The Impact of New Housing Supply on the Distribution of Rents

Andreas Mense

Institute for Employment Research (IAB Nuremberg) and London School of Economics

I estimate the impact of new housing supply on the local rent distribution, exploiting delays in housing completions caused by weather shocks. A 1% increase in new supply (i) lowers average rents by 0.19%, (ii) effectively reduces rents of lower-quality units, and (iii) disproportionately increases the number of second-hand units available for rent. Moreover, the impact on rents is equally strong in high-demand markets. Employing a quantitative model, I explain these results by second-hand supply: New supply triggers moving chains that free up units in all market segments. The estimate translates into a short-run demand price elasticity of −0.025.

I thank Gabriel Ahlfeldt, Rainald Borck, Thiess Büttner, Yongheng Deng, Sebastian Hanson, Christian Hilber, Markus Nagler, Kate Pennington, Johannes Rincke, Sebastian Siegloch, Niko Szumilo, Matthias Wrede, participants at the 2020 North American Virtual Meeting of the Urban Economics Association, the Virtual Annual Conference of the Verein für Socialpolitik in 2020, the 2021 European Virtual Meeting of the Urban Economics Association, the Virtual Annual Congress of the European Economic Association in 2021, the University of California at Los Angeles/Tel Aviv University/École Supérieure de Commerce de Paris Affordable Housing Conference at Tel Aviv in 2022, the European Meeting of the Urban Economics Association in 2023 in Milan, the research seminars at the University of Potsdam, University of Regensburg, Center for Economic Studies/Ludwig Maximilian University Munich, and University of Paris-Cergy, the brown bag seminar at the University of Erlangen-Nuremberg, and the four anonymous referees for valuable comments and suggestions. This research was funded through grant ME 4963/1-1 by the German Research Foundation (DFG). I am grateful to the London School of Economics for its hospitality. The paper was edited by Joe Vavra. All errors are my own.

Electronically published January 27, 2025

Journal of Political Economy Macroeconomics, volume 3, number 1, March 2025.

https://doi.org/10.1086/733977

I. Introduction

In this paper, I study the impact of new market-rate housing supply on the local distribution of private-market rents in Germany.[1] I rely on two different approaches: a causally identified empirical analysis and a structural model of a local housing market.

Housing markets are to a large extent second-hand markets. In fact, the data used in this study indicate that a mere 5.2% of rental units offered in Germany are new, whereas 94.8% are second-hand units. Most second-hand units are of considerably lower quality than—and may thus be poor substitutes for—new housing. Although a lack of substitutability is a potential barrier to the propagation of a supply shock, in second-hand markets such as the housing market, substitutability is not a necessary condition for market integration across different market segments. The reason is that adjustment costs prevent households from updating frequently their housing choices. As a consequence, many renters moving into new housing leave vacant units of relatively low quality, which then become available to the second-hand market. This triggers moving chains that free up additional housing. The results in this paper suggest that this mechanism is central to market integration and to the propagation of shocks in the housing market.

The paper makes three main contributions: First, it provides causal estimates of rent price elasticities based on a nationally representative sample. According to the baseline reduced-form estimate, a 1% increase of annual new supply lowers average rents by 0.19%.[2] This estimate translates into a short-run demand price elasticity of −0.025. It is highly policy relevant, since it helps local governments to assess by how much rental prices are going to decrease when issuing a larger number of building permits. Moreover, changes in housing costs are a key component of consumer price inflation, and they are captured particularly well by rental prices. Finally, the demand price elasticity is an important ingredient for quantitative models of the housing market. Yet, causal estimates are remarkably scarce.[3]

[1] The German homeownership rate is low by international standards, 45.7% according to the 2011 census. I explore the role of the homeownership rate for the findings below.

[2] I corroborate the magnitude of this estimate using the structural model. The model-based elasticity is somewhat larger with −0.44 when the supply shock is to new owner-occupied housing, and −0.79 when it is to new rental housing.

[3] The only existing estimates that treat observed (rental) prices as endogenous date back to an experiment conducted in Phoenix and Pittsburgh between 1973 and 1976 (Hanushek and Quigley 1980; Friedman and Weinberg 1981). There is an extensive literature that estimates long-run demand price elasticities from observed prices, with prices taken to be exogenous. Loosely speaking, there are two main approaches. The first approach exploits time-series or cross-sectional variation in housing costs and relates this variation to housing demand (e.g., Polinsky and Ellwood 1979; Eberts and Gronberg 1982; Albouy, Ehrlich, and Liu 2016). This literature mostly finds long-run elasticities between

Second, this paper is the first to provide clean, quasi-experimental evidence on the impact of new housing supply on the tails of the local rent distribution. It documents that new housing supply effectively enhances the affordability of housing for renters across the board, even in markets experiencing strong demand growth. This finding has significant implications for housing policy in general. It demonstrates that new housing benefits low-income households even when it is not targeted at low incomes and that supply-side interventions are an effective policy tool for local governments. This is particularly important in light of the fact that many demand-side policy responses to rising housing costs in high-demand locations around the world have proven to be distortionary and mostly ineffective (Metcalf 2018).

Third, the paper proposes second-hand housing supply as a key determinant of market integration between rental and owner-occupier markets. The degree of segmentation plays an important role in models of dual housing markets, for example, Favilukis, Ludvigson, and Van Nieuwerburgh (2017), Greenwald and Guren (2020), and Kaplan, Mitman, and Violante (2020). In a nutshell, moving costs restrain households from making gradual adjustments to their housing arrangements. This loosens the relationship between household income and housing quality, which in turn creates cross-connections between submarkets and thus fosters market integration without requiring substitutability. In other words, it is not a necessary condition for a large cross-price elasticity between two given market segments that there exist marginal agents who are indifferent between buying or renting in the two segments. This also suggests that treating housing as a homogeneous product is a sensible modeling choice in many circumstances, especially if the main interest is in house price or rent dynamics.

In the reduced-form empirical analysis, I exploit unusual weather conditions during the construction phase that cause long-lasting delays as an exogenous supply shifter.[4] The analysis builds on a unique administrative dataset comprising the universe of housing completions in Germany between 2010 and 2017,[5] in conjunction with grid-level weather data and data on 6.9 million housing units offered for rent between 2011 and 2018.

−0.4 and −0.8. The second approach uses household-level panel data and estimates demand equations, again taking observed price as exogenous (e.g., Ermisch, Findlay, and Gibb 1996; Rapaport 1997; Goodman 2002; Barrios Garcia and Rodriguez Hernandez 2008; Fontela and Gonzales 2009). This delivers somewhat smaller long-run elasticities that fall in the range −0.1 to −0.8.

[4] The weather-induced delays have a long-lasting impact on aggregate new housing supply in the local market, consistent with tight capacity constraints among housing developers during the most recent housing boom in Germany starting in 2010, and with evidence for the United States (Coulson and Richard 1996; Fergus 1999).

[5] I do not observe whether the newly built units are owner or renter occupied.

The baseline estimate of −0.19 does not vary much across housing unit types or local markets. First, there is no statistically significant difference between the impact on rents of high- versus low-quality units, as measured by the unit's position in the local rent/square meter (sqm) distribution. Effects at the lower end are somewhat weaker with −0.13 and increase in magnitude up to −0.28 at the upper end. Hence, new supply of market-rate housing affects the entire rent distribution. Second, consistent with this result, the effect size varies only modestly with building age and housing unit size. Overall, these patterns cannot be explained by substitution relationships between new housing and existing units in the rental market. Rather, second-hand supply triggered by the shock to new supply explains well why the effect spreads swiftly across the entire local market. In line with the second-hand supply channel, the number of second-hand rental units that appear on the local market increases by a factor of 4 for every newly constructed housing unit, arguably due to moving chains triggered by the new units.

Local markets experiencing increasing housing demand are of particularly high policy relevance. The study period, 2011–18, is well-suited to address the question of whether new supply is an effective means for curbing rent growth in such markets. During this period, fueled by a robust economic development in Germany with employment growing from 28.6 to 32.9 million persons, rental prices increased strongly in many locations. When restricting the sample to locations with above-median growth in employment, average gross labor income, and household income, respectively, the estimates remain close to the baseline estimate of −0.19.

Arguably, the weather shocks affect rents only through the supply of new housing. I address potential concerns regarding this assumption in a series of robustness checks. First, the baseline estimate remains robust when excluding years with large flood events, indicating that the results are not driven by the potentially long-lasting impacts of local floods. Second, specific sectors such as tourism and agriculture, as well as buyers and sellers in the housing market, could be directly affected by weather shocks.[6] Yet, the baseline estimate is robust to controlling for housing demand factors that may be correlated with the weather shocks. Additionally, the weather shocks are uncorrelated with the pretreatment outcome and with potential observable confounders prone to being affected directly by

[6] Deng et al. (2021) show that temperatures above 32.2°C lead to a greater number of nonrecourse mortgage defaults in the United States, most likely because high temperatures affect the borrowers' home valuation. However, the argument does not apply to recourse loans, as common in Germany where the number of hot days is much lower than in the United States and exhibits much less regional variation; see https://www.umweltbundesamt.de/bild/anzahl-der-tage-einem-lufttemperatur-maximum-ueber.

the weather, such as total work hours. Finally, I exploit the fact that February frost depth is almost orthogonal to the summer rainfall instrument, which makes it highly unlikely that the two variables share important unobserved confounders. The results are very similar when using either of the two instruments, and when using alternative definitions of the rainfall instrument. Overall, these results lend strong support to the claim that the weather shocks are plausibly exogenous.

In the second part of the paper, I develop a structural model of a local housing market in which housing units differ by quality and size. The purpose of the model is to investigate more deeply why rental prices for low-quality housing are affected swiftly by shocks to new housing supply, even if new supply is catering mostly to homeowners. The model characterizes both housing demand and supply of second-hand rental housing and is estimated using data from the German Socio-Economic Panel (SOEP).

In the model, renters who move appear simultaneously on both the demand and the supply side—the latter because they add vacant units to the market. In this way, each move triggers a series of adjustments across rental submarkets until all submarkets clear. As a result, second-hand supply creates strong cross-connections between different market segments. Moreover, renters tend to "jump up the housing ladder" rather than take small steps because they face moving costs and therefore refrain from making small adjustments to their housing consumption. This mechanism contributes to the tight integration of all segments in the rental market, and of the owner-occupied and rental markets, irrespective of the substitutability between particular segments. That is, because of the second-hand market effect, the cross-price elasticity between units may decrease with substitutability because the utility difference between two similar units may be too small to justify a move when faced with high moving costs. Thus, a price shock in a particular segment may affect the prices of close substitutes less than the prices of less similar alternatives.

The paper ties into the following strands of the literature: First, it adds to the growing empirical literature on the impact of new housing supply on housing costs (Pennington 2021; Li 2022; Asquith, Mast, and Reed 2023) and filtering (Rosenthal 2014, 2019; Nathanson 2019; Bratu, Harjunen, and Saarimaa 2023; Mast 2023). The most closely related papers are Pennington (2021), Li (2022), and Asquith, Mast, and Reed (2023). All three papers study the effects of new supply of multifamily housing on income-based sorting, gentrification, and housing costs at the neighborhood level, capturing a direct supply effect, externalities, and effects of income-based sorting. These papers do not, however, consider the aggregate effects of new housing supply at the level of the local or regional housing market, where externalities and income-based sorting responses are fully internalized.[7] Moreover, they do not investigate the role of second-hand housing supply.

Second, the results complement work studying housing choices of homeowners and renters and the relationships between different housing market segments (Landvoigt, Piazzesi, and Schneider 2015; Epple, Quintero, and Sieg 2020; Piazzesi, Schneider, and Stroebel 2020). Landvoigt, Piazzesi, and Schneider (2015) and Epple, Quintero, and Sieg (2020) develop a structural framework in which households optimize their consumption of housing and goods without frictions in each period. Under standard assumptions, this implies perfect sorting of households by income into housing units ordered by quality. The dynamic framework proposed in this paper breaks up this perfect sorting and explicitly models second-hand supply. These two ingredients allow for complex interdependencies between market segments, which help to explain high degrees of market integration, as observed, for example, between local markets in the United States prior to the Great Financial Crisis (Cotter, Gabriel, and Roll 2015).

Third, the paper contributes to the large literature on the role of housing supply and housing supply constraints for prices and rents, housing affordability, and the local housing market more generally (Quigley and Raphael 2004, 2005; Glaeser, Gyourko, and Saks 2005; Saks 2008; Saiz 2010; Van Nieuwerburgh and Weill 2010; Gyourko, Mayer, and Sinai 2013; Hilber and Vermeulen 2016; Büchler, Ehrlich, and Schöni 2021; Hilber and Mense 2021; Almagro, Chyn, and Stuart 2022; Molloy, Nathanson, and Paciorek 2022; Anagol, Ferreira, and Rexer 2023). Most of this literature examines the impact of demand shocks on house prices in locations that differ in terms of their housing supply constraints. More recent papers also consider the impact on rents, for example, Büchler, Ehrlich, and Schöni (2021), Hilber and Mense (2021), and Molloy, Nathanson, and Paciorek (2022). However, the evidence from these papers on the impact of new housing supply on housing costs is only indirect. Moreover, these papers do not address the question of whether new supply at market rates is an effective means for achieving housing affordability for low-income households and in locations experiencing strong demand pressures.[8]

The remainder of this paper is structured as follows: In section II, I first describe the housing supply, weather, and rent data, and motivate

[7] However, Nathanson (2019) considers an endogenous response of city-level amenities to a housing supply shock through income-based sorting across markets.

[8] Credit constraints may represent a barrier between the owner-occupied and the rental housing segments (Ortalo-Magné and Rady 2006), and out-of-town buyers may step in to occupy the newly built units (Favilukis and Van Nieuwerburgh 2021). These factors may limit the degree to which new supply can reduce housing cost pressures for vulnerable groups.

the instrumental variable strategy. Then, I analyze the effects of new housing supply on the local rent distribution. Section III is devoted to the structural model, which is used to investigate the underlying mechanism. The final section draws conclusions and offers suggestions for policy and future research.

II. Reduced-Form Evidence: The Impact of New Housing Supply on Rents

A. Data

For the reduced-form analysis, I rely on three data sources: the administrative Building Completions Statistic, data on posted rents from online platforms, and weather data.

The Building Completions Statistic reports information on all new housing units completed in Germany between 2010 and 2017, including municipality and month of completion.[9] Unfortunately, it is not possible to identify new affordable housing in the data. In recent years, only a small share of new supply in Germany was subsidized.[10] In all other cases, developers can sell units at any price. Moreover, as I show below, the instrument mainly affects the supply of single-family housing, a type of housing that rarely qualifies for subsidies in the German institutional setting.

The rent data were web-scraped from three large online real estate market places between July 2011 and December 2018, covering around 80%–90% of the units offered in the German rental housing market. The data capture the rent distribution of vacant units, rather than the overall rent distribution. Variables include the net rent, the size in square meters, the post code, the month of the first appearance, and housing characteristics. The main outcome is a log hedonic index capturing constant-quality rents per square meter net of utilities and heating costs. In addition, I employ data on listing prices of single- and multifamily units web-scraped from the same platforms, to compute imputed prices of the rental housing units based on hedonic regressions. Appendix A (apps. A–D are available online) provides details on the data and the construction of the hedonic rent index.

The instrumental variables are derived from data on rainfall and frost depth from 2010 to 2017, provided by the German Weather Service for 1×1 km^2 grid cells.[11]

[9] Source: Research Data Centres of the Federal Statistical Office and Statistical Offices of the Federal States, *Statistik der Baufertigstellungen*, survey years 2010–17.

[10] According to a parliamentary interpellation from March 2017, about 6% of new housing supply was subsidized in 2013 and 2014 (Deutscher Bundestag, 18/11403).

[11] Sources: Deutscher Wetterdienst (DWD) Climate Data Center (2010–17): REGNIE grids of daily precipitation; DWD Climate Data Center (2010–17): Monthly grids of the maximum frost depth under uncovered soil at midday.

The main analysis is conducted at the level of local housing markets, using German planning regions (PRs) (*Raumordnungsregionen*). Housing units and weather shocks are assigned to PRs based on their geocodes and the municipality identifier. For each PR, I employ ordinary and quantile hedonic regressions to compute quality-adjusted local rent indexes. The resulting yearly panel is balanced and covers 94 PRs over 8 years.[12] To these data, I add variables capturing important determinants of local housing demand from the INKAR database of the Federal Institute for Research on Building, Urban Affairs, and Spatial Development (BBSR). Table 1 provides summary statistics.

B. *Quality of New Housing*

Renters' decisions to move are key for understanding spillovers between rents and prices more generally both because they are more mobile than homeowners and because they are the largest group of buyers of owner-occupied housing: According to the SOEP, moves of renters make up about 90% of all moves in Germany. In 5% of all moves, a homeowner moved to another owner-occupied housing unit, whereas about 15% of moves were from rental to owner-occupied housing. Moreover, 49% of new unsubsidized units in Germany are absorbed by renters becoming homeowners, but only 19% are bought by former homeowners. The remaining 32% are rental units.[13] These numbers underscore that the modal person occupying newly built housing in Germany is a former renter.

To describe the housing quality of newly built and existing rental housing, I compare prices of newly built units offered for sale to the imputed prices of existing housing offered for rent. The price as a measure of quality captures the quality of all housing characteristics, including the unit's location. The direct impact of new supply on rents should be confined to quality segments where the two price distributions overlap.

Figure 1*A* shows the residualized log price distributions, netting out the average price by PR and year to account for differences across local markets and time. The distribution of imputed prices for existing rental housing has far more weight at lower qualities, and it overlaps only partly with the distributions for newly built single- and multifamily housing.

[12] In total, there are 96 PRs. The month of completion is not reported in the Building Completions Statistic for Bremen and Saar. Since this is a key variable in the empirical strategy, I exclude these two PRs from the analysis.

[13] These numbers refer to mover households for which the year of construction equals the year of observation, between 2010 and 2017 (excluding subsidized housing); 56 such moves were observed in the SOEP. The 2011 census reports very similar shares for housing built between 2009 and 2011, with 61% owner-occupied housing, and 39% rental housing (including subsidized housing).

TABLE 1
DESCRIPTIVE STATISTICS FOR PR PANEL ($N = 94$, $T = 8$)

	Minimum	Mean	Q25	Median	Q75	Maximum
	A. Rents and Hedonic Rent Indexes, 2011–18					
Real monthly rent/sqm	4.33	6.57	5.49	6.27	7.37	15.48
Log mean real rent index	−.045	.059	.003	.043	.095	.322
Log real rent index 1st decile	−.164	.042	.000	.026	.070	.322
Log real rent index 3rd decile	−.034	.055	.001	.038	.091	.344
Log real rent index 5th decile	−.040	.063	.002	.046	.105	.379
Log real rent index 7th decile	−.044	.073	.006	.053	.118	.394
Log real rent index 9th decile	−.081	.086	.006	.063	.140	.516
	B. New Housing Completions and Weather Shocks, 2010–17					
New supply Oct–Dec	.047	.492	.374	.457	.579	1.130
Log new supply (whole year)	4.70	7.28	6.78	7.28	7.79	9.29
Average summer rainfall spell	−6.355	−.001	−1.247	.022	1.258	6.171
February frost depth	−13.900	.001	−5.040	−2.853	.596	41.304
Longest rainfall spell	−3.279	.000	−.735	−.086	.536	4.320
Number of spells with 5+ days	−1.113	.003	−.280	−.057	.280	1.825
	C. Control Variables in Year of Weather Shock, 2010–17					
Employment (thousands)	62	311	155	214	356	1,426
Unemployment rate	.021	.065	.040	.060	.083	.148
Students per 1,000 residents	.0	27.1	11.1	26.9	38.6	100.0
Share without school degree	.028	.062	.046	.056	.074	.159
Hours worked per worker in year	1,252	1,336	1,304	1,320	1,355	1,680
Gross average labor income	1,765	2,488	2,243	2,444	2,690	3,745
Dummy: Heavy flood	.000	.114	.000	.000	.000	1.000

NOTE.—The real monthly rent per sqm is based on the average rent per sqm as observed in 2011 and the real average rent index, deflated by the CPI (2018 = 1). The log rent indexes are constant-quality hedonic indexes (2011 = 0); see app. A for details. New supply in October–December is expressed relative to the yearly average number of new builds. The weather variables are measured as deviations from the local average. Control variables are taken from the INKAR regional data base. Data on hours worked are not available for four PRs (1601, 1602, 1603, 1604) in the years 2010–13. The share without school degree is the share of children leaving school without a school degree. The heavy flood dummy captures years with severe floods in the federal state the planning region belongs to (2013: Lower Saxony, Hesse, Rheinland-Palatinate, Baden-Wuerttemberg, Bavaria, Saxony, Saxony-Anhalt, Thuringia; 2017: Lower Saxony, Saxony-Anhalt, Thuringia).

Figure 1*B* translates these distributions into the share of new housing supplied at each quality level, by evaluating the densities shown in figure 1*A* and scaling by overall market sizes in each group. The dashed gray lines mark the points where the share exceeds 1% and 10%, respectively. Less than 1% of units in the 38% lowest-quality segments are new, and the share exceeds 10% only in the top-23% quality segments. Overall, the vast majority of new units exhibit a housing quality comparable to or beyond the top end of the second-hand rental market.

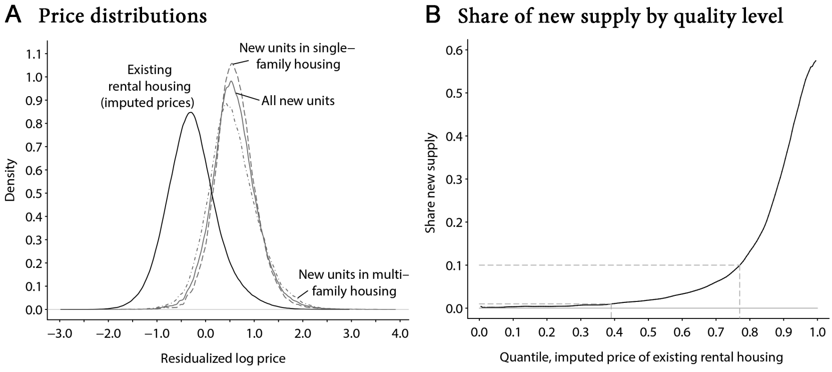

FIG. 1.—Quality of existing rental housing and newly built housing. *A*, Residualized log price distributions (net of PR- and year-average prices) for existing rental housing (black), newly built single-family housing (gray dash-dotted), newly built multifamily housing (gray dotted), and overall newly built housing (gray solid). *B*, Share of overall new supply at each quantile of quality distribution of existing rental housing. It is constructed using the black and gray solid lines from *A*, scaled by the number of observations in each group.

C. Weather Shocks as Instrument for New Housing Supply

1. Technical Mechanism

In order to identify shifts in new housing supply, I exploit fluctuations in housing completions at the end of the year, caused by unfavorable weather conditions during spring and summer. Previous studies have found that local weather conditions influence the number of housing completions, creating persistent supply shocks (see, e.g., Fergus 1999 for the United States). Moreover, poor weather conditions are recognized by German building law as a reason for an extension of building time (§ 6 Abs. 2 Nr. 1 VOB/B).

As soon as the soil has thawed out, developers can begin groundwork, usually erecting the building walls until midsummer.[14] During the summer months, heavy rainfall may cause delays for multiple reasons. First, certain building materials, such as concrete and mortar, require a sufficient drying period, which is prolonged by unfavorable weather conditions. In the absence of adequate drying, residual moisture can damage the building fabric and facilitate the growth of mold. Second, in the summer, sunny weather allows for extended work hours during the day without the use of electric

[14] There is no official statistic on building starts in Germany, and I am not aware of a dataset that documents the timing of the construction process. However, various newspaper and magazine articles suggest that most housing starts occur in late winter or early spring, and that walls are erected within approximately 4–5 months, e.g., https://www.immonet.de/service/zeitplanung-hausbau, https://www.hausausstellung.de, or https://www.n-tv.de/ratgeber.

light, enabling construction work from the early morning until the late evening. Conversely, rainy weather reduces effective daytime hours, impedes construction workers, and diminishes their motivation when working outdoors. Third, concrete, bonding agents, and certain other materials cannot be applied when there is heavy or continuous rainfall over multiple days.[15] Fourth, muddy and sodden soil impedes the setup of cranes and the operation of heavy vehicles on-site. Consequently, profit-maximizing construction firms operating in different regions may either shift their attention to sites with more favorable conditions[16] or temporarily lay off workers (Bosch and Zühlke-Robinet 1999).

The climatic conditions in Germany during winter time are typically unsuitable for outdoor construction work on buildings, so that construction work is usually suspended during that time.[17] Consequently, a delayed start in the spring and/or less favorable conditions in the summer may result in delays that extend building times beyond the winter period. Crucially, if capacity constraints in the construction sector are binding, developers are unable to make up lost time in the following year. In such cases, delays result in persistent supply shifts that can last months or even years. I demonstrate below that this accurately characterizes the situation studied in this paper.

2. Definitions of the Instrumental Variables

I use four instrumental variables that build on these considerations. The main instrument is the average longest spell of consecutive rainfall days (>20 mm per sqm) in each summer month. Alternative definitions are the longest total spell, and the number of spells with at least 5 consecutive days of rain between July and September. All of these instruments capture the idea that builders respond to prolonged periods of rainfall by stopping or relocating construction activity.[18]

[15] See https://www.nwzonline.de/bauen-wohnen/hausbau.

[16] According to the Leibniz-Institut für Wirtschaftsforschung Halle (IWH) Construction Sector Survey 2011 conducted in East Germany, 57% of East German firms have projects in West German states (Loose 2012). Moreover, collective bargaining agreements in the construction sector define compensation for the distance between the construction site and the residential address of the worker, for distances up to 500 km (see chap. 5.4 in Bosch and Hüttenhoff 2022), suggesting that it is common for firms to operate on an interregional scale.

[17] Many construction materials require outside temperatures above 5–10 degrees Celsius. Although it is technologically feasible to build also in a cold winter, this increases tremendously the construction costs (see, e.g., F. Wilke, "Fünf Grad, die magische Grenze" [five degrees Celsius, the magic threshold], *Süddeutsche Zeitung*, January 1, 2016, https://www.sz.de/201601/bauen).

[18] In contrast to many consecutive rainy days, a large total number of rainy days scattered throughout the summer is unlikely to have much effect on construction activity. Therefore, I do not consider the total amount of rainfall or the total number of rainy days during the summer as instruments.

The fourth instrumental variable is frost depth in February. Rainfall has the advantage of being a relevant factor in all parts of Germany, unlike snow and frost, which are rare in the northern and northwestern regions. However, February frost depth is largely unrelated to summer precipitation and thus provides a valuable alternative source of variation.

The rainfall instruments are constructed from daily rainfall data on a 1×1 km^2 grid. I remove time-constant differences in weather conditions between locations, as well as differences in seasonal patterns, by subtracting the grid cell mean of the respective calendar month. Thus, the identifying variation comes from weather conditions that are unusual for the location. The final step is to aggregate to the PR and year. Figure B1 (figs. A1, B1, B2, C1, and D1–D6 are available online) shows that the instrument has significant spatiotemporal variation. The alternative instrumental variables are defined in an analogous way.

3. First-Stage Relationship

Table 2 summarizes the results of a series of regressions with the three rainfall instruments and the frost depth instrument as explanatory variables. In this table, all instruments are scaled to have a standard deviation of 1 and a mean of 0. The unit of observation is the municipality by year. In columns 1–5, the dependent variable is the number of new units completed in the 3 months following the rainfall shock (October, November, and December), relative to the average number of new units built per year. Using the summer rainfall shock in column 1, the coefficient is highly significant and negative, with an *F*-statistic of 16.4. An increase in the rainfall shock by 1 standard deviation (2.4 days) reduces the supply of new housing at the end of the year by about 1.42% of the average annual new supply.

The other two variants of the rainfall instrument yield comparable results, albeit with lower *F*-statistics. Deeper frost depth in February also reduces the number of units completed at the end of the year, as demonstrated in column 4. When the average summer rainfall spell and frost depth are included jointly in column 5, both coefficients are significant and stable, arguably due to the very low correlation between the two variables of 0.09.[19]

[19] Figure B2 displays estimates for the impact of the rainfall and frost instruments on housing completions in each month of the year, analogous to col. 5 of table 2. There is virtually no effect between January and September, but both instruments marginally increase the number of completions in October. This is consistent with builders shifting from projects that are affected by bad weather to nearly completed projects that they can safely finish before the end of the construction season, despite poorer weather conditions in the fall and winter. In November and December, both types of weather shocks strongly reduce new supply.

TABLE 2
Weather Shocks and End-of-Year Completions

	Dependent Variable: New Housing Units Completed Oct–Dec as Share of Average Annual New Supply					
	in All Types of Buildings					in MFHs
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS
Average summer rainfall spell	−.0142***				−.0151***	−.0011
	(.0035)				(.0035)	(.0011)
Longest summer rainfall spell		−.0109***				
		(.0034)				
Number of rainfall spells 5+ days			−.0122***			
			(.0034)			
Frost depth in February				−.0153**	−.0185***	−.0041*
				(.0067)	(.0067)	(.0023)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic	16.4	10.0	12.6	5.2	12.4	2.0
Observations	83,632	83,632	83,632	83,632	83,632	83,632

Note.—Standard errors are clustered by municipality. In cols. 1–5, the dependent variable is the number of housing units completed in October, November, and December as a share of average annual supply in the municipality. In col. 6, the dependent variable is the number of housing units in multifamily housing completed in October, November, and December, as a share of average annual supply. The explanatory variables are scaled to have a mean of 0 and a standard deviation of 1.

* $p < .1$.

** $p < .05$.

*** $p < .01$.

One question not addressed so far is whether the impact of the weather shocks varies by building type. Larger buildings have longer construction times, so that it may be easier for builders to make up for weather-related delays.[20] In column 6, the dependent variable is the number of units in multifamily buildings completed between October and December. Despite the signs of the instruments remaining unchanged, both instruments have a much smaller impact. Therefore, the weather shocks mainly identify shocks to the supply of single-family housing.

During a housing boom, when the construction sector is operating at full capacity, a temporary decline in construction output can lead to a

[20] In Germany, about 25%–30% of newly built single-family homes are completed within 12 months after having obtained the building permit, and 58%–65% within 18 months. The shares are substantially lower for multifamily homes, with 7% and 28% (Schwarz 2018).

sustained reduction in new supply. This accurately reflects the situation in Germany since the start of the most recent boom in 2010. Waiting times for construction firms (the time between the signing of a contract and the start of its execution) more than doubled, from 6.5 weeks in 2009 to 13.4 weeks in 2019, and never declined significantly after 2010 (fig. 2*A*). The ratio of skilled jobseekers to vacancies fell by a factor of 3 (installations subsector) to 5 (construction) (fig. 2*B*). In particular, skilled workers were extremely scarce in the installations subsector, with only about three skilled jobseekers for every ten open positions in 2018 (fig. 2*C*). This picture is in

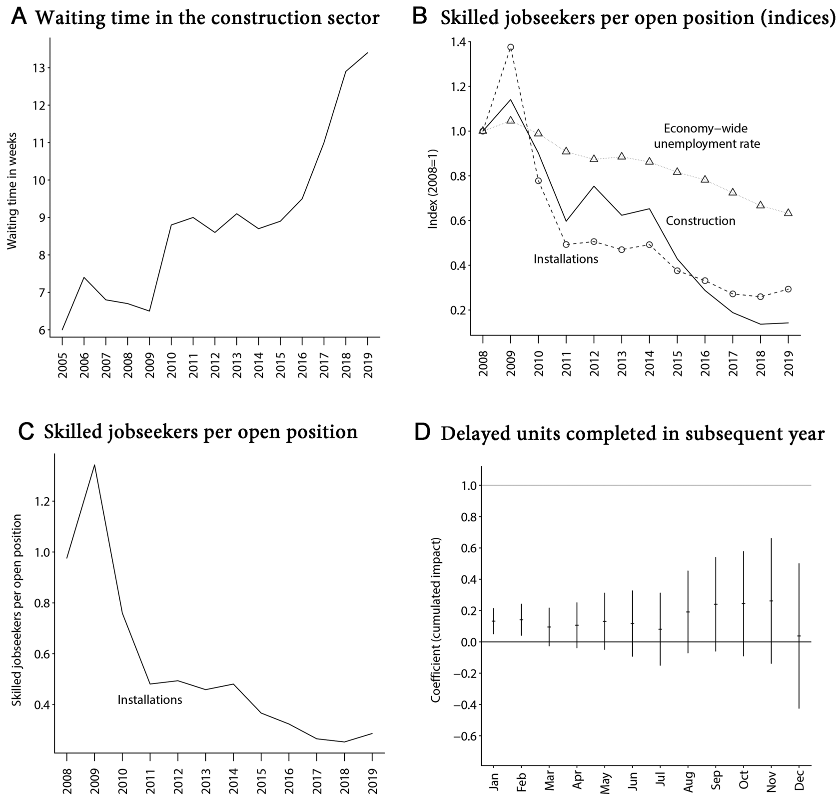

FIG. 2.—Delayed housing completions and capacity constraints in building sector. *A*, Average waiting times in construction industry, from signing of contract to start of execution (source: ZDH Konjunkturbericht). *B*, Indexes for number of skilled job searchers per open position in building construction and installations subsectors, and for overall unemployment rate in Germany (base year 2008; source: Federal Employment Agency). *C*, Number of skilled job searchers per open position in installations subsector (source: Federal Employment Agency). *D*, Estimated share of delayed units completed by month m of subsequent year (cumulative) with 90% confidence intervals; standard errors clustered by municipality.

line with reports of severe capacity constraints in the construction sector during the most recent boom (Gornig, Michelsen, and Bruns 2019).

To investigate the aggregate effect of weather-induced delays on local new housing supply in the subsequent year, figure 2*D* shows the impact of one unit not being completed due to bad weather at the end of the previous year, on the number of units completed between January and the given month. The estimates are based on IV regressions of the number of housing completions between January and month m of the year following the rainfall shock, on the number of completions in the 3 months following the rainfall shock, conditional on year and municipality fixed effects. The graph shows that fewer completions at the end of the year due to unusually bad weather conditions only marginally increase the number of completions in the following year. The aggregate catching-up never exceeds 25% and falls close to zero when looking at the whole year. This strongly suggests that additional projects were delayed as the initially delayed projects were completed. Overall, figure 2 suggests that the effects of the weather-induced supply shocks are well captured by the reduction in end-of-year completions and last longer than 1 year, consistent with earlier evidence for the United States.

4. IV Balance

Figure C1 summarizes a series of balancing tests that scrutinize the identifying assumption, namely that the local rental housing market is affected by summer rainfall only through its impact on new housing supply. These tests confirm that the rainfall shock is uncorrelated with the hedonic rent index in the year of the rainfall shock, with pretreatment housing completions, and with several other potential confounders. Appendix section C.1 provides further details.

D. Estimation Results

1. Baseline Effects on Average Rents

I first examine the impact of new housing supply on average local rents in panel fixed-effect IV regressions at PR level. PRs are a fairly broad definition of a local housing market, so that local spillovers triggered by the supply shock are contained within the location. The estimating equation is

$$\ln \text{Index}_{rt} = \gamma \left[\frac{S_{r,t-1}^{\text{Oct–Dec}}}{H_r} \right] + \psi_r + \phi_t + x'_{r,t-1}\beta + \varepsilon_{rt}, \tag{1}$$

where Index_{rt} is a hedonic rent index for PR r in year t, $S_{r,t-1}^{\text{Oct–Dec}}$ is the number of units completed in the final 3 months of year $t-1$, H_r is the average number of new units supplied per year in r, and $S_{r,t-1}^{\text{Oct–Dec}}/H_r$ is instrumented by the rainfall shock. Here ψ_r and ϕ_t denote PR and year fixed effects, and $x_{r,t-1}$ are controls for important determinants of local housing demand. In the baseline regression, these are log employment, the log unemployment rate, and the number of university and college students per capita, all measured in the year of the rainfall shock. Students are likely to be renters, and they were an important demand factor in many medium-sized cities during the sample period. Similarly, employment opportunities drive local housing demand, while the unemployed are constrained in their housing demand. Standard errors are clustered at PR level.

Panel A of table 3 displays the results. Column 1 includes as controls log employment and the fixed effects only. The coefficient of main interest is negative and highly significant. Adding the log unemployment rate in column 2 and the share of university and college students in column 3 hardly affects this estimate. Column 3 suggests that a 1% increase in yearly new supply lowers rents by about 0.2%, hence a rent price elasticity with respect to the flow of new supply of −0.192.

The first-stage relationships are summarized in panel B. Notably, the coefficient of the rainfall shock is very stable when adding further controls. Moreover, the Kleibergen-Paap F-statistics do not indicate weak instrument problems.

2. Robustness of Baseline Results

The identification strategy relies on variation that is arguably exogenous to local housing market conditions. Even though the local housing market cannot possibly affect the weather in the previous summer, the weather may influence the local economy in ways that could—in theory—induce a spurious correlation between weather conditions and local rents 1 year later. I therefore investigate the robustness of the results in more detail in appendix section C.2.

In particular, I test whether the results are confounded by larger floods or spurious correlations with local demand factors, whether they depend on the functional form, and whether they are robust to the use of alternative weather instruments, definitions of the endogenous variable, and delineations of local housing markets. I also consider regressions in changes. These tests support the conjecture that the weather shocks are valid instruments and that the results are robust.

3. Interpretation as a Demand Price Elasticity and Comparison to the Literature

The baseline estimate captures the effect of a change in supply on rental prices in the first year, which can be transformed into a demand price

TABLE 3
IMPACT OF NEW HOUSING SUPPLY ON AVERAGE RENTS

	A. SECOND-STAGE RELATIONSHIP		
	DEPENDENT VARIABLE: LOG HEDONIC RENT INDEX		
	(1) IV	(2) IV	(3) IV
Units completed Oct–Dec in $t-1$ per average number of units completed annually	−.199***	−.204***	−.192***
	(.072)	(.072)	(.065)
Log employment, year $t-1$	.991***	1.009***	.949***
	(.143)	(.145)	(.142)
Log unemployment rate, year $t-1$		−.028	−.050
		(.038)	(.040)
University and college students per 1,000 inhabitants, year $t-1$			.002**
			(.001)
Year fixed effects	Yes	Yes	Yes
PR fixed effects	Yes	Yes	Yes
Kleibergen-Paap F	17.4	17.4	19.0
Number of PRs	94	94	94
Observations	752	752	752

	B. FIRST-STAGE RELATIONSHIP		
	DEPENDENT VARIABLE: UNITS COMPLETED OCT–DEC IN $t-1$ PER AVERAGE NUMBER OF UNITS COMPLETED ANNUALLY		
	(1) OLS	(2) OLS	(3) OLS
Rainfall spell instrument (average length, Jul–Sep of year $t-1$)	−.009***	−.009***	−.010***
	(.002)	(.002)	(.002)
Log employment, year $t-1$	.653**	.663**	.508*
	(.282)	(.290)	(.271)
Log unemployment rate, year $t-1$		−.019	−.086
		(.081)	(.080)
University and college students per 1,000 inhabitants, year $t-1$			.007***
			(.002)
Year fixed effects	Yes	Yes	Yes
PR fixed effects	Yes	Yes	Yes
Adjusted R^2	.855	.853	.863
Number of PRs	94	94	94
Observations	752	752	752

NOTE.—Standard errors are clustered by PR. The instrument in cols. 1–3 of panel A is the rainfall shock in year $t-1$. Panel B shows the respective first-stage regressions.
* $p < .1$.
** $p < .05$.
*** $p < .01$.

elasticity. The average annual new supply at PR level is 0.48% of the stock. Thus, the baseline estimate of −0.192 translates into a short-run demand price elasticity of −0.48% /19.2% = −0.025, with the 95% confidence interval ranging from −0.074 to −0.015.[21]

This estimate is smaller in magnitude than earlier causal estimates of the short-run demand price elasticity in Hanushek and Quigley (1980) and Friedman and Weinberg (1981). Both papers analyze data from a field experiment conducted in Phoenix and Pittsburgh between 1973 and 1976. Hanushek and Quigley (1980) report 1-year elasticities of −0.12 and −0.16 for the two cities, respectively, whereas Friedman and Weinberg (1981) find a 2-year elasticity of −0.22 for movers. The latter estimate translates into an overall 2-year elasticity of −0.145.

There are at least three important differences between the setting studied in this paper and the Phoenix and Pittsburgh experiment that likely account for the smaller magnitude. First, the experiment sampled only low-income households, whereas the underlying demand for rental housing in the present setting is representative of the population as a whole. To the extent that low-income households are more price sensitive, this contributes to a larger elasticity in the experiment. Second, according to the SOEP, only 10.1% of renters and 1.4% of homeowners in Germany moved in a given year between 2011 and 2017, but over 30% of the participants in the experiment did so. This relatively lower mobility should translate into a lower demand price elasticity, all else equal. Third, the experiment focused exclusively on urban residents, while the present study includes both urban and rural areas. To the extent that households with particularly strong preferences for housing services such as floor space or gardens both exhibit a lower demand price elasticity and choose to live in rural areas, housing demand in rural areas should be less elastic.[22] Overall, these differences are likely to explain why housing demand is relatively less price elastic in Germany than in the United States.

4. Impact in Markets with Increasing Housing Demand

A particularly policy-relevant question is whether new housing supply can effectively reduce rents in markets experiencing sustained demand

[21] I thank an anonymous referee for pointing this out. A regression using the log change in the housing stock as the outcome variable yields an elasticity of −0.024 (see table C5; tables A1, C1–C9, D1–D7 are available online).

Li (2022) estimates that a 1% expansion of supply decreases rents of nearby units by 0.1%. Using a similar approach, Asquith, Mast, and Reed (2023) find a reduction of around −0.3% in low-income areas. Both papers consider highly local impacts that are difficult to compare to a market-level elasticity.

[22] To test this, I run again the baseline regression for PRs with below- and above-average population density in table C7. The results suggests somewhat lower elasticities in rural areas.

growth. In such markets, one concern is that increased supply could be absorbed by incoming households. Therefore, this section considers PRs with above-median demand growth over the sample period, as captured by the long difference (from 2011 to 2018) in log employment at workplace, log average labor income, and log household income. The German economy experienced a sustained boom during this period, with a median PR-level change in log employment of +0.14 from 2011 to 2018. Table 4 reports the results for these high-demand PRs.

As column 1 shows, the impact of the supply expansion on rents is significantly negative and of a similar magnitude to that in the baseline regression in PRs with a strong positive trend in log employment. This also holds for locations with strong growth of average gross labor income in column 2, and of average household income in column 3. Overall, these results show that expanding new housing supply is a very effective means for improving housing affordability in such markets.

5. Effects on the Local Rent Distribution

Baseline results.—To investigate the extent to which new housing supply affects the tails of the local rent distribution, I replace the hedonic index

TABLE 4
Effect of New Supply in Markets with Increasing Housing Demand

	Dependent Variable: Log Rent per Square Meter		
	(1) IV	(2) IV	(3) IV
Sample restricted to locations with above-median growth of	Employment	Average gross labor income	Average household income
Units completed Oct–Dec in $t-1$	−.176** (.069)	−.191* (.111)	−.265** (.106)
Year fixed effects	Yes	Yes	Yes
PR fixed effects	Yes	Yes	Yes
Other controls	Yes	Yes	Yes
Kleibergen-Paap F	19.0	10.2	13.4
Number of PRs	47	47	47
Observations	376	376	376

Note.—Standard errors are clustered by PR. All regressions control for PR and year fixed effects, and the controls used in table 3. The endogenous variable is the number of units completed October–December in $t-1$ per average number of units completed annually. It is instrumented by the summer rainfall shock. The functional form for all three regressions is identical to that of the baseline regression, col. 3 of table 3. Demand growth is measured as the logged long difference between 2011 and 2018 in the variable indicated in each column.
* $p < .1$.
** $p < .05$.
*** $p < .01$.

in equation (1), which captures average conditional rents, with conditional rent quantile indexes. The quantile indexes are estimated from hedonic quantile regressions and are therefore quality adjusted. The regression is otherwise identical to the baseline regression.

Figure 3*A* shows the impact of the housing supply shock on the first to ninth deciles of the PR-level rent distribution. The gray horizontal line shows the impact on average rents reported in column 3 of table 3. All coefficients are negative and significant at least at the 5% level. The impact is stronger at the top of the distribution, but this variation is not large, ranging from −0.13 at the first decile to −0.28 at the ninth decile, with the differences not being statistically significant. Overall, this suggests that the markets for new (single-family) homes and all quality segments of the rental market are tightly integrated. Moreover, the pattern is consistent with filtering.

External validity.—The impact of new supply on the rent distribution could depend on the size of the rental housing market, and the homeownership rate in Germany is relatively low by international standards. Given the large rental market, it seems likely that the range of housing qualities in the rental market in Germany is wider than in countries with higher homeownership rates and smaller private rental markets.

To examine this point, I split the sample of PRs by homeownership rate at the median of 51%, based on the 2011 census. Figure 3*B* shows that the effect is uniform in PRs with homeownership rates above 51%, while it is more skewed toward higher qualities in PRs with homeownership rates between 15% and 51%.

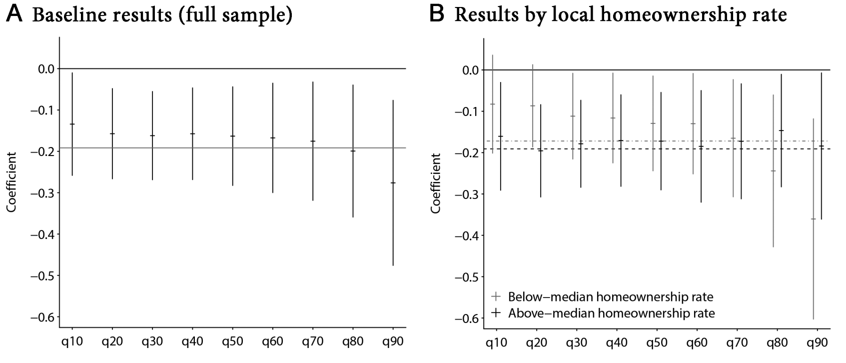

FIG. 3.—Impact of new housing supply on distribution of rents per sqm. *A*, Coefficient estimates for equation (1), using indexes for conditional quantile of local rent/sqm distribution (constant quality) as outcomes. Housing completions at the end of the year are instrumented by the rainfall shock. Vertical bars represent cluster-robust 95% confidence intervals. *B*, Results for PRs with above- and below-median homeownership rates in 2011, with horizontal lines representing respective impact on mean.

In PRs with below-average homeownership rates in 2011, rents are 7% higher than in other PRs, and the local rent distribution is more dispersed, with the difference between the ninth and the first decile being 12% larger. Figure A1 shows the distributions of (imputed) prices for new single-family homes and existing rental housing. In PRs with below-average homeownership rates, new single-family homes are relatively more expensive than existing rental housing. Thus, an average first-time buyer is likely to free up a rental unit further up the quality distribution. In addition, a greater dispersion of the rent distribution implies a greater quality distance between higher- and lower-quality units.[23] Given the second-hand supply mechanism, these patterns are consistent with the more heterogeneous effects in PRs with below-median homeownership rates.

6. Heterogeneity by Housing Unit Type

The data on housing completions do not allow for the identification of built-to-rent units. Although the instrument primarily affects the supply of new single-family housing, the results could still be driven by a direct effect of built-to-rent completions. Moreover, larger units may be affected more strongly if they are closer substitutes for newly built single-family homes. Appendix section C.4 explores whether build-to-rent units and larger units are more strongly affected. This is not the case, suggesting that substitution relationships cannot explain the observed pattern.

E. Impact on the Quantity of Rental Housing Traded in the Market

The second-hand supply mechanism implies that newly built units trigger moving chains in the rental market. This should increase the number of second-hand units offered for rent. To test this conjecture, I regress the number of second-hand rental units offered on the market in each year on the number of new housing completions at the end of the previous year. Both variables are expressed as a share of the average annual supply of new housing. Although I do not observe movers, the number of existing units offered for rent is closely related to moves within the rental market. Table 5 displays the results.

In column 1, when controlling for log employment only, the coefficient is positive with 4.384 and significant at the 10% level. This suggests

[23] To the extent that the quality of existing housing in gentrifying neighborhoods is much lower than the quality of new single-family homes, rents in these neighborhoods may be less strongly affected.

TABLE 5

EFFECT OF NEW SUPPLY ON NUMBER OF UNITS OFFERED ON RENTAL MARKET

	Dependent Variable: Number of Units Offered for Rent in t per Average Number of Units Completed Annually					
	Second-Hand Rental Units			Newly Built Rental Units		
	(1) IV	(2) IV	(3) IV	(4) IV	(5) IV	(6) IV
Units completed Oct–Dec in $t-1$	4.384*	4.158*	3.808	−.338	−.271	−.296
	(2.600)	(2.476)	(2.557)	(.470)	(.447)	(.441)
Log employment, year $t-1$	−30.612***	−29.550***	−28.189***	−1.771	−2.089	−1.990
	(6.804)	(6.504)	(5.883)	(1.972)	(2.027)	(2.075)
University and college students per 1,000 inhabitants, year $t-1$		−.031	−.014		.009**	.011***
		(.032)	(.033)		(.004)	(.003)
Log unemployment rate, year $t-1$			−3.032			−.220
			(2.201)			(.367)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
PR fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Kleibergen-Paap F	17.4	19.2	19.0	17.4	19.2	19.0
Number of PRs	94	94	94	94	94	94
Observations	752	752	752	752	752	752

NOTE.—Standard errors are clustered by PR. All regressions control for PR and year fixed effects. The endogenous dependent variable is the number of housing units completed in the previous October, November, and December as a share of the average annual supply of new housing, instrumented by the summer rainfall shock. The outcome variable is the number of housing units of the given type offered for rent in the year following the shock, as a share of the average annual supply of new housing.

* $p < .1$.

** $p < .05$.

*** $p < .01$.

that one newly supplied housing unit triggers about 4.4 moves in the rental housing market over the following 12 months. The coefficient remains significant when adding the share of university and college students in column 2. Controlling for the log unemployment rate in column 3 does not affect the point estimate much, but the p-value is slightly above 10% in this regression.

The remaining columns of the table show the results from an analogous set of regressions using built-to-rent units as the outcome. To the extent that the rainfall shock affects newly built rental housing, one would expect a positive effect on the number of new rental units in the following year. This does not appear to be the case, as the main coefficient is small and insignificant in all three regressions.

III. Quantitative Model of a Rental Housing Market with Second-Hand Supply

This section develops and estimates a second-hand supply model of a local rental housing market to further investigate the channels through which new supply affects the rent distribution. In the model, renters determine the demand for rental housing, but they also contribute to the supply when they move. Thus, the model is well suited to capture the supply-demand shifts induced by shocks to new supply and thereby complements the reduced-form analysis, which focuses mainly on price effects.

A. Second-Hand Supply Model: Setting and Definitions

The model is populated by renter households indexed by n. Each household lives in one of 40 rental housing types characterized by combinations (q, s) of quality $q \in \{1, \dots, 10\}$ and size $s \in \{1, \dots, 4\}$. The choices of these households determine aggregate second-hand supply of and demand for rental housing in each submarket. In addition, households can leave the local market or become homeowners.

Aggregate supply.—Rental supply of units with quality q and size s is

$$S_{q,s}(r) = S_{q,s}^{\text{new}} + S_{q,s}^{\text{second-hand}}(r). \tag{2}$$

Here, $r \in \mathbb{R}_{+}^{40}$ is a vector of rents, $S_{q,s}^{\text{new}}$ is exogenously given new supply, and

$$S_{q,s}^{\text{second-hand}}(r) = \sum_{n} \mathbf{1}(s_n = s)[1 - p_0(r, q_n, s_n, r_n, \tau_n; x_n^-)]\ell(q \mid q_n, \tau_n)\omega_n \tag{3}$$

is second-hand supply, where $1 - p_0(r, q_n, s_n, r_n, \tau_n; x_n^-)$ is the probability that a household with characteristics x_n^- facing rent vector r and currently occupying a unit with quality q_n and size s_n at rent r_n for τ_n years chooses to move out of the current housing unit. Landlords upgrade a unit of quality q_n occupied for τ_n years to quality q with probability $\ell(q \mid q_n, \tau_n)$, where $\ell(q \mid q_n, \tau_n) = 0$ if $q_n e^{-\delta\tau_n} < .8$, which represents a "minimum quality requirement."[24] The term ω_n is a sampling weight.

Aggregate demand.—Aggregate demand consists of local and external demand,

$$D_{q,s}(r) = D_{q,s}^{\text{local}}(r) + D_{q,s}^{\text{external}}(r), \tag{4}$$

$$D_{q,s}^{\text{local}}(r) = \sum_n p_{(q,s)}(r, q_n, s_n, \tau_n; x_n^-)\omega_n, \tag{5}$$

$$D_{q,s}^{\text{external}}(r) = \sum_n p_{(q,s)}(r, q_n, s_n, \tau_n; x_n^-)\omega_n'. \tag{6}$$

Here, $p_{(q,s)}(r, q_n, s_n, \tau_n; x_n^-)$ is n's propensity to move into a unit with quality and size (q, s) when facing rents r.

External households do not contribute to second-hand supply in the local market when moving. The weight ω_n' reflects external household n's propensity to move to the local market, and $\omega_n' = 0$ for households already living in the local market.

Market equilibrium.—The equilibrium rent vector r^* satisfies

$$D_{q,s}(r^*) = S_{q,s}(r^*) \quad \forall(q, s) \in \{1, \dots, 10\} \times \{1, \dots, 4+\}. \tag{7}$$

I also require that the demand for new and existing owner-occupied housing matches the exogenously given supply of these housing types.

1. Dynamic Discrete Choice Model of Housing Quality and Tenure Choice

To parameterize p_0 and $p_{(q,s)}$, I employ a dynamic discrete choice model in discrete time with moving costs. I omit the n subscript in this section for ease of exposition.

Choice set.—In each period, the household faces a set of $J = 44$ mutually exclusive alternatives $j = 0, \dots, 43$. The baseline choice $j = 0$ is to stay in the current dwelling. Rental units differ in quality $q \in \{1, \dots, 10\}$ and number of rooms $s \in \{1, 2, 3, 4+\}$. Quality q is measured as the normalized rank in the local distribution of rents per square meter, binned into deciles. This definition is akin to that in Landvoigt, Piazzesi, and Schneider (2015) and Epple, Quintero, and Sieg (2020) and does not involve value judgments about unit characteristics, including neighborhood

[24] I rule out that landlords self-occupy rental units. The probability $\ell(\cdot \mid q_n, \tau_n)$ accounts for depreciation and scrappage of units at the bottom of the quality distribution. Appendix D provides details.

characteristics, some of which are unobserved. In contrast to Landvoigt, Piazzesi, and Schneider (2015) and Epple, Quintero, and Sieg (2020), it allows for separate valuation of quality and size, consistent with the reduced-form analysis.

Households can buy and occupy an existing ($j = 41$) or a new unit ($j = 42$), or leave the local housing market ($j = 43$). The subsequent choice path following one of these three choices is not explicitly modeled; that is, these choices are terminal. This greatly simplifies the estimation, without compromising the purpose of the model, which is to identify the preferences that shape rental demand and supply of existing homes. The lifetime utility associated with these choices still captures the possibility that the household will become a renter again in the future.

State space.—Households have an unobserved type z that captures preferences for residential mobility and for the two types of owner-occupied housing (strong/weak, $2^3 = 8$ combinations).

The observable state of the household in period t is $x_t = (r_t, q_t, s_t, \tau_t, y_t, w_t, a_t, m_t, k_t, (r_t^q)_{q=1,\ldots,10})$. The first set of observables is specific to the housing unit, namely the net rent r_t, housing quality $q_t \in \{1, \ldots, 10\}$, size $s_t \in \{1, \ldots, 4+\}$, and length of tenure τ_t. The second set describes the household, where y_t is household income net of taxes and social security contributions, w_t is financial wealth,[25] a_t is the age of the household head, $m_t \in \{0, 1\}$ is an indicator for couple households, and $k_t \in \{0, 1, 2\}$ is the number of dependent children.[26] Finally, r_t^q is the current market rent per square meter for a unit of quality q. These observables capture both housing characteristics and important determinants of individual housing demand over the life cycle.

State transitions.—Household income, financial wealth, the couple indicator, and the number of children follow a stochastic transition path. The income transition depends on current income, the number of adults and children, and the age of the household head, incorporating life-cycle effects, earnings persistence, and labor supply effects of having children. The wealth transition is a function of disposable income net of housing costs, the expected change in income, and an indicator for moving, the latter because moving costs may reduce the amount saved. The transitions of the couple indicator and the number of children depend flexibly on household composition and age. Appendix section D.1 provides details. The other state variables evolve in a straightforward way: $a_{t+1} = a_t + 1$, and $\tau_{t+1} = \tau_t + 1$ if $j = 0$, and $\tau_{t+1} = 1$ otherwise.

[25] I use financial assets reported in the 2002, 2007, and 2012 SOEP "wealth modules" and savings reported in each survey year to calculate financial wealth forward and backward. For simplicity, I ignore potential returns through interest, as well as withdrawals.

[26] Size $s_t = 4$ for units with at least four rooms, and $k_t = 2$ if there are at least two dependent children.

Furthermore, I assume that the household expects the real rent of the currently occupied unit to remain constant in the future, motivated by the fact that rent regulation in Germany prevents (large) rent increases during a tenancy. Since data on rent expectations are not available, I also assume that households expect real rents of vacant units to remain constant. This latter assumption should reduce the propensity to move today, since tenants do not expect to face higher rents if they move in the future.

Flow utility of rental housing.—The deterministic flow utility from living in rental housing of quality and size (q, s) is

$$u_{jt}(x_t) = \theta_0 \log \text{dispinc}_{jt} + \theta_1 \text{qual}_{jt} + \theta_2 \log \frac{s_{jt}}{1 + m_t + k_t} + \theta_3 \tau_{jt}, \quad j \in \{0, \ldots, 40\}. \tag{8}$$

Households receive utility from equivalized disposable household income net of housing costs, $\text{dispinc}_{jt} := [y_t - r_{jt} - 2.5\, S(s_{jt})](1 + m_t + k_t/2)^{-0.5}$, where r_{jt} is the rent, $2.5\, S(s_{jt})$ captures expenses for heating and utilities,[27] and $S(s)$ is the floor area of a unit with s rooms. They also value housing quality, $\text{qual}_{jt} := q_{jt} e^{-\delta \tau_{jt}}$, $\delta > 0$. Attachment to the unit is assumed to be linear in length of tenure τ_{jt}.

For $j > 0$, (q_{jt}, s_{jt}) equals the pair (q, s) corresponding to j, and the rent is $r_{jt} = r_t^{q_{jt}} S(s_{jt})$. I follow Calder-Wang (2019) in assuming that households take $r_t^{q_{jt}}$ as given because they face a competitive housing market with an atomistic demand side.

Moving costs.—Moving costs are key to rationalizing why households move only infrequently, which in turn affects the distribution of secondhand supply. Following Kennan and Walker (2011) and Buchinsky, Gotlibovski, and Lifshitz (2014), moving costs (MCs) are household specific:

$$\text{MC}_{jt}(x_t, z) = \mathbf{1}(j > 0)(\mu_0^z + \mu_1 a_t + \mu_2 a_t^2 + \mu_3 m_t + \mu_4 k_t). \tag{9}$$

In contrast to Kennan and Walker (2011) and Buchinsky, Gotlibovski, and Lifshitz (2014) these moving costs reflect renters' costs of moving within a local housing market. They depend on the age of the household head, the presence of a partner and of children, and the unobserved type.

Lifetime utility of terminal choices.—The valuations of the terminal choices are modeled in reduced form. The total deterministic payoff of choosing $j \in \{41, 42, 43\}$ is

$$\begin{aligned} v_{jt}(x_t, z) = {} & \gamma_{j0}^z + \gamma_{j1} \ln(y_t) + \gamma_{j2} w_t + \gamma_{j3} w_t^2 + \gamma_{j4} a_t \\ & + \gamma_{j5} a_t^2 + \gamma_{j6} m_t + \gamma_{j7} k_t. \end{aligned} \tag{10}$$

For $j \in \{41, 42\}$, γ_{j0}^z is specific to the unobserved household type.

[27] Heating and utility costs are assumed to be 2.5 EUR per square meter, the average cost for heating and utilities of German renters in 2009 (deflated to 2018 EUR), according to the German Renters' Association (*Deutscher Mieterbund*; press release March 30, 2011).

Idiosyncratic component of utility.—I assume that the payoffs for each choice have an idiosyncratic component ϵ_{jt}, which represents household- and period-specific preferences for alternative j. The preference shocks are distributed type I extreme value, independent over time and alternatives. Due to the unobserved heterogeneity across household types, the model does not suffer from "independence of irrelevant alternatives," as the unobserved heterogeneity introduces dependence over choices.

Choice problem.—The household maximizes lifetime utility by selecting an optimal choice sequence $d^*(t) := (d_{t'}^*)_{t' \geq t}$, where $d_t = (d_{0t}, \ldots, d_{43t})$ and d_{jt} is an indicator for choosing alternative j in period t. Letting $\chi_{t,t'} = \prod_{\tilde{t}=t}^{t'-1}(1 - \Sigma_{j=41}^{43} d_{j\tilde{t}})$ be an indicator for not having made a terminal choice between periods t and $t' - 1$, and defining $\tilde{u}_{jt} = u_{jt} - \text{MC}_{jt}$ and $\tilde{v}_{jt} = v_{jt}^r - \text{MC}_{jt}$, the expected discounted sum of payoffs for choice j is

$$\max_{d(t)} \sum_{t'=t}^{T} \chi_{t,t'} \beta^{t'-t} \left[\sum_{j=0}^{40} d_{jt'} \mathbb{E}_t[\tilde{u}_{jt'}(x_{t'}) + \epsilon_{jt'}] + \sum_{j=41}^{43} d_{jt'} \mathbb{E}_t[\tilde{v}_{jt'}(x_{t'}, z) + \epsilon_{jt'}] \right]. \quad (11)$$

Here, β is the discount factor and $\mathbb{E}_t$ represents the expectation at time t.

2. Discussion of Model Mechanisms

In the model, an increase in new supply in one segment attracts demand from other segments. Close substitutes experience the largest decrease in demand.

At the same time, part of the new supply is absorbed by former "stayer" households who now decide to move. This increases second-hand supply, in line with table 5. The distribution of the second-hand supply effect depends on the types of dwellings occupied by the former stayer households.[28] However, households rarely adjust their housing arrangements, so that the unit currently occupied need not be a close substitute for the unit the household wishes to move to.

One reason why prospective first-time buyers may prefer relatively cheaper rental housing and move only infrequently is the desire to save for a down payment. The model incorporates this channel, as both moving and high housing costs slow down the accumulation of financial wealth.[29]

[28] Moving chains are implicit rather than explicit in this framework. This differs from Bratu, Harjunen, and Saarimaa (2023) and Mast (2023). Both papers model the probability that a moving chain will end, to then calculate the number of second-hand units along all moving chains. When all moving chains have ended, this implicitly defines a new market equilibrium. In contrast, the model developed here determines the new equilibrium directly, which implies that all moving chains have ended.

[29] In a setting with rent control and/or sticky rents during tenancies, second-hand supply in segment q does not necessarily increase when rents in segment q increase. This amplifies the second-hand effect of a supply shock since only one side of the market moves toward the new equilibrium as rents adjust. In that case, the change in rents required to restore equilibrium needs to be larger.

Finally, because of the idiosyncratic component of utility, observationally similar households may prefer different housing options. This contributes to a more dispersed impact of the supply shock. Among other things, the idiosyncratic term is likely to capture unobserved barriers to household mobility.

B. *Estimation of Structural Parameters*

1. Household Panel Data

The main data source for the model is the Socio-Economic Panel (SOEP). I use waves 2001 to 2017 because an improved indicator for residential moves became available in 2001. Housing quality is captured by the unit's position in the local distribution of rent/sqm. To measure the rent distribution going back to 2001, I employ rich data on rents from the *Mikrozensus,* a large repeated cross section of about 400,000 households.[30]

The sample consists of renter households who moved at least once between 2001 and 2017. There are 2,945 such households with complete information on all variables. Table 6 reports summary statistics, and table D1 shows the number of households by number of consecutive years observed;[31] 640 households appear in the data for 10 or more consecutive years, and 280 renters move into existing and 117 into new units to become homeowners. There are 2,422 moves within the local rental market, and 399 moves to other local markets. Households are removed from the sample when they make a terminal choice, that is, when they leave the local market or become a homeowner.

Figure D1 shows that the quality of rental housing units occupied by subsequent first-time buyers of new homes is relatively dispersed, partly due to deprecation. Likewise, a substantial share of renters moving into high-quality rental housing previously lived in units of rather low quality, as shown in figure D2. In fact, 22% of renters moving into the top segment came from units of below-median quality. This figure is strikingly similar to the findings in Mast (2023), who reports that 20% of movers into newly built housing come from areas with below-median income. It suggests that the expansion of second-hand supply in response to a shock to new supply is relatively dispersed across quality levels.

[30] Source: Research Data Centres of the Federal Statistical Office and Statistical Offices of the Federal States, *Mikrozensus,* survey years 2006, 2010, 2014, and 2018. Details can be found in app. sec. D.2.

[31] Table D2 compares the means and standard deviations for the model variables of all renters interviewed in SOEP waves 2001–17 with the renters in the analysis sample, showing that the analysis sample is fairly representative of the overall population of renters.

TABLE 6
DESCRIPTIVE STATISTICS FOR SOEP HOUSEHOLD SAMPLE

	Mean	Standard Deviation	Quantile .25	Quantile .5	Quantile .75	Minimum	Maximum
Housing quality	5.85	2.92	3.00	6.00	8.00	1.00	10.00
Housing unit size	2.88	.86	2.00	3.00	4.00	1.00	4.00
Length of tenancy	2.41	2.76	.00	2.00	4.00	.00	15.00
Rent	559.2	265.8	396.3	504.2	669.1	15.5	7,799.8
Rent/m^2	7.25	2.31	5.80	6.93	8.32	.28	35.71
Adjusted rent/m^2	7.20	2.26	5.76	6.86	8.24	.27	34.74
Monthly net income	2.48	1.44	1.52	2.21	3.10	.22	44.17
Yearly savings	2.60	5.25	.00	.72	3.11	.00	150.00
Accumulated savings	52.4	416.0	1.7	12.3	40.9	.0	33,350.8
Age of household head	44.14	15.37	32.00	41.00	54.00	18.00	94.00
Couple household	.55	.50	.00	1.00	1.00	.00	1.00
Children (0/1/2+)	.61	.82	.00	.00	1.00	.00	2.00
Year	2010	4	2007	2010	2013	2002	2017

NOTE.—Sample of SOEP households used in the estimation, excluding the period when the household was first observed. Housing quality is determined by the position in the local rent/sqm distribution when moving in. The adjusted rent/m^2 is corrected for the correlation between size and rent/m^2, using a regression estimated from the rent data employed in sec. II. Accumulated savings were imputed from SOEP waves 2002, 2007, and 2012 ("wealth module"), using the savings variable (reported in all waves). Euro values refer to the price level in 2017. Monthly net income, yearly savings, and accumulated savings are expressed in 1,000 EUR.

2. Discount Factor and Housing Quality Decay

I follow the literature and assume a discount factor of $\beta = .95$. In the present context, β is only relevant one period ahead. Discount factors in periods beyond $t + 1$ are included in the nonparametric control factor; see appendix section D.5. Thus, the estimation allows for downward-sloping discount rates over long horizons (Giglio, Maggiori, and Stroebel 2014; Giglio et al. 2021).

Depreciation of housing quality captures the change of the unit's position in the local rent/sqm distribution and is estimated from the rent data. The estimated depreciation factor is 3.9% per annum, which captures pure depreciation without the impact of maintenance. Appendix section D.3 provides details.

3. Dynamic Discrete Choice Problem

The discrete choice model is estimated using the maximum-likelihood-based EM algorithm of Arcidiacono and Miller (2011); see appendix section D.5 for technical details.

Flow utility of rental housing and moving costs.—Table 7 shows parameter estimates for the flow utility of rental housing in panel A and for the

TABLE 7
Estimated Flow Utility Parameters and Model Summary Statistics

	Model 1: No Unobserved Household Types		Model 2: Eight Unobserved Household Types	
	Coefficient	Standard Error	Coefficient	Standard Error
	A. Rental Housing Utility Parameters, Equation (8)			
Log equivalized disposable income	.313***	.025	.344***	.015
Housing quality	.044***	.009	.044***	.004
Log rooms per person	1.249***	.070	1.382***	.029
Tenancy duration	.154***	.010	.078***	.006
	B. Moving Cost Parameters, Equation (9)			
Intercept (high-MC type)	4.903***	.198	4.880***	.134
Intercept (low-MC type)			2.886***	.137
Age/100	.620	.889	2.441***	.607
$(\text{Age}/100)^2$	.522	.913	−.440	.628
Couple household	−.251***	.047	−.212***	.033
Number of children in household	−.254***	.027	−.205***	.020
	C. Model Summary Statistics			
Log likelihood	−18,544		−17,594	
Likelihood ratio statistic (critical value $\chi^2_{11} = 21.92$)			1,899.7	

Note.—Standard errors were obtained by block bootstrapping over individuals, with 500 repetitions. Panel A displays parameter estimates for the flow utility of rental housing, eq. (8). Panel B shows estimates for the moving cost component, eq. (9). For model 1, the uncertainty related to estimating the conditional choice probability of $j = 42$ is taken into account in the calculation of the standard errors. For model 2, the bootstrap procedure takes the distribution over unobserved types and the model for the conditional choice probability of $j = 42$ as given; see the technical details in app. D.

*** $p < .01$.

moving cost component in panel B, for two versions of the model. Model 1 does not allow for unobserved heterogeneity, while model 2 is the unrestricted model. Panel C reports the log likelihood and a likelihood ratio test that supports model 2. The distribution of unobserved types is displayed in table D4.

Regarding the parameter estimates for model 2 in panel A, flow utility increases with log disposable income, housing quality, and with the number of rooms per person. It also increases with the time since the last move, which captures attachment to the unit. Panel B reveals that older renters are less mobile, while couples and renters with children move more often.

Terminal utility.—The coefficients in equation (10) are generally difficult to interpret because they capture the valuation of the three terminal choices relative to the lifetime utility of alternative choice paths. It is therefore useful to consider how the variables in equation (10) affect the relative valuations of the three terminal choices. Table D5 shows the differences in parameter estimates between the terminal choices. Households are more likely to buy a new rather than an existing home when they have a higher income or are older. Compared to buying an existing home, the propensity to make a long-distance move decreases with household wealth and age, the latter at an increasing rate. In addition, the presence of a partner and of children reduces the propensity to leave the local market relative to buying an existing home.

Transition functions.—Estimates are reported in appendix section D.5.

C. *Model-Based Simulations*

Parameterization and data.—I use the discrete choice model to parameterize p in the system defined by equations (2)–(7). The population of model households is constructed from the SOEP in 2014, the middle of the sample period of the reduced-form analysis. Since the rent distribution is PR specific, I focus on the PR of Berlin, Germany's largest city. In the analysis sample, there are 91 renter households observed in Berlin in 2014.

To obtain a smoother distribution of the housing variables—quality, size, and length of tenure—I create a larger simulation sample based on the 91 sample households. To do so, I first estimate OLS models with observed quality, size, and length of tenure as outcomes, using the renters observed in Berlin as the underlying data. I then perturb 100 times the income, wealth, and age for each of the 91 households. This results in a total of 9,100 simulation households. Employing the OLS models, the initial housing arrangements of the 9,100 model households are given by the OLS predictions plus randomly drawn regression errors. I drop 161 cases with housing expenditure shares below 5% or above 80%. The final simulation sample has a total of 8,939 model households. Finally, I draw the unobserved household type from the estimated conditional distribution over household types. Further details on the simulation sample can be found in appendix section D.6.

To ensure that the distributions of income, wealth, age, and household composition, as well as the rent distribution in the baseline equilibrium, match the distributions observed in the data, I reverse-engineer sample weights $\omega_{\tilde{n}}^{d}$ for each underlying SOEP household $\tilde{n}$ and draw d such that the baseline rental price vector solves the equilibrium equation (7). In doing so, I require that each of the 91 SOEP households receive the same total weight, $\Sigma_d \omega_{\tilde{n}}^{d} = \bar{\omega} \ \forall \ \tilde{n}$.[32]

[32] The population of households moving in from other locations is a copy of the simulation sample, but the weight of each external household is equal to the probability of making a long-distance move as predicted by the discrete choice model. I fix these weights throughout.

New housing supply consists of new supply of rental and owner-occupied units. I calibrate new supply in the following way: (i) New supply of quality (q, s) rental housing is set to exactly match the fraction of new rental units of quality q and size s in the rent data from section II. (ii) $\Sigma_{q,s} S^{\text{new}}_{q,s}$ makes up 31.6% of new supply, the share of new rental housing supply in the SOEP data. This also ensures that the share of total new supply to owner-occupiers is the same as the corresponding share in the SOEP data. (iii) The number of new units supplied to owner-occupiers is set to match demand in the baseline equilibrium. These three constraints pin down the number of rental units supplied in each quality bin, and of new owner-occupied units.

Scenarios.—The model counterpart to the reduced-form analysis is an exogenous change in the supply of new housing. The rental price vector adjusts to bring the model economy back into equilibrium. This allows one to determine a simulation-based elasticity of the rental price with respect to new supply, the impact on quantities traded in each housing quality segment, and distributional consequences.

I consider two sets of scenarios. The first set features a reduction of new supply of owner-occupied housing. Arguably, this type of housing is not a close substitute for low-quality rental housing, so that these scenarios help to better understand the transmission channels. I present results using the full model, and using a version of the model with reduced uncertainty about future paths of income, wealth, and household composition. In the second set of scenarios, the supply shock is to new rental supply. These scenarios employ different quality distributions of the supply shocks to examine how expanding the supply of more and less affordable housing can help to reduce price pressures.

1. Scenario 1: Reduction of New Supply to Owner-Occupiers

Scenario 1(i) features a shock to the supply of new owner-occupied housing, while the supply of existing owner-occupied housing is perfectly inelastic. Figure 4 shows the impact on rents and quantities traded by quality bin.[33] It relates the percentage change in rental prices and quantities to the percentage change in total new supply to the market, which closely mimics the setting in the reduced-form analysis.[34]

[33] Figure D5*A* shows the case of perfectly elastic supply.

[34] Total new supply includes new supply to owners and renters, accounting for the fact that new supply to owners consists of new supply to first-time buyers and to other buyers. The group of other buyers is not explicitly modeled. I assume that the size of this group corresponds to the German average of 19.3% of total new supply.

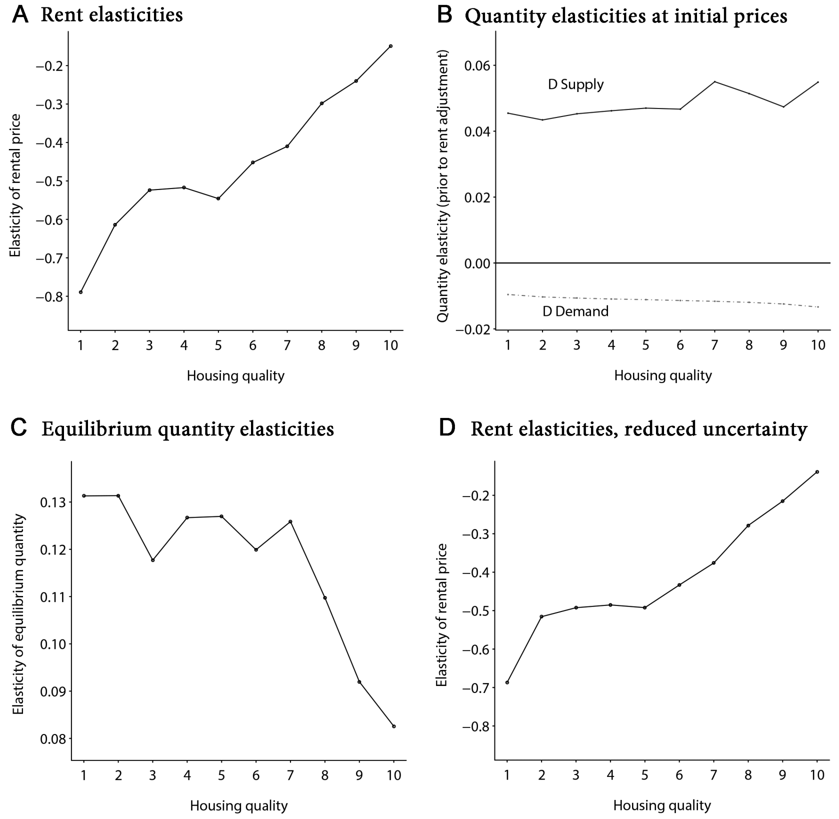

FIG. 4.—New housing supply: price and quantity elasticities by housing quality bin in scenario 1. The figure displays the impact of a shock to new owner-occupied housing supply on rental prices (*A*), demand and supply elasticities at initial prices (*B*), and equilibrium quantities traded (*C*), aggregated by housing quality bins. The effects are represented as an elasticity with respect to the total flow of newly built housing in the location. The supply of existing owner-occupied housing is constant. *D*, Rent elasticities for scenario with reduced uncertainty.

The rent elasticity in figure 4*A* is larger than the reduced-form baseline estimate, with an average across all quality segments of −0.46. All segments are affected, and the elasticities are larger in magnitude for lower qualities. This is plausible given the main mechanism of the model: Higher-income households have stronger demand for new owner-occupied housing and high-quality rental housing. Thus, for many households currently occupying a high-quality rental unit, the utility differential between the current unit and new owner-occupied housing is too small to offset the high moving costs. For this reason, the typical buyer of new owner-occupied housing is a high-income household occupying a medium-quality rental housing unit. This also implies that greater substitutability can reduce the cross-price elasticity between two goods, relative to other less similar alternatives, when the second-hand effect dominates.

This can be seen in figure 4*B*, which plots the initial changes in demand and supply in response to the supply shock, that is, before rental prices adjust to restore equilibrium. Demand initially falls most sharply for high-quality rental housing. This confirms that, in the model, high-quality rental housing is a closer substitute for newly built owner-occupied housing. However, the resulting change in supply is much more uniform across quality bins, with the largest increase for the seventh bin. This change in rental supply is due to units being vacated by renters who now prefer to move into new housing. The figure also reveals that the initial shift in supply is much larger in absolute terms than the initial shift in demand. This is because a large part of the demand for the newly built owner-occupied units comes from former "stayers."

Figure 4*C* displays the change in quantities traded by segment in the new equilibrium. Consistent with the explanation given above, the low- to medium-quality segments of the rental market experience the largest increases in quantities traded as new supply to the owner-occupied market increases. Higher-quality segments are less affected, despite the fact that the initial change in demand was relatively stronger in these segments. Moreover, when comparing figures 4*B* and 4*C*, the equilibrium quantities increase by a factor of 2–3 beyond the initial change in second-hand supply. Although the moving chains triggered by the new units are not explicitly defined in this framework, this discrepancy between quantity changes at initial prices and equilibrium quantities can be understood as consisting of (simultaneous) moving chains that quickly reach all segments of the local rental market. This is consistent with findings by Bratu, Harjunen, and Saarimaa (2023) and Mast (2023), who show that around 60%–70% of moving chains triggered by new supply eventually reach a residential location with below-median average income.[35]

With less uncertainty about future states of the world, a larger number of households should be willing to adjust their housing consumption in response to a supply shock. Arguably, in this case, rental prices need to react less strongly to the shock to restore equilibrium. Moreover, as argued above, such adjustment costs contribute to market integration. Figure 4*D* shows the impact on rents in scenario 1(ii), where all stochastic

[35] As noted above, the modeling approaches differ in important respects, making it hard to compare the findings more directly. For example, Mast (2023) treats migration into the local market as an event that ends the moving chain, the counterfactual being that such migration would not have occurred without the supply expansion. In contrast, the present paper allows for migration into the local market in the baseline equilibrium, and immigration reacts endogenously to supply.

state variables are deterministic and constant between the current and next period. This lowers the opportunity costs of moving. The rent changes are less pronounced, as compared to figure 4*A*. Across quality levels, they are lower by about 16% for the bottom segments and by about 8% for the top segments. This lends support to the conjecture that high adjustment costs contribute to a larger overall effect and to a swift propagation of the effects across the entire rent distribution.

2. Scenario 2: Reduction of New Rental Housing Supply

Scenario 2 features a supply shock to new rental units. In the baseline equilibrium, new supply in each of the 40 segments is equal to the share of new rental units in each quality-size bin in the rent data. I consider three types of supply shocks: (i) a shock that proportionally reduces supply in each segment, (ii) a shock to the supply of high-quality rental units, and (iii) a shock to the supply of low-quality rental units. In each case, the supply of existing and new owner-occupied housing is fixed.

Proportional shock.—Figures 5*A* and 5*B* show elasticities for the proportional shock to new rental supply. The rent elasticities in figure 5*A* are larger than in scenario 1, but exhibit a similar pattern. Figure 5*B* shows the impact on the total quantity traded including the supply shock as a black line, and on the quantity traded net of the supply shock as a gray dashed line. The difference between the two lines represents the distribution of the supply shock. It is larger for high qualities because new supply of rental housing is predominantly of higher overall quality. The impact on the quantity traded net of the shock is again stronger at the lower end, as was the case in scenario 1.

High-quality rental supply shock.—Figures 5*C* and 5*D* show results for a supply shock concentrated on the top two quality segments, with the overall size of the shock being identical to the proportional shock. The impact on rental prices for high-quality units is now much stronger, but there is again a considerable reduction of rents at lower qualities. This is due to a broad distribution of the second-hand supply effect across quality segments, shown as the gray dashed line in figure 5*D*.

Low-quality rental supply shock.—Finally, figures 5*E* and 5*F* display the case of a supply shock to the bottom two segments. This case is particularly policy relevant, as subsidized housing is typically of lower overall quality. It thus addresses the question of whether affordable housing policies are capable of reducing the overall price pressure in the local market. Not surprisingly, increasing exogenously the supply in the bottom two quality segments has a far larger impact on these two segments. However, rents in adjacent segments also decrease considerably: Whereas the elasticities in segments 3 and 4 were around -0.88 for the proportional

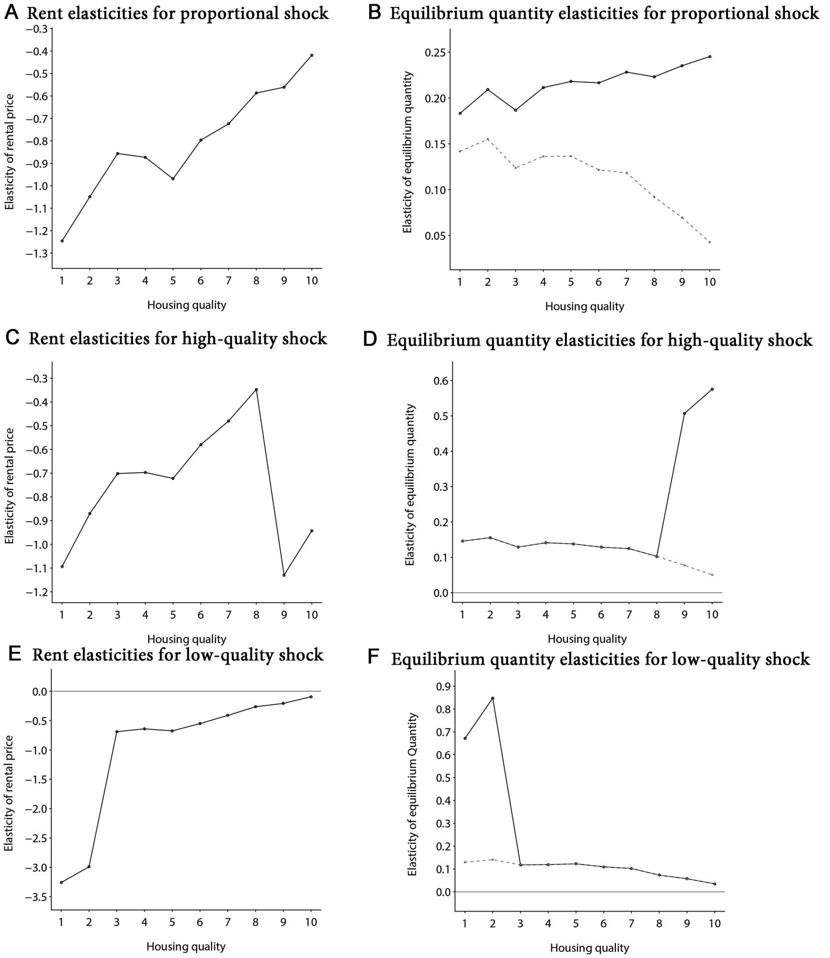

FIG. 5.—New housing supply: price and quantity elasticities by housing quality bin in scenario 2. The figure displays the impact of a shock to new rental housing supply on rental prices (*A*, *C*, and *E*), as well as equilibrium quantities traded (*B*, *D*, and *F*), for three different types of shocks to new rental supply. In *B*, *D*, and *F*, the black line shows the overall change in quantities traded. The gray line shows the endogenous change net of the exogenous supply shock, representing the second-hand supply effect. All effects are expressed as elasticities with respect to the total flow of newly built housing. The supply of new and existing owner-occupied housing is held constant.

supply shock considered in scenario 3(i), they are still at −0.72 in the present case. This suggests that new low-quality housing effectively improves housing affordability also in moderate-quality segments.

Figures D6*A* and D6*B* present additional results using alternative assumptions regarding second-hand supply. In these simulations, 50% of second-hand units in the bottom quality segment and 25% in the second-lowest segment are taken off the market, reflecting the possibility that some low-quality housing is refurbished and sold to owner-occupiers, a channel not captured in the estimation of ℓ. This reduces somewhat the rent impact at the lower end of the market. Figures D6*C* and D6*D* repeat this simulation, but for a more dispersed high-quality supply shock. In this case, the impact is much less pronounced at lower qualities, and increases monotonically between the third and the tenth segments, albeit still being largest at the bottom of the market.

3. Change in Household Utility

The estimated valuations from the discrete choice model can be used to assess which households benefit from the supply shocks. To do so, I simulate the expected utility change for each household in response to an expansion of new housing supply by 1%, by drawing 1,000 times the idiosyncratic preference terms from an extreme-value type I distribution. This yields maximum utility values under the initial and adjusted rents, respectively. The average over the 1,000 repetitions is an estimate of the expected utility change.

I express this change in terms of the expected utility difference that would result from increasing household income by 1 EUR and run regressions to characterize which households benefit the most in each scenario. The explanatory variables are the age of the household head, a dummy for couple households, the number of children, log income, a dummy for being in the top quartile of accumulated savings (> 55.9k EUR), housing quality, the number of rooms, and tenancy duration. Table 8 summarizes the results.

In scenario 1(i) shown in column 1, younger households, couples, and households with children benefit more strongly from the supply expansion, likely because they have a relatively stronger preference for owner-occupied housing and are more mobile. Households with longer tenancy duration and in larger and higher-quality units experience smaller utility increases, arguably because new owner-occupied housing is a relatively closer substitute to large rental housing, making a move less worthwhile given that moving costs are high, and because longer tenancy duration implies stronger attachment to the current unit. With lower uncertainty of future income, wealth, and household composition in scenario 1(ii), all of these differences are somewhat more pronounced.

Columns 3–5 display results for the three types of rental housing supply expansions simulated in scenarios 2(i)–2(iii). In column 3, the supply expansion is proportional across quality segments. Here, younger households, couples, and lower-income households benefit more strongly. The latter is in contrast to the first two scenarios, where the relationship

TABLE 8

New Housing Supply: Expected Change in Household Utility

	Dependent Variable: Implicit EUR Value of Expected Change in Valuation				
	Scenario 1(i)	Scenario 1(ii)	Scenario 2(i)	Scenario 2(ii)	Scenario 2(iii)
	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS
Age of household head	−.0028***	−.0028***	−.0008***	−.0008***	−.0007***
	(.0004)	(.0004)	(.0001)	(.0002)	(.0001)
Two adults in household	.0469***	.0778***	.0129**	.0162***	.0091*
	(.0177)	(.0279)	(.0051)	(.0057)	(.0055)
Number of children in household (0, 1, 2+)	.1046***	.1754***	.0143	.0129	.0169
	(.0287)	(.0540)	(.0100)	(.0089)	(.0119)
Log household income	.1120**	.1330***	−.0979***	−.0874***	−.1003***
	(.0437)	(.0507)	(.0065)	(.0067)	(.0067)
Household in top wealth quartile (>55.9k EUR)	.0158	.0063	.0081**	.0021	.0147***
	(.0264)	(.0286)	(.0039)	(.0042)	(.0043)
Housing quality (1–10)	−.0127**	−.0187*	−.0038***	−.0048***	−.0024**
	(.0055)	(.0111)	(.0010)	(.0013)	(.0010)
Number of rooms (1, 2, 3, 4+)	−.0418***	−.0534**	−.0423***	−.0490***	−.0346***
	(.0151)	(.0217)	(.0042)	(.0045)	(.0045)
Tenancy duration	−.0129***	−.0212**	−.0062***	−.0073***	−.0049***
	(.0039)	(.0090)	(.0005)	(.0005)	(.0004)
Adjusted R^2	.089	.110	.363	.321	.318
Households	8,939	8,939	8,939	8,939	8,939

Note.—Robust standard errors in parentheses. The outcome is the expected change in utility from a 1% expansion of new housing supply, expressed relative to the change in utility that would result from having one additional EUR of household income. Regressions are weighted by the household weights ω_n^d; see the description in the text.

* $p < .1$.

** $p < .05$.

*** $p < .01$.

between household income and change in utility was positive. It is consistent with stronger preferences for renting among lower-income households. Housing quality is again negatively associated with the change in utility, arguably because households already occupying a high-quality unit have little to gain from moving to a new unit.

Scenario 2(ii) features an expansion of high-quality rental housing supply. The overall pattern is similar to scenario 2(i), with a less negative coefficient for log income, but more negative coefficients for housing quality and the number of rooms. This is consistent with higher demand for high-quality housing from households with higher incomes, and from households that do not already occupy a large or high-quality unit. Finally, column 5 shows results for scenario 2(iii), where the supply shock is to low-quality rental housing. Here, these patterns are reversed, with a slightly more negative coefficient for log income and less negative coefficients for housing quality and number of rooms.

Overall, these results show that expanding housing supply in general, and rental housing supply in particular, alleviates housing problems among low-income households.

IV. Conclusions

Market integration in second-hand markets with heterogeneous products—such as the housing, car, and smartphone markets—depends crucially on direct links created by buyers of new and used products who simultaneously act as sellers on the second-hand market. This paper investigated the role of such interactions for the propagation of supply shocks across market segments by identifying the impact of new housing supply at market rates on rental prices in different segments of the local housing market.

The channel through which these effects operate is second-hand housing supply: Units freed up by renters moving into the newly built housing trigger a cascade of moves. Through this cascade, the supply effects quickly reach all parts of the local rent distribution. This contributes crucially to tight market integration, despite potentially low substitutability between two given market segments.

The results imply that restrictions to market-rate housing supply can be harmful to low-income renters, as even the supply of single-family homes can lower this group's housing cost burden. According to the model-based simulations, the supply of new multifamily housing has even greater potential to reduce housing costs of low-income households in expensive locations. Policymakers should thus focus on removing barriers to the supply of new housing, and on creating a tax system that provides incentives encouraging optimal land use.

The effectiveness of other housing policies likely depends both on the forward-looking nature of housing choices and on the peculiarities of the housing market as a second-hand market. Taking into account these factors and their distributional consequences when studying housing markets and housing policy seems to be a promising avenue for future research.

Data Availability

Data and code replicating the tables and figures in the paper, as well as information about the restricted-access data used in section III of this article, can be found in Mense (2025) in the Harvard Dataverse, https://doi.org/10.7910/DVN/LWRXA9.

References

Albouy, David, Gabriel Ehrlich, and Yingyi Liu. 2016. "Housing Demand, Cost-of-Living Inequality, and the Affordability Crisis." Working Paper no. 22816 (November), NBER, Cambridge, MA.

Almagro, Milena, Eric Chyn, and Bryan A. Stuart. 2022. "Urban Renewal and Inequality: Evidence from Chicago's Public Housing Demolitions." Working Paper no. 2022-163, Becker Friedman Inst. Econ., Chicago.

Anagol, Santosh, Fernando V. Ferreira, and Jonah M. Rexer. 2023. "Estimating the Economic Value of Zoning Reform." Working Paper no. 29440 (March), NBER, Cambridge, MA.

Arcidiacono, Peter, and Robert A. Miller. 2011. "Conditional Choice Probability Estimation of Dynamic Discrete Choice Models with Unobserved Heterogeneity." *Econometrica* 79 (6): 1823–67.

Asquith, Brian J., Evan Mast, and Davin Reed. 2023. "Local Effects of Large New Apartment Buildings in Low-Income Areas." *Rev. Econ. and Statis.* 105 (2): 359–75.

Barrios Garcia, Javier A., and José E. Rodriguez Hernandez. 2008. "Housing Demand in Spain According to Dwelling Type: Microeconometric Evidence." *Regional Sci. and Urban Econ.* 38:363–77.

Bosch, Gerhard, and Frederic Hüttenhoff. 2022. *Der Bauarbeitsmarkt: Soziologie und Ökonomie einer Branche.* Frankfurt am Main: Campus Verlag.

Bosch, Gerhard, and Klaus Zühlke-Robinet. 1999. "Der Bauarbeitsmarkt in Deutschland: Zum Zusammenhang von Produktionsstrukturen, Arbeitsmarkt und Regulierungssystem." *German J. Indus. Relations* 6 (3): 239–67.

Bratu, Cristina, Oskari Harjunen, and Tuukka Saarimaa. 2023. "JUE Insight: City-Wide Effects of New Housing Supply: Evidence from Moving Chains." *J. Urban Econ.* 133:103528.

Buchinsky, Moshe, Chemi Gotlibovski, and Osnat Lifshitz. 2014. "Residential Location, Work Location, and Labor Market Outcomes of Immigrants in Israel." *Econometrica* 82 (3): 995–1054.

Büchler, Simon, Maximilian v. Ehrlich, and Olivier Schöni. 2021. "The Amplifying Effect of Capitalization Rates on Housing Supply." *J. Urban Econ.* 126:103370.

Calder-Wang, Sophie. 2019. "The Distributional Impact of the Sharing Economy on the Housing Market." Working paper, Wharton School, Univ. Pennsylvania.

Cotter, John, Stuart Gabriel, and Richard Roll. 2015. “Can Housing Risk Be Diversified? A Cautionary Tale from the Housing Boom and Bust.” *Rev. Financial Studies* 28 (3): 913–36.

Coulson, N. Edward, and Christian Richard. 1996. “The Dynamic Impact of Unseasonable Weather on Construction Activity.” *Real Estate Econ.* 24 (2): 179–94.

Deng, Yongheng, Congyan Han, Teng Li, and Timothy J. Riddiough. 2021. “Whither Weather? High Temperature, Climate Change and Mortgage Default.” Paper presented at the EUROFIDAI-ESSEC Paris December Finance Meeting.

Eberts, Randall W., and Timothy J. Gronberg. 1982. “Wage Gradients, Rent Gradients, and the Price Elasticity of Demand for Housing: An Empirical Investigation.” *J. Urban Econ.* 12:168–76.

Epple, Dennis, Luis Quintero, and Holger Sieg. 2020. “A New Approach to Estimating Equilibrium Models for Metropolitan Housing Markets.” *J.P.E.* 128 (3): 948–83.

Ermisch, J. F., J. Findlay, and K. Gibb. 1996. “The Price Elasticity of Housing Demand in Britain: Issues of Sample Selection.” *J. Housing Econ.* 5 (4): 64–86.

Favilukis, Jack, Sydney C. Ludvigson, and Stijn Van Nieuwerburgh. 2017. “The Macroeconomic Effects of Housing Wealth, Housing Finance, and Limited Risk Sharing in General Equilibrium.” *J.P.E.* 125 (1): 140–223.

Favilukis, Jack, and Stijn Van Nieuwerburgh. 2021. “Out-of-Town Home Buyers and City Welfare.” *J. Finance* 76 (5): 2577–638.

Fergus, James T. 1999. “Where, When, and by How Much Does Abnormal Weather Affect Housing Construction?” *J. Real Estate Finance and Econ.* 18 (1): 63–87.

Fontela, Matías, and Fidel Gonzales. 2009. “Housing Demand in Mexico.” *J. Housing Econ.* 18:1–12.

Friedman, Joseph, and Daniel H. Weinberg. 1981. “The Demand for Rental Housing: Evidence from the Housing Allowance Demand Experiment.” *J. Urban Econ.* 9:311–31.

Giglio, Stefano, Matteo Maggiori, and Johannes Stroebel. 2014. “Very Long-Run Discount Rates.” *Q.J.E.* 130 (1): 1–53.

Giglio, Stefano, Matteo Maggiori, Krishna Rao, Johannes Stroebel, and Andreas Weber. 2021. “Climate Change and Long-Run Discount Rates: Evidence from Real Estate.” *Rev. Financial Studies* 34 (8): 3527–71.

Glaeser, Edward L., Joseph Gyourko, and Raven E. Saks. 2005. “Why Have Housing Prices Gone Up?” *A.E.R.* 95 (2): 329–33.

Goodman, Allen C. 2002. “Estimating Equilibrium Housing Demand for ‘Stayers.’” *J. Urban Econ.* 51:1–24.

Gornig, Martin, Claus Michelsen, and Martin Bruns. 2019. “Bauwirtschaft weiter im Vorwärtsgang: Staatliche Impulse treiben die Preise.” *DIW Wochenbericht* 2019 (1–2): 4–14.

Greenwald, Daniel L., and Adam Guren. 2020. “Do Credit Conditions Move House Prices?” Working paper, Sloan School Management, Massachusetts Inst. Tech.

Gyourko, Joseph, Christopher Mayer, and Todd Sinai. 2013. “Superstar Cities.” *American Econ. J. Econ. Policy* 5 (4): 167–99.

Hanushek, Eric A., and John M. Quigley. 1980. “What Is the Price Elasticity of Housing Demand?” *Rev. Econ. and Statis.* 62 (3): 449–54.

Hilber, Christian A. L., and Andreas Mense. 2021. “Why Have House Prices Risen So Much More than Rents in Superstar Cities?” Discussion Paper no. 1743, Centre Econ. Performance, London School Econ.

Hilber, Christian A. L., and Wouter Vermeulen. 2016. “The Impact of Supply Constraints on House Prices in England.” *Econ. J.* 126 (591): 358–405.

Kaplan, Greg, Kurt Mitman, and Giovanni L. Violante. 2020. “The Housing Boom and Bust: Model Meets Evidence.” *J.P.E.* 128 (9): 3285–345.

Kennan, John, and James R. Walker. 2011. “The Effect of Expected Income on Individual Migration Decisions.” *Econometrica* 79 (1): 211–51.

Landvoigt, Tim, Monika Piazzesi, and Martin Schneider. 2015. “The Housing Market(s) of San Diego.” *A.E.R.* 105 (4): 1371–407.

Li, Xiaodi. 2022. “Do New Housing Units in Your Backyard Raise Your Rents?” *J. Econ. Geography* 22 (6): 1309–52.

Loose, Brigitte. 2012. “IWH-Bauumfrage zum Jahresauftakt 2012: Ostdeutsches Baugewerbe mit ausgesprochen guter Jahresbilanz 2011.” *Wirtschaft im Wandel* 18 (2): 68–72.

Mast, Evan. 2023. “JUE Insight: The Effect of New Market-Rate Housing Construction on the Low-Income Housing Market.” *J. Urban Econ.* 133:103383.

Mense, Andreas. 2025. “Replication Data for: ‘The Impact of New Housing Supply on the Distribution of Rents.’” Harvard Dataverse, https://doi.org/10.7910/DVN/LWRXA9.

Metcalf, Gabriel. 2018. “Sand Castles before the Tide? Affordable Housing in Expensive Cities.” *J. Econ. Perspectives* 32 (1): 59–80.

Molloy, Raven, Charles G. Nathanson, and Andrew Paciorek. 2022. “Housing Supply and Affordability: Evidence from Rents, Housing Consumption and Household Location.” *J. Urban Econ.* 129:103427.

Nathanson, Charles G. 2019. “Trickle-Down Housing Economics.” Working paper, Kellogg School Management, Northwestern Univ.

Ortalo-Magné, François, and Sven Rady. 2006. “Housing Market Dynamics: On the Contribution of Income Shocks and Credit Constraints.” *Rev. Econ. Studies* 73 (2): 459–85.

Pennington, Kate. 2021. “Does Building New Housing Cause Displacement? The Supply and Demand Effects of Construction in San Francisco.” Working paper, Dept. Agricultural and Resource Econ., Univ. California, Berkeley.

Piazzesi, Monika, Martin Schneider, and Johannes Stroebel. 2020. “Segmented Housing Search.” *A.E.R.* 110 (3): 720–59.

Polinsky, A. Mitchell, and David T. Ellwood. 1979. “An Empirical Reconciliation of Micro and Grouped Estimates of the Demand for Housing.” *Rev. Econ. and Statis.* 61 (2): 199–205.

Quigley, John M., and Steven Raphael. 2004. “Is Housing Unaffordable? Why Isn’t It More Affordable?” *J. Econ. Perspectives* 18 (1): 191–214.

———. 2005. “Regulation and the High Cost of Housing in California.” *A.E.R.* 95 (2): 323–28.

Rapaport, Carol. 1997. “Housing Demand and Community Choice: An Empirical Analysis.” *J. Urban Econ.* 42:243–60.

Rosenthal, Stuart S. 2014. “Are Private Markets and Filtering a Viable Source of Low-Income Housing? Estimates from a ‘Repeat Income’ Model.” *A.E.R.* 104 (2): 687–706.

———. 2019. “Owned Now Rented Later? The Effect of Housing Stock Transitions on Affordable Housing and Market Dynamics.” Working paper, Dept. Econ., Syracuse Univ.

Saiz, Albert. 2010. “The Geographic Determinants of Housing Supply.” *Q.J.E.* 125 (3): 1253–96.

Saks, Raven E. 2008. “Job Creation and Housing Construction: Constraints on Metropolitan Area Employment Growth.” *J. Urban Econ.* 64:178–95.

Schwarz, Thomas. 2018. “Baufertigstellungen im Wohnbau 2017.” Statistisches Monathsheft (August), Landesamt für Statistik Baden-Württemberg, Stuttgart.

Van Nieuwerburgh, Stijn, and Pierre-Olivier Weill. 2010. “Why Has House Price Dispersion Gone Up?” *Rev. Econ. Studies* 77:1567–606.