Technische Universität München

What Makes Munich's Housing Shortage

A District-Level Analysis of Housing Supply Responsiveness and Urban Planning Metrics

Working Paper

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Table of Contents

List of Abbreviations

ABBREVIATION	MEANING
BBSR	Bundesinstitut für Bau-, Stadt- und Raumforschung (Federal Institute for Research on Building, Urban Affairs and Spatial Development)
CPI	Consumer Price Index
DEMO	Demolition Rate
Destatis	Statistisches Bundesamt (Federal Statistical Office of Germany)
EGZR	Exploitation of Granted Zoning Rights
FNP	Flächennutzungsplan (preparatory land-use plan)
HLOR	Housing Land Occupation Ratio
HLUR	Housing Land Utilization Ratio
HLZR	Housing Land Zoning Ratio
PE	Plot Efficiency
RFSD	Residential Floor Space Density
RSBLM	Referat für Stadtplanung und Bauordnung Landeshauptstadt München (Department of Urban Planning and Building Regulations City of Munich)
SH	Social Housing Ratio

1. Introduction

The challenge of housing shortage in Munich, and by extension in Germany, has been insufficiently examined through the integrative lens of urban planning and urban economic development. Such an approach is important for fostering synergistic cooperation between developers and planners with the aim of enhancing affordable housing provision. Applying econometric modeling within this framework demands methodologies that resonate with the peculiarities of the German housing milieu, such as a rental-centric market and stringent zoning regulations. This paper employs a novel dataset to analyze the recent escalation in Munich's housing demand against the backdrop of an accompanying supply deficit. It illustrates a research framework that could be extrapolated to broader German housing market evaluations while providing a contextual exposition of the Munich scenario.

The scope of this inquiry spans 17 district-level spatial units in Munich, concentrating on two specific periods: 2012-2015 and 2018-2020. It employs the concept of price elasticity of housing supply as a metric for gauging supply responsiveness to the changing demand and deploys multivariate regression analysis to dissect the correlation with an array of urban planning metrics, including the social housing ratio and the density parameters of residential spaces. This analysis is tailored to the character of Munich's housing environment and its data architecture.

The findings of this paper, articulated through a detailed analysis of numerical and spatial data, demonstrate a marked inelastic supply environment among private developers within Munich's housing market and suggest that local building regulations may significantly constrain the activities of these private housing developers.

The composition of this paper is as follows: **Section 2** depicts Munich's affordable housing problem. **Section 3** describes the methods employed, including the calculation of housing supply elasticity and the multivariate regression analysis of urban planning metrics. **Section 4** presents the results of this investigation, supplemented by information from the spatial dataset. **Section 5** discusses the constraints of our study and argues for improvement in data infrastructure. Finally, **Section 6** concludes by considering the implications of our empirical evidence in the context of Munich's housing policy framework.

2. Context

2.1 The Housing Affordability Crisis in Munich

Between 2000 and 2021, Munich experienced a substantial increase in population (Statistisches Amt München, 2022b), elevating housing demand to a new level. However, the city's ability to construct new housing struggled to keep up with this growing demand, a trend illustrated in **Fig. 1**. As shown, with the year 2000 as the base index of 100 and a persons-per-dwelling ratio of 1.92, the population growth rate outpaced the rate of dwelling units construction. Moreover, from

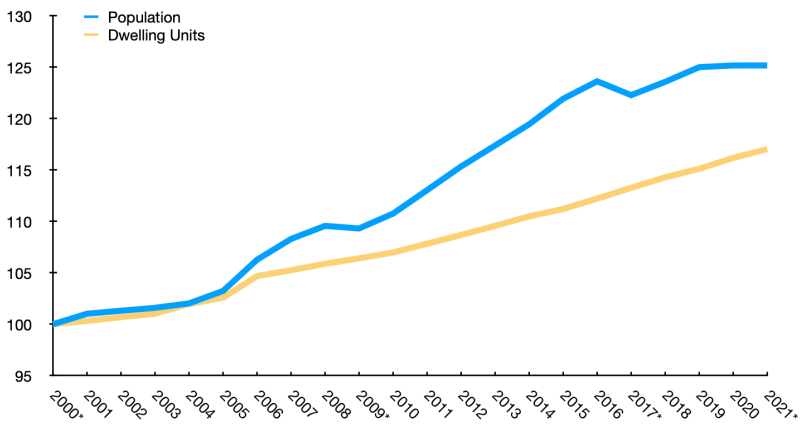


Fig. 1. Trends in Population and Housing Supply Development in Munich, 2000 to 2021. The blue line signifies the total population, whereas the yellow line indicates the number of dwelling units. The year 2000 serves as the base value, set at 100, to provide a comparative perspective on how the housing supply has responded to demographic changes. An asterisk (*) on the x-axis denotes years when administrative corrections influenced the population data. *Data Source: Statistisches Amt München, 2022a&b.*

2011 to 2021, Munich has experienced persistently low vacancy rates, showing a downward trend within a narrow range of 0.20% to 0.60% (empirica, 2022a). This was also confirmed by Rink & Egner (2021, Table 1), who found that the rate of new construction in Munich from 2011 to 2017 significantly lagged behind the increase in the number of households, showing inadequacies compared to other major German cities.

The city's inadequate housing provision has been paralleled by a consequential challenge issue: escalating housing expenses. Between 2005 and 2020, housing costs in Munich have seen an unremitting surge (empirica, 2023), conspicuously surpassing the rise seen in other major German cities (Referat für Stadtplanung und Bauordnung Landeshauptstadt München [RSBLM], 2017, p.17, Fig. 4; empirica 2023b, c&d).

Within Germany, there exists a widespread consensus, as underscored by Rink & Egner (2021) in their literature review, on the necessity of augmenting the supply of affordable housing to reduce housing costs. Deutsche Bank Research (Möbert, J., 2018), specifically examining Munich, even attributed the exorbitant rise in housing prices directly to the sluggish supply response of the housing market. This forms the backdrop of this paper: if Munich had maintained a sufficient rate of new construction, housing prices might have been more controlled.

Forecasts indicate that Munich’s population and number of households will continue to grow (BBSR, 2021). However, in contrast, there was an overall decline in the number of building permits issued in Germany in 2023 (Destatis, 2023). This suggests that the issue of providing adequate housing remains a significant and ongoing challenge.

2.2 City-Led Strategies and Unsatisfactory Outcomes

Munich's housing market is an ecosystem composed of various stakeholders, including municipal housing companies, housing cooperatives, private housing companies, and individual homeowners. These participants operate according to their individual principles and objectives, together contributing to the dynamics of the city's affordable housing development.

As outlined in the housing policy action program "Living in Munich VI" (Wohnen in München [WiM] VI, RSBLM, 2017), municipal housing companies, including entities owned by the city like GEWOFAG, center their operations around providing affordable housing. Housing cooperatives, operating under democratic principles and comprised of residents, also concentrate on offering reasonably priced homes rather than pursuing profits. As noted in WiM VI, these organizations receive support from the city and often collaborate on housing projects. Typical features of these projects include large social housing quotas or the introduction of rent control measures.

On the other end, private housing companies and individual homeowners, primarily driven by profit, occupy a substantial portion of Munich's housing market. According to the study by Rink & Egner (2021, Table 3), this sector accounted for 89.2% of the market in 2011 and 88.9% in 2017.

Over the past thirty years, the Munich city government has actively pursued an extensive housing policy aimed at addressing the need for affordable housing. This approach has established Munich as a leading example in Germany for such initiatives, but its results have not been sufficient.

As outlined by Egner & Kayser (2020), the city's housing policy revolves around four key instruments within the WiM program: economic incentives, direct provision of housing, building law restrictions, and assistance to tenants through subsidized housing. Notably, two of these tools — direct housing provision and subsidized housing — are primarily targeted at the affordable housing segment of the housing market, which constitutes only a marginal part of the overall market.

During the WiM V program (2011-2016), substantial financial resources were allocated to housing policy measures, with the city and state contributing 475 million Euros and 255 million Euros, respectively[1]. However, these investments did not conspicuously alleviate the tension in the housing market. In fact, despite these substantial efforts, the proportion of social housing notably decreased by 7.7% between 2011 and 2017 (Rink & Egner, 2021, Table 4). Furthermore, in 2018, the proportion of private household residents in Munich receiving housing-related social security benefits was lower than that in other major German cities (Schürt, 2021, Map 4).

These challenges — high housing costs coupled with insufficient government support — have left a considerable portion of low to middle-income households without viable options for affordable housing.

2.3 The Absence of a Dominant Opinion on Strategies to Enhance Supply

There are a variety of proposed solutions aimed at alleviating the pressures in the housing market. These include strategies to reduce housing demand in areas with high tension and measures to increase the supply of affordable housing where needed. Notably, the idea of polycentric development within the Munich Metropolitan Region has been gaining traction as a demand-reduction strategy (Bentlage, Müller & Thierstein, 2021; Kinigadner et al, 2015). However, effective methods to increase the availability of affordable housing remain a subject of intense debate.

Egner & Kayser (2020) conducted a comprehensive analysis of the local debates about how to increase affordable housing availability in Munich, which emphasizes the varied views of major stakeholders. Tenant associations and grassroots movements advocate for stringent market regulations on investors, aiming to control the rise in real estate prices. On the other hand, the German Real Estate Association argues that easing building regulations and simplifying bureaucratic processes can help solve Munich’s housing shortage. Politicians have also suggested various strategies to address this issue.

This highlights a key issue: there is no consensus on the best approach to address the housing affordability crisis in Munich. The different perspectives on housing policy represent a complex interplay of various beliefs and interests, making the formulation of effective strategies a challenging task. Especially considering that existing methods have not produced the anticipated results, relying on empirical evidence to identify measures to increase the supply of affordable housing becomes crucial. Establishing an evidence-based narrative is vital for guiding local discussions in a constructive direction.

2.4 The Lack of Quantitative Empirical Studies in the German Context

Econometric research on housing supply dynamics, particularly those related to land resources and zoning systems, has progressed in the United States and the United Kingdom but is less prevalent in Germany. However, the distinct urban planning environments of these countries limit the applicability of their empirical findings in Germany.

The UK's politically driven planning system, especially in terms of building permits, contrasts sharply with the more stringent zoning or master planning systems prevalent in continental Europe (Cheshire et al., 2018). Hall (2002, pp. 182-187) also pointed out differences in post-war urban development strategies at regional and local levels between the UK and other Western European countries.

Similarly, while both the U.S. and Germany use zoning planning systems, their urban governance approaches are fundamentally different. The U.S. is characterized by a complex network of urban influencers, in contrast to the more streamlined system in Europe (Hall, 2002,

[1] for an overview of the program budget history, see Egner & Kayser, 2020, Table 2

pp 202-206). Additionally, the urban morphology and population densities between the U.S. and German cities differ significantly.

So far, empirical research in Germany on this issue is still in progress. Although qualitative research is abundant, including studies on economic policy and regulatory analyses, quantitative research focused on German housing supply is not widespread, possibly due to a lack of detailed data. This gap is particularly noticeable in the context of combining urban planning and urban economic perspectives.

Nonetheless, there have been some notable and encouraging developments. In Germany, for example, Kholodilin (2015) devised indices to measure the regulatory intensity of Germany's rental market, and Mense (2020) assessed how new housing supply affects prices in German cities using a quasi-experimental design. In neighboring countries, Vermeulen & Rouwendal (2007) revealed how strict land-use policies lead to an inelastic housing supply and higher costs in the Netherlands, and Accetturo et al. (2018) linked the rigidity of the Italian housing supply with slower job growth and price surges under increased demand.

3. Research Questions

Generally, there are two main strategies to increase the stock of affordable housing: limiting housing costs and increasing supply. Considering the documented lag of housing stock growth relative to population increase in Munich, and the greater accessibility of data on this aspect, this study will focus on the latter strategy.

The essence of this research is to explore how housing supply in Munich responded to the continuously growing demand during a period of housing boom. Understanding this dynamic is crucial as it directly affects the affordability of housing. Situations where demand spikes lead predominantly to price increases, without corresponding growth in housing stock, can result in gentrification and displacement.

Based on these considerations, we formulate two research questions:

1. How did the housing supply in the different Munich districts (*Stadtbezirken*) respond to price changes during 2012-2020?
2. During this period, which urban planning metrics were closely associated with this responsiveness?

4. Methods

4.1 Price Elasticity of Housing Supply: Calculation

In this study, the concept of price elasticity of housing supply is utilized as a quantitative metric to assess the responsiveness of housing supply to changes in price. Mathematically, this elasticity represents the percentage change in housing supply resulting from a one percent change in housing prices.

A lower value of housing supply elasticity indicates a supply that is less responsive to price changes, suggesting a more rigid housing market. Conversely, a higher elasticity points to a housing supply that can rapidly adjust to price changes, reflecting a more adaptable and dynamic market. By analyzing how the value of supply elasticity varies in relation to other factors, we can discern which factor has a more pronounced association with the housing supply curve.

4.1.1 Area of Study

The focus of this study is the housing market within the city of Munich, selected due to its unique housing market tensions.

Different German cities exhibit a range of baseline characteristics and circumstances (Rink & Egner, 2021). By framing our analysis within Munich, we ensure a consistent background regarding urban governance, market conditions, and data infrastructure. This enhances the study's validity by providing a controlled basis for analysis and mitigates potential errors arising from varied data collection methodologies across different administrative systems.

The choice of the spatial unit for analysis is influenced by the data structure. Housing cost data, sourced from real estate companies, are categorized according to housing market areas, while construction data, provided by the city administration, are grouped by city districts (*Stadtbezirke*). To reconcile these differing organizational structures, our study has identified 17 district-level units where both types of data are available for analysis (**Fig. 2**). These units have been named and numbered following the respective districts to simplify referencing.

Despite the study's geographical focus on a relatively compact region, the selected spatial units exhibit a variety of urban housing characteristics. In the more centrally located areas, average household sizes tend to be smaller than those in the peripheral areas, according to the report series *Wohnungssituation* (RSBLM, 2014, 2016, 2018, 2020, 2022a). Additionally, there is a notable variation in the percentage of built-up areas across different spatial units. These differences signal their diverse conditions in terms of land availability, population density, and housing demand, all of which could significantly influence the dynamics of the housing market. Consequently, this may lead to a spectrum of housing market elasticity values, offering an abundant field for analysis.

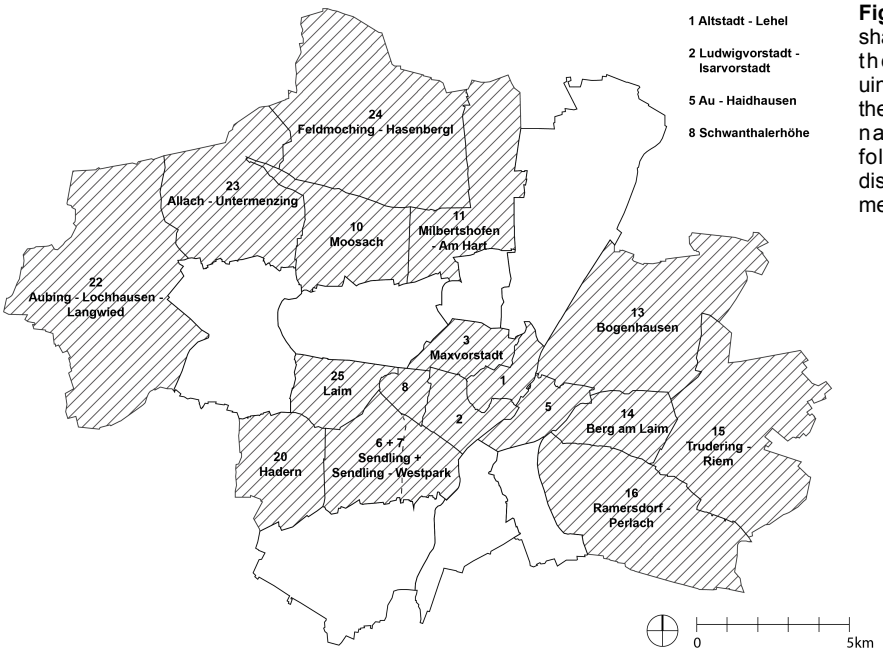


Fig. 2: Area of Study. The shaded regions represent the seventeen spatial uinits. They are shown in the map of Munich, each named and numbered following the respective districts. Districts 6&7 are merged as one spatial unit.

4.1.2 Research Period

The study spans from 2012 to 2020, a timeframe selected based on theoretical relevance and data availability.

From a theoretical standpoint, considering the durable nature of housing and its tendency towards supply rigidity during economic downturns, housing supply elasticity often approaches zero (Glaeser & Gyourko, 2005). To effectively examine the impediments to housing supply

responsiveness, a period of housing market expansion is necessary. Munich recently experienced such an expansion phase from 2005 to 2020 (empirica, 2023).

In terms of data availability, district-level housing market data from municipal reports are predominantly available from 2010 onward, and detailed construction permit data from the Munich statistical office are available only from 2013. Comprehensive information on these data sources is meticulously documented in the **Appendix**, titled “Data Description.”

As a result, the study period has been limited to the end of 2012 to 2020. Due to the absence of continuous housing price data, we have further divided the analysis of supply elasticity into two separate timeframes: 2012-2015 and 2018-2020. We treat each of these intervals as a temporal unit. This method helps to counteract the impact of yearly fluctuations in elasticity values, thus enabling a clearer identification and understanding of the underlying trends.

4.1.3 Elasticity Calculation

The calculation of elasticity during the recent housing market boom period is conducted for each spatial unit and temporal unit. The formula used is:

$$\frac{Permit_{i,t}}{Stock_{i,t}} = Elasticity_{i,t} \times \left(\frac{\Delta HP_{i,t}}{IHP_{i,t}} \right) \quad (1)$$

In the above, $Permit_{i,t}$ (m²) represents the residential floor space[2] for which building permits were issued, $Stock_{i,t}$ (m²) is the initial residential floor space in the housing stock, $IHP_{i,t}$ (€/m²) is the initial real housing price[3], $\Delta HP_{i,t}$(€/m²) denotes the difference in real housing prices between the end and the beginning of each temporal unit, and $Elasticity_{i,t}$ is the price elasticity of housing supply. The subscript *t* designates the different temporal units (t=1 refers to data from 2012-2015, t=2 refers to data from 2018-2020), and the subscript *i* refers to the different spatial units.

Housing Price

In this study, rental prices are used as proxies for housing prices, primarily for two reasons. Firstly, Munich has a predominant rental housing market, with rentals constituting approximately 75% of the living accommodations between 2013 and 2019 (RSBLM, 2014, 2016, 2018, 2020a). Secondly, renters, being purely economic consumers, provide a more accurate reflection of housing demand than homeowners, who may have dual roles as users and investors.

Due to the lack of district-level data on rent for first occupancy before 2017, the rental prices for relet properties are used instead in our analysis.

Housing Supply

Building permits are used as indicators of housing construction activity, reflecting market reactions to housing price changes. Although the time to file such requests can vary, the acquisition of a building permit typically concludes within three months following the submission of the request. Employing building permits as a measure ensures a relatively consistent and brief time lag between price changes and the corresponding supply response.

For our analysis, we have selected price data from the second quarter of 2012-2015 and the first half of 2018-2020. We then pair this data with building permit data collected at the end of

[2] for a detailed definition, see Appendix: Data Description

[3] cold rental price for reletting, deflated by CPI

each of these years. By doing so, we aim to effectively capture the time lag between the change in housing prices and the subsequent issuance of building permits.

To quantify housing supply, this study measures residential floor space. This approach accounts for the diverse sizes of housing units across Munich's districts (RSBLM, 2014, 2016, 2018, 2020, 2020a). Additionally, by using residential floor space as the unit of measurement, we ensure consistency with the unit used for rental prices, thus enhancing the accuracy of the

Table 1: Measurable Metrics

METRIC	DEFINITION	TIMEFRAME
Demolition Rate (DEMO)	Ratio of year-average demolished residential floor space to the year-average residential floor space	Year-average demolished residential floor space (t=1): Year-average of the sum value from the beginning of 2013 to the end of 2015 Year-average demolished residential floor space (t=2): Year-average of the sum value from the beginning of 2019 to the end of 2020 Year-average residential floor space (t=1): Average value of the year-end values in 2012, 2013, 2014, and 2015 Year-average residential floor space (t=2): Average value of the year-end values in 2018, 2019, and 2020
Social Housing Ratio (SH)	Ratio of the mid-period social housing units to the mid-period total dwelling units	Mid-period social housing units (t=1): Year-end value in 2013 Mid-period total dwelling units (t=1): Year-end value in 2013 Mid-period social housing units (t=2): Year-end value in 2019 Mid-period total dwelling units (t=2): Year-end value in 2019
Year Dummy (d2)		d2 = 0 (t=1) d2 = 1 (t=2)
Residential Floor Space Density (RFSD)	Ratio of mid-period residential floor space to total land	Mid-period residential floor space (t=1): Average of year-end values in 2013 and in 2014 Mid-period residential floor space (t=2): Year-end value in 2019
Housing Land Zoning Ratio (HLZR)	Ratio of mid-period designated housing land to total land	Mid-period designated housing land (t=1): Value as of March 2014 Mid-period designated housing land (t=2): Value as of January 2020
Exploitation of Granted Zoning Rights (EGZR)	Ratio of mid-period residential floor space to mid-period designated housing land	Mid-period residential floor space: Same as before Mid-period designated housing land: Same as before
Plot Efficiency (PE)	Ratio of mid-period residential floor space to mid-period utilized housing land	Mid-period residential floor space: Same as before Mid-period utilized housing land (t=1): Value as of March 2014 Mid-period utilized housing land (t=2): Value as of December 2019
Housing Land Utilization Ratio (HLUR)	Ratio of mid-period utilized housing land to mid-period designated housing land	Mid-period utilized area for residential purpose: Same as before Mid-period designated housing land: Same as before
Housing Land Occupation Ratio (HLOR)	Ratio of mid-period utilized housing land to total land	Mid-period utilized area for residential purpose: Same as before

calculated elasticity values.

4.2 Elasticity and Urban Planning: Correlational Analysis

This subsection applies multiple regression analysis to examine the relationships between housing supply elasticity and specific urban planning variables, using the previously obtained elasticity values.

Given the absence of notable policy shifts during the study period and the limited number of observations, we determined to combine the data from the two temporal units into a single pooled dataset, yielding 31 observations. The multivariate analysis follows the subsequent regression model:

$$Elasticity_{i,t} = \beta_0 + \beta_{i,t} X_{i,t} + u_{i,t} \quad (2)$$

Here, *i* indexes spatial units and *t* denotes temporal units. The dependent variable, housing supply elasticity is regressed against a series of measurable urban planning metrics $X_{i,t}$, which are detailed in **Table 1**.

5. Results

5.1 District-Level Housing Supply Elasticity: Calculation

We calculated the price elasticity of housing supply across 17 spatial units in Munich for two intervals (2012-2015 and 2018-2020). All observations showed increases in both price and supply, except for "23 Allach-Untermenzing (t=1)". To preserve the focus on housing boom markets, this outlier has been omitted from further analysis. The elasticity calculations for the remaining areas are detailed in **Table 2**.

Fig. 3 illustrates the spatial variation of the results for the two temporal units. On one hand, a notable spatial pattern is observed where central areas generally display lower elasticity values compared to the peripheral areas. On the other hand, while there are discernible variations between the two temporal units, no conspicuous overarching temporal trend emerges from the map representations.

The scatterplot in **Fig. 4** illustrates the components of elasticity by displaying a comparison between the percentage changes in supply and the corresponding percentage changes in price. Except for "22 Aubing - Lochhausen - Langwied (t=2)" and "23 Allach - Untermenzing (t=2)", changes in supply stay within a narrow range of 0 - 2.2%. In contrast, price changes varied more broadly, ranging from 2% to over 7%.

This pattern suggests that differences in elasticity across Munich's spatial units are mainly due to fluctuations in prices, rather than changes in supply. This implies a housing market with inelastic supply, where spikes in local demand tend to cause substantial price increases rather than proportional rises in supply.

Additionally, the few instances where the supply change exceeds 2% – specifically Units 22 and 23 (t=2) and Unit 15 (t=1&2) – occur on the outskirts of Munich. These areas are home to some recent municipal-led housing projects. It appears that the supply changes are influenced more by these housing developments rather than by market-driven price incentives.

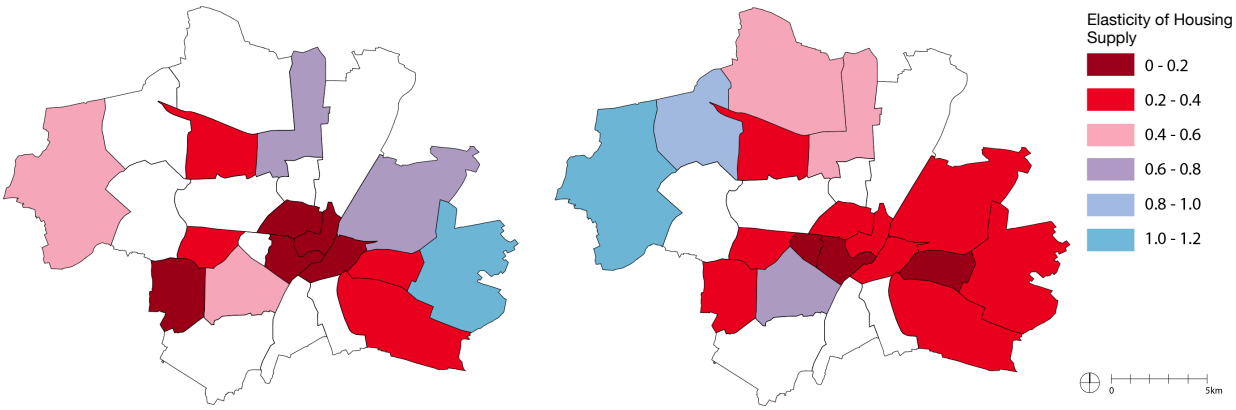
5.2 Urban Planning Variables: Correlation with Elasticity

In the initial stage of our regression analysis, as shown in **Table 3** column (1), we included a range of metrics to represent various aspects of urban planning and policy impacts. These metrics include: Residential Floor Space Density (RFSD), which measures the proportion of residential floor space to land; Demolition Rate (DEMO), which indicates the rate at which

Table 2: Estimated Price Elasticity of Housing Supply

	2012-2015	2018-2020
01 Altstadt - Lehel	0.072	0.233
02 Ludwigvorstadt - Isarvorstadt	0.150	0.049
03 Maxvorstadt	0.194	0.297
05 Au - Haidhausen	0.134	0.263
06 Sendling & 07 Sendling - Westpark	0.480	0.674
08 Schwanthalerhöhe	-	0.147
10 Moosach	0.290	0.368
11 Milbertshofen - Am Hart	0.606	0.422
13 Bogenhausen	0.706	0.250
14 Berg am Laim	0.339	0.194
15 Trudering - Riem	1.036	0.372
16 Ramersdorf - Perlach	0.227	0.279
20 Hadern	0.114*	0.283
22 Aubing - Lochhausen - Langwied	0.599*	1.189
23 Allach - Untermenzing	-	0.996
24 Feldmoching - Hasenbergl	-	0.467
25 Laim	0.235	0.340

Notes: The elasticity values are calculated based on each timeframe as a single unit. An asterisk (*) indicates that the value is based on data 2012-2014, as there is insufficient data available for 2015 in the respective district. A dash (-) indicates that data is unavailable for the corresponding timeframe and district. For study area "23 Allach - Untermenzing", the value in the first interval is excluded because of the decrease in price in the time.



Map A: Housing Supply Elasticity in Munich (2012-2015) Map B: Housing Supply Elasticity in Munich (2018-2020)

Fig. 3: Spatial Distribution of Housing Supply Elasticity in Munich Across Two Periods. These maps depict the spatial distribution of housing supply elasticity in Munich for two periods. Shades of blue indicate areas with higher housing market responsiveness, while red shades denote lower responsiveness. White areas denote sections of Munich for which elasticity data was not available.

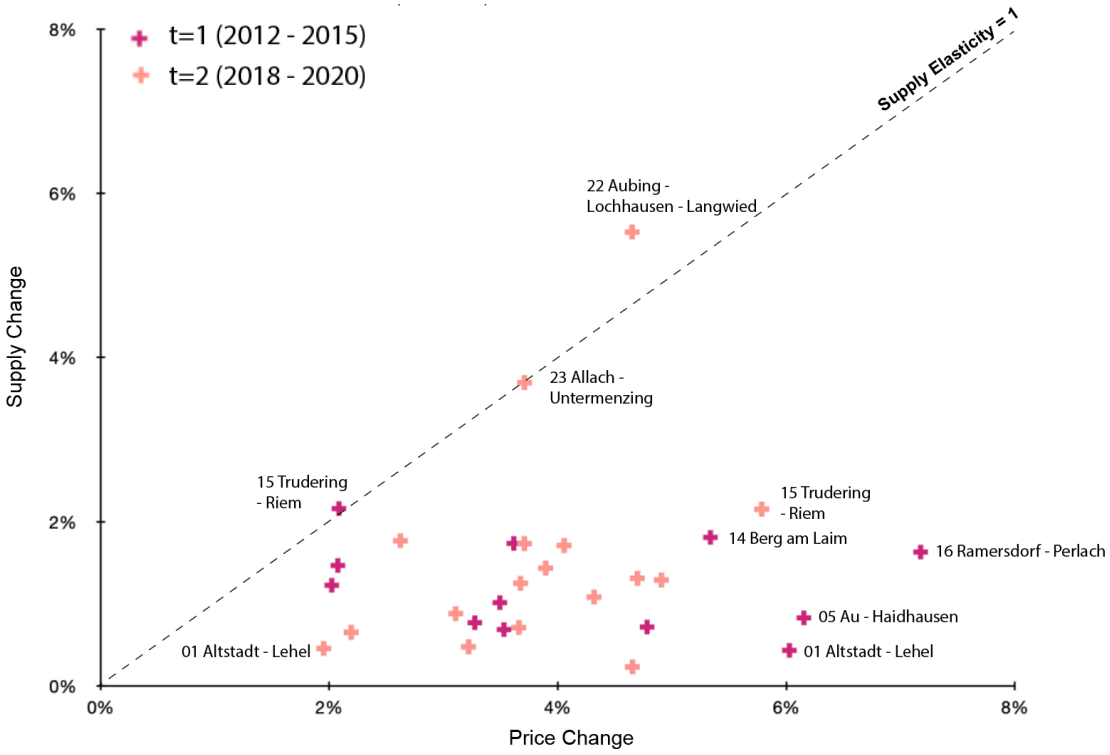


Fig. 4: Scatterplot of Housing Supply versus Price Changes in Munich by District for 2012-2015 and 2018-2020. Darker pink crosses represent data from 2012-2015, and lighter pink crosses correspond to 2018-2020. The dashed line indicates a hypothetical scenario where the supply elasticity is 1, meaning supply changes proportionally with price changes. Labels identify key districts with notable changes.

housing stock is demolished; Social Housing Ratio (SH), which shows the proportion of social housing units to stock units; and a year dummy (d2), to differentiate between the temporal units t=1 (2012-2015) and t=2 (2018-2020).

The results of the regression analysis show a significant negative correlation between RFSD and housing supply elasticity. However, the other variables—DEMO, SH, and the year dummy—do not exhibit a statistically significant connection with supply elasticity.

Subsequent investigations focus specifically on RFSD and its constituent elements. **Fig. 5** breaks down RFSD into three components: Plot Efficiency (PE), Housing Land Utilization Ratio (HLUR), and Housing Land Zoning Ratio (HLZR). PE represents the ratio of residential floor space to utilized housing land, indicating how efficiently housing plots are used for residential space. HLUR measures the ratio of utilized housing land to designated housing land. HLZR calculates the ratio of designated housing land to total land.

5.2.1 Plot Efficiency (PE): Indicative of Building Rights Constraints

Fig. 6 presents a correlation matrix that illustrates the relationships between RFSD and its components. A notable finding is the strong correlation between RFSD and Plot Efficiency (PE), indicating that changes in RFSD are primarily driven by variations in PE. Additionally, the regression analyses shown in **Table 3** (columns 3 and 4) demonstrate significant negative correlations between the logarithmic value of PE and housing supply elasticity.

PE is a specific measure of the volumetric density of residential space, in contrast to the Housing Land Zoning Ratio (HLZR) and Housing Land Utilization Ratio (HLUR), which relate to the allocation and usage of land for housing. This suggests that areas with densely developed housing plots have limited potential to further increase density in response to rising housing demand.

Despite the limited number of observations available for analysis, the pronounced negative correlation between Plot Efficiency (PE) and supply elasticity, as highlighted in the results, still underscores the significance of PE in comparison to other variables.

This result becomes pertinent when considering Munich's building regulations. The local development plans (*Bebauungspläne*) and §34 of the BauGB (Federal Building Code) regulate the permissible volume and density of residential constructions. A *Bebauungsplan* outlines rules regarding floor area ratio and building height (or equivalent metrics as per §16 BauNVO). The §34 BauGB ensures that the footprint and size of buildings conform to the character of their immediate surroundings. In effect, these regulations inherently limit the potential for housing plot densification. This could be a key reason why areas with densely developed housing plots (indicated by high PE) demonstrate limited ability to adapt in response to rising housing demand.

The findings suggest that from a policy standpoint, modifying building regulations to allow for increased densification could improve the adaptability of the supply side. By relaxing these restrictions, it may be possible to align the housing supply more closely with market demands. This could lead to a more elastic and responsive housing market, better equipped to adjust to demographic and economic changes.

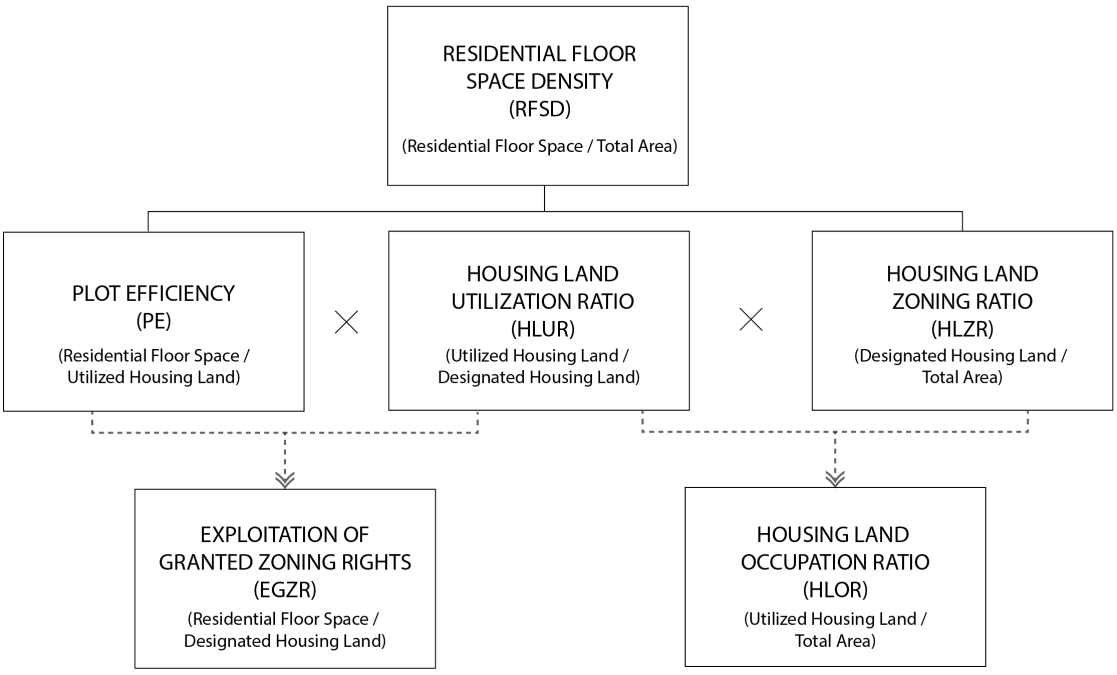


Fig. 5: Interconnectedness of Land Use and Zoning Metrics. This schematic diagram elucidates the multiplicative relationships among Residential Floor Space Density (RFSD), Plot Efficiency (PE), Housing Land Utilization Ratio (HLUR), Housing Land Zoning Ratio (HLZR), Exploitation of Graned Zoning Rights (EGZR), and Housing Land Occupation Ratio (HLOR).

	RFSD	PE	HLUR	HLZR
RFSD	**1.0000**			
PE	**0.9450**	**1.0000**		
HLUR	**0.6564**	**0.5787**	**1.0000**	
HLZR	**0.5849**	**0.3492**	**0.2591**	**1.0000**

Fig. 6: Correlation Matrix of Residential Floor Space Density (RFSD) with Its Component Indicators. Displayed are the correlation coefficients between RFSD, Plot Efficiency (PE), Housing Land Utilization Ratio (HLUR), and Housing Land Zoning Ratio (HLZR), highlighting a notably high correlation between RFSD and PE.

Table 3: Regression Analysis of Various Determinants on Housing Supply Elasticity in Munich

	(1)	(2)	(3)	(4)
constant	-0.065 (0.113)	-0.058 (0.094)	-0.100 (0.120)	-0.042 (0.100)
d2	0.015 (0.082)			
DEMO	12.550 (52.043)			
SH	-0.099 (1.189)			
log(RFSD)	-0.275*** (0.070)	-0.282*** (0.054)		
log(HLZR)			-0.299** (0.141)	
log(HLUR)			0.981 (0.610)	
log(PE)			-0.434*** (0.109)	-0.324*** (0.099)
log(HLOR)				-0.215 (0.142)
Observations	31	31	31	31
Prob > F	0.000	0.000	0.000	0.000
R-squared	0.484	0.481	0.553	0.487
Adj R-squared	0.404	0.463	0.504	0.450

Notes: Regression estimates of Eq. 2, where the dependant variable is the supply elasticities between 2012-2015 and 2018-2020. Robust hetereoskedastic standard errors in parentheses. Asterisks, *, **, and ***, denote statistical significance at the 10%, 5%, and 1% levels.

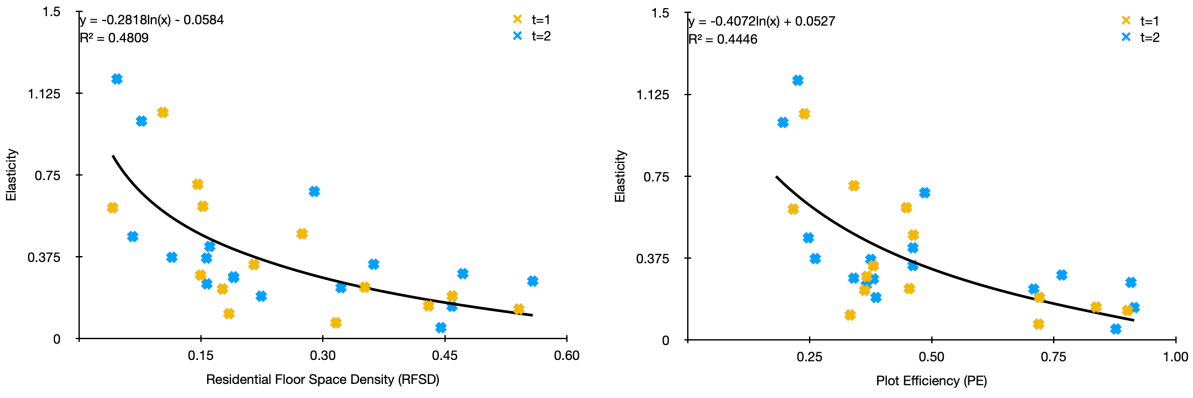


Fig. 7: Correlation between Housing Supply Elasticity and Residential Floor Space Density (RFSD), and between Elasticity and Plot Efficiency (PE), in Munich. The scatterplots show a logarithmic decrease in elasticity with increasing RFSD and PE, highlighting a robust negative correlation over the study period.

5.2.2 Land Ratio Factors: Analysis of Non-Significant Variables

The regression test in **Table 3**, column (4) reveals that the coefficient for log(HLOR) (Housing Land Occupation Ratio) was not statistically significant, suggesting that within the scope of this study, land resource constraints may play a less critical role in urban development compared to the constraints on construction density on housing plots.

Table 3, column (3), presents a marginally significant coefficient for the logarithm of the Housing Land Zoning Ratio (log(HLZR)) and an insignificant coefficient for the logarithm of the Housing Land Utilization Ratio (log(HLUR)). This lack of significance of both coefficients may be attributed to some misalignments between the designated zoning of land and its actual usage, as depicted in **Fig. 8**. In practice, the way land is used sometimes differs from the original zoning plans, indicating a mismatch between the planned and actual types of development.

In this study, the Flächennutzungsplan (FNP), or preparatory land-use plan, is used as the basis for land-use designation data. Although the FNP is instrumental in aligning regional urban planning goals with local land use development, its steering power has limitations. These limitations are twofold: First, while the FNP's binding effects are realized through the *Bebauungspläne* (development plans), its control over land use in established built-up areas (*Innenbereich*) can be bypassed under § 34 BauGB. This clause allows new building uses without a formal *Bebauungsplan* (Schmidt-Eichstaedt, 2019, p. 153). Secondly, in areas up to 70,000 sqm, the FNP can be modified without a formal amendment procedure (§ 13a BauGB) to establish a Bebauungsplan, provided it does not impede municipal urban development objectives (Feiertag & Schoppengerd, 2022). Therefore, at the local level, the actual use of land can be more aligned with the requirements of the *Bebauungspläne* and §34 BauGB, rather than the FNP.

Considering the FNP's constrained role and the intricate nature of land-use regulations, identifying the primary regulatory factors affecting land utilization is a complex task. The following subsection will utilize spatial data to further examine the evolution of housing land designation and utilization in the context of this study.

5.2.3 Examination of Changes in Housing Land Surface Area

This analysis of housing land surface evolution in Munich relies on spatial data from Flächennutzungplan (FNP) as of March 2014 and January 2020, and ATKIS (land utilization data) as of March 2014 and December 2019.

Fig. 9 illustrates the changes in utilized housing land from 2014 to 2019. To represent the affordable housing sector in Munich, we use the footprints of subsidized housing projects (RSBLM, 2014, Map 6; 2018, Map 8; 2020, Map 8) as indicators. This reveals a distinct pattern compared to profit-driven housing land developments. The affordable housing sector (**Map B, Fig. 9**) mainly expands through larger plots of land, dispersed unevenly across Munich. This uneven distribution likely results from the municipality's strategy to develop significant, underused spaces. On the other hand, the profit-driven sector (**Map A, Fig. 9**) shows a mix of expansion and contraction in housing land, with smaller, more evenly dispersed increments across central and peripheral areas, and reductions more common in central locations.

Fig. 10 presents a comparison of FNP (designation) and ATKIS (utilization) data. While the FNP data indicates minimal change, ATKIS data shows considerable shifts in land use. Comparing **Map A in Fig. 10** with **Fig. 9**, the FNP's trends appear more aligned with the municipal affordable housing program than with the profit-oriented market. This alignment occurs because the FNP is able to adapt to changes made in the *Bebauungsplänen*, especially for the projects led by the municipality.

In addition, an analysis of the ATKIS data indicates a tendency to convert some housing land for public and community services, including educational institutions, religious facilities, sports areas, and senior homes. Meanwhile, there is a noticeable shift from industrial, mixed-use,

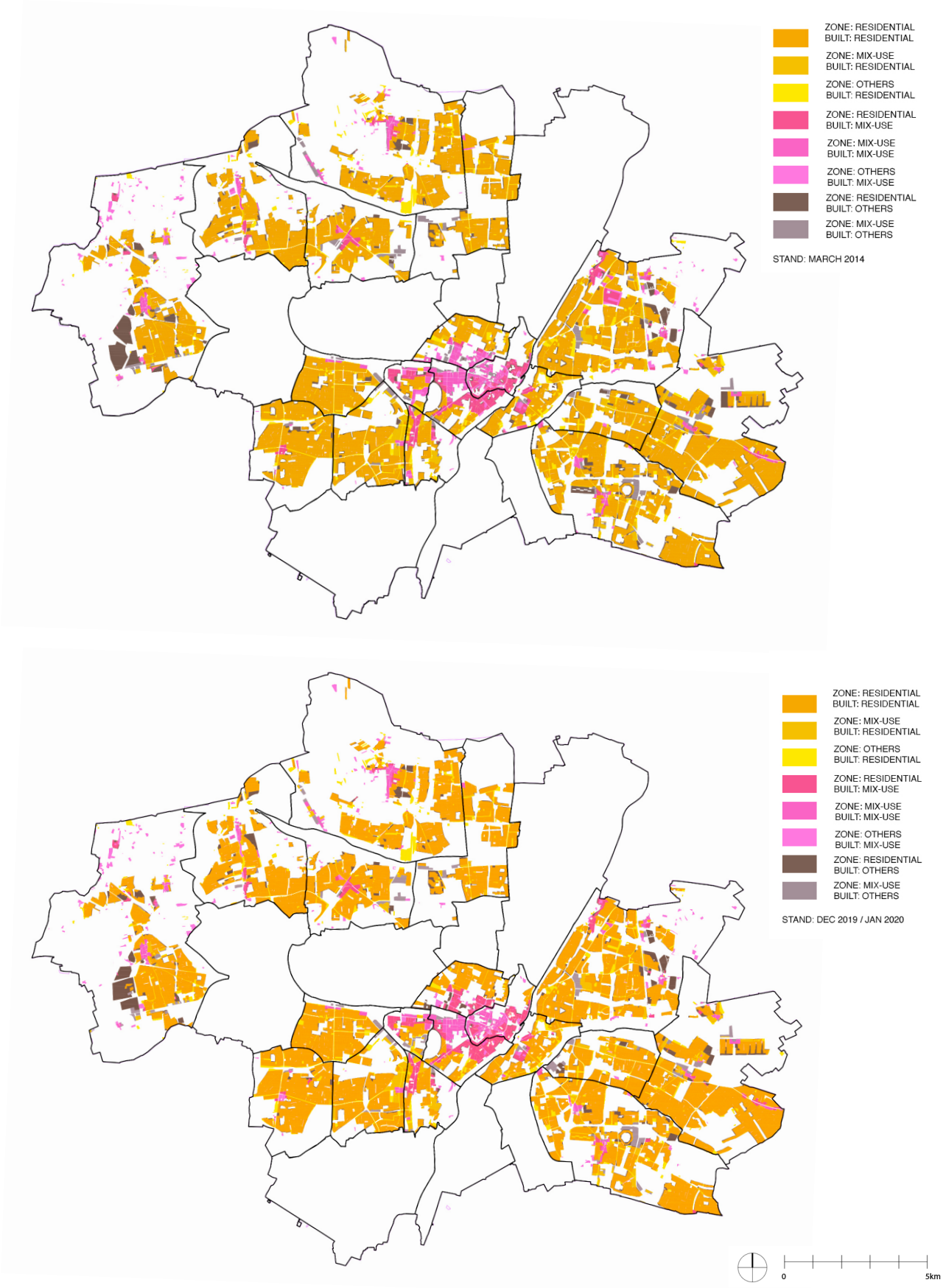
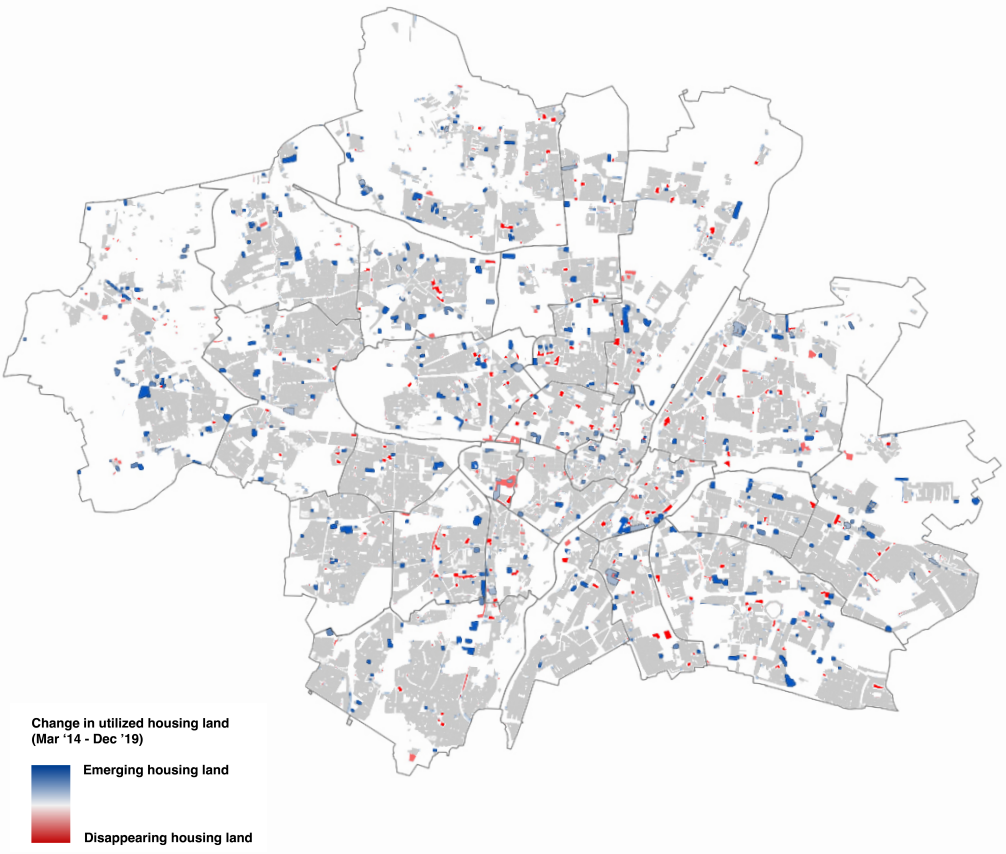
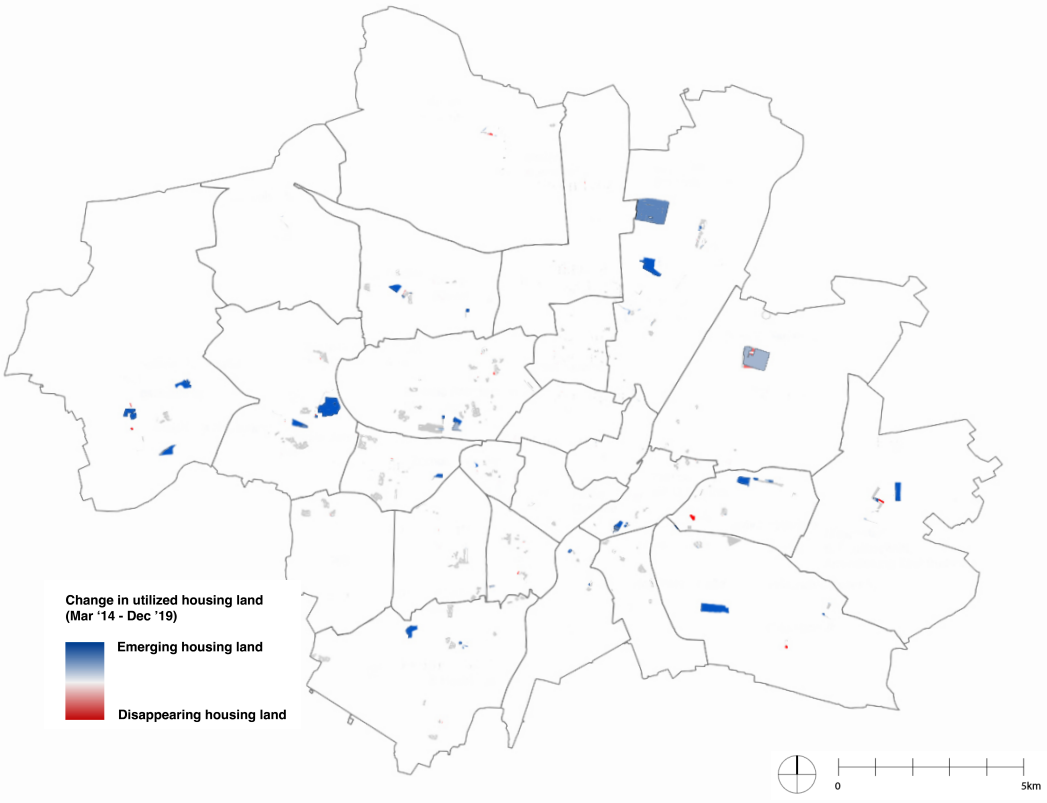


Fig. 8: Comparative Zoning vs. Utilization in Munich's Residential and Mixed-Use Areas (2014 vs. 2019/2020). Areas utilized for residential purposes are depicted in varying shades of yellow, while mixed-use areas are represented in varying shades of pink. The intensity of the color signifies the land designation: darker shades correspond to residential designation, medium shades correlate with mixed-use designation, and lighter shades relate to other designations. Grey zones illustrate land areas designated for housing but are yet to be utilized in the expected manner. Among these, dark grey signifies areas designated for residential use, whereas light grey marks those designated for mixed-use. *Data Source: FNP from Landeshauptstadt München and ATKIS from Landesamt für Digitalisierung, Breitband und Vermessung.*

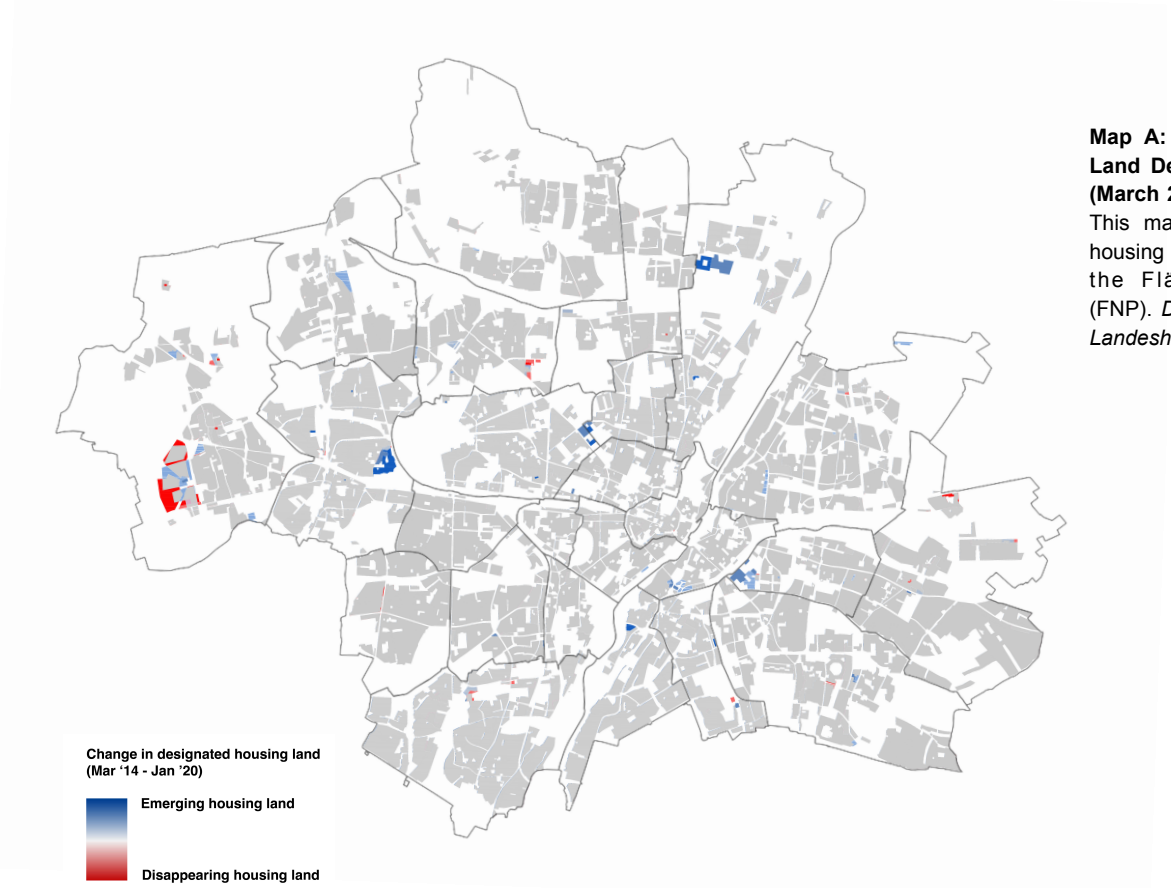


Map A: Dynamics of Profit-Oriented Housing Market Land Utilization in Munich (March 2014 - December 2019). This map contrasts areas of Munich where housing land use has evolved within a profit-driven market. *Data source: ATKIS from Landesamt für Digitalisierung, Breitband und Vermessung.*

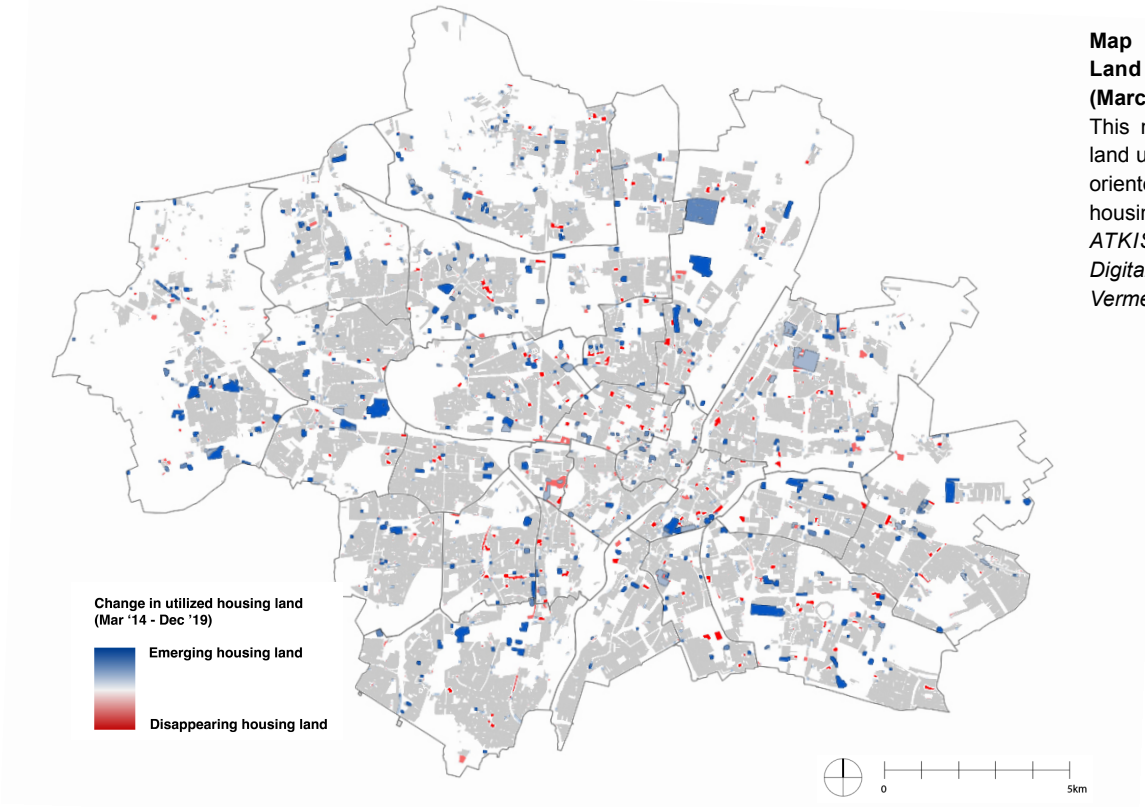


Map B: Evolution of Affordable Housing Market Land Utilization in Munich (March 2014 - December 2019). This map details changes in land utilization of social housing. *Data source: ATKIS from Landesamt für Digitalisierung, Breitband und Vermessung. Social housing footprint is taken from maps in RSBLM's Wohnungssituation report series.*

Fig. 9: Housing Land Changes in Munich's Profit-Oriented and Affordable Housing Markets (March 2014 - December 2019). This dual map representation contrasts the shifts in land utilization for housing within two different market dynamics. Blue and red respectively delineate the emergence and disappearance of housing zones. Darker shades of color correspond to areas undergoing a more comprehensive transformation, while ligher shades of color represents areas that have seen partial changes. Unchanged zones are represented in light grey.



Map A: Change in Housing Land Designation in Munich (March 2014 - January 2020). This map details changes in housing land designation by the Flächennutzungsplan (FNP). *Data source: FNP from Landeshauptstadt München*



Map B: Change in Housing Land Utilization in Munich (March 2014 - January 2020). This map illustrate changes in land utilization in both the profit-oriented market and the social housing market. *Data source: ATKIS from Landesamt für Digitalisierung, Breitband und Vermessung.*

Fig. 10: Transition in Housing Land Designation and Utilizaiton in Munich (March 2014 - January 2020). This dual map representation contrasts the shifts in housing land designation and utilization. Blue and red respectively delineate the emergence and disappearance of housing zones. Darker shades of color correspond to areas undergoing a more comprehensive transformation, while ligher shades of color represents areas that have seen partial changes. Unchanged zones are represented in light grey.

special function, and agricultural land to residential purposes. This trend suggests a development focus on housing and community services.

The above findings collectively indicate considerable diversity in housing land developments, especially when comparing sectors focused on affordability versus those driven by profit. Although the land surface ratio variables we tested did not directly correlate with the overall responsiveness of the housing supply, they might still influence specific segments of the housing supply. This complexity in land developments highlights the need for more detailed data, which is essential to fully grasp how land zoning regulations and different stakeholders affect housing supply elasticity.

Furthermore, it would be inaccurate to claim that the inability to construct more homes stems solely from a shortage of available land parcels. This conclusion emerges from two key observations: firstly, the Housing Land Occupation Ratio did not show a significant connection to the variations in housing supply elasticity; and secondly, there is clear evidence of ongoing changes in how land parcels are utilized even in the central areas.

6. Discussion and Limitations

The design and implementation of this research were significantly shaped by the scope of data accessibility. This section outlines the principal limitations that arose from data-related constraints and considers their impact on the study's conclusions.

1. Social Housing Data Limitations: While district-level social housing data is available, it only provides the number of units without specifying the residential floor space. Given that housing units can vary considerably in size, the "SH" indicator employed in the multivariate regression may not fully capture the true extent of municipal investments in social housing. Therefore, despite the study's findings of an insignificant correlation, the potential influence of such investments on supply elasticity should not be prematurely discounted.

2. Constraints on Long-Term Housing Price Data: The study periods were selected based on the availability of consecutive housing price data, limiting the research to two specific intervals. The availability of a comprehensive, consistent set of long-term housing price data could enable a deeper investigation into the fluctuations and trends of the housing market, potentially allowing for time-series analyses that could be more directly correlated with specific policy interventions.

3. Challenges Due to Non-Standardized GIS Data Formats: The historical data from the FNP are only accessible in vector PDF file format, while information on subsidized housing projects is limited to rough pictorial footprints in municipal reports. Furthermore, the varying counting methods employed by the FNP and ATKIS hinder straightforward comparisons. Implementing a standardized measurement system and transitioning data into a GIS-compatible format would significantly improve the precision of analyses.

4. Absence of an Open Data Platform from RSBLM: Data procurement from RSBLM is currently a labor-intensive process, involving the examination of published reports or direct email requests. This method could inadvertently result in missing important data and extend the duration of research projects. The establishment of an open data platform would significantly enhance the efficiency and thoroughness of data acquisition, providing researchers with immediate access to essential information.

These limitations define the scope of this study's findings and highlight opportunities for future research to build upon our work with better data. Acknowledging these constraints is crucial for properly interpreting our conclusions and identifying further research possibilities to deepen the understanding of housing supply elasticity in Munich.

7. Conclusion

This research proposed an integrated perspective of urban economics and planning in addressing Munich's housing shortage, emphasizing the criticality of collaboration between planners and developers in developer-centric markets. We conducted an econometric analysis to assess the price elasticity of housing supply in Munich and its correlation with urban planning metrics, within the existing framework of data infrastructure, public policy, and zoning regulations.

The investigation revealed, across 17 district-level spatial units during 2012-2015 and 2018-2020: (1) the housing market was largely inelastic, showing minimal responsiveness in supply to price changes, except in areas impacted by large-scale housing projects led by the municipality; (2) the multivariate regression analysis, exploring the relationship between supply elasticity and urban planning metrics, revealed pronounced correlations with Residential Floor Space Density (RFSD) and Plot Efficiency (PE), both of which are indicators of volumetric housing density; (3) alterations in housing land surface area were substantially affected by municipal housing development actions, while the contributions of private developers appeared fragmented and dispersed, showing no clear connection to land valuation or development density.

These findings show that, despite a thriving housing market, the impetus for housing supply predominantly came from governmental initiatives as opposed to developer-led profit motivations. Considering the strong correlation between PE and supply elasticity, this dynamic implies that developers' reticence may be attributable to the restrictive nature of local building regulations, which constrain the scope and profitability of new housing ventures.

As a hub of productivity and affluence, Munich is expected to increase in population. In such an environment, notwithstanding substantial fiscal input, a stable social housing safety net is yet to be established, making accelerating housing supply an important measure to improve affordability. In the absence of such measures, gentrification and the consequent displacement of lower-income population may become a major concern.

Considering the relaxation of building regulations as a potential strategy is however a complex matter. It requires a comprehensive evaluation of the infrastructure network's capacity to support densification and its associated impacts on the environment, culture, and living standards. This paper aims to supply urban planners with new information to assess the pros and cons, thereby assisting in the creation of informed policies for a housing market that continues to face significant challenges.

Given the overarching similarities in construction and zoning bylaws among major German cities, the methodologies and conclusions of this analysis may also offer insights for comparable urban settings.

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Appendix: Data Description

Building permits (dt: *Baugenehmigungen*): Documents issued by the local building authorities that grant permission for construction projects, including the construction of new buildings and construction measures on existing buildings. Data source: Statistisches Amt München.

Construction of new buildings: New construction and reconstruction. Reconstruction refers to the construction of destroyed or demolished buildings from the upper edge of the still-existing basement. Data source: Statistisches Amt München.

Construction measures on existing buildings (dt: *Baumaßnahmen an bestehenden Gebäuden*): All structural changes to existing buildings through renovation, expansion, extension (such as annexes or addition of floors), as well as refurbishment measures. In the case of construction measures on existing buildings, apartments can not only be newly created but also eliminated (e.g. through combining apartments). Data source: Statistisches Amt München.

Demolition (dt: *Abgang durch Abriss*): Reduction of residential floor space due to the demolition or removal of residential buildings or units. Data source: Statistisches Amt München.

Residential floor space (dt: *Wohnfläche*): Sum of the eligible floor areas of the rooms that belong exclusively to a dwelling. It includes the area of living rooms, sleeping rooms, kitchens, and ancillary rooms (hallways, storage rooms, bathrooms, and the like). The areas of accessory rooms (such as cellars, laundry rooms, attics, boiler rooms, garages, etc.) are not included in the calculation. In the case of dormitories, the residential floor space includes the floor area of the rooms that are intended for the sole and communal use of the residents. Updated from 2012 data from RSBLM onwards by accumulating housing completions and demolitions. Data source: RSBLM (residential floor space, state: 2012 Dec. 31), and Statistisches Amt München (yearly completions and demolitions 2013-2020).

CPI: Consumer price index for the entirety of the Federal Republic of Germany. Data source: Statistisches Bundesamt (Destatis), Wiesbaden 2023. Publicly available at https://www-genesis.destatis.de/. Search for table results labeled “Consumer price index: Germany, years”

Cold rental prive for reletting (dt: *Kaltmiete für Wiedervermietung*): Average rent per square meter calculated based on available housing offers on specified real estate service platforms. This term applies to rental properties that were previously leased and have since been re-leased to new tenants after the end of the prior lease. This does not include additional costs such as utilities or service charges. Data source: Süddeutsche Zeitung (2012-2015, q2), and Immo24 (2018-2020, first half year). Public available in report series “Wohnungsmarktbarometer 2012-2020”, RSBLM.

FNP / Preparatory land-use plan (dt: *Flächennutzungsplan*): A master plan that outlines the intended land uses for different areas within a municipality or region. In Germany, municipalities regulate constructional development through urban land-use plans (*Bauleitpläne*), which consist of two components: the non-binding preparatory land-use plan (*FNP*) and the legally binding development plan (*Bebauungsplan*). The preparatory land-use plan serves as the foundation for the development plan. Data source: Landeshauptstadt München.

Designated housing land: The area of land that is allocated and zoned for housing use according to the FNP. It comprises two primary categories of land use. The first category encompasses residential areas, including *Wohnbauflächen* (residential building areas), *Kleinsiedlungsgebiete* (small settlement areas), *reine Wohngebiete* (pure residential areas), and *besondere Wohngebiete* (special residential areas). The second category comprises mixed-use areas, which include *gemischte Bauflächen* (mixes-use areas), *Dorfgebiete* (village areas), *Mischgebiete* (mixed areas), and *Kerngebiete* (core areas). The calculation for determining the designated area for housing purposes involves adding 100% of the residential areas to 70% of the mixed-use areas. Data source: FNP by Landeshauptstadt München.

Utilized housing land: The area of land that is actively used for housing purposes, as determined by the Official Topographic-Carthographic Information System (ATKIS). It is calculated by combining 100% of the residential areas (*Wohngebiete*) with 70% of the mixed-use areas (*Mischgebiete*). Data source: Landesamt für Digitalisierung, Breitband und Vermessung.

Social housing (dt: *Sozialwohnung*): A specific category of housing that is subsidized and intended to provide affordable accommodation for individuals and families with low to moderate incomes. It encompasses various programs and initiatives, including *Wohnungsfürsorge* (housing assistance), the former 3rd *Förderweg* (funding path), *KomPro*, and the *München Modell Miete* (rental model Munich). These programs often involve government subsidies, rent controls, income limitations for tenants, and specific allocation criteria to promote affordability and social inclusion. Data source: Footprint data extracted from maps in the "Bericht zur Wohnungssituation in München" for the years 2012-2013 and 2018-2019, published by RSBLM.

Table A.1: Descriptive Statistics of Variables in Equations

	Obs	Mean	Std. Dev.	Min	Max
Permits expressed as residential floor space (year average) (m^2)	34	28,539	21,095	2,935	85,454
Stock expressed as residential floor space (m^2)	34	1,988,821	797,744	928,345	3,707,398
ΔReal Housing Price (ΔHP) (year average) (€/m^2)	31	0.637	0.222	0.268	1.061
Initial Real Housing Price (IHP) (€/m^2)	34	15.978	2.806	11.505	23.089
Demolition Rate (DEMO) (%)	34	$1.199e^{-03}$	$8.953e^{-04}$	0.000	$3.772e^{-03}$
Social Housing Ratio (SH) (%)	34	0.061	0.038	0.012	0.135
Residential Floor Space Density (RFSD) (log) (%)	34	-1.625	0.734	-3.184	-0.584
Plot Efficiency (PE) (log) (%)	34	-0.846	0.495	-1.711	-0.089
Exploitation of Granted Zoning Rights (EGZR) (log) (%)	34	-0.718	0.542	-1.577	0.137
Housing Land Zoning Ratio (HLZR) (log) (%)	34	-0.906	0.296	-1.621	-0.389
Housing Land Utilization Ratio (HLUR) (log) (%)	34	-0.134	0.076	-0.300	0.030
Housing Land Occupation Ratio (HLOR) (log) (%)	34	0.778	0.327	-1.653	-0.242

Sources: Referat für Stadtplanung und Bauordnung Landeshauptstadt München, and Statistisches Amt München

Table A.2: Descriptive Statistics of Land Use

Unit: km^2	Obs	Mean	Std. Dev.	Min	Max	Total	% Change
Designated residential land t=1	17	4.360	2.713	0.733	8.942	74.120	
Designated residential land t=2	17	4.388	2.727	0.732	9.120	74.600	+0.65%
Designated mixed-use land t=1	17	0.490	0.302	0.057	1.001	8.334	
Designated mixed-use land t=2	17	0.493	0.295	0.056	1.016	8.383	+0.60%
Designated housing land t=1	17	4.703	2.816	0.926	9.471	79.953	
Designated housing land t=2	17	4.733	2.820	0.925	9.597	80.469	+0.64%
Utilized residential land t=1	17	4.715	2.975	0.120	9.388	80.163	
Utilized residential land t=2	17	4.844	3.057	0.141	9.647	82.342	+2.72%

continued on next page

Table A.2 (continued)

Utilized mixed-use land t=1	17	0.701	0.581	0.066	1.963	11.921	
Utilized mixed-use land t=2	17	0.641	0.551	0.063	1.857	10.904	-8.53%
Utilized housing land t=1	17	5.206	2.899	1.086	10.165	88.508	
Utilized housing land t=2	17	5.293	2.958	1.038	10.197	89.975	+1.66%

Notes: Owing to the differences in counting methods between FNP and ATKIS, the values for designated land and utilized land are not directly comparable.
Sources: Landesamt für Digitalisierung, Breitband und Vermessung, and Landeshauptstadt München