten.

Table 2.A.5: Main regression results – Number of purchase offers

Dependent variable: Number of purchase offers per month and postal code area (log)	**(1) Diff-in-diff, Subjected dwellings only**	**(2) Diff-in-diff, Berlin only**	**(3) Triple-difference**
Dwelling in Berlin, post introduction of rent-freeze	0.026		0.022
	(0.025)		(0.029)
Dwelling subjected to rent freeze, post introduction of rent freeze		-0.073	-0.089 *
		(0.056)	(0.041)
Dwelling subjected to rent freeze		1.184 ***	0.816 ***
		(0.063)	(0.038)
Dwelling subjected to rent freeze, in Berlin			0.282 ***
			(0.051)
Dwelling in Berlin, subjected to rent freeze, post introduction of rent freeze			0.007
			(0.039)
Postal code fixed effects	YES	YES	YES
Indicator time relative to introduction of rent freeze	YES	YES	YES
N	28,944	15,110	41,720
R^2	0.446	0.472	0.426
logLik	-26094.812	-15544.834	-41221.746
AIC	53353.625	31597.667	83617.492

Notes: Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and . indicate significance at the 0.1, 1, 5, and 10 percent levels.
Source: Authors' calculations based on Value Marktdaten.

Chapter 3 – HOUSING PRICE SPILLOVERS AFTER REAL ESTATE AGENT FEE REDUCTION: EVIDENCE FROM THE GERMAN HOUSING MARKET

Notes: A condensed version of this chapter is undergoing a second round of revisions for publication in *Housing Studies* at the time of this dissertation.

3.1 Abstract

This paper examines the impact of changes in the real estate agent fee (REAF) for homebuyers on housing market dynamics following the implementation of a new law in Germany in 2020. The law prohibits real estate agents from charging fees to non-hiring parties if the hiring party does not pay a fee and requires equal fee splitting between buyer and seller if both parties hire an agent. Leveraging a comprehensive micro dataset of dwellings offered for sale, I find a significant decrease in the average REAF for homebuyers. Making use of hedonic difference-in-differences regressions with both binary and continuous treatment approaches, supplemented by an event study design, I find that the reduction in the REAF for homebuyers translates into increases in housing prices. Effects are heterogeneous across dwelling types and regions. Effects are more pronounced for apartments in tense housing markets rather than for single-family houses in less sought-after markets.

3.2 Introduction

Price developments in the German housing market in the 2010s will likely be remembered as either the "terrible tens" or the "tremendous tens" depending on who is asked. Driven by steadily decreasing mortgage rates, strong labour markets, large real wage increases, and high demand for housing, prices in Germany as in many other countries increased strongly (Brausewetter et al., 2024). These price increases as well as the large competition, were of course, terrible for those looking for a new dwelling to rent or buy, while landlords and investors saw their asset wealth sore, making it a tremendous period for them. In the light of these rising market prices, policy measures in Germany targeted both the rental market and the purchase market. The rent brake which was introduced in 2015 and was reformed several times since then, is aimed at reducing price increases for rents (Thomschke, 2019; Breidenbach et al., 2022). For a short period, Berlin even introduced a strict rent freeze and cap (Sagner & Voigtländer, 2022; Hahn et al., 2023). For the purchase market, there were several subsidy programs. The most prominent was the "Baukindergeld", a federal subsidy program for families with children, which was introduced in 2018 (KfW, 2023). Until 21 March 2021, families with at least one child and an income below a certain threshold had been eligible to receive a subsidy of 12,000 euros per child if they bought their first self-occupied home. The subsidy is paid out over ten years, i.e. in case of one child, 1,200 euros per year. This form of subsidy is effectively subsidising the mortgage payments.

Another form of potential leeway to make housing more affordable is to target real estate transaction costs. As transaction costs in Germany depend on a dwelling's price and are paid upfront, rising house prices mean that market entry barriers continuously increased in the 2010s and the beginning of the 2020s. Motivated by this, the "Law on the distribution of real estate agent fees when brokering purchase contracts for apartments and single-family houses" was introduced on 23 December 2020 (BGBl., 2020a). The law targets the real estate agent fee (REAF) for homebuyers, aiming to reduce it. The reduction of transaction costs is effectively an upfront subsidy of the total costs of purchasing a dwelling. However, in this specific case, the first-round effects are not directly associated with costs for the government. If the law reached its intended goal of decreasing the real estate transaction costs for homebuyers, sellers might adapt by trying to raise prices. The potential for sellers to do so might be high as demand for housing was high in the period analysed which is from June 2019 to March 2022. This paper investigates the effects of the new legislation, first on the REAF for homebuyers, second whether the REAF changes led to spillovers on prices. Additionally, the paper discusses who profited from the law: buyers, sellers, or real estate agents.

I find that the law decreased the REAF for buyers significantly and lead to a pass-through to prices. That is, while transaction costs expressed as a share of the dwelling's price decreased, the sales price of the dwellings themselves increased. I further show that the price pass-through was most pronounced for apartments in growing housing markets. The findings overall suggest that buyers of single-family houses profited from the reform while buyers of apartments did not as their total costs after the introduction of the law were larger than before. For the sellers I find that the opposite holds true. Sellers of apartments likely profited from the new law while sellers of single-family houses did not. Additionally, these findings suggest that, while not intended from a policy maker's perspective, the ones who profited from the new law might be the real estate agents also.

The paper is organised as follows: first the institutional background on real estate transaction costs in Germany is introduced, then the structure of the new law is outlined. Next, the data used to test the research hypothesis is illustrated. After having formulated the main hypothesis and identification strategy, the paper is placed within the existing literature. The results section presents the findings of the main research question and discusses their implications. The paper concludes with policy implications and a summary of the central findings.

3.3 Institutional background

3.3.1 Real estate transaction costs in Germany

In Germany, real estate agents are often involved in the transaction of a dwelling. Agents are usually paid a percentage of the dwelling's sales price by the seller, the buyer, or both. A typical total real estate agent fee is in the range of 2.38 to 7.14 percent including value added tax (VAT) of the agreed upon selling price of the dwelling. The REAF makes up a large part of the total transaction costs for homebuyers. In addition to the REAF, homebuyers pay a real estate transfer tax (RETT) of 3.5 to 6.5 percent, a notary fee of around 1.5 percent, and a fee for the entry in the land registry of approximately 0.5 percent. Total transaction costs for the homebuyers can amount to 9 to 12 percent of the purchase price, as illustrated in Table 3.1.

Table 3.1: Transaction costs for homebuyers before the introduction of the law

Real estate agent fees (REAF)	**Real estate transfer tax (RETT)**	**Notary fee**	**Entry in land registry**	**Total costs**
2.38 to 7.14 percent	3.5 to 6.5 percent	1.0 to 2.0 percent	0.5 percent	9 to 12 percent

Notes: This table shows the typical range of transaction costs for homebuyers in Germany before the introduction of the new "Law on the distribution of real estate agent fees when brokering purchase contracts for apartments and single-family houses". Individual costs, and consequently total costs, can vary by region and transaction. Values include VAT, where applicable.
Source: Author's illustration.

The REAF as well as the RETT vary by region. While the mandatory RETT is set at a state level, i.e. the 16 “Bundesländer”, and follows their respective legislation, the REAF has not been subjected to legal thresholds. What is more, the REAF has not been, and even after the introduction of the “Law on the distribution of real estate agent fees when brokering purchase contracts for apartments and single-family houses,” is still not bound by any legal upper or lower limits. In the past, if a real estate agent was involved in a transaction, the REAF was either paid by one of the involved parties, i.e. the buyer or seller, or split between the two. Whether the total REAF was split or paid by one of the parties has followed local common practices in the past. In some regions it has been common for buyers to pay the total REAF and sellers did not have to pay the fee at all. Additionally, there were regions where the buyer paid the larger share of the REAF and the seller a smaller share. It was argued by policy makers that potential homebuyers had little to no influence on the REAF (Deutscher Bundestag, 2019). In the tense sellers’ market, Germany had experienced in the 2010s and the beginning of the 2020s, buyers had no chance to negotiate the REAF – had they tried, they had likely not been considered as a serious buyer by the real estate agent. Furthermore, in regions where buyers had to pay the REAF fully and sellers were not faced with the REAF at all, sellers had little to no incentive to negotiate the REAF. This means that, at least in some regions, real estate agents were hired by sellers, but only the buyers had to pay for their services. Typically independent of their individual efforts, real estate agents set their fees to the local customary rates.

3.3.2 New legislation

The “Law on the distribution of real estate agent fees when brokering purchase contracts for apartments and single-family houses” was introduced on 23 December 2020 and announced on 23 June 2020 (BGBl., 2020a). After the introduction of the new law, it is no longer possible to have the party involved in the sale that did not hire the real estate agent, typically the buyer, pay a larger REAF than the hiring party, typically the seller. If only one party hired the real estate agent, then the other party can be charged the same REAF that is paid by the hiring party, at most. If both, the buyer and the seller, hired the real estate agent, the REAF is to be split equally between them. This means that if a real estate agent is involved in the sale of a dwelling and she charges a fee for her service to one (hiring) party, she can charge the same to the other party at most. In practice, this makes dwelling sales where only the buyer pays a REAF no longer common, as in Germany usually the seller hires the real estate agent. The new legislation is targeted at future owner-occupiers and the main idea is to reduce transaction costs which have posed an increasing market entrance barrier for potential homebuyers as they are linked to the dwelling's price (Deutscher Bundestag, 2019). However, per construction, not just owner-occupiers are affected by the new law, but investors as well. Formally, the distribution of the total REAF before and after the new law can be summarised as follows:

Before introduction:

$$\phi_B^T = \phi_B^B + \phi_B^S, \text{ with } \phi_B^B \in \{0; \phi_B^T\} \text{ and } \phi_B^S \in \{0; \phi_B^T\} \tag{3.1}$$

After introduction:

If both parties hire the agent:

$$\phi_A^T = \phi_A^B + \phi_A^S, \text{ with } \phi_A^B \stackrel{!}{=} \phi_A^S = \frac{1}{2}\phi_A^T \tag{3.2.A}$$

If only one party H hires the agent:

$$\phi_A^T = \phi_A^H + \phi_A^{NH}, \text{ with } \phi_A^H \in \{0; \phi_A^T\} \text{ and } \phi_A^{NH} \in \left\{0; \frac{1}{2}\phi_A^T\right\} \tag{3.2.B}$$

Before (subscript B) the introduction of the law, the total (superscript T) REAF ϕ_B^T was comprised of the share paid by the buyer (superscript B) ϕ_B^B and the seller (superscript S) ϕ_B^S. The distribution of these shares was open to any possibility with both shares summing up to the total REAF, as formalised in Equation 3.1. After (subscript A) the introduction of the law, the total REAF ϕ_A^T is still made up of the individual contributions of the buyer and seller, however there are two cases to distinguish: if both parties hire the real estate agent, then both parties must pay the same share, i.e. $\phi_A^B \stackrel{!}{=} \phi_A^S$, see Equation 3.2.A. If only one party H hires the real estate agent, then this party can pay any share of the total REAF, but if the hiring party wants to pass on some of the total REAF, then she can pass on at most half to the non-hiring party NH, as formalised in Equation 3.2.B. Note that in theory, a real estate agent does not have to charge any fees for her services making zero a viable option.

3.4 Data setup and descriptives

3.4.1 Descriptives

In the following empirical analysis, I make use of a large micro dataset of dwellings offered for sale provided by Value Marktdaten, a professional real estate data provider. The data includes online real estate offers from all major platforms and over 100 sources in total. Making use of asking price data comes with some caveats. The main caveat is that the asking price is not necessarily the agreed upon sales price. However, it is common practice in the research on the German housing market (Thomschke, 2019; Breidenbach et al., 2022; Sagner & Voigtländer, 2022). Each observation in the data analysed is a dwelling offered for sale. In addition to the price, a set of dwelling characteristics is included, such as the dwelling's size in square metres, the number of rooms, the construction year, and indicator variables for the dwelling's amenities and its location. The data covers dwellings which were offered for sale last between June 2019 and March 2022. The data analysed includes information for single-family houses, i.e. detached, semi-detached, and terraced dwellings, as well as apartments in multi-family houses. Table 3.2 gives an overview of the data, stratified by whether the dwelling is offered with or without a REAF for the buyer and before or after the introduction of the law.

3.4.2 Identifying REAF for homebuyers

The data includes information on the REAF to be paid by the buyer of the dwelling. This information is included in a messy string variable. To make use of the information in the analysis, I restrict the data to observations with a percentage indicator and extract the corresponding numeric value. To avoid potential data errors, I then restrict the REAF to be within sensical thresholds. I additionally apply a common outlier filter and restrict the observed prices per square metre to be within 1.5 times the interquartile range by object type, month and county. Out of the total data, 4.6 percent have no information on the REAF, i.e. the variable is missing, 34.9 percent of the offers are explicitly declared to be without a REAF for the buyer (in German: "provisionsfrei"), 54.4 percent satisfy the condition of containing the percentage indicator and being within common thresholds, i.e. larger than 1 percent and up to 7.14 percent, 1.5 percent contain a percentage indicator but the numeric value, if there is any, cannot be parsed, or is not within common thresholds. The chosen strategy allows me to make use of 89.3 percent of the observations containing those with a valid REAF and those declared explicitly as without a REAF for the buyer.

3.4.3 Identifying treatment time

I analyse the dwellings by their last date of being offered online. I assume that a dwelling has found a buyer as soon as it is no longer offered. As I analyse asking price data, I adjust the treatment time by moving it two weeks into the future, i.e. instead of declaring dwellings last offered for sale from 23 December 2020 as subjected to the new legislation, I move the treatment time to 6 January 2021. This adjustment is based on the minimum time homebuyers must be given in Germany to review the sales contract before signing it at a notary (BeurkG, 2021, § 17 Abs. 2a Satz 2 Nr. 2). As the new legislation is only relevant regarding the purchase date, not the offer date online, this moves the observed data closer towards an actual treatment date. This serves to reduce the chance of attributing potential pre- or post-treatment trends as anticipation effects of the new legislation, as, again, it is not the date of being offered online that is relevant for the new legislation to have potential effects, it is the actual sales date. However, it might still be possible for an online offer to remain online even though it has already found a buyer. Unfortunately, this is one of the caveats of analysing online offers. Later, as a robustness check, I additionally analyse the data by their start date.

Table 3.2: Descriptive statistics

	Dwelling offered with REAF			
	No		Yes	
	Dwelling offered after introduction of law			
	No	Yes	No	Yes
	N = 172,755±	N = 133,214±	N = 308,078±	N = 183,771±
Price in euro per sqm.	3,212 (1,757)	3,770 (1,990)	2,931 (1,718)	3,458 (1,988)
Dwelling size in sqm.	110 (57)	109 (57)	119 (69)	114 (67)
Construction year	1,985 (42)	1,982 (43)	1,968 (42)	1,967 (42)
Dwelling type				
1-room apartment	7,092 (4.1%)	6,646 (5.0%)	13,612 (4.4%)	9,511 (5.2%)
2-room apartment	28,962 (17%)	23,026 (17%)	48,971 (16%)	31,791 (17%)
3-room apartment	41,147 (24%)	31,496 (24%)	61,698 (20%)	38,348 (21%)
4-room apartment	20,796 (12%)	15,514 (12%)	25,064 (8.1%)	15,002 (8.2%)
5+-room apartment	4,931 (2.9%)	3,889 (2.9%)	8,814 (2.9%)	5,247 (2.9%)
Detached house	44,574 (26%)	33,206 (25%)	105,873 (34%)	57,384 (31%)
Semi-detached house	14,201 (8.2%)	10,599 (8.0%)	24,936 (8.1%)	14,506 (7.9%)
Terraced house	11,052 (6.4%)	8,838 (6.6%)	19,110 (6.2%)	11,982 (6.5%)
Terrace or balcony				
No	32,168 (19%)	26,272 (20%)	61,856 (20%)	37,944 (21%)
Yes	140,587 (81%)	106,942 (80%)	246,222 (80%)	145,827 (79%)
Basement				
Explicitly No	5,916 (3.4%)	3,932 (3.0%)	13,073 (4.2%)	8,038 (4.4%)
Unknown	42,676 (25%)	33,019 (25%)	57,152 (19%)	32,673 (18%)
Yes	124,163 (72%)	96,263 (72%)	237,853 (77%)	143,060 (78%)
Built-in kitchen				
No	104,003 (60%)	75,854 (57%)	153,834 (50%)	92,338 (50%)
Yes	68,752 (40%)	57,360 (43%)	154,244 (50%)	91,433 (50%)
Parking space				
No	38,111 (22%)	32,609 (24%)	66,006 (21%)	43,732 (24%)
Yes	134,644 (78%)	100,605 (76%)	242,072 (79%)	140,039 (76%)
State of dwelling fit-out				
High-quality	39,162 (23%)	26,809 (20%)	81,626 (26%)	43,214 (24%)
Good	69,566 (40%)	52,504 (39%)	116,673 (38%)	69,565 (38%)
Normal	56,121 (32%)	46,977 (35%)	92,952 (30%)	59,792 (33%)
Simple	7,906 (4.6%)	6,924 (5.2%)	16,827 (5.5%)	11,200 (6.1%)
State of dwelling overall				
Good	99,810 (58%)	75,300 (57%)	128,200 (42%)	78,127 (43%)
Normal	64,500 (37%)	50,971 (38%)	150,125 (49%)	87,010 (47%)
Bad	8,445 (4.9%)	6,943 (5.2%)	29,753 (9.7%)	18,634 (10%)
Region type				
Large city	49,706 (29%)	42,174 (32%)	92,930 (30%)	58,818 (32%)
Urban county	70,290 (41%)	52,150 (39%)	121,850 (40%)	70,263 (38%)
Rural, more densely populated county	28,742 (17%)	21,109 (16%)	50,235 (16%)	29,559 (16%)
Rural, sparsely populated county	24,017 (14%)	17,781 (13%)	43,063 (14%)	25,131 (14%)

Notes: ±Mean (SD); n (%). This table shows selected summary statistics for dwellings in the asking price data analysed. The data is split by whether it is offered with a REAF for the buyer or not and whether the dwelling is offered before or after the introduction of the law.
Source: Author's calculations based on Value Marktdaten.

3.5 Effectiveness of the law on the distribution of the REAF

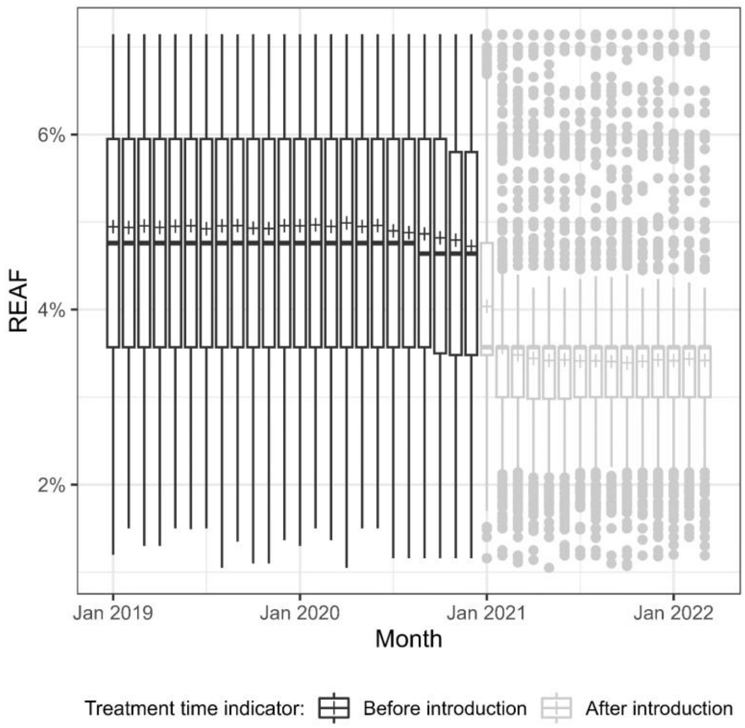
3.5.1 Overall changes in the REAF for homebuyers

Before I formulate the main research hypothesis and corollaries to be explored in the empirical analysis of this paper, I first discuss some descriptive findings. As the data includes information on the magnitude of the REAF for the homebuyers, I start by exploring an initial and central question: whether the new legislation had a measurable effect on the REAF for homebuyers and, if it had one, how large it was.

Figure 3.1 shows the development of the REAF for buyers over time. Before the introduction of the law the mean (median) REAF was 4.93 (4.76) percent. With the introduction of the law, the REAF decreased to 3.49 (3.57) percent which corresponds to a decrease of 1.44 (1.19) percentage points. The data show only small anticipatory decreases in the REAF prior to the law's introduction and an imminent and sharp decrease right after the introduction of the law. What is more, the change in the REAF remains constant in the months after the introduction. To illustrate that this change is not driven by changes in data-composition, i.e. changes in dwelling types, quality, or region, I ran an ordinary least squares regression with time-dummy indicators controlling for dwelling types, other dwelling characteristics, as well as regional fixed effects. The dependent variable is the REAF for homebuyers. Figure 3.A.1 in the appendix shows the coefficients of the time dummies underlining the finding that after the introduction of the law a decrease in the average REAF relative to the pre-introduction period followed, and the results depicted in Figure 3.1 are not driven by changes in data composition.

In the next section, I present changes and level differences in the REAF at a state and county level. Examining local-level changes and differences in the REAF serves to evaluate the extent to which the new law affects regions differently with regards to its intended objective of reducing transaction costs and improving affordability for homebuyers.

Figure 3.1: Real estate agent fee for homebuyers over time



Notes: The graph shows Tukey-style boxplots with median values (thick horizontal bars), quartiles, whiskers, and outliers as individual points, if there are any. Additionally, the graph includes mean values indicated by the plus symbol. The underlying data consists of the real estate agent fee (REAF) for buyers, expressed as a percentage and aggregated by month. The number of observations is 644,628. The period shown here extends from January 2019 until March 2022.
Source: Author's calculations based on Value Marktdaten.

3.5.2 Regional heterogeneity in the REAF

In magnitude, the REAF is not bound by any legal restrictions, neither by the German Federal law, nor by local laws, e.g. neither on a state nor a county level. This means the REAF is generally subject to negotiation between real estate agents and the hiring parties. However, the REAF for homebuyers followed regional common practices before the introduction of the new legislation which, by and large, followed state borders. See Figure 3.A.2 and Table 3.A.1 in the appendix for a breakdown of the REAF on a state level.

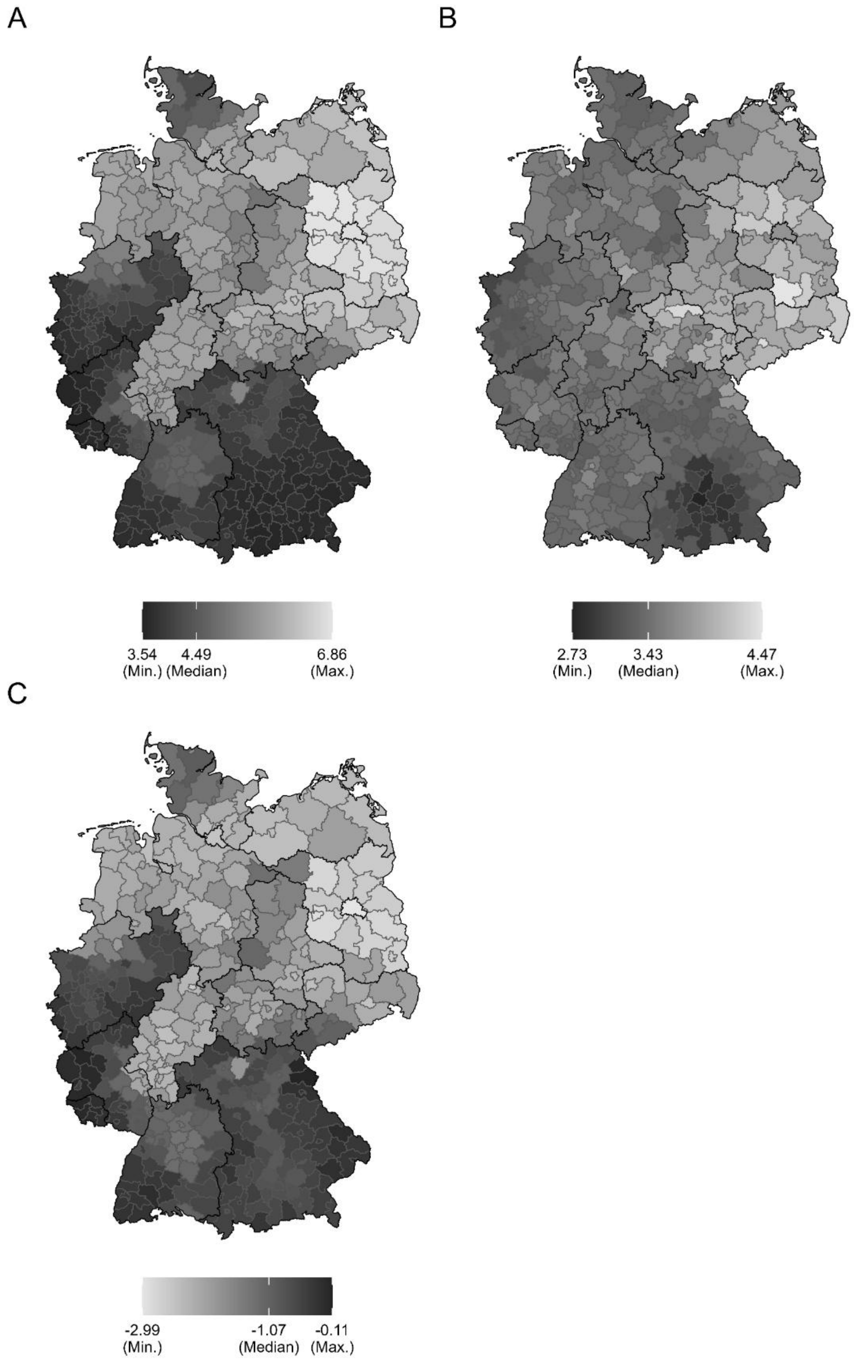
Figure 3.2.A shows the mean REAF before the introduction of the new legislation on the county level, the period considered is January 2019 until December 2020. The graph shows clear differences in the REAF for buyers on a county level. Counties in the western states

North-Rhine-Westphalia, Saarland, Rhineland-Palatinate, and the two southern states Baden-Wuerttemberg and Bavaria generally had a lower REAF for homebuyers in the past than other states. The data show, with few exceptions, that counties in these states had a REAF below the overall Germany-wide county median of 4.49 percent. The next group of counties belong to the states Schleswig-Holstein, Hessia, Thuringia, Saxony, Saxony-Anhalt, Lower Saxony, Mecklenburg-Western Pomerania, Hamburg, and Bremen: in these counties, the REAF used to be above the county median but below the counties in Brandenburg and Berlin where the mean REAF was just below 7 percent for the buyer. The ex-ante heterogeneity in the REAF for buyers directly translates to changes in the REAF after the introduction of the law. Counties with a higher average REAF for homebuyers before the introduction of the law experienced a larger percentage-point decrease in the average REAF than counties with a lower ex-ante REAF. This change in the REAF in percentage points is depicted in Figure 3.2.C. Figure 3.2.B shows the average REAF after the introduction of the law. The data shows a decrease in the average REAF in all counties, ranging from 2.99 to 0.11 percentage points. In half the counties, the average REAF decreased by more than 1.07 percentage points. After the introduction of the law, the average REAF on a county level ranges from 2.73 to 4.47 percent, with more than 3.43 percent in half the counties.

The main takeaway of this section is that there is a measurable effect of the new "Law on the distribution of real estate agent fees when brokering purchase contracts for apartments and single-family houses" on the REAF for the buyer in the data. The mean REAF decreased by 1.44 percentage points. However, the effect of the law is regionally heterogeneous with some regions experiencing a decrease of up to 3 percentage points and others with a smaller decrease. What is more, the change in the REAF is dependent on the height of the REAF before the introduction of the law.

The next section builds on these findings and introduces the main research hypothesis and its corollaries.

Figure 3.2: Regional variation and change in the REAF on a county level



Note: A: Mean REAF by county in percent before introduction of the law, i.e. January 2019 until 5 January 2021. B: Mean REAF by county in percent after introduction, i.e. 6 January 2021 until 31 March 2022. Note that the introduction date is shifted by two weeks into the future as discussed above. C: Change in mean REAF by county from before the introduction to after in percentage points. The maps show the 401 German counties. The thick dark lines represent the borders of the 16 federal states.
Source: Author’s calculations based on Value Marktdaten.

3.6 Empirical analysis

3.6.1 Hypothesis and corollaries

Motivated by the finding that the "Law on the distribution of real estate agent fees when brokering purchase contracts for apartments and single-family houses" led to a decrease in the REAF for homebuyers, I formulate the main hypothesis to be explored in the following empirical analysis:

H: The decline in the REAF for homebuyers led to an increase in housing prices.

The central hypothesis is based on the reasoning that if transaction costs for homebuyers are lower, i.e. their REAF decreases, homebuyers will have more funds available to invest in the purchase price rather than having to spend them on transaction costs. If the seller side realises this, they could demand a higher purchase price for the dwelling. What is more, as discussed in the related literature section, a large body of research finds subsequent price effects after changes in real estate transfer costs and subsidies. Beyond the main hypothesis, I want to explore in the following who would benefit from a decrease in the REAF. Hence, the main hypothesis comes with a set of corollaries.

Potential corollary 1: If H was rejected, i.e. no price effect:

First off, if the law had no price effect and H is rejected, the buyer clearly benefits from a reduction in the REAF, as the total cost of a dwelling decreases, giving her the option to either increase her downpayment, thereby reducing the overall mortgage and ensuing costs, or leaves her with funds to spend outside of the housing purchase.

The effect on the real estate agents as well as the sellers cannot be answered directly with the data analysed. This is because the data includes information on the REAF for the buyers only, not the sellers. However, it is highly likely that a decrease in the REAF for the buyer is associated with an increase in the REAF for the seller. This follows from the construction of the law and how real estate agents are typically hired. In Germany, it is usually the seller who hires the real estate agent. If this holds and a REAF for the buyer is observed in the data after the introduction of the law, then the seller must at least pay the same REAF as the buyer. In this case, the total REAF paid to the real estate agent might remain unchanged. Before the introduction of the law, the buyer likely paid a higher REAF than the seller, in some regions the whole amount. After the introduction of the law, the buyer pays a lower REAF, and the seller compensates the real estate agent for this decrease. In this likely scenario, the real estate agent remains unaffected by the new legislation.

The seller, however, is negatively affected, as he now must pay a higher REAF than if he had sold the dwelling before the introduction of the law, thereby reducing his overall profits from the sale.

Potential corollary 2: If H was not rejected, i.e. positive price effect:

If there was a positive price effect of the reduction in the REAF for the buyer, i.e. H cannot be rejected, then who benefits or is negatively affected by the change is not clear a priori.

Potential corollary 2a: Effect on seller:

The seller benefits from an increase in the housing prices if and only if the change in the dwelling's price is large enough to compensate him for the REAF increase he is faced with. Let the seller's profit, PR, from the sale be the price p less the REAF in percent ϕ times the price, then the following holds (see Equation 3.A.1 in the appendix):

$$PR_B^S < PR_A^S \Leftrightarrow \frac{\Delta\phi^S}{1-\phi_A^S} < \delta \tag{3.3}$$

In Equation 3.3 subscript B indicates the time before the introduction of the law, subscript A the time after. The superscript S is for the seller. $\Delta\phi^S$ is the change in the REAF for the seller (ϕ_A^S - ϕ_B^S) in percentage points and δ is the dwelling's price increase in percent. This implies that, depending on the REAF before and after the introduction of the law, as well as the dwelling's price increase, the seller either makes a larger profit from the sale of the dwelling or a smaller profit if the price increase does not compensate him for having to pay a higher REAF.

Potential corollary 2b: Effect on buyer:

Next, I derive conditions for which the buyer of the dwelling would profit from the law if there was a price pass-through. This is somewhat more complex, as there are two cases to be distinguished. In the first and simpler case, the buyer pays for the dwelling in cash. This is usually not the case, only 19 percent of homebuyers in Germany do not turn to a bank for a mortgage when buying a dwelling (Ammann, 2019). In this scenario, whether the buyer profits depends, again, on the REAF and its change as well as the price change of the dwelling. The condition for the buyer's ensuing costs C after the introduction of the law to be lower than before is summarised in Equation 3.4.A and derived in Equation 3.A.2 in the appendix. It should be noted that a lower REAF usually leads to a larger down payment (see Equation 3.A.3 in the appendix), even if the REAF decrease is fully absorbed in prices.

In most cases, buyers make use of a mortgage to finance their purchased dwelling. In this case, whether they profit from a reduction of the REAF additionally depends on the way their mortgage is set up, i.e. on the interest rate and the down payment, expressed in percent of the dwelling's price. I assume the buyer makes use of a full repayment loan and to keep calculations simple, I assume that potential changes in the buyers down payment do not affect the interest rate. This simplifying assumption is not unrealistic. As the changes in the REAF after the introduction of the law are likely to be around 3.57 percentage points at most, significant changes in the interest rate offered for the loan are not to be expected if the downpayment would increase by the same amount. Thus, the condition in Equation 3.4.B holds if the mortgage conditions μ remain identical before and after the REAF change, as is summarised in Equation 3.4.B and derived in Equation 3.A.4 in the appendix.

Without mortgage: $$C_A^B < C_B^B \Leftrightarrow \frac{\Delta\phi^B}{1+\phi_A^B} > \delta \tag{3.4.A}$$

With mortgage: $$C_A^B < C_B^B \Leftrightarrow \frac{\Delta\phi^B}{1+\phi_A^B} > \delta \Leftrightarrow \mu_A = \mu_B \tag{3.4.B}$$

Potential corollary 2c: Effect on real estate agent:

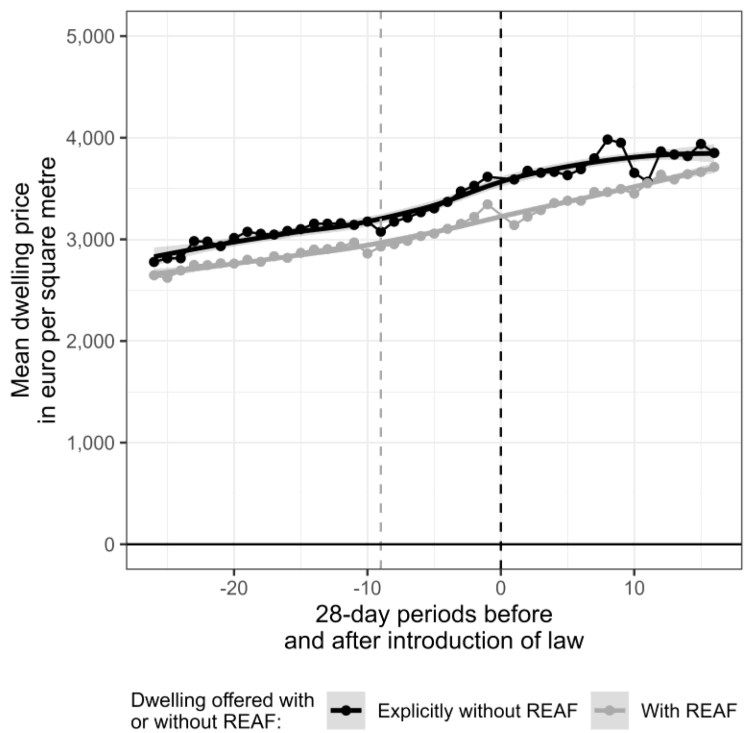
Finally, consider the real estate agent. As her profit is dependent on the price, ceteris paribus, her profit increases if the dwelling's price increases. If the sum of the buyer's and seller's REAF remained the same after the introduction of the law, the real estate agent profits. Again, as the data analysed here only includes the REAF for the buyers, it is unclear how the REAF for the sellers changed after the law's implementation. However, the decrease in the REAF for the buyer is likely associated with an increase in the REAF for the sellers. This point is further elaborated in the discussion of policy implications. Next, the empirical identification strategy to test the main hypothesis is outlined.

3.6.2 Identification strategy

I employ two different estimation strategies. Both strategies are related to the difference-in-differences approach (Bertrand et al., 2004; Angrist & Pischke, 2009). This empirical approach has been widely adopted in recent studies evaluating policy interventions in Germany and their impacts on the housing market (Thomschke, 2019; Breidenbach et al., 2022; Sagner & Voigtländer, 2022; Krolage, 2023; Hahn et al., 2023; Dolls et al., 2025). I continue by outlining the estimation strategies and their caveats.

In the first approach, I define those dwellings offered with a REAF for the buyer as the treatment group and the dwellings offered explicitly without a REAF for the buyer as the control group. This approach relies on the following central assumption: the price of the dwellings explicitly offered without a REAF for the buyer would have developed the same after the introduction of the new legislation as the price of the dwellings which include a REAF for the buyer, had the new legislation not been introduced. This describes a counterfactual unobserved scenario. Figure 3.3 shows the price trends for the dwellings offered for sale with a REAF and those offered explicitly without a REAF for the buyer. The mean prices per square metre seem to follow a parallel trend before the introduction of the law with the price for dwellings offered without a REAF being larger than those offered with a REAF. Based on this, I conclude that the pre-treatment trends in the dependent variable for the treatment and control group are similar, satisfying the parallel trends assumption.

Figure 3.3: Price trends for dwellings offered with or without a REAF



Notes: This figure shows the mean price per square metre for dwellings offered explicitly without a REAF for the buyer and those offers which include a REAF, aggregated by 28-day periods before and after the introduction of the law. In addition to the mean values, a smoothed trend line (LOESS) is included. The light-grey vertical dashed line indicates the month of the announcement of the law, the dark-grey vertical dashed line indicates the month of the introduction of the law.
Source: Author's calculations based on Value Marktdaten.

Based on these assumptions, formally, I estimate the OLS regression in Equation 3.5, where the dependent variable is the natural logarithm of the price in euro per square metre for dwelling i at time t. α is the intercept. Φ_i is a dummy variable equal to one if the dwelling is offered with a REAF for the buyer and zero if the dwelling is offered explicitly without a REAF. β represents the average treatment effect, capturing the difference in outcomes between the treatment and control groups before the treatment. D_t is a dummy variable equal to one after the introduction of the law and zero before. γ captures the average effect of time, representing the change in outcomes over time for the control group. The main coefficient of interest is δ which captures the price change for dwellings offered with a REAF vis-à-vis dwellings offered without a REAF after the introduction of the law while taking pre-introduction differences into account. X_{it} is a vector of dwelling characteristics, such as its type, e.g. detached house, one room apartment, etc., size in square metres, year of construction, whether it has a terrace, balcony or basement, whether a kitchen is included, whether it comes with a parking space, as well as an indicator for the state of the dwelling's amenities and its overall condition. ρ describes postal code fixed effects, ω captures region type × time fixed effects. Region types are distinguished into four categories: sparsely populated rural areas, more densely populated rural areas, urban areas, and large cities. By interacting these region types with time, I allow for heterogeneous time trends by region type. ζ is an indicator variable for the calendar month which should capture seasonal trends. $\varepsilon_{i,t}$ captures the error term.

$$\ln(p_{it}) = \alpha + \beta\Phi_i + \gamma D_t + \delta(\Phi \times D)_{it} + \theta X_{it} + \rho + \omega + \zeta + \varepsilon_{it}. \tag{3.5}$$

The approach described above comes with some caveats. First, there might be spillovers from the treated to the untreated dwellings. This would be the case if one considers the price-setting of dwellings with a REAF to be influential on the price setting for dwellings without a REAF. One could argue that real estate agents, as experts in local market dynamics, influence market prices, and that sellers not using a real estate agent base their prices on those set by agents, as observed on online platforms. In this case, prices for dwellings with a REAF would likely see an increase relative to dwellings without a REAF in the short and mid-term, if prices made by real estate agents are first-mover prices and adapt more quickly to the new law on the REAF, after which prices might converge again as prices without a REAF are adapting to the now overall higher price level. I explore this implicitly in the following event study design. A second, potentially more significant, spillover threat might arise from sellers being less likely to hire a real estate agent after the introduction of the law. Especially in regions where sellers previously did not have to pay or paid a lower REAF, they might choose to sell the dwelling themselves without hiring an agent, thereby saving on the REAF. I address this potential spillover in a robustness check. These sources of potential endogeneity also provide reason to explore alternative estimation approaches, as outlined in the following paragraph.

The second estimation approach is a difference-in-differences estimation with a continuous treatment variable. This form of estimation strategy and especially its interpretability as causal is discussed intensively (Callaway et al., 2024). A difference-in-differences estimation strategy with a continuous treatment variable can be interpreted as measuring treatment intensity. This estimation approach may be applicable in situations where constructing a control group is not possible, i.e. a group of observations that should not have been affected by a policy intervention does not exist, or when potential spillover effects arise from treated to untreated observations, and treatment intensity varies among the treated observations.

As shown in Figure 3.2, there is considerable variation in the reduction of the REAF. To make use of this variation, rather than employing a bivariate difference-in-differences approach, I construct a treatment intensity variable $\mathrm{I_k}$. The treatment intensity is defined as the post-introduction average of the REAF for homebuyers in county k minus the pre-introduction average REAF of the dwellings in county k. Formally,

$$\mathrm{I}_k \equiv \bar{\phi}_{k,post} - \bar{\phi}_{k,pre}. \tag{3.6}$$

This continuous variable then becomes the treatment variable, and the following regression is estimated:

$$\ln(p_{it}) = \alpha + \beta \mathrm{I}_k + \gamma D_t + \delta(\mathrm{I} \times D)_{kt} + \theta X_{it} + \rho + \omega + \zeta + \varepsilon_{it} \tag{3.7}$$

Equation 3.7 includes the treatment intensity interacted with the treatment time indicator instead of a bivariate indicator for the dwelling being offered with or without a REAF. This estimation approach only makes use of the dwellings offered with a REAF.

I additionally supplement the time-pooled difference-in-differences analysis with an event study design which offers a nuanced perspective on treatment effects. While the pooled analysis averages treatment effects over time the event study design makes it possible to delve into temporal dynamics, uncover lagged effects and treatment heterogeneity over time. The equivalent of Equation 3.5 as an event study then becomes Equation 3.8. Here, treatment occurs at time $\tau = 0$ and q periods before the introduction of the law are included as well as

m periods after the introduction of the law. The event study setup for the continuous treatment case can be formulated equivalently and is omitted here.

$$\ln(p_{it}) = \alpha + \sum_{\tau=-q}^{-1} \beta_\tau D_{i\tau} + \sum_{\tau=0}^{m} \delta_\tau D_{i\tau} + \theta X_i + \rho + \gamma + \zeta + \varepsilon_{i,k,t}. \quad (3.8)$$

Before presenting the main results of the estimation approaches, the research in this paper is placed within the existing literature in the next section.

3.7 Related literature

This study contributes to the existing literature by examining the impact of decreasing the REAF for buyers on housing market dynamics. Since the total costs of purchasing a dwelling can be influenced through various external channels, this paper must be positioned within the body of literature that examines policy measures related to the overall costs of a housing purchase. These measures often operate under a similar logic in terms of their impact on housing prices. Generally, decreasing (increasing) taxes or fees related to buying property or granting (removing) subsidies when buying property reduces (increases) the overall costs of buying a dwelling. This raises the question whether these are capitalised into housing prices and who benefits to what extent from those measures.

Capitalisation effects of housing purchase subsidies into real estate prices are found in many countries. Instead of granting lump sum direct subsidies, many countries granted mortgage interest deductions (MIDs), whose size depends on both, the price of the dwelling or property, and the individual marginal tax rates. Several studies suggest substantial capitalisation effects of MIDs into house prices. A review of international evidence on the impacts of MIDs by Bourassa et al. (2013) finds that tax policies both affect the price of housing, most likely due to capitalisation effects, as well as the costs of owner-occupied housing and the probability of becoming a homeowner. Sommer & Sullivan (2018) find that eliminating MIDs leads to lower property prices, increased homeownership, decreased mortgage debt and improved welfare. Similarly, Hilber & Turner (2014) using U.S. data from 1984 to 2007 suggest that MIDs promote homeownership attainment only among higher income households in less tightly regulated markets, but the reverse holds true for lower income households in highly regulated markets. Thus, MIDs neither seem to boost homeownership nor improve social welfare. Evidence from Sweden and Denmark also suggests a capitalisation of after-tax interest rate subsidies into housing prices (Berger et al., 2000; Gruber et al., 2021). Specifically, Gruber et al. (2021) find that a reduction of MIDs distorts homeowners at the intensive margin in the sense that large and more expensive homes are bought while indebtedness increases but does not affect homeownership.

In addition to the above evidence on indirect subsidies, other studies focus on direct subsidies. Employing a general equilibrium model with heterogenous agents, Floetotto et al. (2016) examine both the effect of homebuyer tax credits and the asymmetric tax treatment of owner-occupied and rental housing on prices. They find the first to temporarily increase housing prices and transaction volumes, while the removal of the latter can generate significant welfare gains for most agents across steady states.

In contrast to the REAF studied in this analysis, the RETT has been subject to a lot of studies in many different countries. Their results can be helpful when assessing the potential impact of the REAF. Krolage (2023) investigates the effect of the 2018 introduction of housing purchase subsidies for existing and newly constructed properties in Bavaria which was applied on top of a national subsidy. In Bavarian border regions, the prices of single-family homes increased by approximately 10,000 euros more than in neighbouring regions of other states. This is equal to a full absorption of the lump sum subsidy of 10,000 euros. Krolage (2023) argues that because the lump sum subsidy is fully absorbed into prices, the Bavarian subsidy scheme led to rising housing prices and mainly benefitted the sellers.

Benjamin et al. (1993) find that as a result of higher tax rates, sales prices of properties inside of Philadelphia decreased relative to properties outside of Philadelphia. Kopczuk & Munroe (2015) investigate the introduction of the 1 percent “mansion tax” on residential transactions over 1 million dollars in New York and New Jersey. They find evidence of substantial bunching just below the price notch, creating a significant burden for sellers, and signs of market unravel near the notch, reducing the incentives of market participants to pursue transactions close to the notch. Furthermore, there is a permanent increase of price reductions and discounts above the threshold, indicating that the search and matching process is affected by the tax. Apart from that, they document a higher discrepancy between sale and asking price, pointing towards inefficiencies in the search process. In contrast, Slemrod et al. (2017) exploiting notched tax rate changes in Washington D.C. find little evidence of welfare costs resulting from altering the RETT.

Studies for the UK make use of the 2008 to 2009 stamp duty holiday to analyse the effects of a transaction tax on housing (Best & Kleven, 2018; Besley et al., 2014). Employing administrative data on all property transactions between 2004 and 2012, Best & Kleven (2018) suggest transaction taxes to have a highly distortionary effect on price, volume, and timing of property transactions. Due to the notch in the UK stamp duty tax, property prices decreased by an amount roughly equal to the tax for a single transaction. Moreover, they find temporary tax cuts to effectively stimulate housing market activity, which is reversed only to a small extent after the reintroduction of the tax. Besley et al. (2014) document a decrease in the post-tax sale price and an increase of transactions of properties because of a tax reduction. However, they find that most of the latter was rapidly reversed after the withdrawal of the policy.

In line with the evidence above, Dachis et al. (2012) study a permanent tax change, namely the introduction of the land transfer tax in Toronto on single-family house sales in 2008. They document that the 1.1 percent tax increase led to both, a decline in housing prices of the same magnitude as the tax, as well as to a 15 percent decline in the number of sales. For Germany, Fritzsche & Vandrei (2019) find a negative correlation for single-family homes between an increase in the RETT and the number of transactions taking place, suggesting that RETT rate hikes are anticipated by market participants. Dolls et al. (2025) find that increasing the RETT was followed by lower dwelling prices in Germany.

3.8 Results

In this section, the results of the empirical analysis are presented. First, the time-pooled results are discussed for the two identification strategies employed. Next, the analysis is extended to an event study design. Finally, the section concludes with an exploration of potentially heterogeneous effects and a presentation of robustness checks.

3.8.1 Main – Time-pooled difference-in-differences estimation

Table 3.3 shows the reduced-form results for the time-pooled difference-in-differences estimations with only two time indicators: before and after the introduction of the law, i.e. variants of Equation 3.5 (columns (1) to (3)) and Equation 3.7 (columns (4) to (6)). The full regression tables can be found in the appendix (Table 3.A.2 and Table 3.A.3). I begin with the case of a binary treatment indicator with those dwellings offered with a REAF as treated dwellings and those offered without a REAF serving as a control group, results are depicted in columns (1) to (3). First, it should be noted that the main coefficients all have the expected sign and are of sensical magnitude. Results in column (1) indicate that in the bare bones model without any control variables other than postal code fixed effects to control for differences in regional price levels, the introduction of the law lead to an increase in the prices of dwellings which were offered with a REAF of 1.304 percent relative to dwellings which were explicitly offered without a REAF for the buyer. In this case, this would mean almost a full absorption of the reduction in agent fees for homebuyers into housing prices. Recall that the average REAF for buyers decreased by 1.44 percentage points after the introduction of the law. Adding further fixed effects reduces the coefficient as expected and seen in column (2). When additionally controlling for dwelling characteristics, the effect decreases to 0.610 percent as depicted in column (3). However, as I will show later, this time-pooled effect is masked by heterogeneous effects over time.

In case of the continuous treatment indicator (columns (4) to (6)), the interpretation of the coefficients is not as straightforward as in the classical difference-in-differences approach with a binary treatment indicator. The continuous treatment hinges on the assumption that price changes in counties with small changes in the REAF provide a good counterfactual for the changes in prices that would have been observed in counties with larger changes in the REAF, if their REAF had changed similarly. Assuming this untestable form of a common trends assumption holds (Callaway et al., 2024), I find that a 1 percentage point decrease in the REAF led to a price increase of 0.757 percent in the preferred regression with a full set of controls (column (6)). This alternative identification strategy supports the conclusion that the decrease in the REAF for the buyer, caused by the introduction of the "Law on the distribution of real estate agent fees when brokering purchase contracts for apartments and single-family houses", resulted in a purchase price pass-through. In the next chapter, I explore the timing aspect of the introduction of the law further and employ an event study design. Investigating intertemporal dynamics is crucial, as it provides insights into how the effects of the policy evolve over time, allowing for a more nuanced understanding of the timing and magnitude of price adjustments.

Table 3.3: Main results – Time-pooled difference-in-differences

	Binary treatment (Main)			**Continuous treatment (Supplementary)**		
	(1)	(2)	(3)	(4)	(5)	(6)
$\boldsymbol{\delta}$	1.304*** (0.228)	0.899*** (0.226)	0.610*** (0.178)	0.806*** (0.176)	1.035*** (0.170)	0.757*** (0.148)
Postal code FE	✓	✓	✓	✓	✓	✓
Region type × time FE	✗	✓	✓	✗	✓	✓
Calendar month FE	✗	✓	✓	✗	✓	✓
Dwelling characteristics	✗	✗	✓	✗	✗	✓
N	874,981	874,981	797,818	522,858	522,858	491,384
Adj. R^2	0.700	0.706	0.793	0.729	0.735	0.809

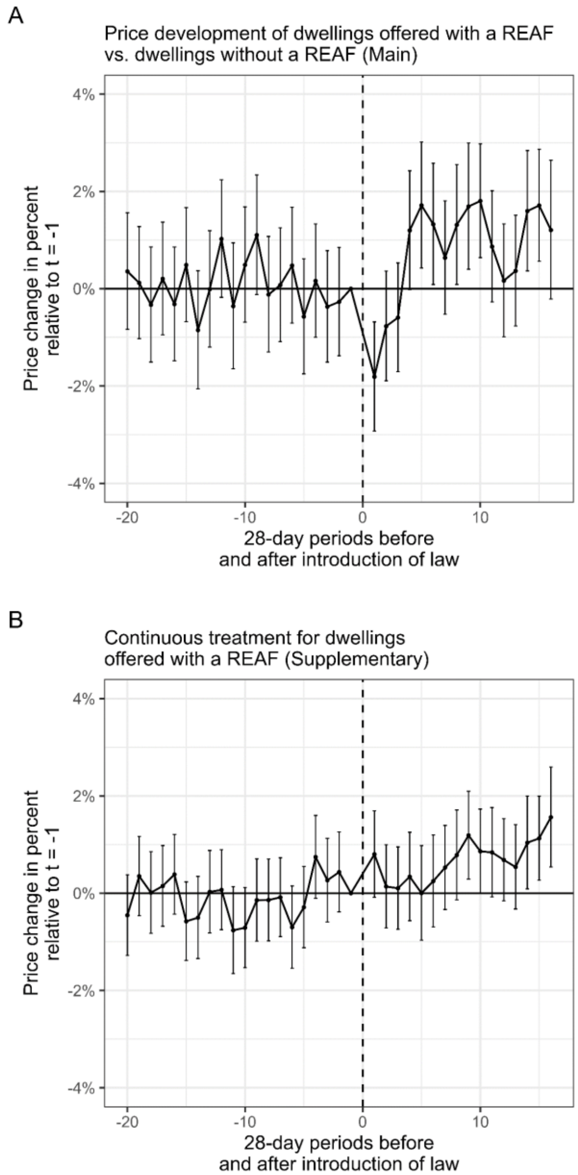
Notes: The dependent variable is the natural logarithm of a dwelling's price in euro per square metre. Coefficients and standard errors are transformed and represent percentage changes. Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and + indicate significance at the 0.1, 1, 5, and 10 percent levels.
Source: Author's calculations based on Value Marktdaten.

3.8.2 Main – Event study design

The results of the event study design are illustrated in Figure 3.4. The dashed vertical line indicates the time of the introduction of the law. The results in Figure 3.4.A clearly show that there are no time-variant pre-treatment differences in purchase prices in relation to the last month before the introduction of the law, i.e. no anticipation effects. After the introduction of the law, prices for treated dwellings decrease, this is due to data collection errors. The data problem is due to data cleaning at the end of the year on the data provider's side, as offers no longer active are excluded from the data. The negative deviation in prices is only statistically significant for the first month after the introduction of the law. Four months after the introduction of the law, the prices for dwellings offered with a REAF start to increase and differences remain positive. The price difference has its peaks between 1.6 and 1.9 percent. Excluding the data problem in the first month after the introduction of the law, the mean price difference compared to the control group after the introduction is equal to 0.95 percent. Hence, event study results point to an absorption of the decrease in the REAF into prices and underline the findings of the time-pooled estimation approach.

Figure 3.4.B shows further support for the REAF reduction to have led to an increase in purchase prices. This figure shows the event study results for the continuous treatment approach. I find that there are no price differences for dwellings with a larger REAF decrease to those with a smaller REAF relative to the last month before the introduction of the law in the pre-treatment period. However, after the introduction of the law, I find that price differences for dwellings with a smaller REAF decrease and those with a larger REAF decrease widen, pointing towards price adjustments in the expected direction. At the mean, a 1 percentage point decrease in the REAF results in statistically significant higher prices of around 1 percent, peaking at 1.56 percent. In the following chapter, I further investigate heterogeneous effects by dwelling and region type. I continue the analysis by focusing on the main identification strategy.

Figure 3.4: Main results – Event study



Notes: The figures show 28-day-period event study estimates. Error-bars indicate 95-percent confidence intervals. Coefficients and illustrated confidence intervals are transformed and represent percentage changes. Control variables correspond to those of the full model in Table 3.3, column (3) for subfigure A and column (6) for subfigure B. The number of observations for subfigure A is 797,818, for subfigure B it is 491,384.
Source: Author's calculations based on Value Marktdaten.

3.8.3 Dwelling type heterogeneity

Exploring dwelling type heterogeneity is highly relevant to assess the potentially affected buyers and sellers. As pointed out by Dolls et al. (2025) and reported by Deutsche Bundesbank (2018), in Germany apartments in multi-family houses are more likely to be bought by investors to be rented out while single-family houses are typically bought by owner-occupiers. However, especially in urban areas, dwellings in apartment buildings are much more common than single-family houses, making them a more likely option for owner-occupiers, as well. Table 3.4 shows the results for the data stratified by dwelling type. The results show that overall effects are driven by apartments with a price increase for those apartments offered with a REAF relative to those without a REAF after the introduction of the law of 1.552 percent (column (3)) which would reflect a full pass-through of the REAF decrease to purchase prices. I find no effect for single-family houses. The finding that prices for apartments react more sensitively to changes in transaction costs are in line with findings by Dolls et al. (2025) and their analysis of price effects due to changes in the real estate transfer tax.

Table 3.4: Results – Stratification by dwelling type

	Apartments			**Single-family houses**		
	(1)	(2)	(3)	(4)	(5)	(6)
$\boldsymbol{\delta}$	2.525*** (0.277)	2.009*** (0.277)	1.552*** (0.214)	-0.224 (0.323)	-0.354 (0.319)	-0.369 (0.261)
Postal code FE	✓	✓	✓	✓	✓	✓
Region type × time FE	✗	✓	✓	✗	✓	✓
Calendar month FE	✗	✓	✓	✗	✓	✓
Dwelling characteristics	✗	✗	✓	✗	✗	✓
N	487,189	487,189	441,557	387,792	387,792	356,261
Adj. R^2	0.762	0.772	0.832	0.632	0.639	0.758

Notes: The dependent variable is the natural logarithm of a dwelling's price in euro per square metre. Coefficients and standard errors are transformed and represent percentage changes. Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and + indicate significance at the 0.1, 1, 5, and 10 percent levels.
Source: Author's calculations based on Value Marktdaten.

3.8.4 Regional heterogeneity

Next, I analyse if growing and shrinking housing market regions are affected differently by changes in the REAF. The reasoning behind this stratification is that a seller's bargaining power might be higher in growing housing market regions, as demand for housing is larger. Therefore, the potential to raise prices might be greater (Dolls et al., 2025). Table 3.5 presents the regression results for the full model for growing and shrinking housing market regions, as well as the substratification by dwelling type. Before the introduction of the law, the mean (median) REAF for homebuyers in regions with a growing housing market was 4.89 (4.76) percent, after the introduction of the law it decreased to 3.42 (3.57) percent which represents a change of -1.48 (-1.19) percentage points. In shrinking housing market regions, the mean (median) REAF before the introduction of the law was 5.12 (4.99) percent, in the period after the introduction of the law analysed here, it decreased to 3.73 (3.57) percent, which is a change of -1.40 (-1.42) percentage points. Hence, both, the REAF levels and the REAF change in the region types are of very similar magnitude and potential differences in the effect on prices could be attributed to whether the dwelling is in a growing or shrinking housing market, i.e. the region type itself.

Table 3.5 shows the price effect of the REAF change is larger in growing housing market regions with a plus of 1.193 percent (column (1)) and largest for apartments in growing housing market regions with a price increase of 1.655 percent (column (2)). I also find effects on single-family houses in growing housing market regions in the expected direction, however relatively small and statistically significant at the 10 percent level only. In shrinking housing market regions, I find either statistically insignificant effects or even counterintuitive negative effects on prices. The findings give support to the theory that in growing housing market regions which are typically sellers' markets, changes in transaction costs are more likely to be absorbed by price changes than in shrinking buyers' markets. A finding that Dolls et al. (2025) also underline in their analysis of changes in the RETT.

Table 3.5: Results – Stratification by housing market region and dwelling type

Housing market region:	**Growing**			**Shrinking**		
Dwelling type:	(1) **Total**	(2) **Apartments**	(3) **Single-family houses**	(4) **Total**	(5) **Apartments**	(6) **Single-family houses**
δ	1.193*** (0.183)	1.655*** (0.221)	0.487+ (0.270)	-1.584* (0.647)	-0.638 (0.319)	-1.717* (0.748)
Postal code FE	✓	✓	✓	✓	✓	✓
Region type × time FE	✓	✓	✓	✓	✓	✓
Calendar month FE	✓	✓	✓	✓	✓	✓
Dwelling characteristics	✓	✓	✓	✓	✓	✓
N	631,330	380,247	251,083	96,233	29,704	66,529
Adj. R^2	0.773	0.813	0.729	0.627	0.708	0.630

Notes: The dependent variable is the natural logarithm of a dwelling's price in euro per square metre. Coefficients and standard errors are transformed and represent percentage changes. Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and + indicate significance at the 0.1, 1, 5, and 10 percent levels.
Source: Author's calculations based on Value Marktdaten.

3.8.5 Robustness checks and endogeneity concerns

This section presents results from different sensitivity analyses. To check the robustness of the findings, I modify the empirical identification strategy in two major ways. The first robustness check addresses potential regional spillover effects. The second addresses the chosen treatment time. Additionally, I discuss the possibility of spillovers from dwellings offered with a REAF to dwellings offered without a REAF.

3.8.5.1 Controlling for potential regional spillovers

Regional spillover effects may occur following the REAF change introduced by the law if changes in the REAF cause housing demand to shift across regional borders. Potential homebuyers in border regions, where the REAF decreases in one region but not in the other, might be tempted to purchase a house in the region with the lower REAF to take advantage of the reduced cost. This shift in demand across borders might drive up prices in the regions where the REAF was lowered, hence, the above results would be biased upward. To address this endogeneity concern, I restrict the real estate data to be outside a 10-kilometre buffer zone in either direction of a state border, see Figure 3.A.3 in the appendix for a graphical representation. As summarised in Table 3.A.4 in the appendix, the main results remain unchanged, coefficients are even slightly larger than in the unrestricted sample which includes border regions. In the full model, I find a price effect of 0.660 percent. I additionally re-ran the event study design. Results are shown in Figure 3.A.4 in the appendix. Time trends remain unchanged, also. Post introduction of the law, the prices for dwellings offered with a REAF were offered at a higher price in relation to dwellings offered without a REAF when controlling for pre-law differences in price levels. Starting 16 weeks after the introduction of the law, price differences fluctuate around 1 to 2 percent. I conclude that while there are small differences in the size of the coefficients, both the general trend as well as the main finding of the decreases in the REAF having had a positive price effect are robust to potential cross-border spillovers.

3.8.5.2 Analysis by start date

I chose to analyse the real estate offers by their last date of being available online, as it is the sale date that is relevant for the law to be binding, not the offer date. I argued this form of analysis is more appropriate in the context of the research question at hand. To underline this point, I re-run the main regression and its event study form to investigate whether analysing the data by its first date of being offered online changes the qualitative and quantitative result. Table 4.A.5 in the appendix contains the main regression results. Qualitatively, the results remain unchanged. However, the coefficients are larger. In the full model, I find a price effect of 1.132 percent. The event study shows statistically significant differences in prices for dwellings offered with a REAF and those offered without after the introduction of the law. For the event study in this case, as depicted in Figure 3.A.5 in the appendix, I chose the last month before the announcement of the law as the reference month. Again, qualitatively, the results are in line with the main identification strategy and timing chosen above. However, the event study clearly demonstrates that analysing data based solely on the first day a dwelling is listed online overlooks the time required to sell the property. This approach mistakenly attributes price effects to the post-treatment period when they should be attributed to the pre-treatment period.

3.8.5.3 Caveat: Group spillovers

Another potential source of endogeneity in the chosen main identification strategy could arise from spillover effects between treated and untreated dwellings. With the introduction of the law, in some regions sellers had to either pay a higher REAF than before or pay a REAF for the first time, because it had been common for the buyer to pay a higher share of the REAF or even the REAF in full in the past. This gives sellers incentive to try and sell their dwelling without the services of a real estate agent and save on the REAF altogether. Figure 3.A.6 in the appendix shows the share of dwellings offered with a REAF over time. Before the introduction of the law, the average share of dwellings offered with a REAF was 62.2 percent, after the introduction of the law, it decreased to 55.9 percent. While the share has bounced back to pre-law levels momentarily, the time trend depicted suggests that the share of dwellings offered with a REAF remains lower than before the introduction of the law in the post introduction period analysed here. This could mean that the results presented above are biased. The direction of the bias would likely be upward, as average prices per square metre for dwellings with a REAF before the introduction of the law were lower than those offered without a REAF. This bias would of course only exist if the sellers selling without the services of a real estate agent who would have made use of a real estate agent, had the law not been introduced, set the prices at a comparable level as the real estate agent would have chosen, had they hired one. In that sense, the continuous treatment scenario (Table 3.3, columns (3)-(6) and Figure 3.4.B) might serve as a robustness check, as the underlying identification approach excludes offers without a REAF altogether and this potential endogeneity concern should not apply. That is because it is unlikely that the reform drove sellers who previously would not have hired a real estate agent to do so under the new law. Additionally, descriptives before and after the introduction of the law do not show significant differences in the control variables, as was shown in Table 3.2.

3.9 Discussion of findings and policy implications

3.9.1 Discussion

This section discusses the policy implications of the main findings, specifically in the context of the potential corollaries formulated. Based on the empirical identification strategy presented in this paper, the findings are consistent with the main hypothesis, and I cannot reject that the introduction of the "Law on the distribution of real estate agent fees when brokering purchase contracts for apartments and single-family houses" had a positive effect on sales prices. Who profits or is negatively affected by this effect on prices can now tried to be answered by making use of the size of price effects estimated in the event study design which was presented in Figure 3.4.A. I refer to the statistically significant positive price effects and make use of the upper, and lower bound which are 1.803 percent and 0.165 percent. The mean price difference, not including the first three 28-day periods which showed a negative price dip, likely due to data problems as discussed above, is 1.199 percent, I consider this as the mean scenario. I additionally refer to the main effects estimated in the heterogeneity analyses.

3.9.1.1 Effect on sellers

I start by discussing the effects on the sellers. For the seller to profit from the introduction of the law, her selling price increase must be large enough to compensate her for potential increases in the REAF she has to pay, which was formally summarised in Equation 3.3. As the data does not include information on the seller's REAF but only on the buyer's REAF, I can only make assumptions to gauge the effect on sellers. I assume, that real estate agents did not decrease their overall fees after the introduction of the law and decreases in the REAF for the buyers directly resulted in increases for the sellers. The condition for the seller to profit becomes the inverse of the scenario for the buyer if he pays in cash. Assuming the sellers paid the difference of the 7.14 percent total REAF minus the average REAF for the buyers, which was 4.93 percent before the introduction of the law, sellers paid an average REAF of 2.21 percent before the introduction of the law. Further assuming, the REAF for the seller increased by 1.44 percentage points which is the average REAF decrease for buyers, sellers now pay an average REAF of 3.65 percent. Note that this would imply that the total REAF, the sum of REAF payments from buyers and sellers, would have increased to 7.22 percent of the dwelling's price after the introduction of the law. If this was the case, the law had a contrary effect to one of its intended goals which was to reduce overall transaction costs. Exploring this research question is beyond this paper's scope and remains to be answered in future research. Plugging in these values into Equation 3.3 shows that in the mean scenario with a price increase of 1.199 percent, sellers are not better off, as the critical threshold is $\delta > 0.01495$. However, the event study scenario showed there were months where price effects were larger. Further focusing on just apartments, Table 3.4 showed that for apartments the average pooled price effect of the REAF reduction was 1.552 percent, for apartments in growing housing markets the effect was 1.655 percent (see Table 3.5, column (2)), peaking at even higher values when considering the event study design. Hence, I conclude that if the above assumptions regarding the symmetric increase in the REAF for sellers, of the same magnitude as the decrease for buyers, hold, then sellers of apartments are likely to have profited from the law change, whereas sellers of single-family houses likely made a smaller profit than they would have without the law change.

3.9.1.2 Effect on buyers

The effect on buyers can be answered in a more straightforward way, as the REAF for the buyer is actually observed in the data. The average REAF decrease for the buyers was 1.44 percentage points resulting in an average REAF after the introduction of the law of 3.49 percent. Plugging in these values into Equations 3.4.A and 3.4.B suggests that buyers profit from the REAF decrease if prices increased by less than 1.391 percent after the introduction of the law. This means, that buyers who purchased a single-family house likely profited from the introduction of the law. On the other hand, those who bought an apartment faced a larger price increase and the REAF reduction had a negative effect on overall affordability.

3.9.1.3 Effect on real estate agents

Real estate agents most likely profited from the introduction of the law. As the overall sales price of dwellings, especially for apartments in growing housing markets, increased after the introduction of the law and real estate agents likely did not decrease their total fees as shown by Stoll (2023). If this holds true, then the introduction of the law, instead of decreasing overall transaction costs of dwellings, had the opposite effect.

3.9.2 Policy implications

The intent of the "Law on the distribution of real estate agent fees when brokering purchase contracts for apartments and single-family houses" is to regulate how real estate agent fees are distributed between the buyer and seller in real estate transactions involving apartments and single-family homes. This law aims to establish fair and transparent guidelines for allocating these costs, potentially reducing financial burdens and promoting more equitable transactions in the real estate market.

I find that the law had unintended effects on prices, resulting in heterogeneous impacts on sellers, buyers, and real estate agents. As the central goal of the law was to reduce transaction costs for potential homebuyers, the law was potentially not as successful as policy makers might have hoped. It led to a price pass-through from transaction costs to the sales price of dwellings, most pronounced for apartments in growing housing markets. This finding is very much in line with the existing literature on changes in the real estate transaction costs and ensuing effects on prices. However, the findings also suggest that the law succeeded when considering single-family homes, as I find no price pass-through for single-family homes and only a small price pass-through for single-family homes in growing housing markets. It can be argued that this splits the market in the segment where investors are more likely to buy, i.e. apartments, and the market for owner-occupiers, i.e. single-family houses. In the investment market, buyers are potentially more competitive and more cost-aware than in the market for owner-occupiers. As the decrease in the REAF on the investment side has a direct positive effect on the expected overall return of a dwelling, investors might quickly realise this and therefore are more likely to pay a higher price. This might explain why the real estate agents, being real estate professionals themselves, and sellers ask for a higher price.

Overall, while the law aimed to create a fairer distribution of real estate agent fees and reduce transaction costs for buyers, its effectiveness has been mixed. The unintended price pass-through effects, particularly for apartments in tense housing markets, highlight the need for policy makers to carefully consider market segmentation and behavioural responses in future regulatory efforts. A more tailored approach, accounting for differences between investment and owner-occupied markets, could enhance the law's intended benefits and minimise adverse side effects.

3.10 Conclusion

This paper exploits a law that was introduced in Germany in 2020 and studies the effects of changes in the REAF for homebuyers on housing prices. The law made it no longer possible for real estate agents to charge a fee from the non-hiring party if the hiring party does not pay a fee and if both the buyer and the seller hire a real estate agent the fee must be split equally among the two. I make use of a large micro dataset of dwellings offered for sale before and after the introduction of the law. The introduction of the law led to a significant decrease in the average real estate agent fee for potential homebuyers. With this initial finding I explore whether this reduction in the transaction costs for homebuyers led to a pass-through to purchase prices. I employ hedonic difference-in-differences regressions with both a binary and a continuous treatment and extend the analysis to an event study design. Results suggest that the decrease in the real estate agent fee led to a price pass-through, i.e. purchase price increase. This price pass-through is most pronounced for apartments in growing housing markets. Comparing ensuing costs for homebuyers, the estimated results imply that buyers of single-family homes are likely to have profited from the law. However, buyers of apartments in tense housing markets are likely to have been negatively affected, as I find a larger price pass-through in this segment making their overall costs after the introduction of the law higher than before.

Appendix

A.3.1 Tables

Table 3.A.1: REAF before and after the introduction of the law on the state level

State	Before		After		Change	
	Mean	Median	Mean	Median	Mean	Median
Baden-Württemberg	4.34	4.76	3.41	3.57	-0.93	-1.19
Bavaria (Bayern)	3.87	3.57	3.15	3.57	-0.73	0.00
Berlin	6.76	7.14	3.79	3.57	-2.97	-3.57
Brandenburg	6.68	7.14	4.06	3.57	-2.62	-3.57
Bremen	5.85	5.95	3.58	3.57	-2.27	-2.38
Hamburg	6.02	6.25	3.50	3.50	-2.52	-2.75
Hesse (Hessen)	5.70	5.95	3.45	3.57	-2.25	-2.38
Lower Saxony (Niedersachsen)	5.65	5.95	3.53	3.57	-2.12	-2.38
Mecklenburg-Vorpommern	6.07	6.00	3.75	3.57	-2.31	-2.43
North Rhine-Westphalia (Nordrhein-Westfalen)	4.08	3.57	3.34	3.57	-0.74	0.00
Rhineland-Palatinate (Rheinland-Pfalz)	4.35	3.57	3.40	3.57	-0.95	0.00
Saarland	3.63	3.57	3.40	3.57	-0.23	0.00
Saxony (Sachsen)	6.08	5.95	4.00	3.57	-2.08	-2.38
Saxony-Anhalt (Sachsen-Anhalt)	5.76	5.95	3.87	3.57	-1.90	-2.38
Schleswig-Holstein	5.24	5.95	3.44	3.57	-1.80	-2.38
Thuringia (Thüringen)	5.64	5.95	3.82	3.57	-1.82	-2.38

Notes: This table shows the mean and median REAF for buyers in percent in the 16 German federal states before and after the introduction of the law as well as the change in percentage points.
Source: Author's calculations based on Value Marktdaten.

Table 3.A.2: Full regression table (Main)

	Binary treatment (Main)		
	(1)	(2)	(3)
δ (DID with REAF and post introduction)	0.013 ***	0.009 ***	0.006 ***
	(0.002)	(0.002)	(0.002)
With REAF	-0.109 ***	-0.107 ***	-0.040 ***
	(0.002)	(0.002)	(0.002)
Post introduction	0.162 ***	-1.070	-0.652
	(0.002)	(355.726)	(218.474)
Dwelling type (ref: 1-room apartment)			
2-room apartment			0.023 ***
			(0.003)
3-room apartment			0.058 ***
			(0.003)
4-room apartment			0.084 ***
			(0.004)
5+-room apartment			0.112 ***
			(0.005)
Semi-detached house			0.168 ***
			(0.005)
Detached house			0.218 ***
			(0.005)
Terraced house			0.132 ***
			(0.005)
Year of construction			-0.030 ***
			(0.001)
Year of construction squared			0.000 ***
			(0.000)
Living space in sqm.			-0.001 ***
			(0.000)
Terrace or balcony			0.049 ***
			(0.001)
Basement (ref.: explicitly no)			
Unknown			0.011 ***
			(0.002)
Yes			0.002
			(0.003)
Built-in kitchen			0.019 ***
			(0.001)
Parking space			0.045 ***
			(0.002)

Continued on next page…

...Table 3.A.2 continued

State of dwelling fit-out (ref.: simple)			
Good			0.105 ***
			(0.002)
High-quality			0.154 ***
			(0.003)
Normal			0.069 ***
			(0.002)
State of dwelling overall (ref.: good)			
Normal			-0.099 ***
			(0.001)
Bad			-0.236 ***
			(0.002)
Postal code FE	✓	✓	✓
Region type × time FE	✗	✓	✓
Calendar month FE	✗	✓	✓
N	874,981	874,981	797,818
Adj. R^2	0.700	0.706	0.793

Notes: Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and + indicate significance at the 0.1, 1, 5, and 10 percent levels. The column numbering refers to the columns in Table 3.3.
Source: Author's calculations based on Value Marktdaten.

Table 3.A.3: Full regression table (Supplementary)

	Continuous treatment (Main)		
	(4)	(5)	(6)
δ (DID treatment intensity and post introduction)	0.008 ***	0.010 ***	0.008 ***
	(0.002)	(0.002)	(0.001)
Treatment intensity	0.119 *	0.119 *	0.088 *
	(0.050)	(0.052)	(0.043)
Post introduction	0.163 ***	-0.029	0.791
	(0.003)	(208.567)	(143.476)
Dwelling type (ref: 1-room apartment)			
2-room apartment			0.028 ***
			(0.003)
3-room apartment			0.065 ***
			(0.003)
4-room apartment			0.096 ***
			(0.004)
5+-room apartment			0.138 ***
			(0.006)
Semi-detached house			0.214 ***
			(0.005)
Detached house			0.273 ***
			(0.005)
Terraced house			0.177 ***
			(0.005)
Year of construction			-0.029 ***
			(0.001)
Year of construction squared			0.000 ***
			(0.000)
Living space in sqm.			-0.001 ***
			(0.000)
Terrace or balcony			0.044 ***
			(0.002)
Basement (ref.: explicitly no)			
Unknown			0.018 ***
			(0.003)
Yes			-0.006 *
			(0.003)
Built-in kitchen			0.026 ***
			(0.001)
Parking space			0.037 ***
			(0.002)

Table continued on next page…

...Table 3.A.3 continued

State of dwelling fit-out (ref.: simple)			
Good			0.107 ***
			(0.003)
High-quality			0.163 ***
			(0.003)
Normal			0.073 ***
			(0.003)
State of dwelling overall (ref.: good)			
Normal			-0.078 ***
			(0.001)
Bad			-0.210 ***
			(0.002)
Postal code FE	✓	✓	✓
Region type × time FE	✗	✓	✓
Calendar month FE	✗	✓	✓
N	522,858	522,858	491,384
Adj. R^2	0.729	0.735	0.809

Notes: Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and + indicate significance at the 0.1, 1, 5, and 10 percent levels. The column numbering refers to the columns in Table 3.3.
Source: Author's calculations based on Value Marktdaten.

Table 3.A.4: Robustness check – Border regions excluded

	Binary treatment indicator (Main)		
	(1)	(2)	(3)
δ	1.345*** (0.264)	0.921*** (0.262)	0.661*** (0.203)
Postal code FE	✓	✓	✓
Region type × time FE	✗	✓	✓
Calendar month FE	✗	✓	✓
Dwelling characteristics	✗	✗	✓
N	654,741	654,741	596,814
Adj. R^2	0.709	0.714	0.801

Notes: The dependent variable is the natural logarithm of a dwelling's price in euro per square metre. Coefficients and standard errors are transformed and represent percentage changes. Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and + indicate significance at the 0.1, 1, 5, and 10 percent levels.
Source: Author's calculations based on Value Marktdaten.

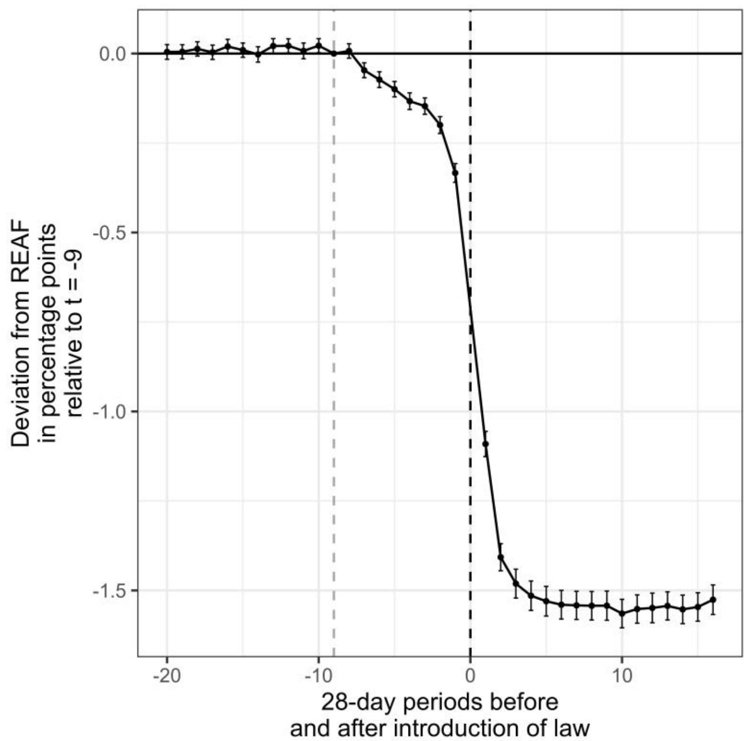
Table 3.A.5: Robustness check – Analysis by start date

	Binary treatment indicator (Main)		
	(1)	(2)	(3)
δ	2.801*** (0.252)	2.161*** (0.250)	1.132*** (0.194)
Postal code FE	✓	✓	✓
Region type × time FE	✗	✓	✓
Calendar month FE	✗	✓	✓
Dwelling characteristics	✗	✗	✓
N	834,914	834,914	759,205
Adj. R^2	0.695	0.701	0.791

Notes: The dependent variable is the natural logarithm of a dwelling's price in euro per square metre. Coefficients and standard errors are transformed and represent percentage changes. Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and + indicate significance at the 0.1, 1, 5, and 10 percent levels.
Source: Author's calculations based on Value Marktdaten.

A.3.2 Figures

Figure 3.A.1: Deviation from REAF before introduction of law over time

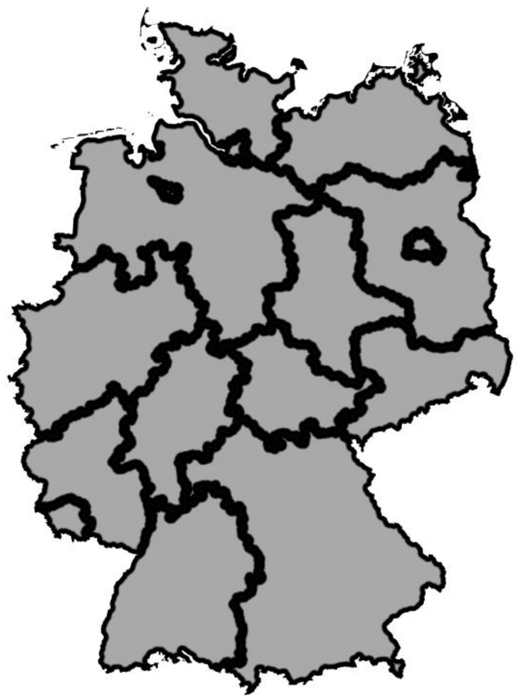


Notes: The figure shows the time dummy coefficients of an OLS regression with the REAF for the buyer as the dependent variable. The reference category for the time dummy is t = -9 (light-grey dashed line) which corresponds to May 2020, i.e. the last month before the announcement of the law. Time dummies are coded as 28-day periods before and after the introduction of the law with the first period after the introduction as t = 1, the last before the introduction as t = -1, hence there is no effect for period t = 0. The graph shows the deviation from the mean REAF in t = -9 in percentage points. 95-percent confidence intervals displayed. The regression includes 491,849 observations. In addition to a set of variables describing the dwelling's characteristics, postal code fixed effects are included. Standard errors are clustered at the postal code level.
Source: Author's calculations based on Value Marktdaten.

Figure 3.A.2: Change in median REAF at state level

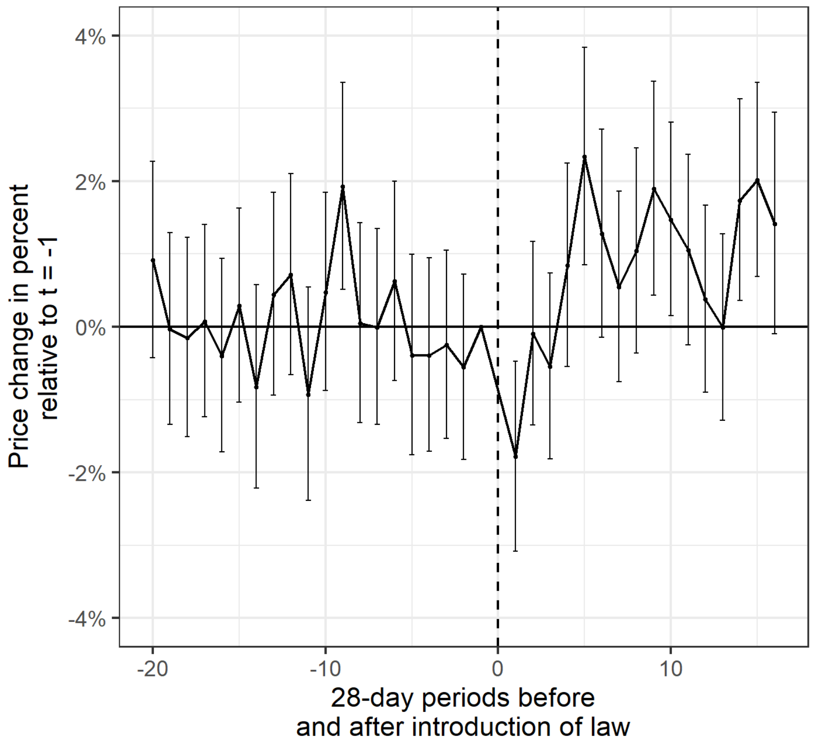
Notes: The map shows the change in the median REAF for the buyer in percentage points after the introduction of the law on the level of the 16 federal states.
Source: Author's calculations based on Value Marktdaten.

Figure 3.A.3: Illustration of border areas excluded for robustness check



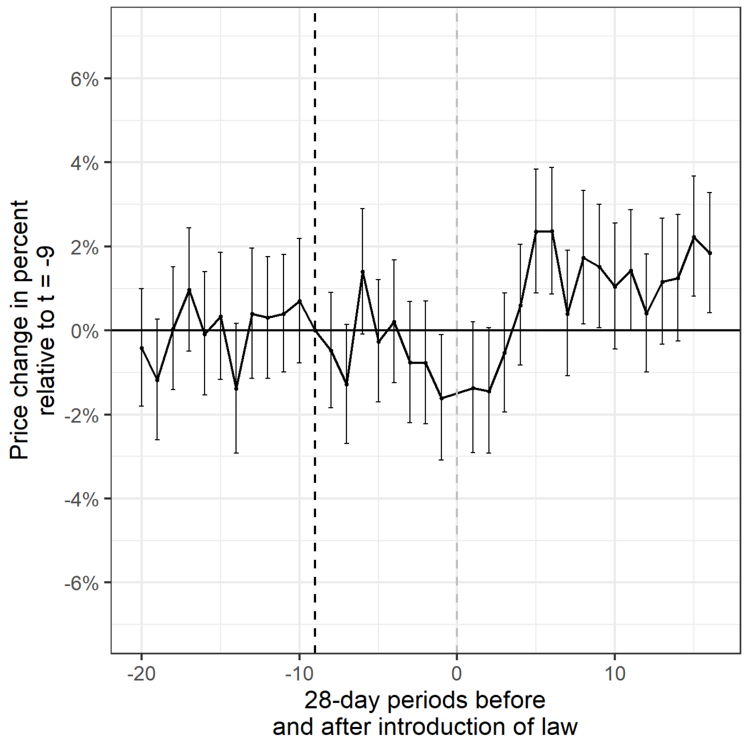
Notes: The map shows a 10-kilometre buffer zone around federal state borders in either direction of the border. For the robustness check, all dwellings offered within the buffer zone indicated by the black area are excluded from the analysis.
Source: Author's illustration.

Figure 3.A.4:



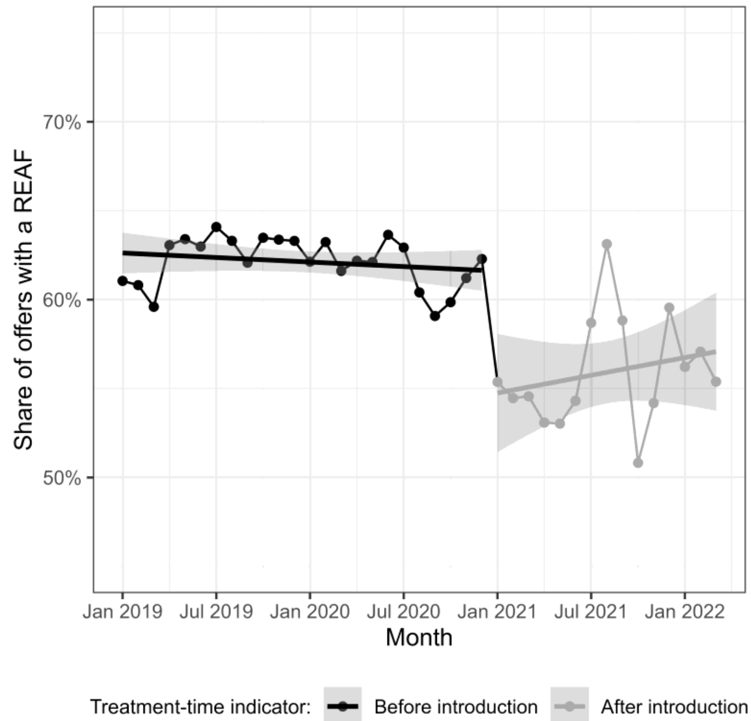
Notes: The figure shows 28-day-period event study estimates. Error-bars indicate 95-percent confidence intervals. Coefficients and illustrated confidence intervals are transformed and represent percentage changes. Control variables correspond to those of the full model in Table 3.3, column (3). The number of observations is 596,814. Dwellings located in a 10-kilometre buffer zone in either direction of the federal state borders are excluded from the regression analysis, as illustrated in Figure 3.A.3.
Source: Author’s calculations based on Value Marktdaten.

Figure 3.A.5: Robustness check – Analysis by start date: Event study



Notes: The figure shows 28-day-period event study estimates. The light dashed vertical line indicates the time the law was introduced. Time dummies are coded as 28-day periods before and after the introduction of the law with the first period after the introduction as t = 1, the last before the introduction as t = -1, hence there is no effect for period t = 0. The reference category for the time dummy is t = -9 (dark-grey dashed line) which corresponds to May 2020, i.e. the last month before the announcement of the law. Error-bars indicate 95-percent confidence intervals. Coefficients and illustrated confidence intervals are transformed and represent percentage changes. Control variables correspond to those of the full model in Table 3.3, column (3). The number of observations is 759,205.
Source: Author's calculations based on Value Marktdaten.

Figure 3.A.6: Share of dwellings offered with a REAF over time



Notes: The figure shows the share of dwellings offered with a REAF over time in percent. Additionally, the graph includes linear regression lines for the periods before and after the introduction of the law as well as 95-percent confidence intervals indicated by the shaded areas.
Source: Author’s calculations based on Value Marktdaten.

A.3.3 Equations

Equation 3.A.1:

The seller's profit before the introduction of the law is $PR_B^S = p_B(1 - \phi_B^S)$. The seller's profit from the sale of the dwelling after the introduction of the law is $PR_A^S = p_A(1 - \phi_A^S)$. Let the price after the introduction of the law be the price before the law plus the price change α in percent, then $p_A = p_B(1 + \alpha)$, I further define the difference in the seller's REAF after and before the introduction as $\Delta\phi^S \equiv \phi_A^S - \phi_B^S$. Then Equation 3.3 is derived as follows:

$$\begin{aligned}
& PR_B^S < PR_A^S \\
\Leftrightarrow\quad & p_B(1 - \phi_B^S) < p_A(1 - \phi_A^S) \\
\Leftrightarrow\quad & p_B(1 - \phi_B^S) < p_B(1 - \alpha)(1 - \phi_A^S) \\
\Leftrightarrow\quad & 1 - \phi_B^S < (1 - \alpha)(1 - \phi_A^S) \\
\Leftrightarrow\quad & \frac{\phi_A^S - \phi_B^S}{1 - \phi_A^S} < \alpha \\
\Leftrightarrow\quad & \frac{\Delta\phi^S}{1 - \phi_A^S} < \alpha
\end{aligned} \tag{3.A.1}$$

Equation 3.A.2:

The buyer's cost when buying the dwelling after the introduction of the law is $C_A^B = p_A(1 - \phi_A^B)$. The buyer's cost before the introduction of the law is $C_B^B = p_B(1 - \phi_B^B)$. Again, I define the price of the dwelling after the introduction of the law to be the price before the law plus a price increase α in percent, i.e. $p_A = p_B(1 + \alpha)$, I further define the difference in the buyer's REAF after and before the introduction as $\Delta\phi^B \equiv \phi_B^B - \phi_A^B$. Then Equation 3.4.A is derived as follows:

$$\begin{aligned}
& C_B^B > C_A^B \\
\Leftrightarrow \quad & p_B(1+\phi_B^B) > p_A(1+\phi_A^B) \\
\Leftrightarrow \quad & p_B(1+\phi_B^B) > p_B(1+\alpha)(1+\phi_A^B) \\
\Leftrightarrow \quad & 1+\phi_B^B > 1+\phi_A^B+\alpha+\alpha\phi_A^B \\
\Leftrightarrow \quad & \frac{\phi_B^B-\phi_A^B}{1+\phi_A^B} > \alpha \\
\Leftrightarrow \quad & \frac{\Delta\phi^B}{1+\phi_A^B} > \alpha
\end{aligned} \tag{3.A.2}$$

Equation 3.A.3:

I begin by showing the conditions for the down payment, i.e. the share of savings σ in relation to the purchase price to increase in the simplest case.

3.A.3.A: Lump sum subsidy

In the case of a lump sum subsidy γ, the down payment always increases, even if the subsidy is fully passed through to the dwelling's price, if the savings are smaller than the purchase price. That is the down payment before the subsidy δ_B is smaller than the down payment after introducing the subsidy δ_A, formally:

$$\begin{aligned}
& \delta_B < \delta_A \\
\Leftrightarrow \quad & \frac{\sigma}{p_B} < \frac{\sigma+\gamma}{p_B+\gamma} \\
\Leftrightarrow \quad & \frac{p_B\sigma+\gamma\sigma}{p_B} < \sigma+\gamma \\
\Leftrightarrow \quad & \gamma\sigma < p_B\gamma \\
\Leftrightarrow \quad & \sigma < p_B
\end{aligned} \tag{3.A.3.A}$$

3.A.3.B: REAF change fully passed through to purchase price

Next, assume that the buyer's change in the REAF $\Delta\phi^B$ is fully resembled in a purchase price increase. That is, the new price is the sum of the old price and change in the REAF times the old price, formally $p_A = p_B + \Delta\phi^B p_B$. With a new REAF ϕ_A, the buyer no longer must pay the old REAF $\phi_B p_B$, but the new REAF times the dwelling's new price. The condition for the down payment to be larger in this scenario is derived below:

$$\begin{aligned}
& \delta_B < \delta_A \\
\Leftrightarrow \quad & \frac{\sigma}{p_B} < \frac{\sigma + \phi_B p_B - \phi_A p_A}{p_A} \\
\Leftrightarrow \quad & \frac{\sigma}{p_B} < \frac{\sigma + \phi_B p_B - \phi_A (p_B + \Delta\phi^B p_B)}{p_B + \Delta\phi^B p_B} \\
\Leftrightarrow \quad & \frac{p_B(1 + \Delta\phi^B)\sigma}{p_B} < \sigma + \phi_B p_B - p_B \phi_A - p_B \phi_A \Delta\phi^B \\
\Leftrightarrow \quad & \sigma\Delta\phi^B < p_B \Delta\phi^B - p_B \phi_A \Delta\phi^B \\
\Leftrightarrow \quad & \sigma < p_B - p_B \phi_A \\
\Leftrightarrow \quad & \sigma < p_B(1 - \phi_A)
\end{aligned} \tag{3.A.3.B}$$

Hence, the savings payment must be smaller than the old price minus the new down payment. For sensical values of the REAF and common savings to price relationships, this condition is met. In the context of the research question at hand and with new REAFs for the buyers in the range of 2.73 to 4.47 percent on a county level, the savings must be at least smaller than 95.53 percent of the purchase price, which is generally the case. Hence, the down payment increases, even if the REAF change is fully reflected in a price increase.

3.A.3.C: General case

As the last case, below, I show the general condition for the down payment to increase. That is, instead of setting the price increase following the REAF change to be exactly as large as the REAF change, I consider the price change to be α. In this case, while α can be as large as the REAF change, it could also be larger. The conditions for the down payment to increase in this general case are derived below:

$$\delta_B < \delta_A$$
$$\Leftrightarrow \quad \frac{\sigma}{p_B} < \frac{\sigma + \phi_B p_B - \phi_A p_A}{p_A}$$
$$\Leftrightarrow \quad \frac{\sigma}{p_B} < \frac{\sigma + \phi_B p_B - \phi_A (p_B + \alpha p_B)}{p_B + \alpha p_B}$$
$$\Leftrightarrow \quad \frac{p_B(1+\alpha)\sigma}{p_B} < \sigma + \phi_B p_B - p_B \phi_A - p_B \phi_A \alpha \qquad (3.A.3.C)$$
$$\Leftrightarrow \quad \alpha(\sigma + p_B \phi_A) < p_B \phi_B - p_B \phi_A$$
$$\Leftrightarrow \quad \alpha < \frac{p_B \phi_B - p_B \phi_A}{\sigma + p_B \phi_A}$$
$$\Leftrightarrow \quad \alpha < \frac{p_B \Delta\phi^B}{\sigma + p_B \phi_A}$$

Consider the following numerical example. Let the dwelling's price p_B be 400,000 euros and the savings 80,000 euros, which is a down payment of 20 percent, before the REAF change. Let the REAF change for the buyer, $\Delta\phi^B$, be 1.5 percentage points, the REAF for the buyer after the change, ϕ_A, be 3.5 percent. In this case, the price increase must be lower than $\frac{400{,}000*0.015}{200{,}000+400{,}000*0.035} \approx 0.063$. In this example, the price increase could be four times larger than the REAF decrease, for the down payment to still be larger.

Equation 3.A.4:

If a buyer makes use of a mortgage, the total costs of the dwelling amount to the sum of all mortgage payments, M, the down payment times the price, $p\delta$, and the REAF times the price, $p\phi$. The mortgage payments are determined with the formula for a full repayment loan. Then the sum of all mortgage payments until the mortgage is paid off is $M = p(1-\delta) \cdot \frac{(1+i)^t \cdot i}{(1+i)^t - 1} \cdot t = p(1-\delta) \cdot \mu$. Then Equation 3.4.B is derived as follows:

$$
\begin{aligned}
& C_A < C_B \\
& \Leftrightarrow \mathrm{M}_A + p_A\delta_A + p_A\phi_A^B < \mathrm{M_B} + p_B\delta_B + p_B\phi_B^B \\
& \Leftrightarrow p_A(1-\delta_A)\frac{(1+i)^t \cdot i}{(1+i)^t - 1} \cdot t + p_A\delta_A + p_A\phi_A^B \\
& \qquad\qquad < p_B(1-\delta_B)\frac{(1+i)^t \cdot i}{(1+i)^t - 1} \cdot t + p_B\delta_B \\
& \qquad\qquad + p_B\phi_B^B \\
& \Leftrightarrow p_B(1+\alpha)\left[1 - \frac{\sigma + \phi_{\mathrm{B}} p_B - \phi_A(1+\alpha)p_B}{p_B(1+\alpha)}\right]\mu \\
& \qquad\qquad + p_B(1+\alpha)\frac{\sigma + \phi_{\mathrm{B}} p_B - \phi_A(1+\alpha)p_B}{p_B(1+\alpha)} \\
& \qquad\qquad + p_B(1+\alpha)\phi_A \\
& \qquad\qquad < p_B\left(1 - \frac{\sigma}{p_B}\right)\mu + p_B\frac{\sigma}{p_B} + p_B\phi_B \\
& \Leftrightarrow \mu\alpha p_B + \mu\alpha p_B\phi_A + \mu p_B\phi_A - \mu p_B\phi_B + \mu p_B - \mu\sigma \\
& \qquad\qquad + \mu + \phi_B p_B - \phi_A p_B - \phi_A\alpha p_B + p_B\phi_A \\
& \qquad\qquad + p_B\alpha\phi_A < p_B\mu - \sigma\mu + \sigma + p_B\phi_B \\
& \Leftrightarrow \mu\alpha p_B + \mu\alpha p_B\phi_A + \mu p_B\phi_A - \mu p_B\phi_B < 0 \\
& \Leftrightarrow \alpha + \alpha\phi_A < \phi_B - \phi_A \\
& \Leftrightarrow \alpha < \frac{\Delta\phi^B}{1+\phi_A}
\end{aligned}
\tag{3.A.4}
$$

Chapter 4 – ENERGY PRICE SHOCK AND HOUSING MARKET DYNAMICS: EVIDENCE FROM GERMANY

Notes: This chapter is undergoing review for publication in *Journal of Housing Economics* at the time of this dissertation.

4.1 Abstract

This paper analyses the impact of the energy price shock following Russia's invasion of Ukraine in 2022 on housing market dynamics in Germany, focusing on the price differences between the most energy-efficient dwellings (MEED) and less energy-efficient dwellings (LEED). Using a difference-in-differences approach and a comprehensive housing market dataset, the study finds that LEED have seen relative price declines in the purchase and rental market, reflecting a growing premium for energy efficiency. The analysis reveals heterogeneity across regions, property types, and years of construction. The paper contributes to the literature on energy price premiums in the housing sector, providing empirical insights into how rising energy costs and policy measures, such as the Energy Performance of Buildings Directive (EPBD) and CO_2 pricing, may shape long-term housing market dynamics. The findings additionally indicate that energy efficiency plays a more significant role in housing valuations, carrying important implications for housing policy and market stability in the short and long term.

4.2 Introduction

The energy price shock triggered by Russia's invasion of Ukraine in February 2022, along with the subsequent disruptions to energy supplies and the European Union's efforts to reduce dependence on Russian fossil fuels, had profound effects on energy costs, and market behaviour in Germany (Bachmann et al., 2022a, b). These events have intensified the focus on energy efficiency in the housing sector, as both consumers and policy makers sought ways to mitigate rising energy costs and enhance energy security (BMWK, 2024).

This paper analyses the impact of the recent energy price shock on the German housing market, with a particular focus on the differentiation between more energy-efficient and less energy-efficient dwellings. Previous research has established that energy price shocks can have broad economic implications, affecting everything from consumer expenditure patterns to housing market stability (Kilian, 2008; Wu & Zilberman, 2019). However, less is known about how such shocks influence housing market dynamics in relation to energy efficiency, especially in the context of a major geopolitical crisis like the war in Ukraine.

Using a comprehensive dataset of listings for the German housing market, this study employs a difference-in-differences framework to isolate the effects of the energy price shock on rents, purchase prices, as well as volumes. The paper further discusses regional disparities, and the long-term implications for housing market dynamics. The paper contributes to the literature on energy price premiums by investigating how energy premiums and discounts evolved over time.

The findings provide insights into the evolving relationship between energy costs and housing markets, with implications for housing policy. The findings suggest that energy efficiency became a more important factor in property valuations. Understanding these dynamics is essential for policy makers, real estate professionals, and homeowners navigating towards a long-term equilibrium of housing and energy prices.

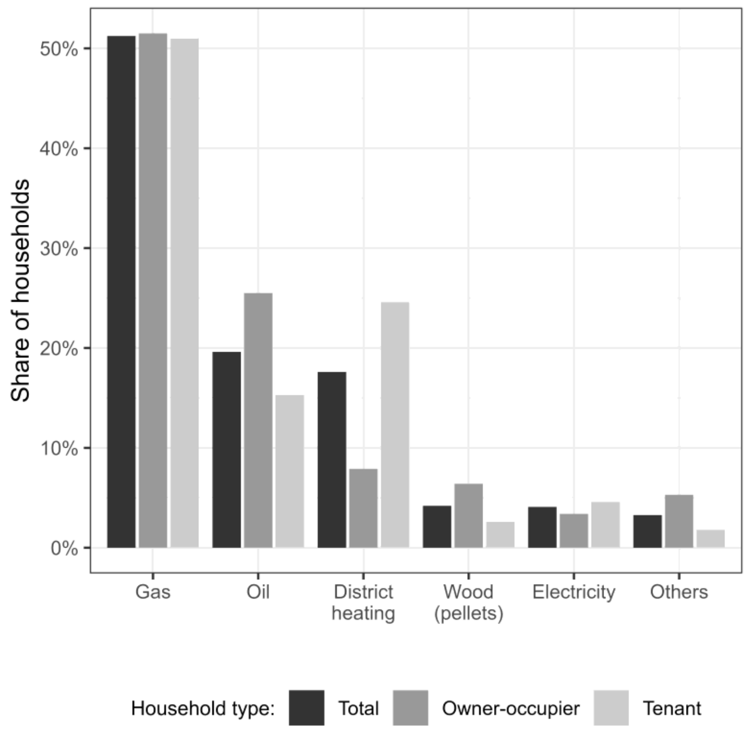
The paper proceeds as follows. Section 4.3 gives background information on the economic consequences of the Russian war in Ukraine and its ensuing effects on energy prices in Germany. Section 4.4 discusses how this paper relates to the existing literature. Section 4.5 introduces the data and provides descriptive analyses of energy efficiency in the German housing market. Section 4.6 presents the identification strategy. Section 4.7 discusses the results of the empirical analysis. The concluding section highlights important policy implications.

4.3 Background and motivation

4.3.1 German housing market's dependence on fossil fuels

Until the beginning of the Russian war in Ukraine in February 2022, Germany had imported about half of its gas and hard coal consumption and one third of oil consumption from Russia (Bachmann et al., 2022b). About half of German households heat their dwellings primarily with gas, while an additional fifth rely on oil heating. Oil heating is more prevalent among owner-occupier households, as these dwellings are often located in suburban or rural areas where alternative heating options, such as district heating, are less accessible. In contrast, tenants tend to reside in urban areas, where district heating infrastructure is more commonly available (see Figure 4.1). This reliance on gas and oil underscores the significant vulnerability of German households to fluctuations in energy prices.

Figure 4.1: Primary energy source to heat living space



Notes: The figure shows the share of households in Germany by primary energy source to heat their living space in 2022 for all households (total) and individually for owner-occupiers and tenants.
Source: Author's illustration based on Federal Statistical Office (2023).

4.3.2 Cut of Russian energy supply to Germany

After the beginning of the war in Ukraine, Russia gradually reduced energy exports to Germany and other European countries, leading to soaring energy costs for households and industry. Even before the war began, Russia had started to reduce gas exports to European countries, beginning in 2021. Long-term contracts with certain countries and individual firms were already being breached (Ruhnau et al., 2023). However, with the onset of the war in February 2022, gas and oil prices in Germany surged to unprecedented levels. Russia's systematic reduction of energy exports to Germany and other European nations culminated in a complete halt of Russian gas supply to Germany by late August 2022. This disruption, combined with market uncertainties, lead to a stark increase in energy prices in Germany, which peaked during the autumn of 2022 (see Figure 4.2.A).

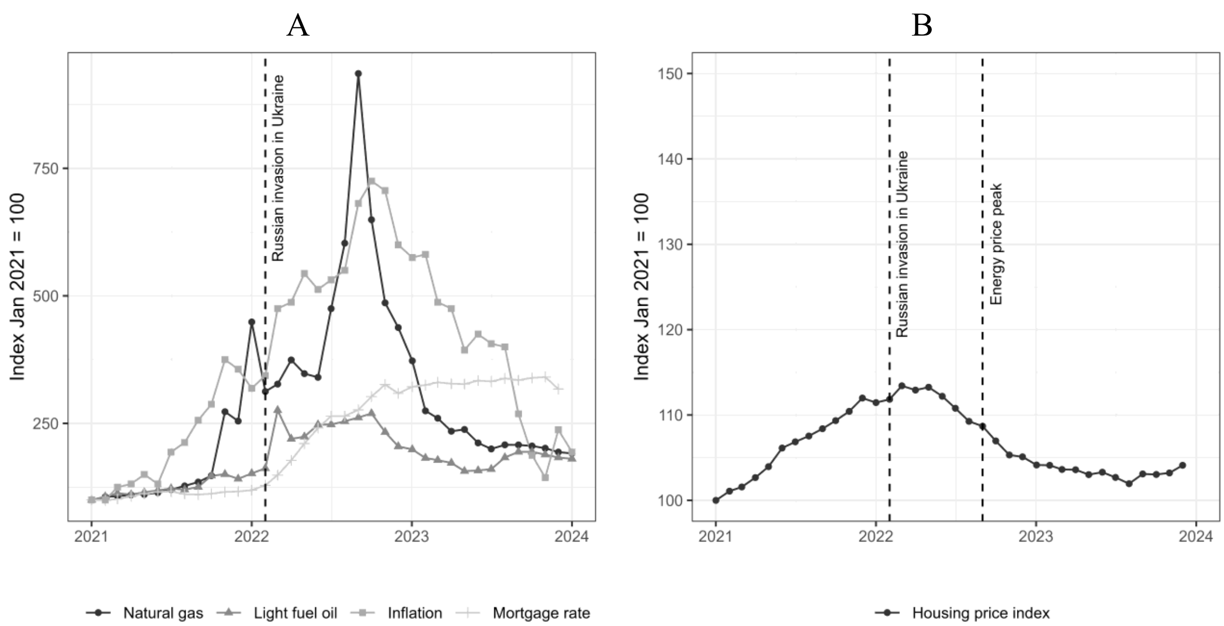
4.3.3 Energy price shock, interest rate hikes, and housing market downturn

The European Central Bank (ECB) reacted to rising inflation rates in 2022, mainly driven by the energy price shock, by increasing key interest rates. This had a significant impact on German mortgage rates, which began to sore from record-low levels. Higher mortgage rates reduced housing affordability as the cost of borrowing increased, making it more expensive for potential homebuyers to finance their purchases. Consequently, this led to a decrease in demand for dwellings offered for sale, putting downward pressure on prices (see Figure 4.2.B). Energy prices at their peak were seven to eight times higher than their respective pre-crisis levels and even after coming down from peak values, were still about twice as high as before the energy price shock. It should be noted that the German government has introduced several measures to protect households from these soaring energy prices and reduce dependency on Russian energy. The measures are summarised and discussed in the appendix in section A.4.1.1. However, these measures did not fully offset the rising energy costs for households.

Higher gas prices in Germany during the energy crisis mainly affected households needing to secure new energy supply contracts. This was especially relevant for those entering the housing market, i.e. either looking for a new dwelling to rent or purchase, because in Germany existing energy supply contracts for private households are typically not transferred to a new address. In most cases, when moving, households need to terminate their current contract and either sign a new one with their existing provider at the new address or choose a different provider. For these households, the energy price shock and the heightened salience of energy costs potentially became more important factors in their decision-making process to find a new dwelling. The growing awareness of energy expenses might have influenced their willingness to pay and shifted preferences towards more energy-efficient dwellings, reflecting the increased importance of long-term cost considerations beyond the net rent or purchase price in housing choices.

The effect of the energy price shock on housing market dynamics could therefore vary depending on the energy efficiency of the dwelling and less energy-efficient dwellings should experience a decline in demand which could manifest itself in relative price decreases. A simple theoretic model outlining the interplay of energy prices, renovation costs, and dwelling prices is included in the appendix in section A.4.1.2. The economic channels through which energy prices and energy efficiency are related to a dwelling's price as well as the impact of energy prices on overall economic outcomes are widely explored in different settings and discussed in the following related literature section.

Figure 4.2: Energy price shock, mortgage rate hike, and housing prices in Germany



Notes: Subfigure A shows natural gas and light fuel oil prices, as well as the inflation and mortgage rate development in Germany. Subfigure B shows the real estate listing prices in Germany during the same period based on a hedonic price index. The first vertical dashed line marks the date Russia invaded Ukraine on 24 February 2022. The second vertical dashed line in subfigure B indicates the peak of energy prices in autumn of 2022. Values are indexed to January 2021 = 100.
Source: Author's calculations and illustration based on Verivox (2024), En2x (2024), Deutsche Bundesbank (2024), Eurostat (2024), Value Marktdaten.

4.4 Related literature

This paper contributes to four strands of literature. The first deals with overall economic outcomes of energy price shocks. Kilian (2008) provides a comprehensive overview of how an energy price shock affects the economy, addressing several key issues, among others, the responsiveness of energy demand to changes in energy prices and consumers' expenditure patterns. Several studies provide estimates of the change in demand for energy sources due to higher energy prices such as Gao et al. (2021) who estimate an income elasticity of energy demand in the range between 0.6 and 0.8 and price elasticities in the range of 0.1 to 0.3. From a theoretical perspective, Auclert et al. (2023) analyse the macroeconomic effects of an energy price shock in an Heterogenous Agent New Keynesian model. Teplova et al. (2019) develop a model which allows for the simulation of economic responses in 47 countries to changes in the equilibrium oil price. Van de Ven & Fouquet (2017) identify changes in the impact of an energy shock to economic activity. Their results suggest that the improvement in vulnerability and resilience to energy shocks of the UK is not due to economic development but closely linked to circumstances related to supply and demand for energy sources.

Second and more closely related to this paper is the literature on the relationship between energy price shocks, environmental risks, and the housing market. Wu & Zilberman (2019) develop a model to investigate the role of gasoline price shocks in triggering a housing market collapse, thereby identifying new channels through which energy price shocks affect the financial market and the macroeconomy. Breitenfeller et al. (2015) exploit a dataset of 18 OECD economies spanning four decades to find that an increase in energy price inflation raises the probability of house price corrections and provide several explanations for this phenomenon, concluding that energy price inflation should serve as a leading indicator for the analysis of macro-financial risk. Several other studies analyse the impact of oil price shocks on housing price movements (Sheng et al., 2021; Grossman et al., 2019). An overview of major work on the main drivers of housing prices and their effects on the economy in general is provided by Duca et al. (2021). This paper is also related to the strand of literature focusing on how external shocks and environmental risks get capitalised into house prices. Bauer et al.

(2017) for instance, find that house prices near nuclear stations declined following the Fukushima Daiichi accident in Japan in March 2011. According to Greenstone & Gallagher (2008), there seems to be no evidence that the clean-up of hazardous waste sides in the U.S. affected prices of nearby properties. Bosker et al. (2019) find that flood risk affects house prices in the Netherlands while Pinchbeck et al. (2020) document a relation between the publication of Radon levels and property prices in England.

Third, this work relates to a growing body of research focusing on the relationship between a dwelling's energy performance and its market value. These studies, as is done in this study, often employ hedonic pricing models to understand how energy efficiency ratings influence buyer preferences and housing prices. In line with the findings in this paper, they typically suggest that more energy-efficient dwellings command a premium in the market. A review of the literature on this topic and quantitative studies conducted in Europe is provided by Wilkinson & Sayce (2020). Cespedes-Lopez et al. (2019) compare results from different regions in a meta-analysis. Many studies find markups for the prices of more energy-efficient dwellings: in California (Kahn & Kok, 2014), the Netherlands (Brounen & Kok, 2011; Chegut et al., 2016), Ireland (Hyland et al., 2013), the UK (Fuerst et al., 2015), and Germany (März et al., 2022; Taruttis & Weber, 2022). The most closely related study to this work is by Braakmann et al. (2023). They also use an event study design and perform a difference-in-differences estimation, analysing the impact of the energy price shock triggered by Russia's invasion of Ukraine in February 2022 on property prices in the UK. They find little reactions of the housing market in the very short time frame considered in their analysis, with price changes for the most energy-efficient properties close to zero and a small energy penalty for the least efficient properties. Aydin et al. (2020) show that private consumers capitalise energy efficiency in the housing market: as the level of energy efficiency increases by 10 percent, the market value of the dwelling increases by 2 percent. However, they find no evidence that the extent of the capitalisation of energy efficiency is related to information provision, questioning the need for continued government-imposed certification programs such as Energy Performance Certificates (EPCs). These findings contradict other studies supporting the view that mandatory disclosure regulations are a powerful instrument to increase market transparency (Frondel et al., 2020). Analysing the survey responses of 206 participants in German residential housing market, Franke & Nadler (2019) find that owners are more familiar with the EPC tool than tenants, therefore giving it stronger consideration. Overall, energy efficiency seems to be of high importance for all participants. The relevance of energy efficiency is stressed by Fetzer et al. (2022) who find, based on granular property micro data covering 50 percent of the English and Welsh dwellings, that 30 percent of energy consumption could be saved if buildings were upgraded to their highest energy efficiency standard. In another study using EPC data to model energy demand and energy consumption, Fetzer (2022) finds that households with the highest energy consumption are the least willing to make energy savings.

Lastly, the paper at hand contributes to the specific literature investigating the economic consequences of, and reactions to, Russia's invasion of Ukraine in 2022. Bachmann et al. (2022a, 2022b) as well as Berger et al. (2022) provide extensive analyses of such, trying to quantify the economic impacts for Germany and the EU. Yagi & Managi (2023) specifically examine how rising energy prices spread to other sectors, while Hartving et al. (2023) argue that Russia's "energy weapon" has only short-term economic consequences but influences the transformation of the EU's energy system. Lutz & Becker (2023) analyse the effect of the energy price shock on Germany's economy, consumer prices for private households as well as their energy cost burden. Ruhnau et al. (2023) focus on the energy saving behaviour by German households and industry. Krebs and Weber (2024) argue that price controls should be part of a policy toolbox when responding to shocks to systematically important sectors, drawing on the experiences from the energy price shock. Bhattacharjee et al. (2022) focus on the design of energy price caps and related measures to support households and firms. In addition, several studies stress the danger of increased inequality resulting from energy and overall price increases (Zhang et al., 2023; Bach & Knautz, 2022).

4.5 Data and descriptive evidence

4.5.1 Data

In the following empirical analysis, I utilise a comprehensive micro dataset of dwellings offered for sale and rent in Germany, provided by Value Marktdaten, a professional real estate data provider. This dataset is based on online real estate listings aggregated from all major platforms and over 100 sources. Although asking price data has inherent limitations, most notably, the fact that asking prices do not necessarily align with final transaction prices, it remains a widely used source in research on the German housing market (Thomschke, 2019; Breidenbach et al., 2022; Sagner & Voigtländer, 2022). Its primary advantage lies in its timeliness and the detailed information it provides on individual dwellings, enabling detailed analyses in the absence of actual sale price data. Each observation includes detailed information such as the asking price, size in square metres, number of rooms, construction year, energy consumption, and various indicators for amenities and location. A descriptive data summary is presented in Table 4.1 and stratified by whether a dwelling was listed for purchase or rent and before or after the Russian invasion of Ukraine.

Table 4.1: Descriptive statistics

	Dwelling offered for			
	Purchase		**Rent**	
	Dwelling offered after the beginning of the war			
Characteristic	**No**, N = 175,621±	**Yes**, N = 468,856±	**No**, N = 352,036±	**Yes**, N = 517,818±
Price in euro per sqm. (purchase price or net rent)	3,552 (2,033)	3,509 (1,957)	9.1 (3.3)	9.8 (3.6)
Energy demand in kWh per sqm. and year	140 (79)	143 (82)	115 (53)	112 (54)
Dwelling size in sqm.	115 (66)	117 (64)	69 (29)	71 (30)
Construction year	1,970 (37)	1971 (36)	1,970 (35)	1,972 (36)
Detailed dwelling type				
1-room apartment	9,581 (5.5%)	22,800 (4.9%)	45,734 (13%)	60,097 (12%)
2-room apartment	30,929 (18%)	74,804 (16%)	138,825 (39%)	199,114 (38%)
3-room apartment	36,673 (21%)	92,544 (20%)	121,655 (35%)	183,105 (35%)

Continued on next page…

Table 4.1 continued…

4-room apartment	14,212	36,629	30,660	47,869
	(8.1%)	(7.8%)	(8.7%)	(9.3%)
5+-room apartment	4,040	10,785	5,233	8,557
	(2.3%)	(2.3%)	(1.5%)	(1.7%)
Detached house	47,623	136,377	3,882	8,028
	(27%)	(29%)	(1.1%)	(1.6%)
Semi-detached house	12,126	35,979	3,172	5,867
	(6.9%)	(7.7%)	(0.9%)	(1.1%)
Terraced house	10,784	32,498	2,693	4,801
	(6.1%)	(6.9%)	(0.8%)	(0.9%)
Unknown	9,653	26,440	182	380
	(5.5%)	(5.6%)	(<0.1%)	(<0.1%)
Terrace or balcony				
No	31,929	74,361	100,267	139,041
	(18%)	(16%)	(28%)	(27%)
Yes	143,692	394,495	251,769	378,777
	(82%)	(84%)	(72%)	(73%)
Basement				
Explicitly No	7,226	20,419	3,618	6,170
	(4.1%)	(4.4%)	(1.0%)	(1.2%)
Unknown	30,610	72,092	86,423	130,576
	(17%)	(15%)	(25%)	(25%)
Yes	137,785	376,345	261,995	381,072
	(78%)	(80%)	(74%)	(74%)
Built-in kitchen				
No	88,250	220,933	208,719	296,487
	(50%)	(47%)	(59%)	(57%)
Yes	87,371	247,923	143,317	221,331
	(50%)	(53%)	(41%)	(43%)
Heating system				
Central	138,151	370,071	270,879	401,685
	(79%)	(79%)	(77%)	(78%)
No information	22,694	59,502	46,856	68,781
	(13%)	(13%)	(13%)	(13%)
Room	4,793	12,056	3,054	4,529
	(2.7%)	(2.6%)	(0.9%)	(0.9%)
Single-storey	9,983	27,227	31,247	42,823
	(5.7%)	(5.8%)	(8.9%)	(8.3%)
Firing of heating system				
Alternative	9,115	27,618	11,210	22,062
	(5.2%)	(5.9%)	(3.2%)	(4.3%)
Coal	355	778	62	139
	(0.2%)	(0.2%)	(<0.1%)	(<0.1%)
Electric	9,733	26,866	11,831	18,121
	(5.5%)	(5.7%)	(3.4%)	(3.5%)
Gas	95,694	257,008	188,397	274,876
	(55%)	(55%)	(54%)	(53%)
Oil	36,321	99,079	29,172	41,734
	(21%)	(21%)	(8.3%)	(8.1%)
Unknown	24,403	57,507	111,364	160,886
	(14%)	(12%)	(32%)	(31%)
Guest bathroom				
No	101,542	255,571	295,330	423,136
	(58%)	(55%)	(84%)	(82%)
Yes	74,079	213,285	56,706	94,682
	(42%)	(45%)	(16%)	(18%)

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Table 4.1 continued…

Parking space				
No	39,302 (22%)	93,749 (20%)	193,689 (55%)	272,069 (53%)
Yes	136,319 (78%)	375,107 (80%)	158,347 (45%)	245,749 (47%)
State of dwelling fit-out				
High-quality	42,755 (24%)	128,539 (27%)	27,324 (7.8%)	46,944 (9.1%)
Good	68,254 (39%)	177,949 (38%)	146,903 (42%)	223,826 (43%)
Normal	56,038 (32%)	139,198 (30%)	169,441 (48%)	236,545 (46%)
Simple	8,574 (4.9%)	23,170 (4.9%)	8,368 (2.4%)	10,503 (2.0%)
State of dwelling overall				
Good	77,907 (44%)	207,827 (44%)	156,205 (44%)	242,561 (47%)
Normal	80,110 (46%)	207,345 (44%)	191,379 (54%)	268,043 (52%)
Bad	17,604 (10%)	53,684 (11%)	4,452 (1.3%)	7,214 (1.4%)
Region type				
Large city	55,320 (31%)	138,191 (29%)	179,348 (51%)	253,106 (49%)
Urban district	68,162 (39%)	190,010 (41%)	96,864 (28%)	148,925 (29%)
Rural, more densely populated district	28,945 (16%)	76,985 (16%)	46,615 (13%)	71,653 (14%)
Rural, sparsely populated district	23,194 (13%)	63,670 (14%)	29,209 (8.3%)	44,134 (8.5%)

Notes: ±Mean (SD); n (%). The table shows descriptive statistics for variables of the observations included in the empirical analysis.
Source: Author's calculations based on Value Marktdaten.

4.5.2 Descriptive evidence

4.5.2.1 Primer on EPC ratings in Germany

In this chapter, I examine the energy efficiency of dwellings offered for sale and rent in Germany, focusing on trends over time and differences across regions and dwelling types. This analysis aims to illustrate how energy efficiency standards in the housing market have evolved over time and how they vary by location and housing type.

Germany, like other countries, uses a classification system for the energy efficiency of residential buildings, aiding in the evaluation and comparison of their energy performance (see Table 4.2). The system, referred to as Energy Performance Certificates (EPC) includes ratings ranging from A+ (highest efficiency) to H (lowest efficiency), measured in kilowatt-hours per square metre and year. This classification encompasses energy consumption related to heating, hot water, and auxiliary energy systems. An EPC in Germany must be provided to potential new renters or buyers during the process leading up to renting or purchasing the dwelling. It must be provided latest with the showing of the dwelling (Buildings Energy Act – GEG, 2020, § 80).

Table 4.2: EPC ratings of residential dwellings in Germany

EPC rating	**Energy consumption (kWh/m²a)**
A+	≤ 30
A	$> 30 \leq 50$
B	$> 50 \leq 75$
C	$> 75 \leq 100$
D	$> 100 \leq 130$
E	$> 130 \leq 160$
F	$> 160 \leq 200$
G	$> 200 \leq 250$
H	> 250

Notes: The table shows the Energy Performance Certificate (EPC) ratings for residential dwellings used in Germany. Energy consumption is measured in kilowatt-hours per square metre and year (kWh/m²a). The ratings range from A+ (highest efficiency) to H (lowest efficiency). The classification includes energy consumption for heating, hot water, and auxiliary energy systems, providing a comprehensive measure of a building's overall energy performance.
Source: Act on the conservation of energy and utilisation of renewable energies for heating and cooling in buildings (Buildings Energy Act – GEG, 2020) Annex 10 (to § 86): EPC ratings of residential buildings.

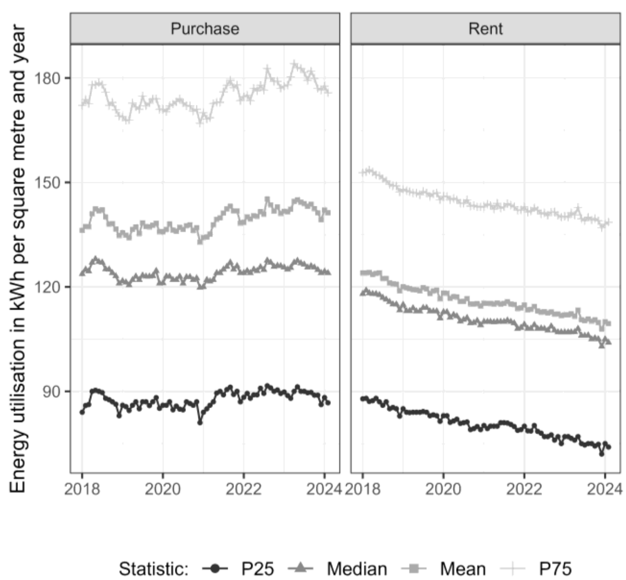
4.5.2.2 Trends in energy efficiency over time

In the German residential market, dwellings offered for purchase and rent show different trends over time with regards to the indicated energy consumption. There is a trend towards higher energy efficiency in rental dwellings as depicted in Figure 4.3. Dwellings offered for rent had a mean (median) energy consumption of 124 (118) kWh per square metre and year which is equivalent to an EPC rating of D in the beginning of 2018. By the beginning of 2024 energy efficiency for rental apartments had improved to an average (median) energy consumption of 110 (104) kWh per square metre and year which is a decrease of 11 (12) percent.

In the purchase market, the average energy consumption has remained constant in recent years. Generally, energy consumption levels per square metre and year are higher in the purchase market than in the rental market. Apartments in multi-family houses have a lower external surface area-to-volume ratio, resulting in a smaller heat-transferring surface compared to detached single-family houses. The purchase market in Germany has a much larger share of (detached) houses offered than the rental market, which explains parts of the level differences in energy utilisation, see Figure 4.A.1 in the appendix for a detailed breakdown. Other reasons include differences in dwelling fit-out, year of construction, as well as differences in heating systems. One key reason for the lack of improvement in average energy utilisation over time in dwellings offered for sale could be that dwellings in the private owner-occupier market are often sold when previous owners move out due to old age. These dwellings are typically sold without having undergone energy-efficient renovations beforehand, contributing to the finding of stagnant energy efficiency levels over time.

The observed trends in the average energy consumption highlight differing dynamics between the rental and purchase markets, with rental dwellings showing improvements in energy efficiency over time while average energy consumption for dwellings on the purchase market remained stagnant. These market-specific developments set the stage for examining whether there are regional variations in the energy performance, to be discussed in the next section.

Figure 4.3: Energy utilisation in the housing market over time

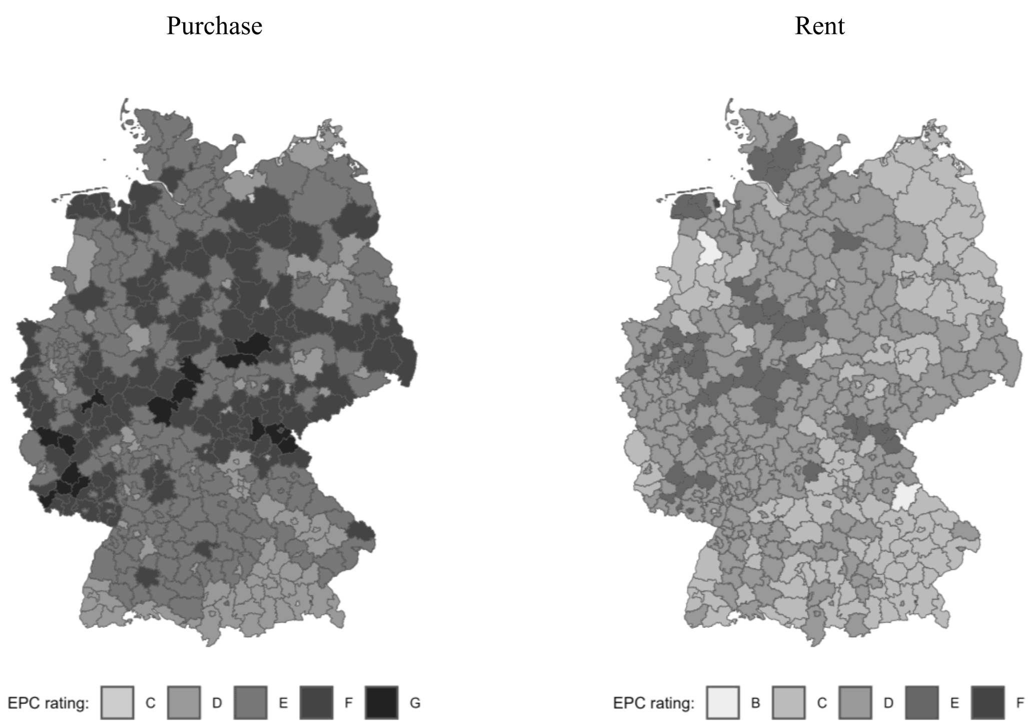


Notes: The graph shows the trends in energy utilisation in kWh per square metre and year for dwellings offered for purchase and rent from 2018 to 2024. Four statistics are depicted: P25 (25th percentile), Median, Mean, and P75 (75th percentile).
Source: Author's illustration based on Value Marktdaten.

4.5.2.3 Regional differences in energy efficiency

Figure 4.4 shows the average EPC rating for dwellings offered for sale and rent in Germany's 400 counties. First, looking at dwellings offered for sale, the highest average energy efficiency rating on a county level is C which is only found in 3 counties, in 87 counties the average is D, in 185 E, in 110 it is F, and in 15 it is G. For the rental market there is less variance in the average energy efficiency; 2 counties show an average of B, 108 C, 236 D, 53 E, and 1 F. There is a statistically significant positive correlation of 0.51 ($p < 0.01$) of the average energy utilisation in the purchase and rental market on a county level. Potential reasons are similarities in dwelling types, i.e. more urban areas have a larger share of apartment blocks, both in the number of dwellings offered for sale and rent, as well as climate which also influences energy consumption.

Figure 4.4: Average EPC rating in German counties based on listing data

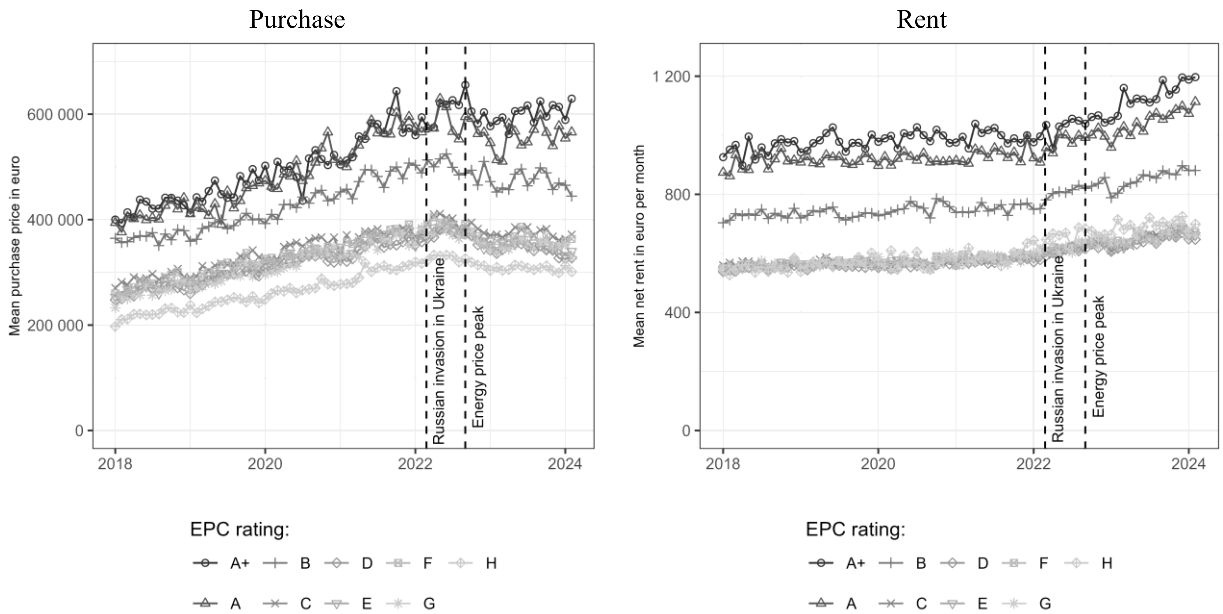


Notes: The graph shows the average EPC rating of dwellings offered for sale or rent in Germany's 400 counties based on their average energy utilisation in kWh per square metre and year in 2023.
Source: Author's illustration based on Value Marktdaten.

4.5.2.4 Raw price development by EPC rating

Both, average purchase and rental prices have, independently of EPC ratings, increased until the first half of 2022, as illustrated in Figure 4.5. The housing market in Germany was influenced by several factors during the years before, driving these price increases. First, there was high quantitative and qualitative demand for housing driven by population growth and urbanisation, which outpaced the supply of new homes. Second, historically low interest rates prior to 2022 made financing more accessible, enabling more people to buy dwellings (Brausewetter et al., 2024). With the increases in mortgage rates in 2022, Germany saw purchase prices drop for the first time in over a decade.

Figure 4.5: Mean price by EPC rating over time



Notes: The figures show the mean price for dwellings offered for purchase in euro and mean net rent for dwellings offered for rent in euro per month between 2018 and the beginning of 2024. The mean values are depicted separately by EPC ratings.
Source: Author's illustration based on Value Marktdaten.

However, looking at average purchase prices by EPC rating, there seem to be divergent trends depending on a dwelling's EPC rating, beginning to emerge in the middle of 2022. More energy-efficient dwellings show a lower average raw price decline than less energy-efficient dwellings. For the rental market, there is no price trend reversal in the middle of 2022, i.e.

average prices continue to rise for all EPC ratings. Still, the net rent for the most energy-efficient dwellings seems to increase more strongly from 2022 onwards than for less energy-efficient dwellings. These initial descriptive findings are in line with expectations, and to be explored further in the main part of the following empirical analysis. I continue by outlining the identification strategy in the next section.

4.6 Identification strategy

To identify the effects of the energy price shock on housing market dynamics, I employ a difference-in-differences (DiD) regression framework within an event study design. As the group of dwellings affected by the energy price and policy shock (treated group), I define "less energy-efficient" dwellings (LEED), which are classified below an EPC rating of A. The group not affected or rather less affected by the energy price shock and policy shift (control group), I define the "most energy-efficient" dwellings (MEED), which are classified with an EPC rating of A and A+. The MEED make up approximately 10 percent of the dwellings in the data for both, the purchase market as well as the rental market. Figure 4.A.2 in the appendix shows the distribution of dwellings offered for purchase or rent by their EPC rating. Model extensions and other specifications of the treatment and control groups are explored in later sections. The central assumption of our identification strategy is the parallel path assumption. This implies that, in the absence of the energy price shock, the prices or alternative outcome variables like volumes, for LEED would have followed the same trend as those for MEED. In other words, any divergence in trends between these two groups after the event can be attributed to the impact of the energy price shock. By comparing the price trends and other relevant outcomes for these two groups before and after the event, I aim to isolate the effect of the energy price shock on the housing market. The approach combined with a hedonic regression framework allows to control for time-invariant differences between the two groups, as well as common time trends affecting both groups, e.g. the overall shift in mortgage conditions, providing a robust framework for causal inference. Formally, I estimate the model in Equation 4.1:

$$\ln(p_{it}) = \alpha + \sum_{\tau=-q}^{-1} \beta_\tau D_{i\tau} + \sum_{\tau=0}^{m} \delta_\tau D_{i\tau} + \theta X_i + \rho + \omega + \varepsilon_{it}. \tag{4.1}$$

To analyse effects on prices $\ln(p_{it})$ is the natural logarithm of either the purchase price in euro or the net rent in euro per month for dwelling i at time t. For the alternative outcome regression on market volumes, the dependent variable is the natural logarithm of the number of dwellings offered for sale or rent per postal code area and month. α is the intercept term. $D_{i\tau}$ are dummy variables indicating whether a dwelling is in the control ($D = 0$) or treatment group ($D = 1$). β_t captures the effects for pre-event periods, serving as placebo tests to check for any pre-existing trends between the treatment and control groups. δ_t captures the effects for post-event periods, indicating how the treatment effect evolves over time following the energy price shock. ρ represents postal code fixed effects. ω captures region type interacted with time fixed effects. Region types are categorised into four groups: sparsely populated rural areas, more densely populated rural areas, urban areas, and large cities. By interacting these region types with time, I account for potential heterogeneous time trends across different region types. X_{it} is a vector of dwelling characteristics, including the type of dwelling (e.g. detached house, one-room apartment), heating system, size in square metres, year of construction, presence of a terrace or balcony, whether the dwelling includes a basement or a kitchen, availability of a parking space, and additional indicators for the dwelling's amenities and overall condition. ε_{it} captures the error term.

4.7 Results

4.7.1 Main price effects

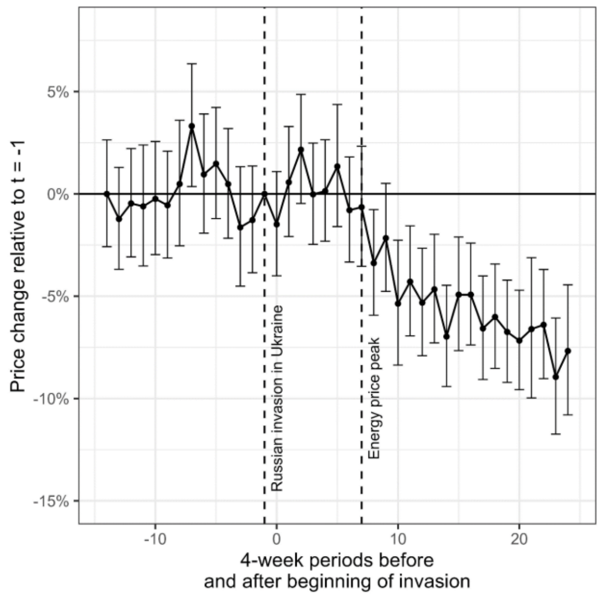
This section presents the main effects of the energy price shock on purchase and rental prices. Following the energy price shock, a strong decline in purchase prices is estimated for LEED relative to the MEED, as presented in Figure 4.6. Statistically significant relative price decreases are estimated nine months after the Russian invasion of Ukraine, directly after the energy price peak in autumn of 2022. Approximately two years after the beginning of the war, LEED have experienced a relative price decline in the purchase market of up to 8.9 percent. Hence, while purchase prices came down from their peak values in 2022 for all EPC ratings, the price decline for LEED was stronger than for the MEED.

For the rental market, I find that price differences for the MEED and LEED widened after the energy price shock, also. However, raw price developments by EPC ratings indicated that prices continued to increase for dwellings of all EPC ratings in the rental market. This means that rental prices for the MEED increased more strongly than for LEED after the energy price shock. The relative price difference increased by 3.3 percent two years after the beginning of the war. Pre-treatment trends show no significant differences relative to the last month before the start of the Russian war in Ukraine.

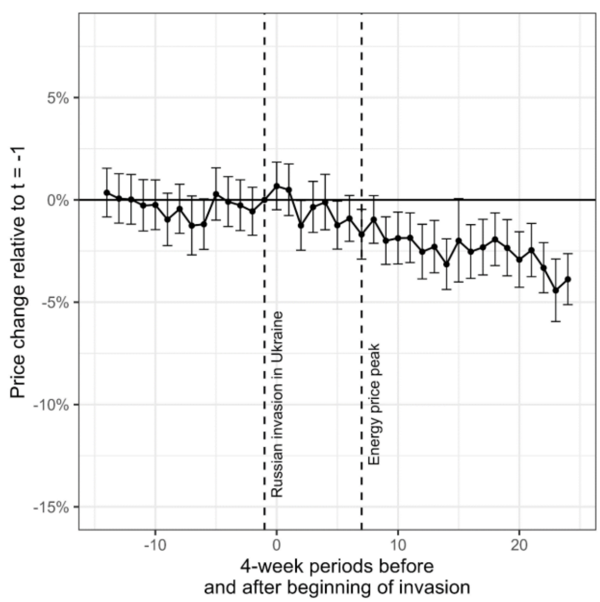
The findings are consistent with economic theory and findings in the related literature, which highlight the impact of energy prices on the valuation of dwellings. The relative price decline for LEED in the purchase market aligns with the notion that higher operating costs or the implicit need for energy-efficient renovations due to higher energy prices diminish the attractiveness of less energy-efficient dwellings relative to those dwellings that area already more energy-efficient. Similarly, the widening price gap in the rental market reflects the increased importance of energy efficiency in pricing decisions, as supported by previous research. The absence of significant pre-treatment trends further strengthens the conclusion that these effects were triggered by the energy price shock, providing empirical evidence of how energy costs influence market dynamics. In the next section, the robustness of the findings is assessed, and several additional analyses are conducted to provide further validation and context.

Figure 4.6: Event study estimates

Purchase



Rent



Notes: The figures show the price development of dwellings with energy efficiency H to B (LEED) relative to dwellings with the highest energy efficiency A to A+ (MEED). The figures show 4-week event study estimates. Error-bars indicate 95-percent confidence intervals. Coefficients and illustrated confidence intervals are transformed and represent percentage changes relative to the last month before the Russian invasion in Ukraine. Standard errors are clustered at the postal code level. For full regression results see Tables 4.A.1 and 4.A.2 in the appendix. The number of observations of dwellings for rent is 869,711, for purchase it is 641,438. The period shown extends from January 2021 to January 2024.
Source: Author's calculations based on Value Marktdaten.

4.7.2 Heterogeneity, robustness analyses, and extensions

4.7.2.1 Regional and dwelling type heterogeneity

In the first step of the heterogeneity analysis, the effects are examined across different region types. Analysing different region types is important because regional characteristics could influence housing market dynamics and the impact of energy price shocks. Levels of urbanisation, for instance, often correlate with differences in housing stock composition, energy infrastructure, and market conditions. Urban areas may have a higher concentration of rental dwellings and newer, more energy-efficient buildings, while rural areas might feature more owner-occupied and older homes, which are less energy-efficient. Examining heterogeneity across region types allows us to assess whether the observed effects are consistent or vary depending on local housing characteristics and market structures.

Table 4.3 shows price effects stratified by four different urbanisation levels. For both, the purchase as well as the rental market, the increase in price differences between the MEED and the LEED were of similar magnitude across region types. Time trends across region types were also similar with the onset of an increase in the price spread between LEED and MEED after the peak of the energy prices (see Figure 4.A.3 and 4.A.4 in the appendix for event study plots). Price effects on the purchase market however are more than double of the effect in the rental market which, again, holds across region types.

While there seem to be no distinctive differences in the price effects by region type, effects vary by dwelling type and size, as summarised in Table 4.4. For the purchase market, LEED in multi-family buildings, i.e. apartments, seem to have experienced a stronger relative price decrease than LEED which are houses. In line with that finding, smaller LEED seem to have experienced a stronger relative price decrease than larger LEED. Differences are however small and confidence bands overlap. This result is somewhat counterintuitive, given that larger dwellings, such as houses, typically have higher energy consumption and thus higher associated costs. However, this could reflect a segmentation of the market: owner-occupiers, who in Germany predominantly purchase houses, versus investors, who are more likely to purchase apartments. This suggests that investors may be more sensitive to the costs associated with the energy price shock, leading to stronger price adjustments in this segment. To explore this further is beyond the scope of this paper and to be analysed in future research. For the rental market, the change in relative prices for the MEED is very similar independent of the dwelling type.

Table 4.3: Price effects stratified by region type

		District-free large city	**Urban county**	**Rural more densely populated county**	**Rural sparsely populated county**
Purchase	Effect	-5.1%***	-6.2%***	-5.4%***	-6.3%***
		(0.7%)	(0.5%)	(1.1%)	(0.9%)
	Adj. R^2	0.89	0.85	0.84	0.79
	Obs.	192,893	257,200	105,174	86,171
Rent	Effect	-2.5%***	-2.2%***	-1.4%**	-2.4%***
		(0.4%)	(0.3%)	(0.5%)	(0.5%)
	Adj. R^2	0.90	0.91	0.91	0.90
	Obs.	432,412	245,737	118,239	73,323

Notes: This table shows the price effects for four region types for the purchase and the rental market. For these regressions, the post-treatment period is set to begin after the peak of the energy price shock. Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and + indicate significance at the 0.1, 1, 5, and 10 percent levels. The full event study graphs for each region type are included in Figure 4.A.3 and Figure 4.A.4 in the appendix. Regressions correspond to the full models presented in Table 4.A.1 and 4.A.2, column (3).
Source: Author's calculations based on Value Marktdaten.

Table 4.4: Price effects stratified by dwelling type and size

		Dwelling type		**Tercile by living space**		
		Apartments	**Houses**	**First**	**Second**	**Third**
Purchase	Effect	-6.9%***	-3.9%***	-6.2%***	-5.7%***	-5.2%***
		(0.5%)	(0.4%)	(0.7%)	(0.4%)	(0.4%)
	Adj. R^2	0.90	0.82	0.88	0.82	0.81
	Obs.	325,693	302,073	209,995	209,189	208,582
Rent	Effect	-2.0%***	-2.2%***	-2.5%***	-1.9%***	-1.6%***
		(0.2%)	(0.5%)	(0.5%)	(0.3%)	(0.2%)
	Adj. R^2	0.90	0.87	0.84	0.83	0.87
	Obs.	821,394	28,159	283,416	283,362	282,775

Notes: This table shows the price effects for different dwelling types and sizes. For these regressions, the post-treatment period is set to begin after the peak of the energy price shock. Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and + indicate significance at the 0.1, 1, 5, and 10 percent levels. Regressions correspond to the full models presented in Table 4.A.1 and 4.A.2, column (3).
Source: Author's calculations based on Value Marktdaten.

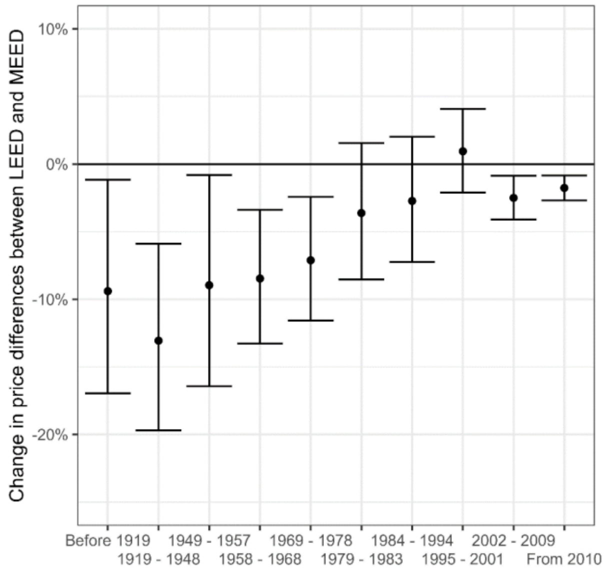
4.7.2.2 Year of construction

Older dwellings are typically associated with being less energy-efficient than newer ones (Taruttis & Weber, 2022; März et al., 2022). It might therefore be of interest to investigate whether relative price differences between the MEED and LEED widened after the invasion and ensuing energy price shock, irrespective of their year of construction. This distinction allows for a deeper understanding of whether energy efficiency influences housing prices consistently across different construction cohorts, given that older dwellings typically exhibit lower energy performance. If price effects were observed across all construction periods, this underscores the broader market-wide impact of energy efficiency considerations.

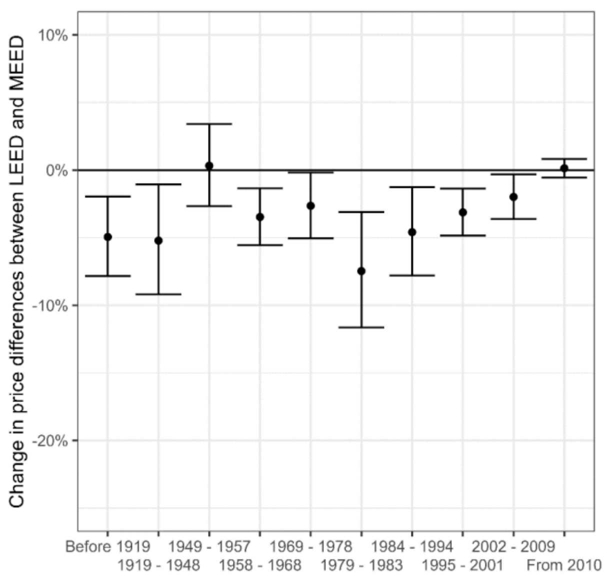
The overall finding of a decrease in relative prices of LEED for both the purchase as well as the rental market after the energy price shock is also found when looking at different construction periods and illustrated in Figure 4.7. Especially for the purchase market, and less pronounced for the rental market, the drop in relative prices decreases with newer construction cohorts. This is to be expected, as the share of less energy-efficient dwellings decreases with newer construction cohorts and the comparison groups are not identical. However, overall, these findings suggest that energy efficiency plays a more important role in a dwelling's price regardless of its year of construction. The findings further indicate that energy-efficient renovations may have become more appealing for older dwellings, as the relative price decline for less energy-efficient dwellings in the older construction cohorts was larger, which has made them more affordable, thereby increasing the financial attractiveness of energy-efficient renovations.

Figure 4.7: Price effects stratified by year of construction

Purchase



Rent



Notes: The figures show the change from before the energy price shock to the period after in relative prices between LEED (EPC rating H to B) and the MEED (EPC rating A to A+) by groups of construction years. The classification of construction years is based on the German residential building typology (Loga et al., 2015). Regressions correspond to the full models presented in Table 4.A.1 and 4.A.2, column (3).
Source: Author’s calculations based on Value Marktdaten.

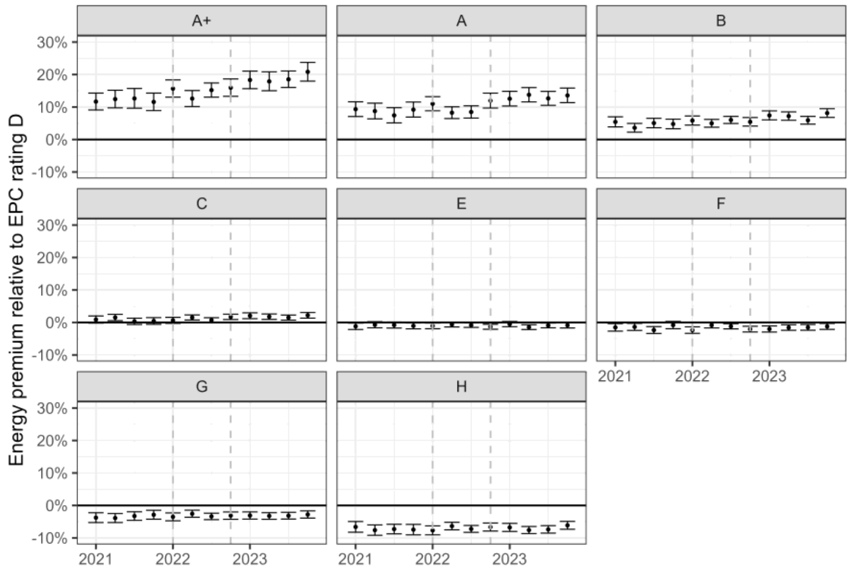
4.7.2.3 Green premium or brown discount?

Up to this point, the analysis focused on the comparison of dwellings with the best EPC ratings, i.e. the MEED with the rest of the dwellings. An alternative approach to this identification strategy is to look at the energy premium over time. The energy premium is the additional upfront cost for buying or renting more energy-efficient dwellings than the less energy-efficient ones (Cespedes-Lopez et al., 2019). In case of a housing purchase, it is the additional purchase price, in case of rental dwellings it is the additional net rent. In the following, the energy premium will be illustrated in two ways. First, building on the EPCs introduced above, I focus on the energy premium a potential buyer or new renter must pay for increases in energy efficiency, depending on the dwelling's EPC rating. To illustrate the energy efficiency premium over time, I run log-linear hedonic housing price regressions stratified by quarter and extract the coefficients associated with a dwelling's EPC rating, with the reference category set to the median EPC rating D. Results are presented in Figure 4.8.

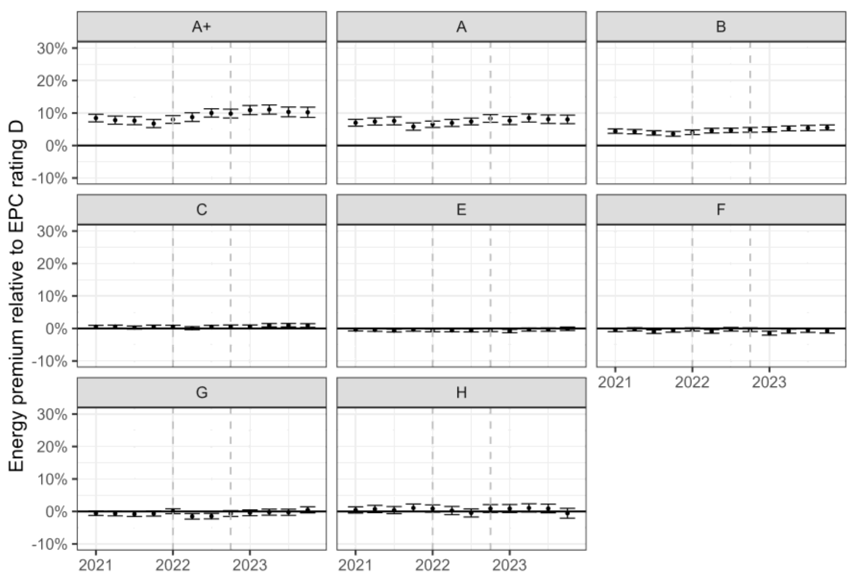
For the purchase market, relative to the median EPC rating D the energy efficiency premium for the highest EPC rating A+ has increased by up to 9.2 percentage points in only two years since the onset of the energy price shock. The quarter with the lowest energy premium in the period considered was the fourth quarter of 2021 with an energy premium for EPC rating A+ relative to D of 11.6 percent, the highest was the fourth quarter of 2023 with an energy premium of 20.8 percent. Averaging the estimated energy efficiency premium over the periods before the energy price shock in the first quarter of 2022 and the quarters after, I find a mean energy premium of 12.8 percent before and 17.0 percent after for the highest EPC rating A+. Increases in the energy efficiency premium are found for the other higher EPC ratings relative to D, as well. The mean energy efficiency premium for rating A relative to D was 9.1 percent before and increased to 11.6 percent after. For B it was 4.9 percent before and increased to 6.5 percent after. For C it was 0.8 percent before and increased to 1.7 percent after. For the rental market, dynamics are similar, however, not as strong. The mean energy premium for the most energy-efficient dwellings with an EPC rating of A+ relative to D was 7.7 percent before and increased to 10.2 percent after.

Figure 4.8: Energy premium relative to median EPC rating D over time

Purchase



Rent



Notes: The figures show the energy efficiency premium relative to the median EPC rating D stratified by quarter. Error-bars indicate 95-percent confidence intervals. Coefficients and illustrated confidence intervals are transformed and represent differences in percent. Standard errors are clustered at the postal code level. The first vertical dashed line indicates the first quarter of 2022, i.e. the beginning of the war in Ukraine, the second indicates the energy price peak in autumn of 2022. The period shown extends from the first quarter of 2021 to the fourth quarter of 2023.
Source: Author’s calculations based on Value Marktdaten.

For dwellings with an EPC rating of A, the premium increased from 6.9 percent to 7.8 percent. I find increases for the EPC ratings B and C as well.

For both, the purchase as well as the rental market, I do not find increases in the energy discounts ("brown discounts") for less energy-efficient dwellings relative to the median EPC rating D. There are several potential reasons for this finding. First, the market may already price in the inefficiency of dwellings with lower EPC ratings, such as those rated E, F, or G. As a result, these properties might not experience additional relative price declines following the energy price shock. This might be because potential energy-efficient renovation costs are similar across the less energy-efficient dwellings. Second, potential buyers and renters may lack sufficient awareness or understanding of the implications of lower EPC ratings. If energy cost considerations are not fully internalised, the energy price shock may not translate into larger "brown discounts". Building on that, dwellings rated below D may be seen as homogeneously inefficient, leading to little differentiation in perceived energy costs. Buyers or renters might not distinguish sharply between E, F, or G ratings, reducing the variability in price changes relative to the median EPC rating.

The results indicate that the EPC ratings have a significant signalling power when it comes to a dwelling's price, especially when considering the highest EPC ratings, and there seems to be a non-linear relationship between a dwelling's price and its energy efficiency which is to be explored in the second specification of the energy efficiency premium.

To further investigate this seemingly non-linear relationship in the increase of the energy premium over time, I re-ran regressions, grouping the dwellings by energy consumption rather than by EPC rating. Each group is categorised into bands of 10 kWh per square metre and year. As the reference category, dwellings with an energy efficiency rating of (110,120] kWh per square metre and year were chosen, which is in the range of EPC rating D. The results are depicted in Figure 4.9 and underline above findings. On a more granular level, the energy premium has increased the most for dwellings with the highest levels of energy efficiency. For the purchase market, results indicate almost a doubling of the energy premium for dwellings with a very low energy consumption in the range of (0,20] kWh per square metre and year from 12.8 percent in the fourth quarter of 2021 to 18.2 percent in the fourth quarter of 2022, to then 23.5 percent in the fourth quarter of 2023 relative to the chosen reference category. Similar findings hold for the rental market. The energy premium at the highest energy efficiency levels, i.e. consumption in the range of (0,20] kWh per square metre and year, increased from 7.3 percent to 11.1 percent between the fourth quarter of 2021 and the fourth quarter of 2023.

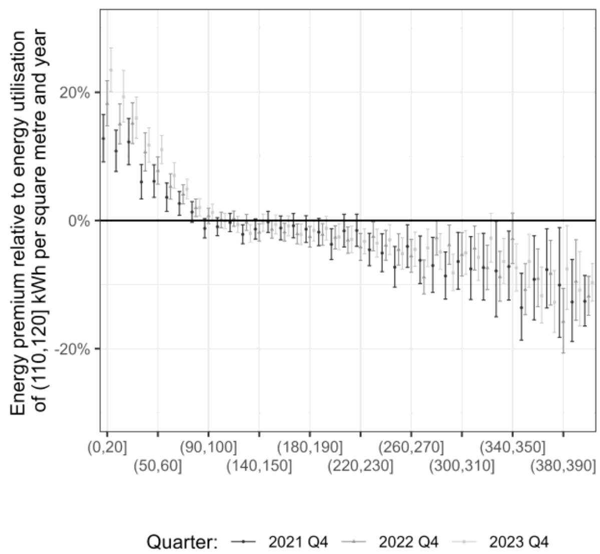
4.7.2.4 Volume effects

Following an energy price shock, the influx of new supply could indicate sellers' intent to offload less energy-efficient dwellings. Additionally, if the number of listings increases after the energy price shock, this could mean that less energy-efficient dwellings are less sought after and sellers are not able to realise their intended prices off market. In the following, I analyse the number of new offers over time. Figure 4.10 shows the development of the number of LEED relative to MEED in comparison to the month preceding the Russian invasion of Ukraine and the subsequent energy price shock. For the purchase market, the number of LEED increased more strongly than the number of MEED after the beginning of the war. At peek values, approximately half a year after the beginning of the war, the ratio of LEED to MEED has increased by 25 percent. Note that there is considerable seasonality in the data. The dips in the event study coefficients shown happen in the months December and January where, due to the holiday season, there are less objects newly offered for sale which seems to affect the LEED more strongly.

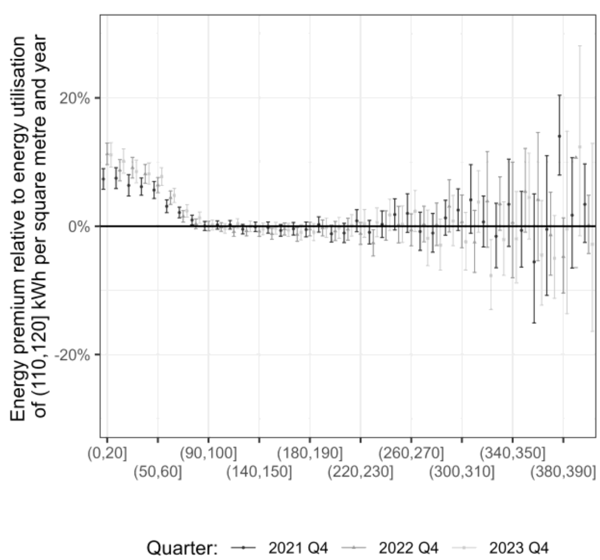
For the rental market, I find no immediate surge in LEED being offered relative to the MEED following the energy price shock. Instead, there is a long-term trend of more MEED being offered over time compared to LEED. This finding is expected, as owners of LEED in the rental market typically do not face a short-term need to find new renters. Dwellings are listed only when they become available, either newly constructed or after becoming vacant. Quick rental turnover is unlikely, as it requires prior vacancy, which depends on tenant turnover rather than landlords' immediate decisions. However, this could also indicate that landlords face little difficulty finding renters off-market for less energy-efficient dwellings. As a result, there is no additional influx of less energy-efficient dwellings into the rental market.

Figure 4.9: Development of energy premium on a more granular level

Purchase



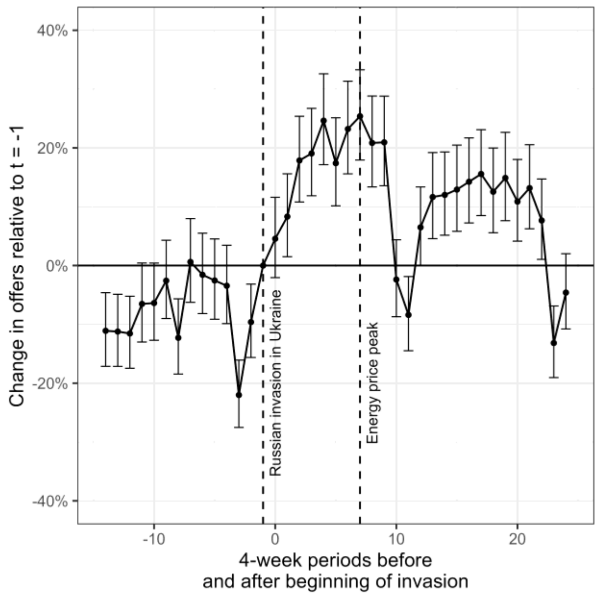
Rent



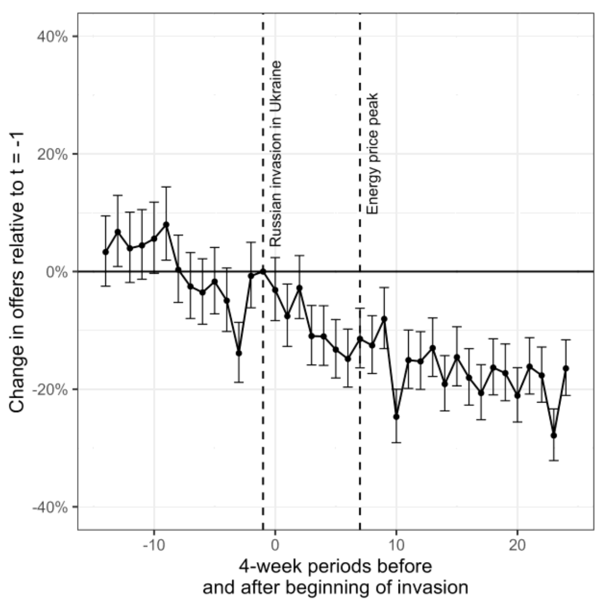
Notes: The figures show the energy efficiency premium relative to an energy utilisation of (110,120] kWh per square metre and year stratified by quarter. Error-bars indicate 95-percent confidence intervals. Coefficients and illustrated confidence intervals are transformed and represent differences in percent. Standard errors are clustered at the postal code level.
Source: Author's calculations based on Value Marktdaten.

Figure 4.10: Change in the number of new offers

Purchase



Rent



Notes: The figures show 4-week event study estimates. They show changes in the number of dwellings offered for sale and rent with energy efficiency H to B (LEED) relative to offers for dwellings with the highest energy efficiency A to A+ (MEED). Coefficients are transformed and represent percentage changes. The period shown extends from January 2021 to January 2024.
Source: Author's calculations based on Value Marktdaten.

4.8 Discussion and policy implications

The energy price shock following Russia's invasion of Ukraine has reshaped the German housing market, with the most energy-efficient dwellings demonstrating resilience in both purchase and rental sectors. These trends offer key insights for policy makers aiming to address the rising importance of energy efficiency in housing.

Energy efficiency plays a more important role in property valuations. The MEED experienced smaller price declines in the purchase market and stronger rental price growth than LEED, signalling a growing market preference for energy-efficient dwellings. This shift reflects the increasing role of energy costs in property valuations, with demand likely to rise as energy prices remain volatile and are expected to increase further in the long term.

The significant relative price decline for LEED underscores the need for retrofitting the existing housing stock. Financial support for homeowners to make energy-efficient improvements will be critical in preventing further market divergence. Expanding programs like the EPC rating system can help drive market transparency. Energy efficiency plays a more important role with regards to affordability in the rental market, also. The rental premium for MEED could reduce affordability for tenants, while landlords face considerable costs for retrofitting. Policy makers should consider financial assistance for landlords to ease the burden of energy efficiency investments, paired with measures that prevent excessive rent hikes. This balance will be essential for keeping energy-efficient housing accessible to all income groups. Energy efficiency's price impact varies by region and property type, with rural areas more affected by rising energy costs, as the share of less energy-efficient dwellings is larger. Targeted regional policies that promote retrofits for less efficient dwellings, particularly in rural settings, will help address these disparities and ensure that all segments of the housing market benefit from energy-efficient improvements.

The findings in this paper should also be considered within a broader, long-term perspective on housing policy. The short-term energy price shock and its influence on housing market dynamics offers valuable insights into longer-term trends that may be influenced by policy measures such as the Energy Performance of Buildings Directive (EPBD), the amended

Buildings Energy Act (GEG), and CO_2-pricing. See section A.4.1.3 in the appendix for a discussion of the (amended) GEG in the light of the energy crisis. In the long-run, such policies are likely to encourage the development of a more energy-efficient housing stock, which may help to stabilise property values, as energy-efficient renovations become more widespread. However, without sufficient financial assistance, less energy-efficient dwellings could experience further value declines, potentially exacerbating market disparities. The short-term shock analysed in this paper provides a glimpse into these possible future trends, emphasising the need for carefully crafted policies to manage the transition towards greater energy efficiency without exacerbating affordability issues or deepening market imbalances.

Appendix

A.4.1 Additional information

A.4.1.1 Policy measures in reaction to the energy price shock

During the energy price crisis triggered by the Russian invasion of Ukraine, Germany implemented several direct policy measures to mitigate the economic impact on households and businesses and to reduce its dependency on Russian energy. The measures can be grouped into energy saving ordinances and subsidies, summarised below (Beznoska et al., 2023; BMWK, 2023; Federal Statistical Office, 2024b).

Energy saving ordinances

There were two ordinances introduced to save on energy. First, on 1 September 2022 the Ordinance on Securing the Energy Supply through Rapid Impact Measures (in German: "Kurzfristenergieversorgungssicherungsmaßnahmenverordnung – EnSikuMaV") was introduced (BMWK, 2022a). The ordinance introduced rapid measures aimed at reducing energy demand during the 2022/2023 heating season, affecting the public sector, as well as households and companies. It was valid from 1 September 2022 until 14 May 2023. Tenants had more flexibility to save energy as minimum temperature clauses in rental agreements were suspended, allowing them to lower heating. Additionally, heating private swimming and bathing pools with gas or electricity was banned, except for therapeutic purposes. In public non-residential buildings, heating was prohibited in spaces not regularly occupied, such as corridors and foyers, unless necessary for technical or safety reasons.

Second, on 1 October 2022, the Ordinance on Securing the Energy Supply through Medium-term Impact Measures (in German: "Mittelfristenergieversorgungssicherungsmaßnahmenverordnung – EnSimiMaV") was introduced (BMWK, 2022b). This ordinance introduced medium-term measures aimed at achieving energy savings for the upcoming and subsequent heating seasons, with lasting effects. It was valid for two years. Measures include mandatory heating system checks for gas-heated buildings within the next two years, and compulsory hydraulic balancing for large buildings with central heating. Companies consuming 10 gigawatt-hours or more annually must implement cost-effective energy efficiency measures, such as upgrading to LED lighting, optimising work processes, and performing hydraulic balancing of their heating systems. These requirements apply to both public and private sectors to enhance overall energy efficiency.

Subsidies to alleviate energy price burden

To alleviate the financial burden of rising energy costs, Germany has introduced a comprehensive set of measures subsequently in three relief packages (Bundesregierung, 2022a, b, c; BMF, 2022). The Renewable Energy Sources Act surcharge (in German: "EEG-Umlage") was abolished on July 1, 2022, saving consumers 6.6 billion euro in electricity costs. Households receiving housing benefits got a one-time heating cost subsidy of 270 euro (350 euro for two-person households, plus 70 euro for each additional family member), with apprentices and students receiving 230 euro. The employee allowance increased by 200 euro to 1,200 euro, and the basic tax allowance rose by 363 euro to 10,347 euro. The mileage allowance for commuting was increased to 38 cents per kilometre from the 21st kilometre onward. A one-time energy price allowance of 300 euro was granted to all income tax-paying workers, and a 2022 child bonus provided families with an additional 100 euro per child. Recipients of social benefits received a one-time payment of 200 euro, and those on unemployment benefits received 100 euro. The energy tax on fuels was reduced from June 1 to August 31, 2022, cutting petrol tax by 29.55 cents per litre and diesel by 14.04 cents per litre. The 9-euro public transport ticket was available from June 1 to August 31, 2022. Pensioners and students received a one-time energy price allowance of 300 euro and 200 euro, respectively, totalling 6 billion euro in relief. A new electricity price brake was introduced to mitigate rising grid charges, offering a discounted rate for a basic level of electricity consumption. Additionally, a gas price brake was implemented to control the soaring costs of natural gas, providing consumers with a reduced rate for a basic level of gas consumption. Additionally, low-income workers were relieved of 1.3 billion euro in social contributions, with full contributions now starting from an income of 2,000 euro. The midijob threshold (reduced social contributions), set to rise from 1,300 euro to 1,600 euro in October 2022, increased further to 2,000 euro in January 2023. Another major initiative was the expansion of the housing benefit program, which increased eligibility from 700,000 to 2 million people. This expansion aimed to provide relief to a larger portion of the population struggling with rising living costs.

A.4.1.2 Simple model of housing demand and energy costs

Consider a simple housing market where potential homebuyers decide between purchasing and renovating an existing home or buying a new energy-efficient home. Key variables include the price of the house P_H, renovation costs R_C, expected energy costs E_C, probability of future energy price shocks π, discount factor β, utility U, household income Y, and time horizon T. Potential homebuyers derive utility from housing and disposable income after accounting for housing and energy costs. The potential homebuyer's utility function is represented as:

$$U = f(H(q), Y - P_H - R_C - E_C), \tag{4.A.1}$$

where H represents utility derived from housing services which depends on a dwelling's characteristics q, and $Y - P_H - R_C - E_C$ denotes disposable income after expenses. Homebuyers consider renovation costs to improve energy efficiency against long-term energy savings. The renovation cost R_C leads to a reduction in annual energy costs ΔE_C. An energy price shock, modelled as an increase in energy costs E_C, occurs due to external factors. Homebuyers evaluate expected utility over the time horizon T, considering energy price shocks and energy efficiency investments:

$$E[U] = \sum_{t=0}^{T} \beta^t [f(H(q), Y - P_H - R_C - E_C^t) - \pi(E_C^t - \Delta E_C^t)], \tag{4.A.2}$$

where E_C^t represents expected energy costs at time t without investment, and ΔE_C^t is the reduction due to higher energy efficiency. Homebuyers face a budget constraint, reflecting their financial limitations:

$$P_H + R_C - S \leq Y - C_O, \tag{4.A.3}$$

where C_O represents other essential expenses. S indicates potential government subsidies for energy-efficient renovations. This constraint indicates that the combined cost of purchasing a house and renovating it to meet higher energy efficiency standards must not exceed the disposable income available after covering other essential expenses. Homebuyers maximize expected utility by: Evaluating current energy costs E_C, and the probability of future energy price shocks π, calculating renovation costs R_C for desired energy efficiency, and lastly by choosing between new energy-efficient homes or existing homes with renovations.

Higher energy prices enhance the perceived importance of energy efficiency, driving investments in renovations and energy-efficient homes. Demand shifts towards energy-efficient homes or buying a less energy-efficient dwelling and renovating, influencing relative housing prices. In this model, if energy efficiency becomes more important, but the potential buyer's overall budget remains unchanged, prices for less energy-efficient dwellings should decrease as either the opportunity cost of energy costs increases, or the less energy-efficient dwelling is renovated. Government policies subsidising energy-efficient improvements or incentivising renovations reduce R_C and E_C, improving a potential buyer's overall utility.

A.4.1.3 The (amended) GEG in the light of the energy crisis

The German Buildings Energy Act (GEG) serves as a national implementation of the EU Energy Performance of Buildings Directive (EPBD) and was first introduced in 2020 (BGBl., 2020b; Buildings Energy Act – GEG, 2020). It ensures that Germany meets the directive's standards and contributes to the broader EU goals of reducing energy consumption and carbon emissions in the building sector. The (amended) GEG in Germany plays a crucial role in addressing the energy crisis exacerbated by the Russian war in Ukraine. The GEG, which aims to enhance energy efficiency in buildings, has become even more significant as Germany sought to reduce its dependency on Russian gas and mitigate the impact of higher energy costs. The amended GEG mandates stricter energy efficiency standards for new buildings and major renovations of existing structures. This is to reduce overall energy consumption, thereby decreasing the reliance on fossil fuels, including natural gas. In the context of the energy crisis, improving building energy efficiency is a vital step towards enhancing energy security and sustainability. The GEG encourages the integration of renewable energy sources, such as solar panels and heat pumps, into building designs. By increasing the share of renewables in the energy mix, Germany can offset the reduction in gas supplies from Russia. This shift not only helps in managing immediate energy needs but also aligns with long-term climate goals. During the energy crisis, the GEG's focus on reducing energy demand in buildings becomes particularly important. Measures such as improved insulation, energy-efficient windows, and advanced heating systems contribute to significant energy savings. Lower energy demand eases the pressure on the national energy grid and reduces the need for energy imports. To facilitate compliance with the GEG, the German government provides financial incentives and subsidies for homeowners and builders. These incentives should make it economically more feasible to undertake energy-efficient renovations, which is critical during times of high energy prices. The amendments to the GEG are part of Germany's broader strategy to achieve long-term energy security (BGBl., 2023). By prioritising energy efficiency and the use of renewables, Germany is laying the groundwork for a more resilient energy system that can withstand geopolitical disruptions, such as those caused by the Russian war in Ukraine (BMWK, 2022c).

A.4.2 Tables

Table 4.A.1: Full regression table – Event study: Purchase prices

	(1)	(2)	(3)
Event study estimates, i.e. treatment time × treated object (LEED) indicator (ref: t = - 1)			
t = - 14	0.014	0.011	-0.000
	(0.024)	(0.024)	(0.013)
t = - 13	0.002	-0.001	-0.012
	(0.024)	(0.024)	(0.013)
t = - 12	0.007	0.005	-0.005
	(0.025)	(0.025)	(0.014)
t = - 11	0.018	0.015	-0.006
	(0.027)	(0.027)	(0.015)
t = - 10	0.012	0.011	-0.002
	(0.027)	(0.027)	(0.014)
t = - 9	0.006	0.005	-0.006
	(0.027)	(0.027)	(0.013)
t = - 8	0.003	0.001	0.005
	(0.027)	(0.027)	(0.016)
t = - 7	0.022	0.020	0.033 *
	(0.028)	(0.028)	(0.015)
t = - 6	-0.029	-0.031	0.009
	(0.029)	(0.029)	(0.015)
t = - 5	0.013	0.011	0.015
	(0.026)	(0.026)	(0.014)
t = - 4	0.016	0.016	0.005
	(0.025)	(0.025)	(0.014)
t = - 3	-0.030	-0.031	-0.016
	(0.026)	(0.026)	(0.015)
t = - 2	-0.002	-0.003	-0.013
	(0.031)	(0.031)	(0.013)
t = 1	0.016	0.016	-0.015
	(0.023)	(0.023)	(0.013)
t = 2	0.034	0.035	0.006
	(0.025)	(0.025)	(0.014)
t = 3	0.040	0.039	0.021
	(0.025)	(0.025)	(0.013)
t = 4	-0.014	-0.015	-0.000
	(0.024)	(0.024)	(0.013)
t = 5	0.006	0.005	0.001
	(0.023)	(0.023)	(0.013)
t = 6	0.039	0.038	0.013
	(0.030)	(0.030)	(0.015)
t = 7	0.028	0.026	-0.008
	(0.025)	(0.025)	(0.013)
t = 8	-0.012	-0.014	-0.006
	(0.026)	(0.026)	(0.015)
t = 9	-0.023	-0.025	-0.034 *
	(0.024)	(0.024)	(0.014)

Continued on next page…

Table 4.A.1 continued…

t = 10	0.002	0.000	-0.022
	(0.026)	(0.026)	(0.014)
t = 11	-0.054 *	-0.056 *	-0.055 ***
	(0.026)	(0.026)	(0.016)
t = 12	-0.024	-0.026	-0.044 **
	(0.027)	(0.027)	(0.014)
t = 13	-0.041	-0.042	-0.055 ***
	(0.025)	(0.025)	(0.014)
t = 14	-0.024	-0.026	-0.048 ***
	(0.023)	(0.023)	(0.014)
t = 15	-0.037	-0.038	-0.072 ***
	(0.023)	(0.023)	(0.014)
t = 16	0.013	0.011	-0.050 ***
	(0.025)	(0.025)	(0.015)
t = 17	-0.028	-0.030	-0.050 ***
	(0.024)	(0.024)	(0.013)
t = 18	-0.048 *	-0.050 *	-0.068 ***
	(0.025)	(0.025)	(0.014)
t = 19	-0.060 *	-0.062 **	-0.062 ***
	(0.024)	(0.024)	(0.014)
t = 20	-0.063 *	-0.065 **	-0.070 ***
	(0.025)	(0.025)	(0.014)
t = 21	-0.044	-0.046	-0.074 ***
	(0.024)	(0.024)	(0.013)
t = 22	-0.045	-0.047 *	-0.068 ***
	(0.023)	(0.023)	(0.019)
t = 23	-0.060 *	-0.063 *	-0.066 ***
	(0.026)	(0.026)	(0.015)
t = 24	-0.065 *	-0.068 **	-0.094 ***
	(0.026)	(0.026)	(0.016)
t = 25	-0.087 ***	-0.089 ***	-0.080 ***
	(0.025)	(0.025)	(0.018)
Dwelling type			
(ref: 1-room apartment)			
2-room apartment			0.379 ***
			(0.004)
3-room apartment			0.602 ***
			(0.004)
4-room apartment			0.748 ***
			(0.005)
5+-room apartment			0.886 ***
			(0.006)
Semi-detached house			0.936 ***
			(0.006)
Detached house			1.026 ***
			(0.006)
Terraced house			0.877 ***
			(0.005)
Two- family house			0.973 ***
			(0.006)
House but exact type not specified			0.926 ***
			(0.009)
Year of construction			-0.040 ***
			(0.002)
Year of construction squared			0.000 ***
			(0.000)

Continued on next page…

Table 4.A.1 continued…

Living space in sqm.	0.005 ***
	(0.000)
Number of rooms	-0.019 ***
	(0.001)
Old building (year of construction before 1945)	0.150 ***
	(0.003)
Dwelling refurbished (ref: explicitly no)	
Unknown	0.049 ***
	(0.003)
Yes	-0.012 **
	(0.004)
Terrace or balcony	0.066 ***
	(0.002)
Basement (ref.: explicitly no)	
Unknown	0.023 ***
	(0.003)
Yes	0.023 ***
	(0.002)
Built-in kitchen	0.030 ***
	(0.001)
Heating system (ref: storey heating)	
Unknown	0.031 ***
	(0.002)
Central	-0.018 ***
	(0.002)
Room	-0.096 ***
	(0.004)
Firing of heating system (ref: oil)	
Alternative	0.038 ***
	(0.003)
Electric	0.062 ***
	(0.003)
Gas	0.018 ***
	(0.001)
Unknown	0.016 ***
	(0.003)
Coal	-0.127 ***
	(0.017)
Guest toilet	0.062 ***
	(0.001)
Parking space	0.064 ***
	(0.002)
State of dwelling fit-out (ref.: simple)	
Good	0.128 ***
	(0.003)
High-quality	0.183 ***
	(0.003)
Normal	0.087 ***
	(0.003)

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Table 4.A.1 continued…

State of dwelling overall (ref.: good)			
Normal			-0.119 ***
			(0.003)
Bad			-0.217 ***
			(0.003)
Postal code FE	✓	✓	✓
Region type × time FE	✗	✓	✓
N	660,613	660,613	641,438
Adj. R^2	0.377	0.377	0.854

Notes: Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and + indicate significance at the 0.1, 1, 5, and 10 percent levels.
Source: Author's calculations based on Value Marktdaten.

Table 4.A.2: Full regression table – Event study: Rents

	(1)	(2)	(3)
Event study estimates, i.e. treatment time × treated object (LEED) indicator (ref: t = - 1)			
t = - 14	0.001	0.002	0.004
	(0.014)	(0.015)	(0.006)
t = - 13	0.007	0.007	0.001
	(0.015)	(0.016)	(0.006)
t = - 12	-0.024	-0.025	0.000
	(0.015)	(0.015)	(0.006)
t = - 11	-0.030 *	-0.029	-0.003
	(0.015)	(0.015)	(0.006)
t = - 10	-0.019	-0.020	-0.002
	(0.015)	(0.015)	(0.006)
t = - 9	-0.044 **	-0.043 **	-0.010
	(0.015)	(0.015)	(0.007)
t = - 8	-0.021	-0.021	-0.004
	(0.015)	(0.015)	(0.006)
t = - 7	-0.028	-0.027	-0.013
	(0.016)	(0.016)	(0.007)
t = - 6	-0.008	-0.006	-0.012
	(0.016)	(0.016)	(0.006)
t = - 5	0.008	0.008	0.003
	(0.015)	(0.015)	(0.007)
t = - 4	-0.004	-0.004	-0.001
	(0.016)	(0.016)	(0.006)
t = - 3	-0.025	-0.024	-0.003
	(0.016)	(0.016)	(0.006)
t = - 2	0.002	0.002	-0.006
	(0.015)	(0.015)	(0.006)
t = 1	0.009	0.011	0.007
	(0.015)	(0.015)	(0.006)
t = 2	-0.001	0.000	0.005
	(0.015)	(0.015)	(0.006)
t = 3	-0.020	-0.018	-0.013 *
	(0.014)	(0.014)	(0.006)
t = 4	-0.008	-0.005	-0.004
	(0.015)	(0.015)	(0.006)
t = 5	-0.003	-0.002	-0.001
	(0.015)	(0.015)	(0.007)
t = 6	-0.023	-0.021	-0.012 *
	(0.015)	(0.015)	(0.006)
t = 7	-0.017	-0.015	-0.009
	(0.015)	(0.015)	(0.006)
t = 8	-0.010	-0.007	-0.017 **
	(0.014)	(0.015)	(0.006)
t = 9	-0.016	-0.012	-0.010
	(0.015)	(0.015)	(0.006)
t = 10	-0.031 *	-0.031 *	-0.020 ***
	(0.015)	(0.015)	(0.006)
t = 11	0.008	0.009	-0.019 **
	(0.016)	(0.016)	(0.007)
t = 12	-0.015	-0.012	-0.019 **
	(0.015)	(0.015)	(0.006)

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Table 4.A.2 continued…

t = 13	-0.030	-0.030	-0.026 ***
	(0.016)	(0.016)	(0.007)
t = 14	-0.031 *	-0.030	-0.023 ***
	(0.016)	(0.016)	(0.007)
t = 15	-0.060 ***	-0.057 ***	-0.032 ***
	(0.015)	(0.015)	(0.007)
t = 16	-0.026	-0.022	-0.020
	(0.019)	(0.019)	(0.011)
t = 17	-0.028	-0.026	-0.026 ***
	(0.016)	(0.016)	(0.007)
t = 18	-0.022	-0.023	-0.023 ***
	(0.015)	(0.015)	(0.007)
t = 19	-0.039 **	-0.037 *	-0.019 **
	(0.015)	(0.015)	(0.007)
t = 20	-0.053 ***	-0.054 ***	-0.024 ***
	(0.015)	(0.015)	(0.007)
t = 21	-0.043 **	-0.044 **	-0.030 ***
	(0.016)	(0.016)	(0.007)
t = 22	-0.027	-0.027	-0.025 ***
	(0.015)	(0.015)	(0.007)
t = 23	-0.039 **	-0.037 **	-0.034 ***
	(0.014)	(0.014)	(0.006)
t = 24	-0.051 **	-0.055 **	-0.045 ***
	(0.017)	(0.017)	(0.008)
t = 25	-0.056 ***	-0.057 ***	-0.040 ***
	(0.015)	(0.015)	(0.007)
Dwelling type			
(ref: 1-room apartment)			
2-room apartment			0.219 ***
			(0.003)
3-room apartment			0.352 ***
			(0.006)
4-room apartment			0.437 ***
			(0.008)
5+-room apartment			0.438 ***
			(0.012)
Semi-detached house			0.456 ***
			(0.011)
Detached house			0.420 ***
			(0.011)
Terraced house			0.500 ***
			(0.011)
Two- family house			0.270 ***
			(0.045)
House but exact type not specified			0.357 ***
			(0.022)
Year of construction			-0.018 ***
			(0.001)
Year of construction squared			0.000 ***
			(0.000)
Living space in sqm.			0.010 ***
			(0.000)
Number of rooms			-0.065 ***
			(0.002)

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Table A.4.2 continued…

Old building (year of construction before 1945)	0.116 ***
	(0.003)
Dwelling refurbished	
(ref: explicitly no)	
Unknown	-0.046 ***
	(0.009)
Yes	-0.100 ***
	(0.009)
Terrace or balcony	0.047 ***
	(0.001)
Basement (ref.: explicitly no)	
Unknown	-0.008 *
	(0.003)
Yes	0.005
	(0.003)
Built-in kitchen	0.066 ***
	(0.001)
Heating system	
(ref: storey heating)	
Unknown	0.008 **
	(0.003)
Central	-0.002
	(0.001)
Room	-0.040 ***
	(0.004)
Firing of heating system	
(ref: oil)	
Alternative	0.033 ***
	(0.002)
Electric	0.030 ***
	(0.003)
Gas	0.011 ***
	(0.001)
Unknown	-0.006 **
	(0.002)
Coal	0.015
	(0.025)
Guest toilet	0.023 ***
	(0.001)
Parking space	0.040 ***
	(0.001)
State of dwelling fit-out (ref.: simple)	
Good	0.064 ***
	(0.003)
High-quality	0.061 ***
	(0.003)
Normal	0.035 ***
	(0.003)

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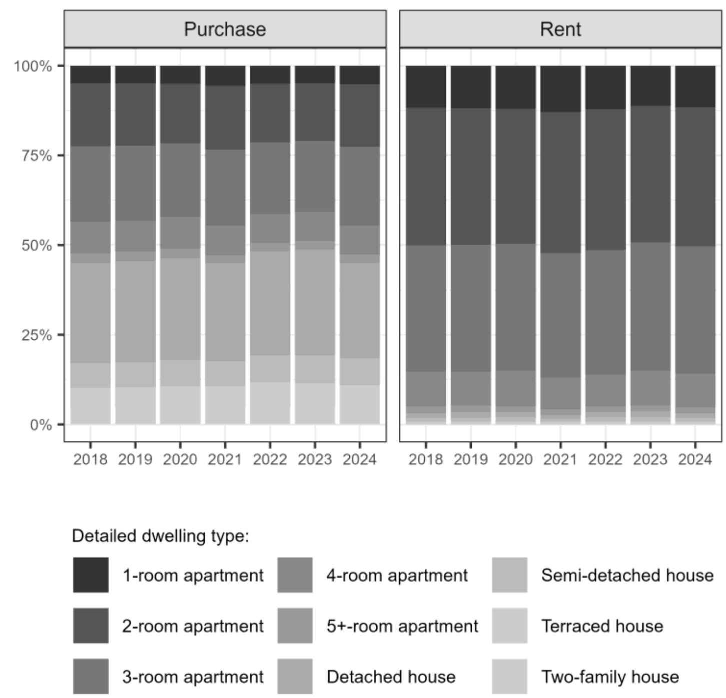
Table 4.A.2 continued…

State of dwelling overall (ref.: good)			
Normal			-0.115 ***
			(0.002)
Bad			-0.191 ***
			(0.005)
Postal code FE	✓	✓	✓
Region type × time FE	✗	✓	✓
N	923,521	923,521	869,711
Adj. R^2	0.467	0.477	0.906

Notes: Standard errors are presented in parentheses and clustered at the postal code level. ***, **, *, and + indicate significance at the 0.1, 1, 5, and 10 percent levels.
Source: Author’s calculations based on Value Marktdaten.

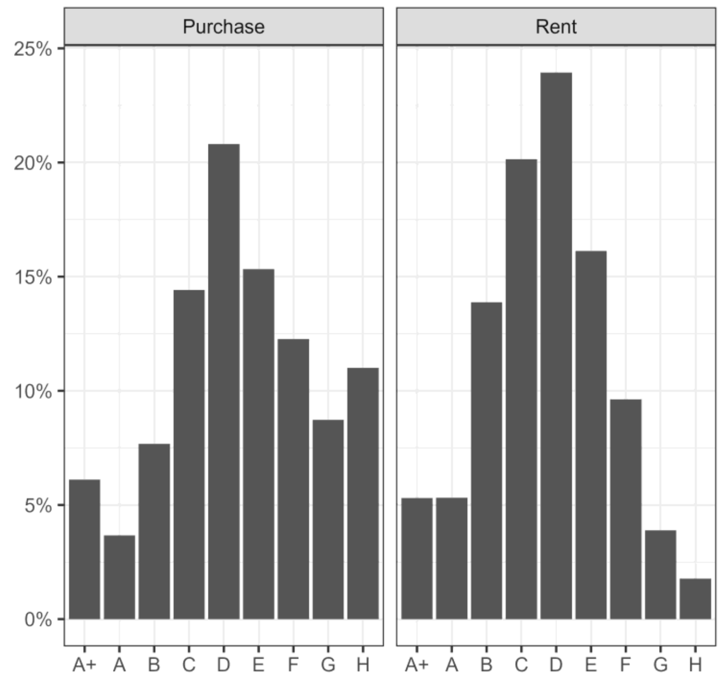
A.4.3 Figures

Figure 4.A.1: Share of dwelling type by availability for purchase or rent



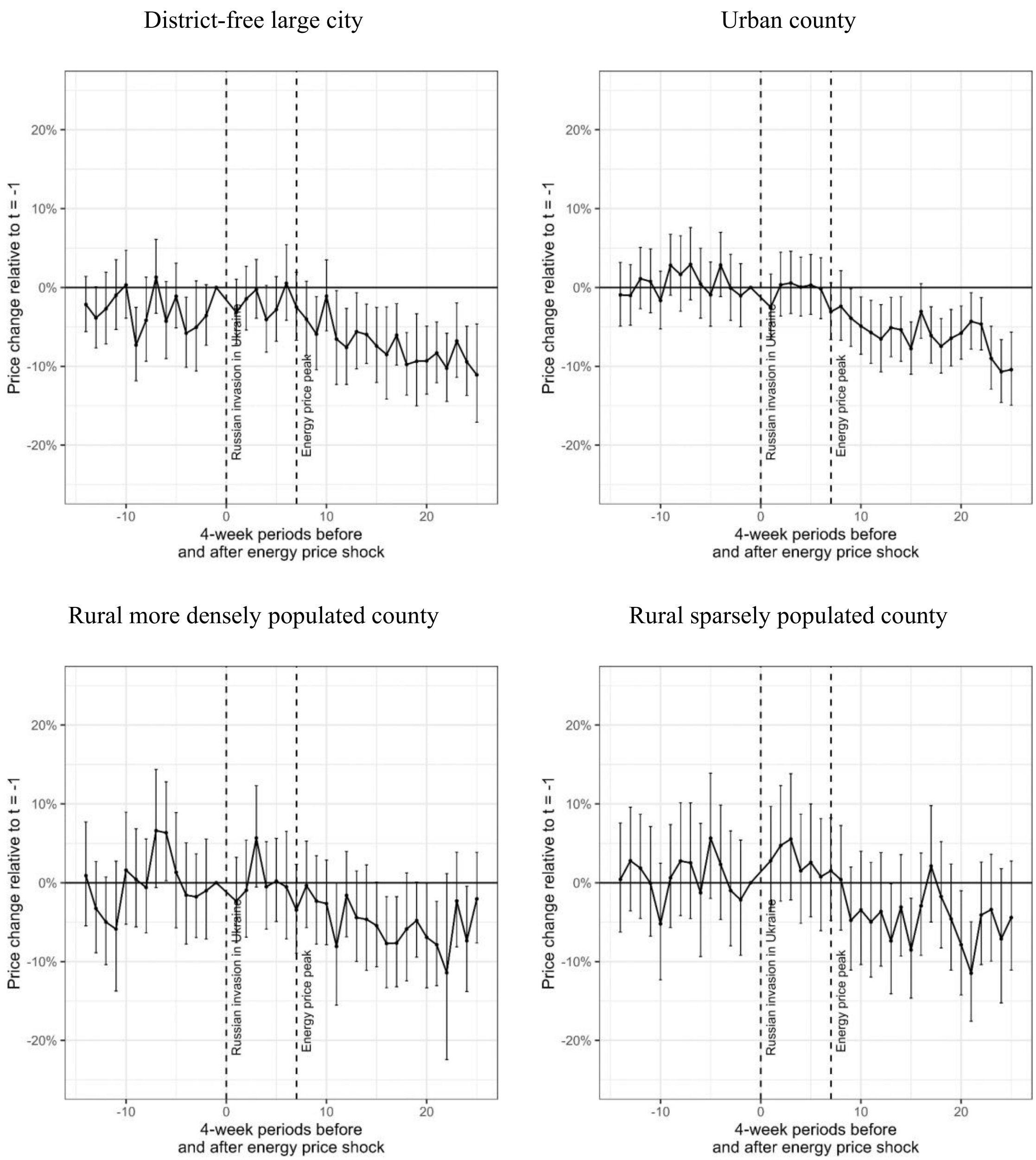
Notes: This figure presents a breakdown of dwellings offered for sale or rent by dwelling type. Larger multi-room dwellings and houses are more prevalent in the purchase market, while the rental market is typically characterised by smaller dwellings.
Source: Author's illustration based on Value Marktdaten.

Figure 4.A.2: Share of dwellings by EPC rating



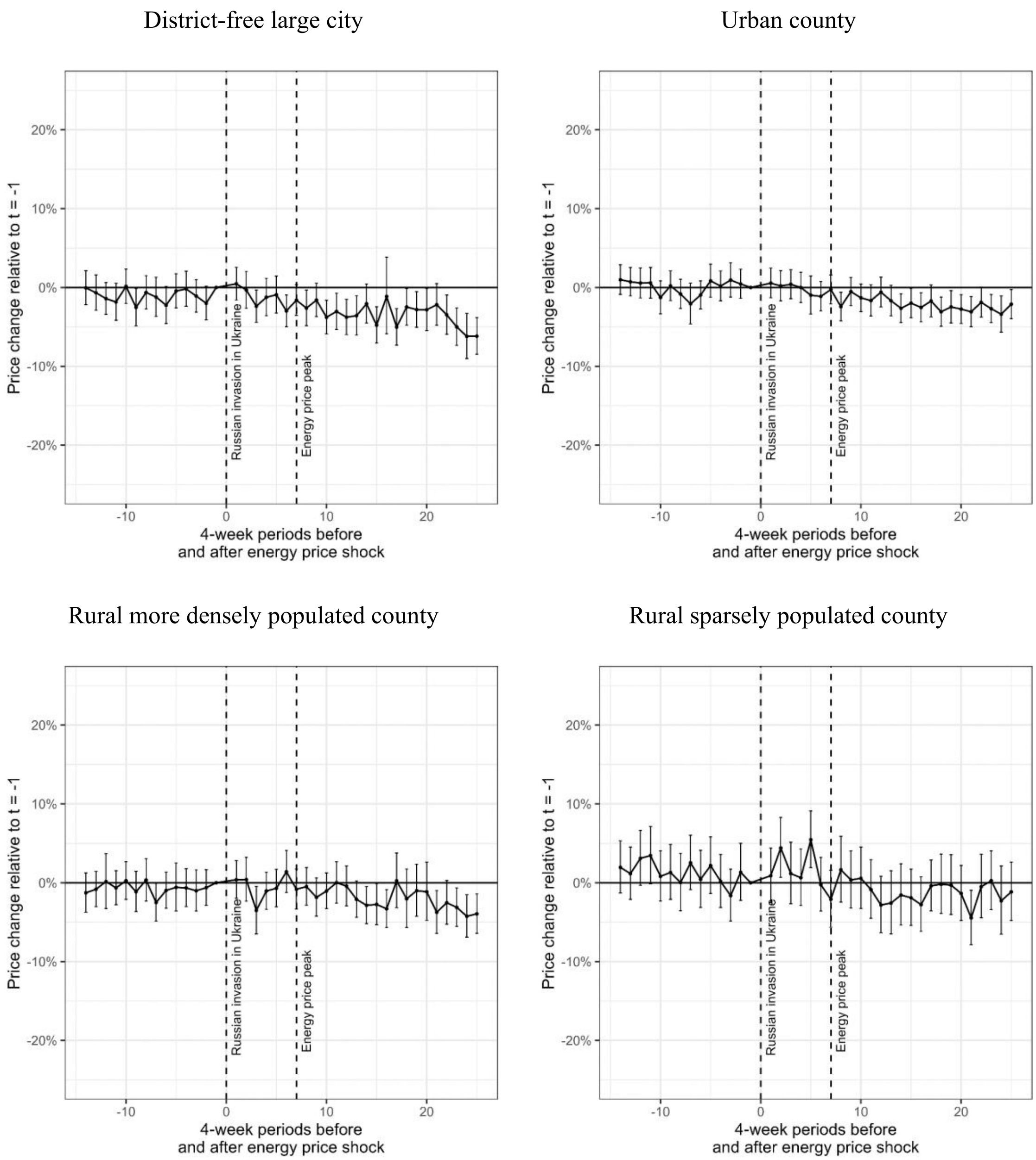
Notes: This figure illustrates the share of dwellings offered for purchase or rent by EPC rating in 2023. The share of MEED with an EPC rating of A+ or A in the purchase market is 9.8 percent, in the rental market it is 10.6 percent.
Source: Author's illustration based on Value Marktdaten.

Figure 4.A.3: Region type heterogeneity of purchase price effects



Notes: The figures show 4-week-period event study estimates. Error-bars indicate 95-percent confidence intervals. Coefficients and illustrated confidence intervals are transformed and represent percentage changes. Standard errors are clustered at the postal code level. The period shown extends from January 2021 to January 2024. Regressions correspond to the full model presented in Table 4.A.1, column (3).
Source: Author's illustration based on Value Marktdaten.

Figure 4.A.4: Region type heterogeneity of rental price effects



Notes: The figures show 4-week-period event study estimates. Error-bars indicate 95-percent confidence intervals. Coefficients and illustrated confidence intervals are transformed and represent percentage changes. Standard errors are clustered at the postal code level. The period shown extends from January 2021 to January 2024. Regressions correspond to the full model presented in Table 4.A.2, column (3).
Source: Author’s illustration based on Value Marktdaten.

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