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# The Heterogeneous Response of Real Estate Asset Prices to a Global Shock

## Abstract

We estimate the transmission of the pandemic shock in 2020 to prices in the residential and commercial real estate market by causal machine learning, using new granular data at the municipal level for Germany. We exploit differences in the incidence of Covid infections or short-time work at the municipal level for identification. In contrast to evidence for other countries, we find that the pandemic had only temporary negative effects on rents for some real estate types and increased asset prices of real estate particularly in the top price segment of commercial real estate.

JEL-Codes: E210, E220, G120, G510, R210, R310.

Keywords: real estate, asset prices, rents, Covid pandemic, short-time work, affordability crisis.

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# 1 Introduction

Empirical and theoretical research has stressed the importance of the real estate market for the economy (Piazzesi & Schneider, 2016): housing services are an important consumption item with an expenditure share of about 20%, housing is the largest asset in household balance sheets in many developed countries, and real estate is a production input for many firms. The price of real estate varies substantially across time and regions. Changes in the valuation of real estate affect the net worth of households and firms, as well as the value of collateral in credit contracts, and thus propagate to consumption and investment (Mian, Rao, & Sufi, 2013; Mian & Sufi, 2011; Schmalz, Sraer, & Thesmar, 2017). Although a lot of progress has been made to understand the way in which real estate markets amplify booms and busts (Jorda, Schularick, & Taylor, 2016), many aspects of how macroeconomic shocks transmit to the real estate market, causing further repercussions in the economy, have not been well understood yet.

We contribute to the literature by estimating the price responses to the large macroeconomic shock of the Covid pandemic in the German real estate market. We use new granular data at the municipal level that allow us to apply causal machine learning for the empirical analysis accounting for possible heterogeneity of the price responses.[1] We uncover heterogeneous effects across different price segments in the real estate market and assess the implications for the premium of urban real estate and its affordability. Methodologically, our analysis adds to the emerging literature that applies recent causal machine learning techniques in the context of asset pricing.

Germany is well suited for the analysis because it has a developed rental market for commercial and residential real estate, with the largest incidence among G7 countries of households renting their main residence (more than 50%). A large macroeconomic shock, such as the Covid pandemic, potentially implies shifts of demand across real estate units with different characteristics. If persistent, one would expect these shifts to be born

[1] With price responses, we imply responses of the asset price of real estate, also referred to as the price of real estate units for sale or sale price in the following, as well as the price paid to landlords for the services derived from real estate rental, i.e., the dividend payments of real estate assets to which we refer as rents.

out in prices in the period right after the shock because the supply of real estate only changes slowly. By estimating responses of rents and sale prices to the pandemic shock, we assess whether demand shifts after the shock have been temporary or are expected to be persistent.

The estimated price responses allow answering the following policy-relevant research questions. Has the pandemic changed prices for real estate, temporarily or persistently? Does this imply that the pandemic mitigated or further exacerbated the affordability crisis by changing prices differently across segments of the residential real estate market?[2] What are the implications of the price responses for the collateral value of commercial real estate and the premium for urban real estate? Beyond asset pricing and the associated macroeconomic consequences of changes in asset valuations, quantitative answers to these questions also matter for public finances and the planning of land use in municipalities that differ in their urbanization or the incidence of employment across industries.

To answer these research questions, we match new granular data on real estate prices at the municipal level (*Gemeinde/Gemeindeverband*), provided by the German real estate company *21st Real Estate*, with data on Covid-19 infections and the incidence of short-time work for municipalities with different industry and employment structures. We focus on the time period from the last quarter of 2019 (2019Q4) to the first quarter of 2021 (2021Q1) to estimate the price responses. The non-parametric estimation allows us to estimate heterogeneous price responses systematically without imposing a restrictive functional form, e.g., on the link between the responses and characteristics of the municipalities.

We estimate the effect of the pandemic on real estate prices in the first quarter of 2021. As measures for the severity of the pandemic at the municipal level, we use the incidence of Covid infections or short-time work cumulated between January and December 2020. We distinguish six different outcomes: rents and sale prices for residential real estate or commercial real estate, for which we can distinguish retail and office real estate. We investigate the heterogeneity of the effects across the following dimensions:

[2]The so-called affordability crisis or housing crisis is relevant in many developed countries. Deutsche Welle (2022) is an example of the discussion on the affordability crisis in the German context.

the (pre-pandemic) price segment, rural versus urban municipalities, household income, the capability of employees to work from home, broadband internet access, and the type of offered real estate units. These characteristics seem particularly interesting to capture some of the heterogeneity on the demand and supply side in local real estate markets.

We find that, on average, the pandemic had stronger effects on prices for commercial than residential real estate in Germany. The estimates of our preferred specification imply that rents for the retail estate in municipalities with a high rather than low incidence of Covid infections have been 3.5% lower in the first quarter of 2021. We do not find a clear-cut effect of the incidence of Covid infections on the rents for residential or office real estate instead. We further find that a high rather than low incidence of short-time work reduced rents for offices by 3.2% in the first quarter of 2021 but had a positive effect on rents for residential and retail real estate.

The effects on prices of real estate units for sale in the same time period allow us to gauge whether the effect of the pandemic on rents has been expected to be short-lived, given that the fundamental value of real estate prices equals the present value of the stream of rents today and in the future. We find that the effect on prices of real estate units for sale has been negligible or very small when rents decreased, indicating that the reduction of rents for commercial real estate in the instances reported above has been expected to be only temporary.[3] One interpretation is that the negative demand shock for some real estate types during the first year of the pandemic in Germany has been (expected to be) only temporary. In particular, we do not find economically significant reductions in the collateral value of the real estate on average, which suggests that the pandemic did not have a lasting impact on economic activity through this channel. A possible explanation for this finding in the German context is that government support programs for households and firms have been generous so that demand for real estate did not fall persistently.

[3]Of course, the relationship between rents and prices of real estate may also be affected by changes in the expected returns of real estate with which the stream of rents is discounted. The expected returns may change because of changes in the risk-free rate or risk premia for real estate. Such changes cannot explain the different signs in the response of rents and sale prices, however, when the estimated response of rents is negative.

In terms of the heterogeneity of the price responses, our results indicate that the effects tend to be larger in absolute terms for municipalities that have been in the high-price segment in the last quarter of 2019, in more urban areas with denser residential housing, higher income households, more jobs with home-office capability, and broadband internet access.

Concerning the affordability crisis for residential real estate, the point estimates imply that a higher incidence of short-time work exacerbated the crisis somewhat by increasing rents for residential real estate more in municipalities in which rents had been high already prior to the pandemic. A higher incidence of Covid infections instead had a countervailing effect. Quantitatively, both effects are negligible though and not statistically different from zero at conventional levels. Further analysis of the effect of the pandemic across the price distribution reveals that the pandemic did not have a clear-cut implication for the affordability crisis of residential real estate in Germany.

Concerning the urban premium for commercial real estate associated with the top price segment, short-time work and the incidence of Covid infections had countervailing effects, with a higher incidence of Covid temporarily reducing the corresponding premium for rents of retail real estate. Overall, we find that the pandemic increased the asset-price premium for real estate units that have been in the top segment of the price distribution prior to the pandemic. However, the premium for rents of some real estate units decreased temporarily.

Prices in real estate markets thus have responded differently to the pandemic shock in Germany compared to other developed countries such as the U.S., where the pandemic reduced price pressure for relatively more expensive commercial and residential real estate in, or close to, city centers (Gupta et al., 2022; Gupta, Mittal, & Van Nieuwerburgh, 2022; Mondragon & Wieland, 2022; Ramani & Bloom, 2021; Rosenthal, Strange, & Urrego, 2022). Hence, the implications of the pandemic for the asset prices of real estate, land-use planning, and public finances are quite different in Germany compared to the U.S., on which much of the recent research has focused. Such different responses of asset prices to the pandemic shock seem intuitive in the context of real estate markets which are

segmented across real estate types and geographic locations and which have been hit by the pandemic with different intensities.

## Our contribution in the context of the related literature

The Covid crisis has triggered a combination of demand and supply shocks across the economy (Baqaee & Farhi, 2022; Guerrieri et al., 2022). Our results suggest that the combinations of these shocks and the associated economic policy responses, on average, have not reduced asset prices of real estate in Germany one year after the pandemic started, i.e., in 2021Q1. The negative effects on rents of retail real estate in response to higher Covid infections, and rents of offices in response to short-time work, have been (expected to be) only temporary.

Compared to evidence for the U.S. (Gupta et al., 2022; Ramani & Bloom, 2021), we find that housing demand in Germany seems to have shifted less from dense urban centers to more spacious suburbs. Gupta et al. (2022) find that the premium for residential real estate in centers of U.S. cities has fallen during the pandemic. Ramani and Bloom (2021) document a 10% decrease in rents in high-density areas of the 10 largest U.S. cities, associated with a fall in prices of commercial real estate in these areas and a higher exposure to working from home. We find instead that in Germany, there have been countervailing effects of more Covid infections and more short-time work on asset prices of real estate in municipalities with more urban characteristics and more jobs with home office capability.

Delventhal, Kwon, and Parkhomenko (2022) and Mondragon and Wieland (2022) analyze the effect of remote work on the demand for housing associated with the pandemic. Mondragon and Wieland (2022) estimate that more than half of the house price increase since 2019 at the national level in the U.S. can be explained by this channel. We find that, for Germany, the estimated price responses of residential real estate to the pandemic shock are quantitatively less sensitive to differences in the incidence of home office capability across municipalities.

We contribute to the literature on the effect of pandemics on cities and real estate

markets, as discussed in Baum-Snow, Glaeser, and Rosenthal (2022) and the references therein. Concerning the effects on commercial real estate, Rosenthal, Strange, and Urrego (2022) estimate that the premium for providing better access to cities, employment dense areas, or transit stations decreased in the U.S. at the beginning of the Covid pandemic. Gupta, Mittal, and Van Nieuwerburgh (2022) estimate a large, persistent decline of 40% for the values of office real estate in New York. Ling, Wang, and Zhou (2020) analyze the effect of the Covid shock on prices of commercial real estate traded on the stock market. They analyze the effect of the Covid-19 pandemic in U.S. regions on the stock-market valuation of real estate investment trusts (REITs) that have different portfolios of commercial real estate.

As mentioned by Ling, Wang, and Zhou (2020), REITs cover only a specific part of the real estate market, and it is unclear to which extent results on price effects for REITs apply to the much larger private real estate markets where transaction costs are larger, and trade is often intermediated by real estate agents. We thus first provide descriptive evidence on the performance of REITs and other real estate investment funds traded on the stock market in Section 2, to put the price response on the German real estate market into an international context. We then analyze the effect on residential and commercial real estate in private markets, exploiting new granular data for Germany. The regional granularity allows us to identify causal price responses to the pandemic by comparing municipalities with different incidences of Covid infections or short-time work. We also use the granular data to estimate heterogeneous price responses for commercial and residential real estate across different types of municipalities.

Related literature has analyzed the effect of pandemics on the real estate market from a historical perspective. Ambrus, Field, and Gonzalez (2020) analyze the effect of the cholera pandemic in London, Francke and Korevaar (2021) investigate the effect of the plague in Amsterdam and the cholera pandemic in Paris, and Wong (2008) gauge the effect of the SARS pandemic in Hong Kong. Their results suggest that the long-run effect of a pandemic on house prices and rents depends on the policy response in terms of infrastructure investment or changes in the type of newly built housing structures. In the

short run, demand effects may trigger non-negligible changes in supply only in specific circumstances when existing real estate units can quickly be put to a different use. For example, rental of housing units shifted from short-term tourist to long-term residential tenancy in Lisbon when the Covid pandemic reduced tourism in Portugal (Batalha et al., 2021).

We estimate the effects on the housing market in Germany during the first year of the pandemic. This provides useful insights into whether there have been quantitatively sizable effects of the shock in the market of real estate units that existed at the time of shock and, if so, whether certain market segments have been affected more strongly. Construction of new real estate as a reaction to the Covid shock is negligible over the time horizon we analyze. In per cent of the stock of existing residential real estate buildings, for example, new residential real estate buildings accounted for less than 1% in 2019 and 2020.[4]

Our analysis adds to recent analyses of the German residential real estate market based on disaggregated data. For example, Kaas et al. (2021) investigate the determinants for the much lower owner occupation rate in Germany than in the U.S. and Kindermann et al. (2022) analyze learning about housing costs in the German real estate market. In particular, the sale prices and rents for residential real estate reported in Kindermann et al. (2022), based on the proprietary data for 401 German counties by *Bulwiengesa*, provide a useful benchmark for our more granular data at the municipal level. The data by *Bulwiengesa* are based on primary and secondary data sources, i.e., transaction prices as well list (ask) prices, whereas the data provided by *21st Real Estate* are based only on list (ask) prices. Key for our empirical analysis is that the new more granular data by *21st Real Estate* allow us to capture the effect of heterogeneous characteristics in real estate markets at the municipal level, as we are able to exploit the ten times larger sample

[4]Statistics with IDs 70370 and 70094 retrieved from the *Federal Statistical Office* on October 16, 2021. Note further that converting real estate from office to residential use, for example, is costly and takes time. Generally, the supply side in the real estate market has not been affected much in Germany in our sample period. The construction sector continued to operate. Both the number of completed real estate units and the number of issued construction permits remained stable between 2019 and 2020. The number of completed real estate units differed across regions, but these differences remained stable between 2019 and 2020.

size of 4,162 observations in the non-parametric analysis of the data.

From a methodological point of view, our paper relates to research applying machine learning techniques to capture the non-linear effects of attributes of real estate units on their prices (Yazdani, 2021). We implement the Modified Causal Forest (Lechner & Mareckova, 2022), a recently developed estimator which builds on the machine learning literature surveyed by Hastie, Tibshirani, and Friedman (2009) to estimate causal effects. The Modified Causal Forest (MCF) extends the Causal Forest of Wager and Athey (2018). It allows for the estimation of effects for multiple treatments at different levels of aggregation (individual, group, population average) with a unified estimation and inference approach. Appendix A provides further details on the application of this method for our analysis.

Our analysis proceeds in the following steps. In Section 2, we provide some background on the real estate market and the Covid pandemic in Germany and descriptive evidence on the geographic variation contained in real estate prices and our measures for the epidemiological and economic incidence of the pandemic. In Section 3, we describe the granular data further and then explain our estimation approach in Section 4. In Section 5, we present the main results on the heterogeneous price responses of real estate across German municipalities and the implications for the premium of real estate in the top price segment. In Section 6, we discuss the results and then conclude in Section 7. In the Appendix we provide additional estimation results on the price responses. We also explain the construction of the sample and compare the aggregate trends in the data on house prices and rents from *21st Real Estate* to other existing data sources. The appendix further contains cross-country evidence on the performance of real estate investment funds which puts the changes in real estate valuations in Germany into an international context.

## 2 Background and descriptive evidence

We describe the real estate market in Germany and the associated economic policies during the Covid pandemic and illustrate the geographic variation contained in real es-

tate rents and sale prices as well as our measures for the epidemiological and economic incidence of the pandemic.

## 2.1 Residential and commercial real estate in Germany

Germany is a country with a low owner-occupation rate of 46.5%, so more than half of the households rent their main residence. There is a large regional variation in ownership rates with an owner-occupation rate of less than 20% in cities such as *Berlin* and a rate of 65% in the *Saarland*.[5] During the low-interest rate environment prior to the pandemic between 2010 and 2019, rents for residential real estate have increased by 14% on average, and house prices doubled in many cities.[6]

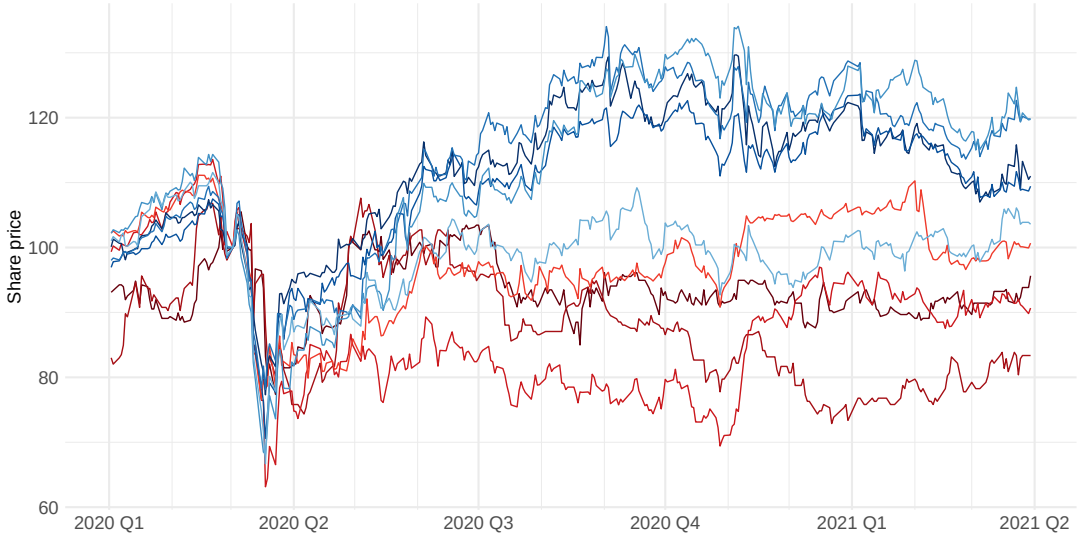



Figure 1: The performance of German real estate investment funds during the pandemic. Notes: Residential real estate funds are in blue colour, commercial real estate funds in red colour. See Appendix B for further details on the funds. Share prices of traded commercial and residential real estate funds are normalized to 100 on March 2, 2020. Source: *YahooFinance*, accessed on October 1, 2022.

We gauge the extent to which the Covid-19 shock may have affected real estate valuations of residential or commercial real estate in Germany by inspecting the stock-market

[5]These reported statistics are based on the last micro census in 2018 and have been retrieved from the *Federal Statistical Office* on October 15, 2021.

[6]The reported statistics have been retrieved from the *Federal Statistical Office* and *empirica-regio* on June 1, 2022. Kaas et al. (2021) provide further background on the German real estate market and Kindermann et al. (2022) show that the recent decade of strong price growth in Germany occurred after decades of modest price growth between the 1970s and 2010.

valuation of real estate funds in Germany. We use daily data from Yahoo Finance on real estate investment funds for Germany. Table 3 in Appendix B contains the names of the funds used for Germany as well as the analogous real estate funds in France, Italy, Spain, Switzerland, the U.K., and the U.S. to put the performance of the funds in Germany into an international context.

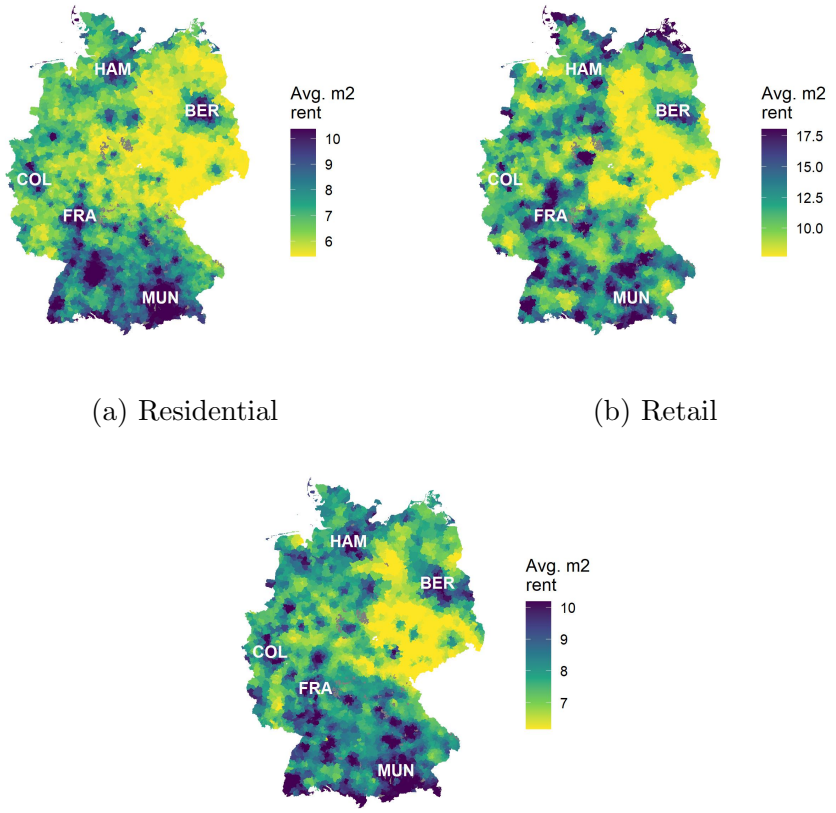
Figure 1 shows that the performance across German funds has been very heterogeneous, in particular since the beginning of March 2020 when the first wave of Covid infections hit Europe and the U.S. In contrast to the other countries (except Switzerland), German residential real estate funds recovered from the initial losses in valuation in March 2020 so that by September 2020 they had a higher valuation than at the beginning of the year. Table 4 in Appendix B shows that the better performance of residential real estate funds than commercial real estate funds is particularly pronounced in Germany and Switzerland relative to the other countries. The table further shows that some commercial real estate funds specialized in real estate used for storing and distributing goods increased in value during 2020, such as Tritax Big Box in the U.K.

Compared to the evolution of aggregate price indexes on residential and commercial real estate, the changes in the valuation of real estate funds have been large. The aggregate price index for residential real estate in Germany increased by 1.3% between the first and second quarter of 2020.[7] The aggregate price index for commercial real estate decreased by 0.3% and thus only moderately between the first and second quarter of 2020.[8] The smaller changes in the aggregate price indexes likely reflect the limited diversification of the traded real estate funds that specialize in certain real estate types.

The descriptive results for the publicly traded real estate funds suggest that the performance of real estate has been very heterogeneous during the pandemic in 2020. The results reveal that it is important to distinguish residential from commercial real estate in our analysis with the more granular data. The difference between the performance of real estate funds and the aggregate real estate price series indicates that the changes in

[7]See the series Q:DE:R:628 provided by the Bank of International Settlement (BIS). Other indices imply similar changes of 1.1% (Pfandbriefbanken), 1.8% (Destatis), and 2.1% (Hypoport).

[8]See the series Q:DE:0:C:0:2:6:0 provided by the Bank of International Settlement (BIS) or the index provided by *Pfandbriefbanken*.




(a) Residential

(b) Retail

(c) Office

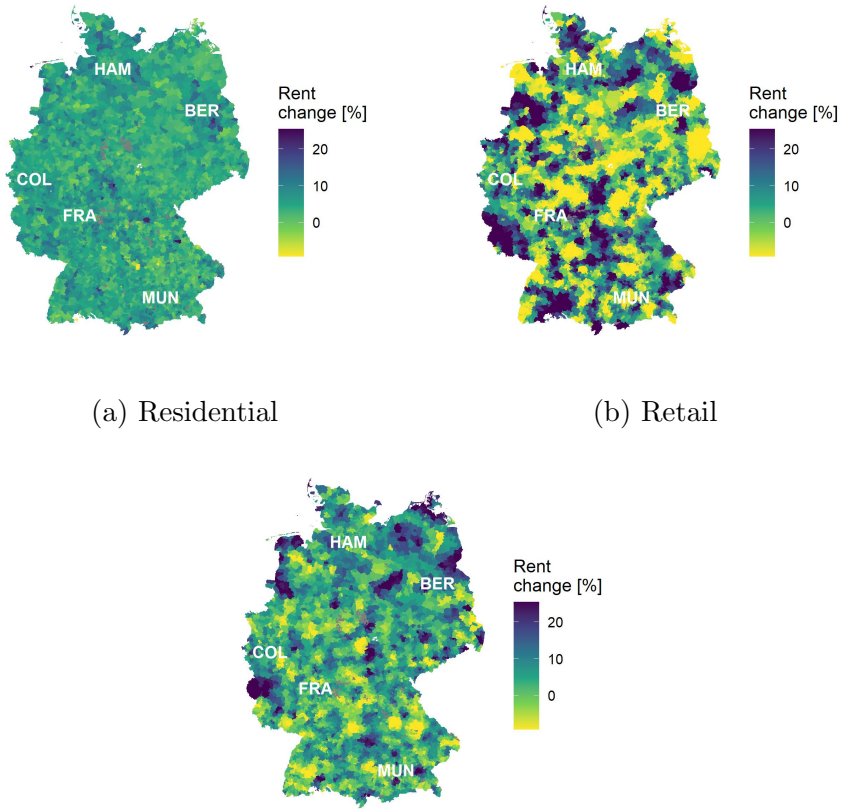
Figure 2: Rents by real estate type, across geographic areas prior to the pandemic in 2019Q4.
Notes: Rents per month and in units of $€/m^2$. The cities indicated on the map are abbreviated as follows. BER: Berlin, COL: Cologne, FRA: Frankfurt, HAM: Hamburg, MUN: Munich. Source: *21st Real Estate*.

real estate prices during the pandemic may have been quite different in private markets compared to publicly traded funds. For a representative analysis of price changes in the real estate market during the pandemic, we thus analyze the new granular data on rents and prices in private markets provided by *21st Real Estate*.

Based on the granular data, Figure 2 (and Figure 12 in Appendix C.4) illustrate that rents and sale prices for residential and commercial real estate in 2019Q4, i.e., prior to the pandemic, have been heterogeneous across German municipalities but highly correlated across real estate types within municipalities. This is intuitive because the price of land is a key determinant for both residential and commercial real estate.

Figure 3 (and Figure 13 in Appendix C.4) illustrate that the *changes* of rents and sale

prices during the pandemic between 2019Q4 and 2021Q1 instead are quite different for residential and commercial real estate. Rents for residential real estate increased between 2% and 9% across municipalities. For office and retail real estate, rents changed between −10% and +25%, thus exhibiting much more heterogeneity, including large decreases in rents in some municipalities.[9] In our analysis, we will combine the different price responses across municipalities and residential and commercial real estate types with different intensities of the pandemic shock at the municipal level, as measured by the incidence of Covid infections or short-time work. We describe these measures further in the next subsection.




(a) Residential

(b) Retail

(c) Office

Figure 3: Changes in rents by real estate type, across geographic areas between 2019Q4 and 2021Q1.
Notes: The cities indicated on the map are abbreviated as follows. BER: Berlin, COL: Cologne, FRA: Frankfurt, HAM: Hamburg, MUN: Munich. Source: *21st Real Estate*.

[9]Figures 12 and 13 in Appendix C.4 show that the level and the change of sale prices have similar patterns as described for rents. Figure 14 in Appendix C.4 further displays the regional patterns in the sale price to annual rent ratio. The population-weighted average of the price-rent ratio is 27 for residential real estate, in line with values reported in Kindermann et al. (2022), Figure 4a.

Combining the evidence of Figures 2 and 3, we investigate whether there is a systematic association between the rent *level* in 2019Q4 and the subsequent *change* until 2021Q1 for commercial real estate. The correlation between the rent level and the subsequent change is −0.01, −0.24, and −0.22, respectively for residential, retail and office real estate. This illustrates that the distribution of rents for commercial real estate has become more equal after the pandemic, whereas this is not the case for residential real estate. Our analysis will allow us to gauge to which extent these descriptive changes (or the lack thereof) are related to the causal effect of the pandemic. We thus return to this evidence in subsection 5.2.1.

## 2.2 The geographic incidence of the pandemic

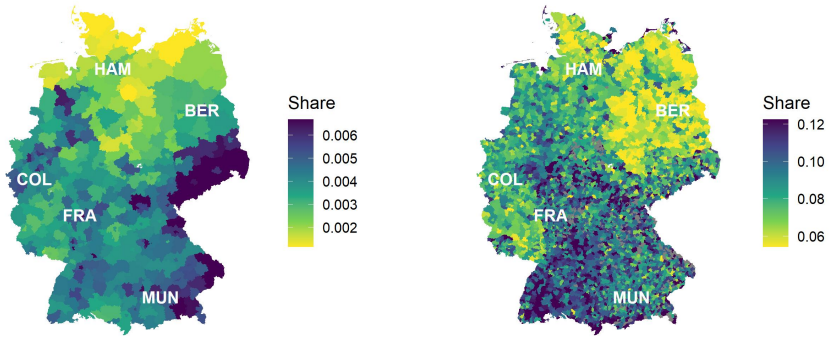
We use the incidence of Covid-19 cases and short-time work, cumulated from January 2020 when the first infections were recorded in Germany, as measures for the epidemiological and economic incidence of the pandemic.[10] We construct the cumulated incidence of short-time work for each municipality by combining data on short-time work in 20 industries at the regional level (*Bundesland*) with the employment shares in these industries in each municipality before the pandemic. Appendix C contains further details on how the measures of the pandemic incidence are constructed.

Figure 4 shows the cumulated share of reported Covid-19 cases and short-time work in Germany in December 2020, at the peak of the second wave. Figure 4a shows that most of the Covid cases until December 2020 occurred in the South, South-East, and the urban, densely populated areas such as Berlin and the Ruhr area. Figure 4b shows that the incidence of short-time work has been highest in the South of Germany, particularly the South-West, and that it is less linked to urban municipalities than the Covid incidence.[11] Figure 10 in Appendix C.2 shows that characteristics of municipalities, such as the share

[10] Estimating joint effects of the epidemiological and economic incidence would lead to such small sample sizes per combined incidence that there are not enough municipalities with similar characteristics across the joint incidence categories to determine the effects (no common support). Thus, we cannot estimate such effects.

[11] Note that information on the Covid incidence is available at the county level (*Landkreise* and *kreisfreie Städte*), implying fewer entries on the map. In the analysis, we assign the same value to all municipalities in a county.

of employment in jobs with home office capability or broadband internet access, are also positively correlated with more urban areas.




(a) Covid incidence (b) Short-time work

Figure 4: Share of reported Covid cases and short-time work across geographic areas cumulated between January and December 2020.
Notes: The Covid incidence is available at the county level. Our measure for the incidence of short-time work varies at the municipal level. The cities indicated on the map are abbreviated as follows. BER: Berlin, COL: Cologne, FRA: Frankfurt, HAM: Hamburg, MUN: Munich.
Sources: *Robert Koch Institute*, *Federal Employment Agency*, *21st Real Estate*.

## 2.3 Policy measures during the Covid-19 pandemic

Economic policy tried to help businesses and households to cope with the economic consequences of the pandemic. Most of the policy measures during the pandemic in Germany were financed by the federal government and some by the regional government or social insurance schemes. The changes reported for the public budget in Germany between 2019 and 2020 reveal that more than 62% of the change in the public budget resulted from a deterioration of the federal government budget, 21% from the regional government budget, 15% from social insurance schemes, e.g., because of increased funding of short-term work, and only 2% from changes in the budget of municipalities (based on the press release 169 of the federal statistical office, accessed on October 29, 2021).

The federal government provided businesses with additional credit, offered subsidies and recapitalizations, credit guarantees, and implemented a moratorium on insolvency rules (as documented on the website of the federal ministry of economic affairs and energy,

accessed on October 29, 2021). These measures tried to help businesses, which typically operate and have business relationships in more than just one municipality. Although we cannot construct a separate variable to capture the incidence of the policy measures at the municipal level, we capture possible heterogeneous outcomes caused by the policy measures in our estimations, e.g., by allowing the price effects of the pandemic to vary across municipalities with different industry structures.

The German government also imposed regulatory measures to contain the pandemic. The different timing of these measures across municipalities implied only very short-lived differences in regulation. To the extent that differences in the epidemiological and economic incidence of the pandemic, i.e., the incidence of Covid infections or short-time work, triggered a faster implementation of regulatory measures in some municipalities, the resulting price effects are included in the price responses we estimate if they persist until 2021Q1.[12]

# 3 Data

The granular data provided by *21st Real Estate* is key for our empirical analysis both from an economic and methodological point of view. The granular data allow us to uncover the heterogeneous responses of real estate prices to the global pandemic shock, exploiting variation at the municipal level. Furthermore, the granularity of the data implies a sample size that allows us to apply causal machine learning so that the heterogeneous responses can be estimated without relying on restrictive functional form assumptions.

The data provided by *21st Real Estate* for 2019Q1 to 2021Q1 are based on web

[12]The different timing of regulatory measures across municipalities, which occurred between the two price measurements in 2019Q4 and 2021Q1 used in the estimations, seem more relevant for the price dynamics *between* 2019Q4 and 2021Q1 rather than for the prices in 2019Q4 and 2021Q1. For the pricing in 2021Q1, the differences in the timing of lockdowns across regions during the first and second waves in 2020 are a matter of the past. From April 2021 onwards, the infection protection act established a common regulatory framework relevant to the fundamental component of real estate prices in 2021 which depends on the present value of expected *future* rental income or the corresponding utility derived from housing services if the unit is owner-occupied. For the pricing in 2019Q4, the regulatory measures during 2020 have been *un*expected so that they have not been priced in the real estate valuations prior to the pandemic. A qualifier is that the price data provided by *21st Real Estate* are one-sided moving averages based on observations in the past year such that price dynamics before 2021Q1 may affect the price in 2021Q1 through this channel.

scraping of list (ask) real estate prices and aggregated to the municipal level for our purposes.[13] Rents and sale prices are available for residential, retail, and office real estate. The quarterly data are weighted averages based on the last four quarters. *21st Real Estate* focuses on market prices for real estate units so that they discard data on publicly subsidized real estate. Various outlier detection procedures ensure that the data is representative and of good quality.

Because these data have not been used for scientific research so far, we validate the data by comparing them with data from other sources in Appendix D. We find similar (aggregate) trends in the granular list price data for residential real estate provided by *21st Real Estate* as, for example, in data provided by *Bulwiengesa* further analyzed by Kindermann et al. (2022). The *Bulwiengesa* data are based on primary and secondary sources but are less granular than the data we use. The *Bulwiengesa* data are constructed using data on transaction prices and list prices as well as survey data from real estate market participants. Our validation reveals similar price trends for residential real estate across the data sets from different sources, which is consistent with evidence for other countries that list prices and transaction prices are highly positively correlated (Ardila, Ahmed, & Sornette, 2021; Gupta et al., 2022).

For commercial real estate, we find that the aggregate trends in the data provided by *21st Real Estate* are somewhat different than in other available data sources, particularly for retail real estate. We discuss possible reasons for these differences in Appendix D and emphasize that our estimations rely not on these aggregate changes but on the differences in price changes across municipalities.

We use municipalities as units of observation.[14] We discard municipalities with less than 2,500 inhabitants to ensure a certain size of the real estate market for each municipality in the sample. This leaves us with quarterly data for 4,162 municipalities between

[13]The price data are generated on very small geographic tiles by gathering the offers closest to each tile and weighting them by distance to the tile center. The aggregation to the municipal level is then achieved by taking a weighted average across the tiles contained in a municipality using the offer frequency for each of the tiles as weight.

[14]More precisely, we use municipalities or associations of municipalities (*Gemeindeverbände*) if they exist. The associations allow very small municipalities to benefit from joint administration while maintaining autonomy otherwise.

2019Q1 to 2021Q1. In Appendix C we provide further details and descriptive statistics for the variables capturing the pandemic incidence and the covariates, together with the respective data sources.

# 4 Estimation

We estimate the response of rents and sale prices in the real estate market to the Covid pandemic, focusing on the changes between 2019Q4 and 2021Q1. We identify the causal effect of the pandemic using variation in the pandemic incidence across municipalities. This approach allows for more credible identification than straightforward comparisons of outcomes over time. Still, it comes at the cost that effects of the pandemic that are common across municipalities are not captured by our estimates.

We use two alternative measures for the epidemiological and economic incidence of the pandemic as our treatments, which both vary at the municipal level: the cumulated incidence of Covid infections and the cumulated incidence of short-time work between January and December 2020. We discretize both incidences into three categories (low, medium, high), corresponding to the terciles of the respective distribution. We take logarithms of rents and sale prices so that the estimations deliver estimates for the changes in rents and sale prices in relative terms. In the benchmark specifications, we weight the observation for each municipality by its population. In subsection 5.1.2 we also present and discuss the results of the unweighted estimation.

We rely on the efficient market hypothesis (EMH) in the benchmark specification and thus use only the prices in 2019Q4 to control for possible confounders (Fama, 1970). According to the EMH, the prices for residential, retail, or office real estate at the municipal level in 2019Q4 capture all information and, thus, all the heterogeneity relevant to the pricing that is available at this point in time. Hence, any changes to the prices after 2019Q4 are true innovations. In particular, the changes in the prices after 2019Q4 are unpredictable with information available in 2019Q4 and may be explained by the subsequent pandemic as measured by the incidence of the Covid cases or short-term work.

Whereas the pure EMH would only require to condition on the respective sale prices in 2019Q4 of the real estate type associated with the outcome variable, we apply a weaker version of the EMH by conditioning on the sale prices of residential, retail and office real estate as well the corresponding rents in 2019Q4 in the specification for each real estate type. This way, we condition on all the information contained in the sale prices and rents across real estate markets in all specifications. It implies that we estimate the same specification for sale prices and rents of residential, retail and office real estate.[15]

Given that empirical evidence suggests some inefficiency in real estate markets (Case & Shiller, 1989; Piazzesi & Schneider, 2016), we check the validity of the EMH by estimating a richer, alternative specification with further control variables in subsection 5.1.2. These controls account for observable heterogeneity across municipalities on the demand and supply side prior to the pandemic, i.e., in 2019Q4. In Appendix C.4 we describe the set of controls in more detail.

We estimate the price responses to the pandemic non-parametrically applying a modified causal forest (Lechner & Mareckova, 2022). Appendix A provides a short description of the methodology of the modified causal forest estimator. The method allows to the construction of estimators for price responses at different levels of aggregation. The average treatment effect (ATE)

$$\text{ATE}(m, l) = \mathbb{E}\left[Y^m - Y^l\right] \tag{1}$$

denotes the average effect between two treatments $m$ and $l$ at the population level. The group average treatment effect (GATE)

$$\text{GATE}(m, l, z) = \mathbb{E}\left[Y^m - Y^l | Z = z\right] \tag{2}$$

denotes the average treatment effect when conditioning only on a subset of covariates $z$ (heterogeneity variables). The individualized average treatment effect (IATE)

[15] Although the EMH applies to asset prices, the rent and the fundamental asset price map into each other in efficient markets. As is well known, a particularly simple linear mapping obtains between the current rent and the sale price if one assumes constant rent growth and discount rates (Campbell & Shiller, 1988).

$$\text{IATE}(m, l, x) = \mathbb{E}\left[Y^m - Y^l | X = x\right] \tag{3}$$

is the lowest level of aggregation and denotes the treatment effect when conditioning on all covariates $x$. The GATE and IATE are well suited to uncover heterogeneity in treatment effects across municipalities which differ, for example, in terms of the price segment in the real estate market, the degree of urbanization, the incidence of jobs with home office capability, or average household income. The full set of heterogeneity variables and covariates is listed in Appendix C.4.

# 5 Price responses to the pandemic shock

We first present the results for the average treatment effect (ATE) of the incidence of Covid infections or short-time work on rents and sale prices. We weight observations with population density in the benchmark specifications to account for changes in rents or prices in densely populated municipalities affecting more persons than in sparsely populated municipalities. We then report the results of robustness checks for specifications without weights or with a richer set of covariates as controls. We also investigate the heterogeneity of the effects by inspecting how the IATEs are associated with covariates of interest.

## 5.1 Average effects

### 5.1.1 Benchmark specification

Figure 5 illustrates the price responses in log point changes after changing from low to high epidemiological or economic incidence of the pandemic. Results for the price responses after changing from low to medium incidence or medium to high incidence are available upon request.

Figure 5 shows that the average effects on rents and sale prices are smaller (in absolute terms) for residential than for commercial real estate. Concerning the average effect of a

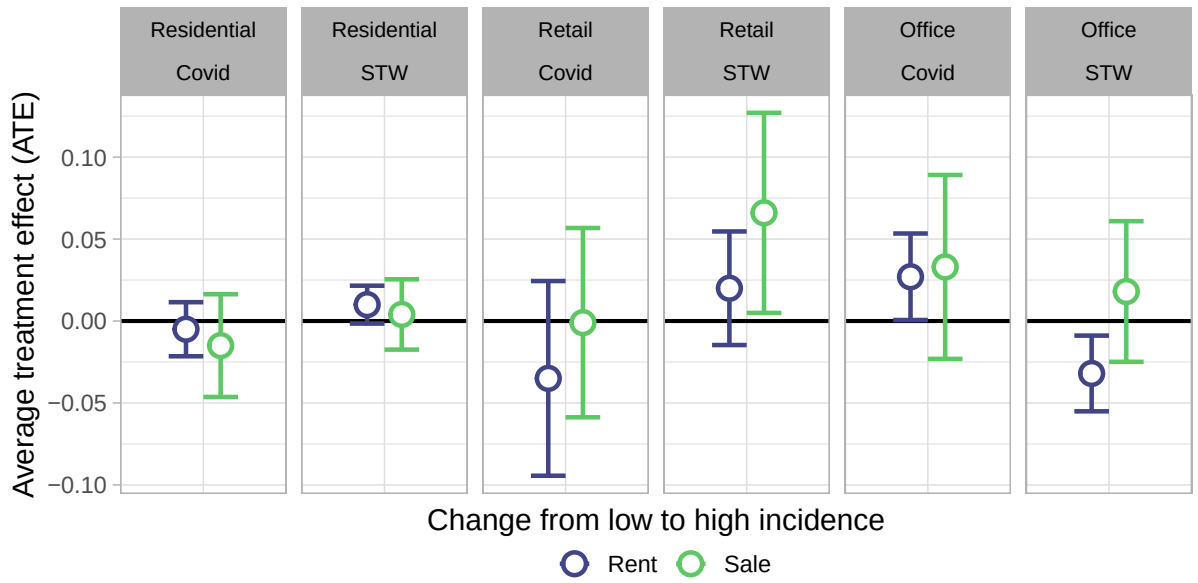



Figure 5: Average effect on rents and sale prices.
Notes: Effect of moving from low to high incidence in log point changes; 90% confidence intervals; *Covid* denotes the effect of a higher Covid incidence, and *STW* denotes the effect of a higher incidence of short-time work.

higher Covid incidence, we find that a high rather than low Covid incidence reduced rents for retail real estate by 3.5%. Although not statistically significant at conventional levels in the benchmark specification, the negative effect on rents of retail real estate turns out to be robust and is more precisely estimated in alternative specifications reported below. We further find that a high rather than low Covid incidence left residential real estate rents almost unchanged, where the point estimate implies a small reduction of −0.5% that is not statistically significant at conventional levels. There is also no clear-cut effect of a higher Covid incidence on office rents. Although the point estimate is positive at 2.7% in the benchmark specification, our robustness checks below reveal that the sign of the coefficient is not robust in the unweighted estimation, and smaller at 2.4% and no longer statistically significant at a 90% level if we add further controls to the specification.

Concerning the average effect of short-time work, Figure 5 shows that a high rather than low incidence of short-time work reduced office rents by 3.2%. The effect on residential and retail real estate has been smaller with point estimates of 1% for residential and 2% for retail real estate, where the estimate for retail is more noisily estimated.

Figure 5 further shows that the effect on sale prices of both a higher epidemiological or

economic incidence of the pandemic is either close to zero or positive. This suggests that market participants expected the negative effect on rents (for retail real estate with higher Covid incidence and for office real estate with higher short-time work incidence) to be only temporary because the fundamental value of the sale price depends on current and expected future rents.[16] The positive effect on sale prices in most estimated specifications suggests that there has been no persistent negative demand effect for real estate on average after the Covid shock in Germany.

In terms of the size of the effects, the 1% increase in rents for residential real estate with a higher short-time work incidence, for example, corresponds to roughly a quarter of the annual increase of rents of residential real estate at the aggregate level reported in Table 9 in Appendix D. Of course, the effect we estimate is identified by variation across municipalities, implying, for the example above, that municipalities with an incidence of short-time work in the top rather than bottom tercile of the distribution of short-time work incidence experienced a slightly stronger growth of rents and no significant change of sale prices for residential real estate.

The finding of sizable, temporary negative effects on rents for commercial rather than residential real estate in some specifications (a higher Covid incidence for retail and a higher short-time work incidence for office real estate) is qualitatively similar to the suggestive evidence on publicly traded real estate in Figure 1. Quantitatively, the temporary changes observed for the publicly traded funds are larger than for the prices in private real estate markets. Differences between results reported in Figures 1 and 5 may be expected for various reasons. The traded funds are typically not well diversified by construction because they focus on specific locations or industries within municipalities. Furthermore, the time series changes in Figure 1 also contain effects that are common across municipalities, caused by the pandemic or any other event in the considered period.

[16]The sale price further depends on the expected return of housing with which the stream of rents is discounted. Changes in the expected return may dampen or amplify how changes in (expected) rents affect sale prices. Still, they cannot explain the different signs of the response of rents and sale prices observed for retail or office real estate in some of the estimated specifications. Returns of housing may differ, for example, because risk premia differ across locations (Amaral et al., 2021).

### 5.1.2 Robustness

We report robustness results for the specifications in which we either do not weight by municipality population or use a rich set of further control variables. For brevity, we focus on the effect on rents for which the benchmark specification revealed more variation across real estate types for the effects of the epidemiological and economic incidence of the pandemic.

**Weighting**


Figure 6: Average effect on rents with and without population weighting.
Notes: Effect of moving from low to high incidence in log point changes; 90% confidence intervals; *Covid* denotes the effect of a higher Covid incidence, and *STW* denotes the effect of a higher incidence of short-time work.

Figure 6 shows that the results are by and large robust when we do not weight municipalities by population in the estimation. An exception is the effect of Covid incidence on office rents which changes signs and becomes negative. Comparing the displayed average effects on rents, the figure shows that the weighted estimates have a somewhat larger magnitude (in absolute terms) in most specifications. This suggests a correlation between individualized effects and the weight to which we return below in the subsection on the heterogeneity of the effects.

**Further controls**

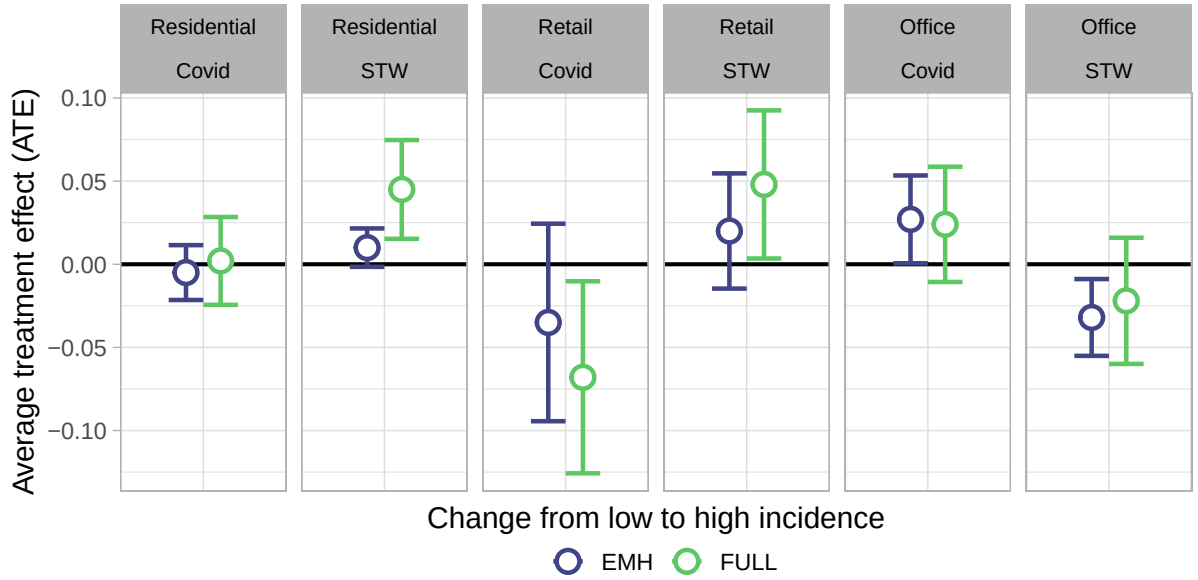



Figure 7: Average effect on rents with further covariates.
Notes: Effect of moving from low to high incidence in log point changes; 90% confidence intervals; *Covid* denotes the effect of a higher Covid incidence, and *STW* denotes the effect of a higher incidence of short-time work.

Figure 7 compares the estimates for the effect on rents in the parsimonious benchmark specification with the estimates in the specification with a set of further control variables, described in Appendix C.4. Figure 7 shows that the efficient market hypothesis (EMH), which motivated our benchmark specification, is a reasonably good approximation in our application. The estimates in the specification with further controls do not differ significantly from the results of the benchmark specification. It is worth mentioning, however, that the point estimates increase substantially in absolute terms and are different from zero at conventional levels of statistical significance for (i) the (positive) effect on rents of residential and retail real estate with a higher short-time work incidence, and (ii) the (negative) effect on rents of retail real estate with a higher Covid incidence. For the (negative) effect of a higher incidence of short-time work on office rents, the point estimate becomes smaller and less precise.

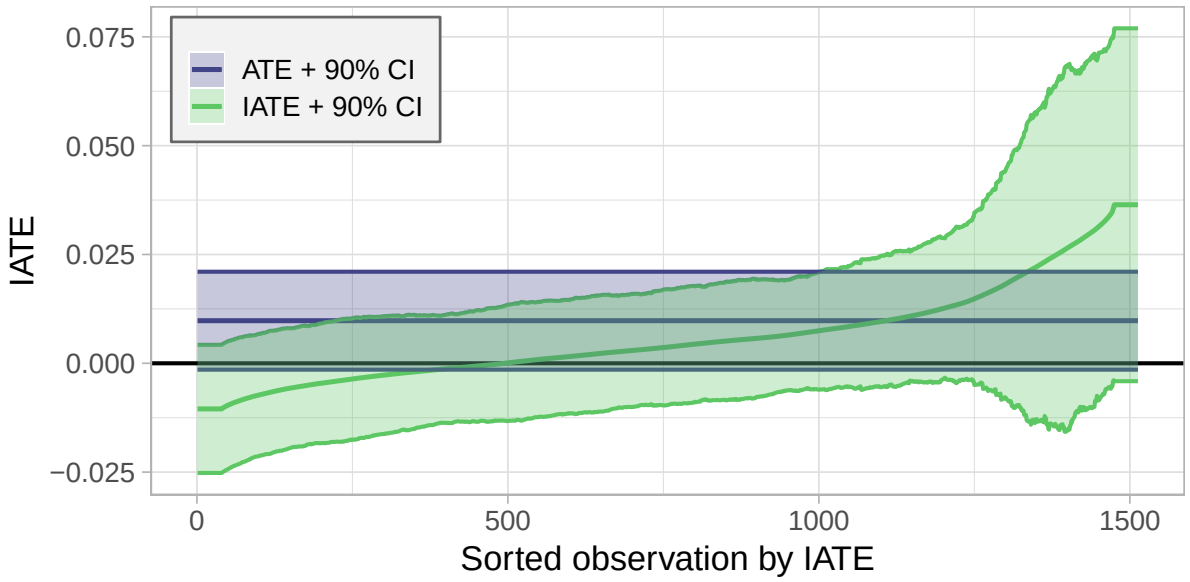



Figure 8: Sorted individualized effect of short-time work on residential rents.
Notes: Effect of moving from low to high incidence in log point changes.

## 5.2 Heterogeneity of the effects

The estimation based on the modified causal forest allows us to investigate to which extent the effects vary across municipalities with different characteristics without making parametric assumptions. Figure 8 displays the sorted individualized average treatment effects (IATEs) for a representative combination of outcome and treatment: the effect of short-time work on rents of residential real estate in the benchmark specification. The figure shows that all IATEs are quite close to the average effect. This evidence suggests that effect heterogeneity is unlikely to be identified along the dimension of a single control variable at a common statistical significance level unless this variable exhibits a near-perfect correlation with the IATEs. Inspecting the GATEs defined in (2) for each of the heterogeneity variables listed in Tables 7 or 8, we do not find statistically significant evidence for heterogeneous effects with respect to a single heterogeneity variable.[17] Because the lack of significance may partly result from the limited sample size, we take an alternative route to illustrate how the characteristics of municipalities are related to the variation in the IATEs.

[17] Estimation results for the GATEs are not reported for brevity and are available on request.

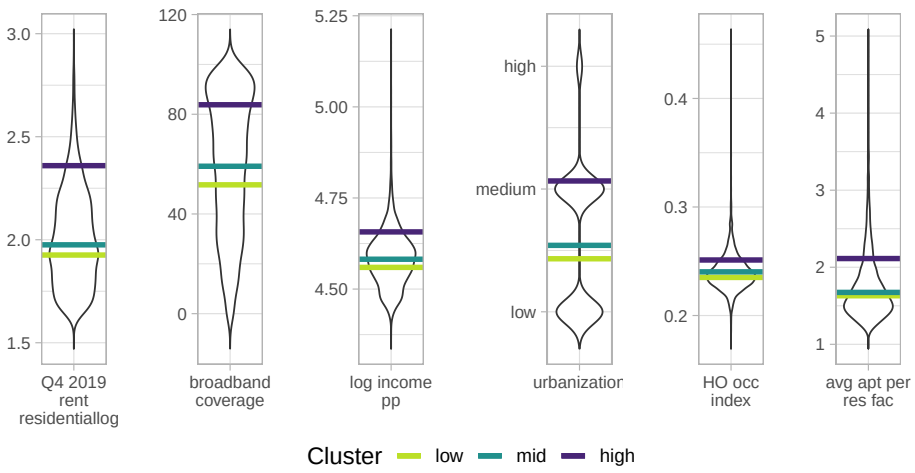
We start from the observation in the robustness analysis to the weighting in subsection 5.1.2, that weights by population in the municipalities seem to be correlated with the individualized effects. Furthermore, the descriptive analysis in Section 2 revealed that price levels in 2019Q4 are associated with subsequent price changes, at least for some real estate types. Thus, we jointly examine heterogeneity along multiple variables that characterize (affluent) urban municipalities. These municipalities typically have higher incomes per person, are in the high-price segment of real estate prior to the pandemic in 2019Q4, have more jobs with home office capability and broadband internet access, are classified as highly urbanized, and have more dense residential facilities. For simplicity, we denote these municipalities as more urban for the remainder of the paper.

Figure 9 illustrates that the effects are stronger in municipalities with such urban features. For the effect of short-time work on rents of residential real estate in Figure 9a, which is positive on average, the *high* IATE cluster is associated with urban municipalities. For the effect of Covid incidence on rents of retail real estate in Figure 9b, which is negative on average, the *low* IATE cluster is associated with urban features.[18] Quantitatively, the difference between the IATEs in the high and low cluster is sizable. The IATE of short-time work on rents of residential real estate is 2.8% in the high cluster and $-0.2\%$ in the low cluster; and the IATE of Covid incidence on rents of retail real estate is 1.5% in the high cluster and $-11.7\%$ in the low cluster.[19] Because the characterizing features of urban municipalities discussed above all exhibit a similar correlation pattern with the IATEs, these findings taken together provide evidence for heterogeneous effects across municipalities that differ jointly across these features.

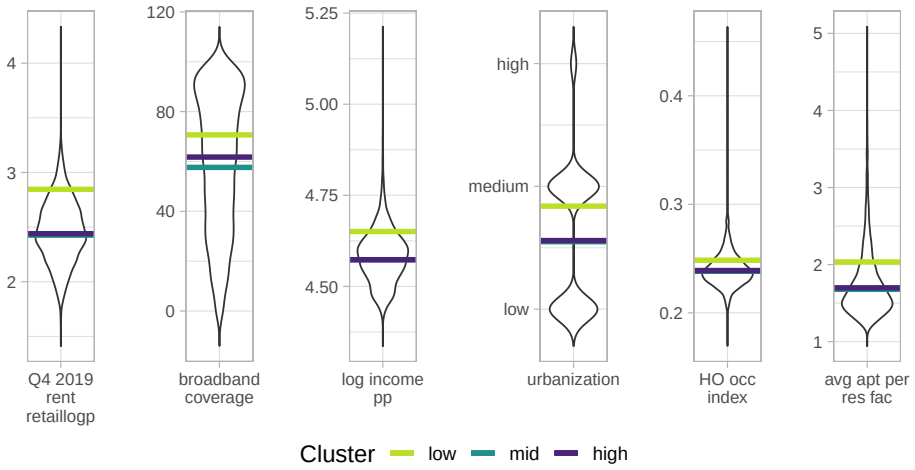
Table 1 summarizes the sign of the correlation between urban features and the IATEs for all considered real estate types and types of the pandemic incidence where the respective graphical illustrations are delegated to Appendix E. Table 1 shows that more urban municipalities have experienced a larger effect on sales prices across all real estate types

[18]The categories for the clusters of the effect *low*, *mid* and *high*, shown for example in Figure 9, should be distinguished from the three categories of the *incidence* that are also denoted with low, medium and high.

[19]In the estimations we use a K-Means cluster without a default number of targeted clusters. If more than three clusters are generated, we aggregate them into three clusters of similar size, respecting the ordering imposed by the size of the effect.




(a) Residential rents with short-time work incidence




(b) Retail rents with Covid incidence

Figure 9: Characteristics of covariates by IATE cluster for residential or retail rents and different measures of the pandemic incidence.
Notes: Average value of covariate in respective IATE cluster in relation to empirical covariate distribution.

both for a higher Covid or short-time work incidence. For rents, the correlations imply stronger effects in absolute terms in more urban municipalities. For residential and retail real estate, the Covid incidence has had a more negative effect in urban municipalities whereas the short-time work incidence has had a more positive effect. For office real estate, the opposite correlation pattern implies a more negative effect of short-time work and a more positive effect of Covid incidence in more urban municipalities.

Note that the correlations as summarized in Table 1 have the same sign as the ATEs in Figure 5. This is intuitive because urban municipalities receive a larger weight in the estimation of the benchmark specification, which aligns the sign of the ATE with the

correlation between the IATEs and urban characteristics.

| | | Residential | Retail | Office |
|---|---|---|---|---|
| Covid incidence | Rent | − | − | + |
| | Sale | · | + | + |
| Short-time work | Rent | + | + | − |
| | Sale | + | + | + |

Table 1: Sign of correlation between urban characteristics and the IATEs for all considered real estate types and incidences of the pandemic.

*Notes:* (+) and (-) define correlations that are consistent across all characteristics. (·) denotes an ambiguous pattern. See Appendix E for the corresponding graphical illustrations.

### 5.2.1 Distributional implications and the urban premium

We further analyze the effect of the pandemic on the price distribution. Given that real estate in affluent urban municipalities is associated with the upper part of the price distribution on average, this generates insights into the affordability crisis concerning residential real estate and the urban premium for commercial real estate. We compute the expected changes in rents and sale prices in a hypothetical scenario in which all municipalities have experienced the lowest incidence of Covid or short-time work. Comparing these hypothetical expected changes with the actual changes allows us to quantify the extent to which the pandemic has mitigated or exacerbated price pressure in the real estate market and in which price segment.

As shown in Table 9 in Appendix D, rents and sale prices increased on average between 2019Q4 and 2021Q1 across all real estate types in the *21st Real Estate* data. A first inspection of the actual and hypothetical expected price changes (not reported for brevity) shows that the pandemic has triggered different price changes across municipalities with real estate in different price segments prior to the pandemic.

Table 2 reports two statistics which illustrate the main findings: First, the difference between the actual and hypothetical expected growth rate of real estate prices conditional on being in the top quintile of the price distribution in 2019Q4 and second, the difference

of prices at the 90th and 50th percentile (the p90/p50 ratio) between the actual price distribution in 2021Q1 and the distribution of expected prices implied by the hypothetical scenario. If the difference between the actual and hypothetical growth rate is negative, this implies that the pandemic reduced price growth in the top price segment. If the difference in the p90/p50 ratio is negative, this further implies that the pandemic reduced the premium for real estate in the top price segment relative to the median price.

Table 2 shows that the effect of a higher incidence of Covid or short-time work on prices in the top quintile of the price distribution of residential real estate has been moderate quantitatively. The results further show that the pandemic did not have a clear-cut effect on the affordability crisis of residential real estate. Whereas a higher Covid incidence reduced the price growth in the top price quintile, a higher incidence of short-time work increased it. Moreover, the differences between the actual and hypothetical p90/p50 ratio of residential real estate prices are at most a percentage point, implying that a higher incidence of Covid or short-time work did not change the premium for residential real estate much in the top price segment.

Concerning retail estate, we find that a higher Covid incidence reduced the growth rate of rents in the top price segment by 9 percentage points (pp) and also reduced the p90/p50 ratio by 7 pp (from 1.19 to 1.12), indicating a lower premium for rents of retail real estate in the top price segment. We find that the premium of office rents in the top price segment has increased instead as a consequence of the pandemic, and more so for a higher incidence of Covid than short-time work. For sale prices of commercial real estate, the respective premiums increased across all combinations of incidences of the pandemic and commercial real estate types. The difference in the growth rate of sale prices in the actual and hypothetical scenario is sizable, between 14 and 27 pp, illustrating that the pandemic only reduced rents in the top price segment temporarily, if at all.

How do these causal results relate to the descriptive negative correlations between the rent level in 2019Q4 and the subsequent rent changes until 2021Q1, which we reported for both types of commercial real estate in Section 2? Recalling that the estimated causal effects are identified from variation in the incidence of the pandemic *across* municipalities,

our results imply that a higher incidence of Covid in municipalities at the top of the rent distribution in 2019Q4 contributes to the negative descriptive correlation between the rent level and the subsequent rent changes for retail but not for office real estate. Moreover, our results imply that a larger incidence of short-time work across municipalities is not driving the negative descriptive correlations.

Comparing the patterns observed in Tables 1 and 2, we note the similarity between the sign of the correlation of the IATE with (affluent) urban characteristics and the changes in the top part of the price distribution. This is intuitive because (affluent) urban municipalities have rents and sale prices that tend to be in the top part of the price distribution. Hence, a larger premium for real estate in the top price segment is associated with a larger urban premium.

| | | Residential | | Retail | | Office | |
|---|---|---|---|---|---|---|---|
| Covid incidence | Rent | −0.9 | −1.1 | −9.3 | −6.7 | 22.5 | 18.1 |
| | Sale | −1.1 | −0.1 | 13.7 | 1.3 | 26.7 | 3.2 |
| Short-time work | Rent | 0.7 | −0.9 | 5.0 | −0.7 | 5.4 | 6.1 |
| | Sale | 4.3 | 0.5 | 19.5 | 3.5 | 20.0 | 2.5 |

Table 2: Differences between price changes in the actual and hypothetical scenario, for all considered real estate types and incidences of the pandemic.

*Notes:* In each cell, the following statistics are displayed: the difference between growth rates in the top quintile in percentage points, and the difference between the p90-p50 ratios in percentage points.

# 6 Discussion

Our results suggest that the pandemic has triggered changes in demand for real estate that have been reflected in rents and prices one year after the Covid shock. Our evidence is consistent with a higher incidence of short-time work increasing the demand for residential housing and retail space and temporarily reducing the demand for office space. A higher Covid incidence instead temporarily reduced the demand for retail space with less clear-cut effects for residential and office real estate. Our results for the pandemic effect on sale prices imply that the collateral value of commercial real estate even increased on

average.

For residential real estate, one may wonder whether the demand shifts resulted from migration or demand shifts of residents. Descriptive evidence suggests the latter because the size and dispersion of net migration flow across municipalities (per resident) are small in Germany.[20] Figure 11 in Appendix C.3 shows that net migration flows in German municipalities in 2020 have been at most 2 per mille on average in each decile of the sale price distribution of the residential real estate. The figure further confirms that there has been no significant change to pre-pandemic trends in these net migration flows during the pandemic: net inflows into municipalities with high sale prices have been decreasing, whereas net inflows into municipalities with low sale prices have been increasing, implying convergence of net migration flows over time across municipalities in different price segments of the residential real estate market. The stable evolution of migration flows implies that changes in these flows until 2021Q1 may have been priced in for real estate units, at least partly, already in 2019Q4. Given the small size and small dispersion of the net migration flows, this suggests that the price changes, which we have estimated using variation across municipalities, have been the result of shifts in the demand for real estate services of residents within municipalities rather than of changes in the number of residents across municipalities.

What could have been driving such demand shifts? The pandemic may have increased the demand for space by households and possibly also by retailers. Households did not only spend more time at home during the lockdowns, in particular, if working shorter hours but possibly also expected to increase their working days in the home office in the future. Firms were incentivised to adjust their demand for office and retail real estate to avoid crowded spaces where the overall effect on demand is not obvious given government regulations on the minimum distance between employees in the office, home office work, and restrictions on the number of clients per square meter. At the same time, government support and the moratorium of insolvency until the end of April 2021 may

[20] Mondragon and Wieland (2022) report in their Table 1 that the dispersion of net inflows across 895 CBSAs in the U.S. (core-based statistical areas, i.e., economically-connected units of counties) doubled during the pandemic implying a standard deviation of 2.4%.

have prevented large downward price adjustments of real estate associated with times of crisis due to foreclosure and fire sales of real estate.

We do not aim to uncover the origins of the demand shifts but rather their consequences for real estate prices. Our analysis reveals that the price effects of the demand shifts have been stronger in urban locations and the top market segment. We have found that a higher incidence of Covid or short-time work both have increased sale prices, particularly in the top market segment for commercial real estate, thus increasing the premium for real estate in that segment. We find that the pandemic has reduced these premiums only temporarily for certain real estate types. A higher Covid incidence has reduced rents for retail real estate in the top market segment where this effect has been expected to be temporary because sale prices have increased at the same time. Short-time work also reduced rents in locations with more urban characteristics but not in the top market segment.

Quantitatively, our findings imply that the pandemic has had less of an effect on residential real estate prices in Germany than in the U.S. (Gupta et al., 2022; Mondragon & Wieland, 2022).[21] The pandemic neither exacerbated nor mitigated the affordability crisis for residential real estate. The effect on commercial real estate has been quantitatively more pronounced than for residential real estate. Temporarily, a higher Covid incidence reduced rents of retail real estate in the high-price segment, consistent with the fall of the urban premium reported in the first half year of the pandemic for other countries (Rosenthal, Strange, & Urrego, 2022). Our findings show that the decrease of rents of office real estate has been less persistent in Germany compared to the U.S. (Gupta, Mittal, & Van Nieuwerburgh, 2022).[22]

Our estimates do not account for spatial correlations and equilibrium effects (spillovers) across municipalities. Equilibrium effects may reduce the size of our estimated

[21] One may argue that this finding is explained by the stricter regulation of rents in Germany relative to the U.S. One would expect, however, that caps for rent increases would constrain rent *in*creases but not rent *de*creases. Analogously, stricter rent regulation of residential than commercial real estate is unlikely to explain the stronger temporary rent decreases for commercial real estate relative to residential real estate that we find in our estimations.

[22] A limitation of these comparisons is that our estimates are identified differently by comparing the effect across municipalities and thus abstracting from the effect of the pandemic that is common across all municipalities.

effects, for example, if households or firms shift their demand to municipalities with relatively lower prices. In this case, our estimates provide a lower bound for the direct effects. The small size of net migration flows into municipalities and the similar migration patterns in 2019 and 2020 discussed above suggest that such effects have been less relevant in Germany than in other countries.

# 7 Conclusion

We have found that the average response of real estate prices to the pandemic shock has been stronger for commercial than residential real estate in Germany. The negative effect of the Covid incidence on rents for retail real estate and the negative effect of short-time work on rents for offices have been expected to be temporary at one year after the pandemic started.

We have provided evidence for heterogeneous effects across municipalities where the price effects have been stronger in more urban municipalities that have been in the high-price segment of the real estate market before the pandemic. Quantitatively, we have found that the price changes in residential real estate markets implied by the pandemic did neither mitigate nor exacerbate the housing affordability crisis in Germany.

For commercial real estate, we have found that a higher Covid incidence temporarily reduced rents for retail real estate, particularly in the top price segment. In this instance, the pandemic reduced the premium for more expensive commercial real estate. The effect has been only temporary, however, because a higher incidence of Covid or short-time work both increased real estate asset prices. We have found that the increase has been stronger in the top price segment thus contributing to a larger premium for commercial real estate in more affluent urban municipalities.

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# A The modified causal forest estimator

We apply the modified causal forest, which builds on causal trees developed by Athey and Imbens (2016). The causal tree continuously splits a fraction of the covariate space along one covariate into two smaller subspaces. This iterative splitting procedure on the covariate space creates small strata, so-called leaves, each containing only a small number of observations. The resulting hypercubes inside the full covariate space are small enough so that selection effects are prevented.

The treatment effect is then locally calculated within each leaf as the difference in the mean outcomes for observations in the treated and the control group. The causal forest estimator by Wager and Athey (2018) aggregates over multiple deep trees as in random forests, (Breiman, 2001) where each tree is generated on a random subsample of observations using a random set of covariate candidates for each split. The modified causal forest (Lechner & Mareckova, 2022) improves the splitting criterion to remove selection bias more effectively and proposes a unified inference procedure to estimate effects and draw inference on any aggregation level.

Our analysis uses the implementation of the modified causal forest as provided in the mcf Python package described in Bodory, Busshoff, and Lechner (2022). We use 1000 trees, 8 randomly drawn covariates in each split, a subsampling rate of 63% and minimum leaf size of 5.

# B Cross-country evidence for real estate investment funds

We select the REITs or funds for the respective countries that have been sufficiently liquid with frequent trades taking place. For the U.S. and the U.K., we focus on REITs with a large market capitalization. For countries without REITs, such as Switzerland, we use similar real estate investment funds.

| Country | Residential | Commercial |
|---|---|---|
| DE | Deutsche Wohnen SE | Alstria Office REIT AG |
| | Grand City Properties SA | Deutsche Industrie REIT AG |
| | LEG Immobilien AG | Deutsche Konsum REIT AG |
| | TAG Immobilien AG | Hamborner REIT AG |
| | Vonovia SE | |
| FR | Altarea SCA | Acanthe Développement SIIC |
| | Nexity SA | Frey SIIC |
| | | Gecina SIIC |
| | | Icade SIIC |
| | | Mercialys SIIC |
| | | MRM SIIC |
| | | Paris Reality Fund SIIC |
| | | Société de la Tour Eiffel SIIC |
| IT | Nova Re SIIQ SpA | Aedes SIIQ SpA |
| | | Brioschi Sviluppo Immobiliare SpA |
| | | Coima RES SpA SIIQ |
| | | Immobiliare Grande Distribuzione SIIQ SpA |
| | | Restart SIIQ SpA |
| | | Risanamento SpA |
| ES | Quabit Inmobiliaria SA | Inmobiliaria Colonial SOCIMI SA |
| | Renta Corporacion Real Estate SA | Lar Espana Real Estate SOCIMI SA |
| | | Merlin Properties SOCIMI SA |
| | | Olimpo Real Estate SOCIMI SA |
| | | Vitruvio Real Estate SOCIMI SA |
| UK | Empiric Student Property REIT PLC | British Land REIT PLC |
| | KCR Residential REIT PLC | Derwent London REIT PLC |
| | Residential Secure Income REIT PLC | Land Securities Group REIT PLC |
| | The PRS REIT PLC | Tritax Big Box REIT PLC |
| | | Workspace Group REIT PLC |
| US | AvalonBay Communities Inc. REIT | Alexandria Real Estate Equities Inc. REIT |
| | Essex Property Trust Inc. REIT | Brandywine Reality Trust REIT |
| | Invitation Homes Inc. REIT | CBL Properties REIT |
| | Mid-America Apartment Communities REIT | Duke Realty Corporation REIT |
| | UDR Inc. REIT | |
| CH | Credit Suisse Real Estate Fund Siat | Intershop Holding AG |
| | Immofonds | PSP Swiss Prime Property AG |
| | Swisscanto (CH) Real Estate Fund IFCA FA CHF | Swisscanto (CH) Real Estate Fund Swiss Commercial FA CHF |
| | UBS Anfos | Swiss Prime Site AG |
| | UBS Direct Residential | UBS (CH) PF Swiss Mixed Sima Ord |
| | | UBS Swissreal |

Table 3: Publicly traded REITs or funds by country and real estate type

| Country and REIT type | Mean | Min | Max | Min fund name | Max fund name |
|---|---|---|---|---|---|
| DE residential | 11.19 | -5.88 | 17.96 | Grand City Properties SA | TAG Immobilien AG |
| DE commercial | -6.26 | -14.38 | 2.56 | Alstria Office REIT AG | Hamborner REIT AG |
| FR residential | -16.20 | -27.08 | -5.32 | Altarea Group SCA | Nexity SA |
| FR commercial | -24.02 | -38.51 | -10.81 | Icade SIIC | Frey SIIC |
| IT residential | -29.79 | -29.79 | -29.79 | Nova Re SIIQ SpA | Nova Re SIIQ SpA |
| IT commercial | -33.36 | -74.32 | 4.35 | Aedes SIIQ SpA | Risanamento SpA |
| ES residential | -56.72 | -66.52 | -46.91 | Quabit Inmobiliaria SA | Renta Corporacion Real Estate SA |
| ES commercial | -20.84 | -37.33 | 4.00 | Merlin Properties SOCIMI SA | Olimpo Real Estate SOCIMI SA |
| UK residential | -20.79 | -51.55 | -2.24 | KCR Residential REIT PLC | The PRS REIT PLC |
| UK commercial | -14.50 | -39.59 | 39.27 | Workspace Group REIT PLC | Tritax Big Box REIT PLC |
| US residential | -11.04 | -20.54 | 1.84 | AvalonBay Communities Inc REIT | Mid-America Apartment Communities REIT |
| US commercial | -22.9 | -88.23 | 15.01 | CBL Properties REIT | Duke Realty Corporation REIT |
| CH residential | 7.14 | 2.15 | 11.59 | Immofonds | Swisscanto (CH) Real Estate Fund IFCA FA CHF |
| CH commercial | -10.34 | -23.32 | 3.50 | Swiss Prime Site AG | UBS (CH) PF Swiss Mixed Sima Ord |

Table 4: Growth rate of share price between February 2020 and February 2021

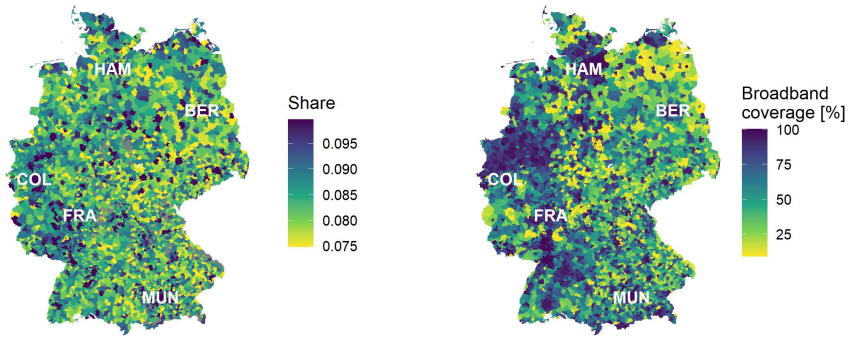
# C Data appendix

## C.1 Construction of the variables measuring the epidemiological and economic incidence of the pandemic

We use the following data sources to construct the variables. The Covid cases are retrieved from the *Robert Koch Institute* which collects and publishes daily infections and deaths at the county level in Germany (*Landkreise* and *kreisfreie Städte*). The number of employees on short-time work by state and WZ-2008 is published by the *Federal Employment Agency*. WZ-2008 is a multi-level classification of the German economy (Statistisches Bundesamt, 2008) where the top level, which we use in this paper, splits the German economy into 21 sectors. We combine the share of employees on short-time work at the regional level with data on the local economic composition of employees by WZ-2008 at the municipal level, as available on request at the *Federal Employment Agency*. We thus obtain a measure for the incidence of short-time work at the municipal level.

## C.2 The geographic incidence of home office capability and broadband internet access

We combine information on the frequency of occasionally working from home prior to the pandemic, by WZ-2008 as provided in Alipour, Falck, and Schüller (2020), with the employment share by WZ-2008 at the municipal level. Figure 10a shows that home office capability varies with the local employment structure. Jobs with higher home office capability tend to be located in more urban areas. Figure 10b shows that broadband internet access is also highly correlated with urban areas. The data on broadband coverage in Germany is published by *MIG* and denotes the share of households with the availability of broadband access of at least 200 MBit/s.




(a) Home office capability (b) Broadband internet access

Figure 10: Employment share of jobs with home office capability and broadband internet access across geographic areas.
Notes: The cities indicated on the map are abbreviated as follows. BER: Berlin, COL: Cologne, FRA: Frankfurt, HAM: Hamburg, MUN: Munich. Sources: Own calculations based on Alipour, Falck, and Schüller (2020), Figure 1; *MIG*.

## C.3 Net migration flows

Figure 11 shows the net inflows per number of residents, averaged across municipalities in a decile of the sale price distribution for residential real estate.

## C.4 Additional descriptive evidence

Tables 5-8 list the data sources and the descriptive statistics of all considered outcomes and covariates for the terciles (low, medium and high) of Covid incidence and short-time work incidence.

| | Covid incidence | | |
|---|---|---|---|
| Variable | low | medium | high |
| *Prices in 2021Q1 (outcomes)* | | | |
| Residential rents | 7.9 (1.6) | 9.0 (1.8) | 10.0 (2.6) |
| Retail rents | 13.2 (4.3) | 14.3 (3.3) | 15.3 (4.0) |
| Office rents | 8.6 (1.3) | 9.3 (1.4) | 10.6 (1.8) |
| Residential sales | 2611 (866) | 3202 (1114) | 3717 (1609) |
| Retail sales | 2486 (823) | 2881 (1110) | 3247 (1644) |
| Office sales | 2265 (737) | 2663 (751) | 2991 (1207) |
| *Prices in 2019Q4* | | | |
| Residential rents | 7.6 (1.4) | 8.6 (1.7) | 9.5 (2.4) |
| Retail rents | 12.8 (3.9) | 13.8 (3.4) | 15.0 (3.9) |
| Office rents | 8.2 (1.2) | 9.0 (1.4) | 10.1 (1.7) |
| Residential sales | 2186 (737) | 2726 (995) | 3209 (1394) |
| Retail sales | 2172 (682) | 2453 (881) | 2859 (1281) |
| Office sales | 1928 (617) | 2276 (688) | 2690 (1129) |

Table 5: Descriptive statistics for real estate rents and sale prices by *Covid* incidence.

*Notes:* Averages and standard deviations in parenthesis. All prices are denoted in logs of [€/m2]. Rents are monthly payments. Data source: *21st Real Estate*.

| | STW incidence | | |
|---|---|---|---|
| Variable | low | medium | high |
| *Prices in 2021Q1 (outcomes)* | | | |
| Residential rents | 8.5 (1.7) | 9.5 (2.2) | 9.5 (2.1) |
| Retail rents | 13.8 (3.6) | 14.7 (3.7) | 14.7 (4.3) |
| Office rents | 9.7 (1.5) | 9.5 (1.6) | 9.4 (1.5) |
| Residential sales | 2887 (965) | 3481 (1378) | 3446 (1321) |
| Retail sales | 2663 (1020) | 3023 (1402) | 3161 (1273) |
| Office sales | 2452 (853) | 2782 (989) | 2898 (936) |
| *Prices in 2019Q4* | | | |
| Residential rents | 8.1 (1.6) | 9.1 (2.1) | 9.1 (2.0) |
| Retail rents | 13.4 (3.4) | 14.4 (3.7) | 14.3 (4.1) |
| Office rents | 9.2 (1.4) | 9.2 (1.5) | 9.1 (1.4) |
| Residential sales | 2435 (845) | 2991 (1211) | 2957 (1142) |
| Retail sales | 2334 (822) | 2618 (1103) | 2727 (1001) |
| Office sales | 2155 (776) | 2433 (935) | 2491 (830) |

Table 6: Descriptive statistics for real estate rents and sale prices by *STW* incidence.

*Notes:* Averages and standard deviations in parenthesis. All prices are denoted in logs of [€/m2]. Rents are monthly payments. Data source: *21st Real Estate*.

| Variable | Source | Covid incidence | | |
|---|---|---|---|---|
| | | low | medium | high |
| *Heterogeneity variables:* | | | | |
| Apt. owned by private enterprise (share) | Census | 0.053 (0.040) | 0.052 (0.035) | 0.094 (0.041) |
| Apt. per residential facility | Census | 2.13 (0.46) | 2.22 (0.39) | 2.92 (0.52) |
| Apt. size [m2] | Census | 97 (13) | 97 (11) | 88 (16) |
| Broadband coverage | MIG | 71 (30) | 76 (26) | 82 (27) |
| FTE in hospitality, arts & leisure (share) | BfA | 0.045 (0.056) | 0.039 (0.043) | 0.042 (0.039) |
| FTE in financial services (share) | BfA | 0.022 (0.014) | 0.024 (0.015) | 0.031 (0.018) |
| FTE with capable home-office job (share) | BfA | 0.247 (0.016) | 0.251 (0.017) | 0.259 (0.017) |
| Log income pp. | Regstat | 4.566 (0.070) | 4.609 (0.069) | 4.589 (0.086) |
| Urbanization (1:high, 2:medium, 3:low) | Destatis | 1.96 (0.57) | 1.81 (0.57) | 1.56 (0.61) |
| *Covariates in rich model:* | | | | |
| Apartments | Census | 40126 (17444) | 107039 (30534) | 337046 (61185) |
| Apt. owned by government (share) | Census | 0.0044 (0.0232) | 0.0046 (0.0091) | 0.0117 (0.0096) |
| Apt. owned by others (share) | Census | 0.29 (0.13) | 0.32 (0.11) | 0.37 (0.13) |
| Apt. owned by private person (share) | Census | 0.65 (0.15) | 0.63 (0.13) | 0.52 (0.15) |
| Area [km2] | Destatis | 138 (91) | 147 (56) | 218 (49) |
| Buildings with $\geq$13 apt. (share) | Census | 0.0121 (0.0078) | 0.0113 (0.0055) | 0.0335 (0.0091) |
| Detached houses (share) | Census | 0.63 (0.13) | 0.57 (0.15) | 0.49 (0.16) |
| DINK households (share) | Census | 0.290 (0.029) | 0.276 (0.028) | 0.266 (0.032) |
| FTE | Destatis | 37006 (17292) | 112338 (33007) | 308351 (57301) |
| FTE commuting in (share) | Destatis | 0.63 (0.12) | 0.63 (0.10) | 0.57 (0.10) |
| FTE in primary sector (share) | BfA | 0.018 (0.044) | 0.007 (0.023) | 0.006 (0.030) |
| FTE in remaining tertiary sector (share) | BfA | 0.50 (0.13) | 0.46 (0.13) | 0.46 (0.14) |
| FTE in secondary sector (share) | BfA | 0.28 (0.13) | 0.32 (0.16) | 0.28 (0.16) |
| FTE in technical services (share) | BfA | 0.136 (0.063) | 0.152 (0.074) | 0.183 (0.073) |
| Family households (share) | Census | 0.259 (0.064) | 0.272 (0.062) | 0.238 (0.073) |
| Households | Census | 36983 (16089) | 102562 (29322) | 322813 (58646) |
| New apartments | Regstat | 214 (108) | 858 (265) | 2701 (513) |
| New non-residential facilities | Regstat | 13.5 (6.9) | 19.5 (6.6) | 54.2 (11.4) |
| New residential facilities | Regstat | 66 (33) | 192 (57) | 380 (70) |
| One-person households (share) | Census | 0.348 (0.061) | 0.350 (0.054) | 0.392 (0.063) |
| Persons per household | Census | 2.18 (0.20) | 2.21 (0.19) | 2.10 (0.23) |
| Population age 0-9 (share) | Regstat | 0.084 (0.011) | 0.087 (0.010) | 0.087 (0.012) |
| Population age 10-19 (share) | Regstat | 0.099 (0.022) | 0.104 (0.018) | 0.095 (0.023) |
| Population average age | Regstat | 45.3 (2.2) | 44.4 (1.9) | 44.0 (2.7) |
| Population inflow (share) | Regstat | 0.067 (0.051) | 0.066 (0.019) | 0.065 (0.027) |
| Population German citizenship (share) | Census | 0.953 (0.027) | 0.920 (0.036) | 0.895 (0.045) |
| Population outflow (share) | Regstat | 0.063 (0.046) | 0.063 (0.018) | 0.061 (0.027) |
| Foreign population from EU27 area (share) | Regstat | 0.018 (0.016) | 0.029 (0.016) | 0.038 (0.022) |
| Ratio unemployed / employed | Destatis | 0.070 (0.031) | 0.063 (0.027) | 0.076 (0.026) |
| Resident employees | Destatis | 29868 (12730) | 86754 (24649) | 258821 (47000) |
| Resident employees commuting out (share) | Destatis | 0.63 (0.16) | 0.63 (0.13) | 0.53 (0.13) |
| Resident employees foreign (share) | Destatis | 0.077 (0.042) | 0.119 (0.053) | 0.152 (0.068) |
| Resident employees over age 55 (share) | Destatis | 0.223 (0.029) | 0.211 (0.024) | 0.200 (0.034) |
| Resident unemployed | Destatis | 2532 (1187) | 7787 (2317) | 25395 (4752) |
| Residential buildings (share) | Census | 0.965 (0.015) | 0.963 (0.016) | 0.963 (0.015) |
| Residential facilities | Census | 12969 (4930) | 32947 (9066) | 66763 (12101) |
| Votes left parties (share) | Regstat | 0.100 (0.050) | 0.080 (0.035) | 0.100 (0.042) |
| Votes mid parties (share) | Regstat | 0.73 (0.11) | 0.75 (0.08) | 0.70 (0.12) |
| Votes right parties (share) | Regstat | 0.123 (0.056) | 0.118 (0.050) | 0.140 (0.087) |

Table 7: Data sources and descriptive statistics by *Covid* incidence for all considered covariates and heterogeneity variables.

*Notes:* Averages and standard deviations in parenthesis. Explanations for sources: Census - *Zensus 2011*, BfA - *Federal Employment Agency*, Regstat - *Regionalstatistik*, Destatis - *Federal Statistical Office*, MIG - *MIG*.

| Variable | Source | STW incidence | | |
|---|---|---|---|---|
| | | low | medium | high |
| *Heterogeneity variables:* | | | | |
| Apt. owned by private enterprise (share) | Census | 0.093 (0.049) | 0.053 (0.033) | 0.041 (0.028) |
| Apt. per residential facility | Census | 2.67 (0.57) | 2.38 (0.45) | 2.14 (0.36) |
| Apt. size [m2] | Census | 90 (15) | 95 (13) | 98 (12) |
| Broadband coverage | MIG | 78 (29) | 78 (27) | 73 (26) |
| FTE in hospitality, arts & leisure (share) | BfA | 0.042 (0.020) | 0.039 (0.028) | 0.046 (0.072) |
| FTE in financial services (share) | BfA | 0.025 (0.018) | 0.028 (0.016) | 0.024 (0.014) |
| FTE with capable home-office job (share) | BfA | 0.257 (0.020) | 0.253 (0.017) | 0.245 (0.013) |
| Log income pp. | Regstat | 4.560 (0.074) | 4.609 (0.079) | 4.612 (0.072) |
| Urbanization (1:high, 2:medium, 3:low) | Destatis | 1.65 (0.61) | 1.76 (0.59) | 2.00 (0.55) |
| *Covariates in rich model:* | | | | |
| Apartments | Census | 264667 (57761) | 88993 (28665) | 123035 (27651) |
| Apt. owned by government (share) | Census | 0.0084 (0.0064) | 0.0064 (0.0106) | 0.0061 (0.0236) |
| Apt. owned by others (share) | Census | 0.33 (0.14) | 0.34 (0.12) | 0.32 (0.11) |
| Apt. owned by private person (share) | Census | 0.57 (0.16) | 0.60 (0.14) | 0.64 (0.12) |
| Area [km2] | Destatis | 223 (94) | 112 (56) | 160 (49) |
| Buildings with $\geq$13 apt. (share) | Census | 0.0264 (0.0091) | 0.0171 (0.0075) | 0.0113 (0.0060) |
| Detached houses (share) | Census | 0.52 (0.15) | 0.56 (0.15) | 0.63 (0.13) |
| DINK households (share) | Census | 0.279 (0.032) | 0.276 (0.030) | 0.273 (0.028) |
| FTE | Destatis | 222996 (49288) | 100199 (33686) | 141975 (32779) |
| FTE commuting in (share) | Destatis | 0.56 (0.11) | 0.64 (0.10) | 0.65 (0.11) |
| FTE in primary sector (share) | BfA | 0.013 (0.050) | 0.008 (0.023) | 0.007 (0.013) |
| FTE in remaining tertiary sector (share) | BfA | 0.53 (0.12) | 0.46 (0.11) | 0.37 (0.11) |
| FTE in secondary sector (share) | BfA | 0.22 (0.11) | 0.30 (0.12) | 0.42 (0.16) |
| FTE in technical services (share) | BfA | 0.167 (0.064) | 0.164 (0.076) | 0.135 (0.068) |
| Family households (share) | Census | 0.232 (0.070) | 0.263 (0.067) | 0.288 (0.061) |
| Households | Census | 252146 (55096) | 85125 (27507) | 118704 (26732) |
| New apartments | Regstat | 2063 (476) | 567 (204) | 1174 (272) |
| New non-residential facilities | Regstat | 36.7 (9.3) | 27.9 (9.6) | 23.2 (6.4) |
| New residential facilities | Regstat | 305 (69) | 111 (37) | 239 (55) |
| One-person households (share) | Census | 0.383 (0.067) | 0.361 (0.059) | 0.338 (0.051) |
| Persons per household | Census | 2.09 (0.22) | 2.18 (0.21) | 2.26 (0.19) |
| Population age 0-9 (share) | Regstat | 0.084 (0.011) | 0.087 (0.011) | 0.088 (0.011) |
| Population age 10-19 (share) | Regstat | 0.093 (0.024) | 0.102 (0.020) | 0.107 (0.019) |
| Population average age | Regstat | 44.7 (2.3) | 44.4 (2.2) | 44.3 (2.3) |
| Population inflow (share) | Regstat | 0.064 (0.037) | 0.068 (0.020) | 0.067 (0.045) |
| Population German citizenship (share) | Census | 0.93 (0.03) | 0.91 (0.04) | 0.91 (0.04) |
| Population outflow (share) | Regstat | 0.059 (0.036) | 0.064 (0.018) | 0.064 (0.039) |
| Foreign population from EU27 area (share) | Regstat | 0.022 (0.017) | 0.035 (0.018) | 0.033 (0.019) |
| Ratio unemployed / employed | Destatis | 0.087 (0.034) | 0.062 (0.023) | 0.051 (0.024) |
| Resident employees | Destatis | 195270 (42533) | 75549 (24402) | 104142 (23344) |
| Resident employees commuting out (share) | Destatis | 0.54 (0.16) | 0.62 (0.14) | 0.64 (0.12) |
| Resident employees foreign (share) | Destatis | 0.096 (0.045) | 0.137 (0.057) | 0.134 (0.061) |
| Resident employees over age 55 (share) | Destatis | 0.214 (0.033) | 0.208 (0.028) | 0.209 (0.026) |
| Resident unemployed | Destatis | 21279 (4717) | 4776 (1666) | 8568 (1991) |
| Residential buildings (share) | Census | 0.967 (0.013) | 0.962 (0.014) | 0.961 (0.018) |
| Residential facilities | Census | 54161 (11641) | 23364 (7135) | 35938 (7918) |
| Votes left parties (share) | Regstat | 0.115 (0.051) | 0.078 (0.036) | 0.076 (0.033) |
| Votes mid parties (share) | Regstat | 0.70 (0.13) | 0.75 (0.10) | 0.74 (0.10) |
| Votes right parties (share) | Regstat | 0.132 (0.075) | 0.121 (0.069) | 0.129 (0.064) |

Table 8: Data sources and descriptive statistics by *STW* incidence for all considered covariates and heterogeneity variables.

*Notes:* Averages and standard deviations in parenthesis. Explanations for sources: Census - *Zensus 2011*, BfA - *Federal Employment Agency*, Regstat - *Regionalstatistik*, Destatis - *Federal Statistical Office*, MIG - *MIG*.

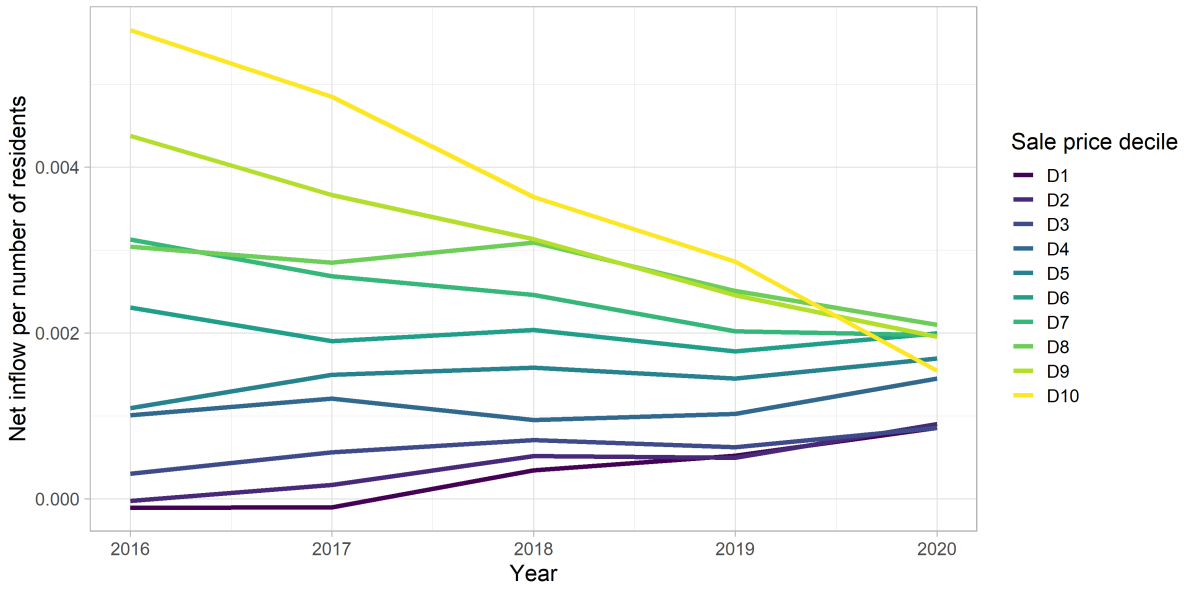
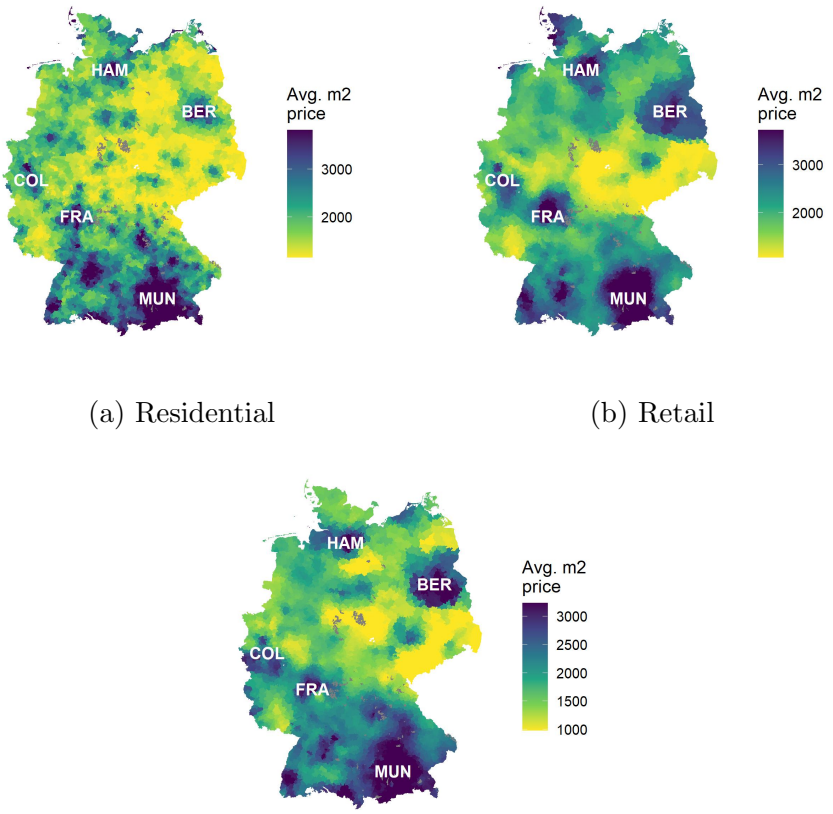



Figure 11: Net migration flows across municipalities in different deciles of the sale price distribution for residential real estate.
Sources: Own calculations based on *Regionalstatistik* and *Federal Statistical Office*.

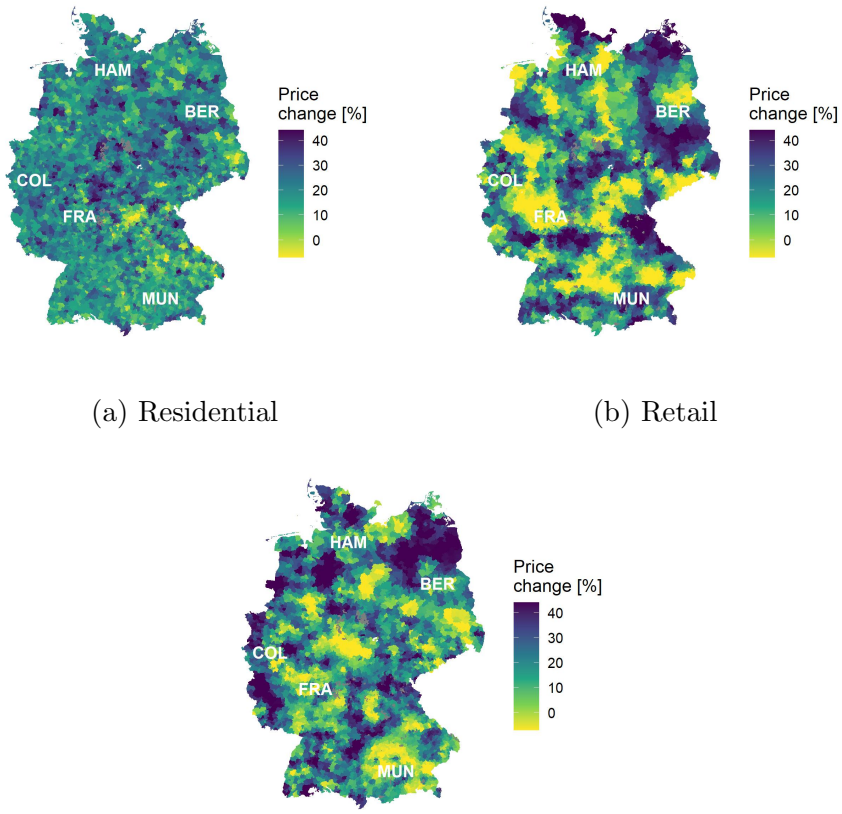



(a) Residential

(b) Retail

(c) Office

Figure 12: Sale prices by real estate type, across geographic areas prior to the pandemic in 2019Q4.
Notes: Sale price in units of €/$m^2$. The cities indicated on the map are abbreviated as follows. BER: Berlin, COL: Cologne, FRA: Frankfurt, HAM: Hamburg, MUN: Munich. Source: *21st Real Estate*.



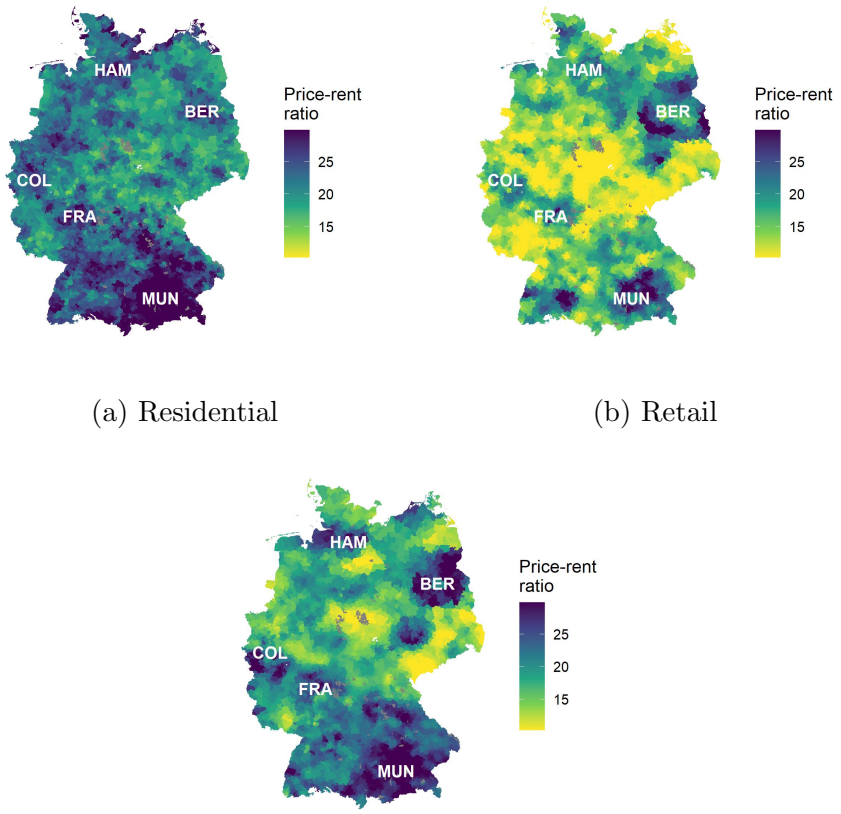

(a) Residential

(b) Retail

(c) Office

Figure 13: Changes in prices by real estate type, across geographic areas between 2019Q4 and 2021Q1.

Notes: The cities indicated on the map are abbreviated as follows. BER: Berlin, COL: Cologne, FRA: Frankfurt, HAM: Hamburg, MUN: Munich. Source: *21st Real Estate*.




(a) Residential

(b) Retail

(c) Office

Figure 14: Ratio between prices and annual rents by real estate type, across geographic areas at 2019Q4.
Notes: The cities indicated on the map are abbreviated as follows. BER: Berlin, COL: Cologne, FRA: Frankfurt, HAM: Hamburg, MUN: Munich. Source: *21st Real Estate*.

# D Comparison of the granular price data with other data sources

We compare the time variation in the granular ask price data of *21st Real Estate* with aggregate trends observed in data on house prices and rents provided by the several established real estate indices for Germany. As mentioned on the website of the Bundesbank, the indexes differ, for example, in terms of coverage (urban versus rural areas), weighting schemes and the use of hedonic models, which makes comparisons not straightforward.

| | Residential | | Commercial retail | | Commercial offices | |
|---|---|---|---|---|---|---|
| | 2019/20 | 2020/21 | 2019/20 | 2020/21 | 2019/20 | 2020/21 |
| *Sales:* | | | | | | |
| *21st Real Estate* | 10.3% | 14.0% | 16.2% | 11.1 % | 13.2% | 11.1% |
| *Pfandbriefbanken* | 6.1% | 7.6% | -1.1% | -2.1% | 8.4% | -1.2% |
| *Bulwiengesa* | 9.7% | 7.8% | -5.5% | -9.4% | 3.5% | 4.5% |
| *Destatis* | 7.7% | 11.0% | | | | |
| *Hypoport* | 11.0 % | 12.8% | | | | |
| *Rents:* | | | | | | |
| *21st Real Estate* | 4.0% | 3.9% | 7.0% | 1.8% | 3.7% | 3.7% |
| *Pfandbriefbanken* | 3.9% | 2.3% | -1.8% | -0.7% | 5.5% | -0.9% |

Table 9: Comparison of annual growth rates of rents and real estate prices

*Notes:* Annual growth rates for rents and real estate prices based on granular ask price data of *21st Real Estate* and real estate indices for Germany.

Table 9 displays the annual growth rates for our six outcome variables between 2019 and 2021. For residential real estate, the annual growth rate of residential rents in the *21st Real Estate* data is 4%, and the growth rate of residential sale prices is $10 - 14\%$. The growth rates have the same order of magnitude as in other existing indexes reported in Table 9 and they are also similar to values for 2020 reported in figures 1a and 4b of Kindermann et al. (2022). The population-weighted average price rent ratio of 27 in the *21st Real Estate* data is similar to values reported for 2019/2020 in Figure 4a of Kindermann et al. (2022).

For commercial real estate, the average growth rates for sale prices and rents in the *21st Real Estate* data differ significantly from the growth rates implied by the other existing

indexes. This is particularly so for retail real estate, for which the other indexes imply declines in rents and sale prices, whereas the data by *21st Real Estate* implies increases. Further analysis suggests that the difference between the aggregate price changes in the data of *21st Real Estate* and the other indexes may result from differences in coverage of urban and rural municipalities. We do not attempt to explain further the differences in the aggregate trends in the *21st Real Estate* data and the other data sources because this is not crucial for our analysis. In our estimation, we exploit differences in price changes across municipalities so that our results do not depend on aggregate changes that are common across municipalities. As shown in Figure 3 in Section 2 and Figure 13 in Appendix C.4, changes of rents and sale prices during the pandemic are very heterogeneous across municipalities in the *21st Real Estate* data and include some very large declines.

# E Heterogeneous effects and more (affluent) urban municipalities

Figures 15-26 show the average characteristics of covariates by IATE cluster in relation to the empirical covariate distribution for all estimated combinations of real estate type, incidence type, and outcome.

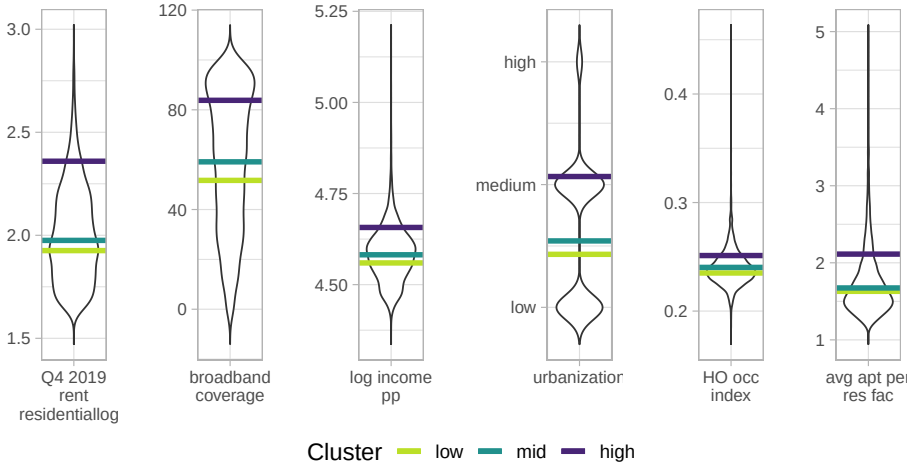



Figure 15: Characteristics of covariates by IATE cluster for residential rents with short-time work incidence.
Notes: Average value of covariate in respective IATE cluster in relation to empirical covariate distribution.

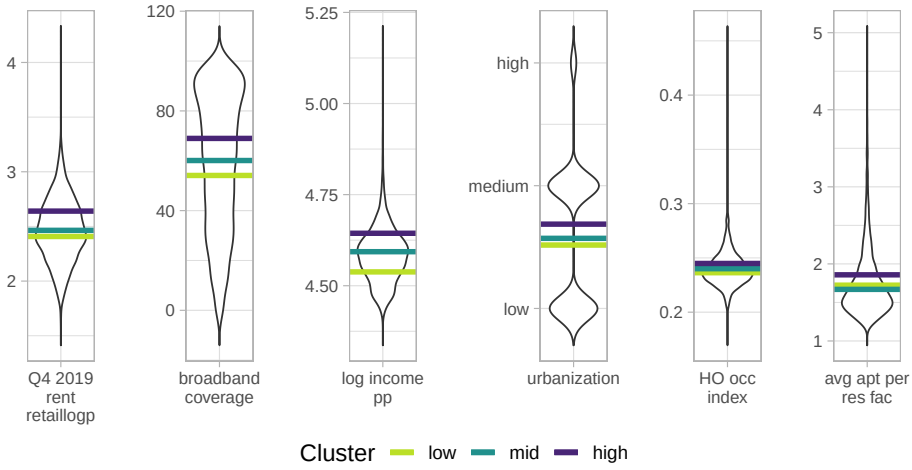



Figure 16: Characteristics of covariates by IATE cluster for retail rents with short-time work incidence.
Notes: Average value of covariate in respective IATE cluster in relation to empirical covariate distribution.

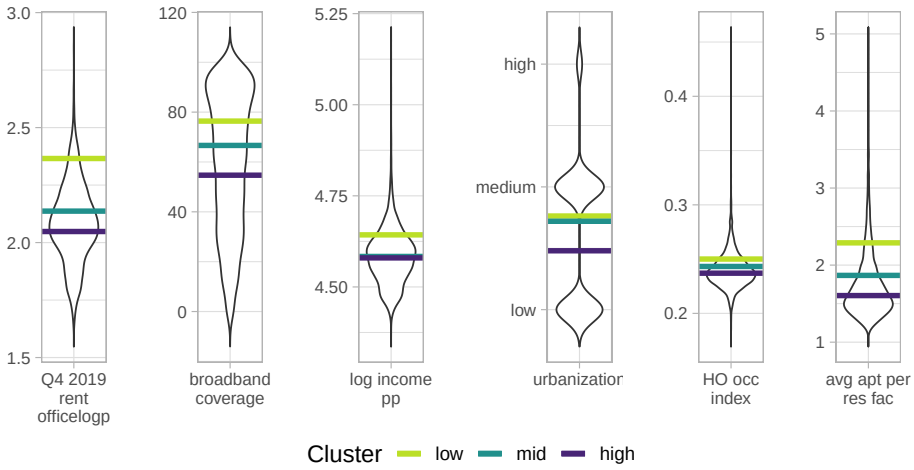



Figure 17: Characteristics of covariates by IATE cluster for office rents with short-time work incidence.
Notes: Average value of covariate in respective IATE cluster in relation to empirical covariate distribution.

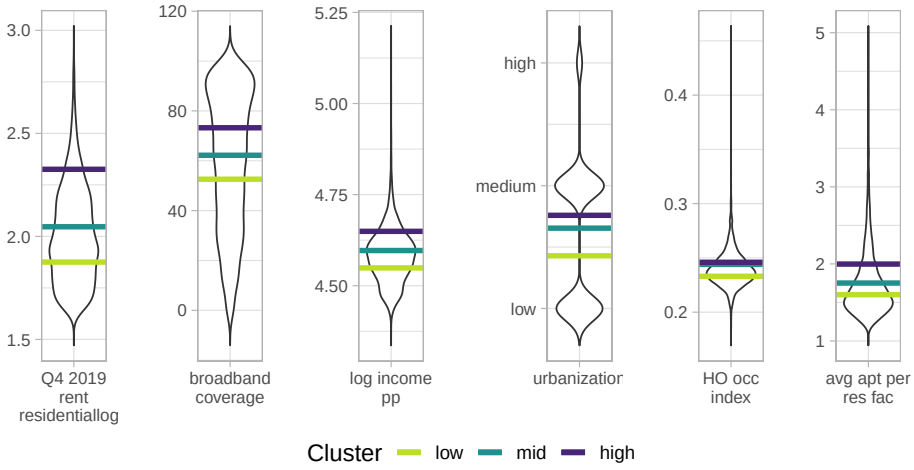



Figure 18: Characteristics of covariates by IATE cluster for residential sales prices with short-time work incidence.
Notes: Average value of covariate in respective IATE cluster in relation to empirical covariate distribution.

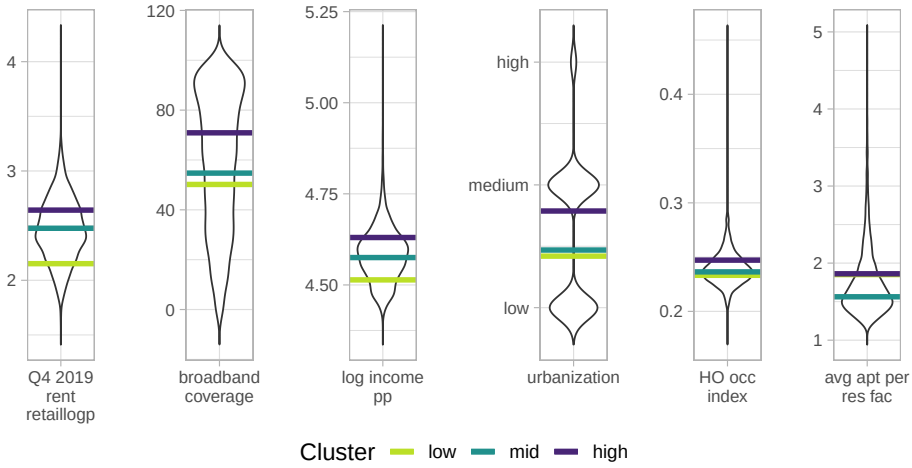



Figure 19: Characteristics of covariates by IATE cluster for retail sales prices with short-time work incidence.
Notes: Average value of covariate in respective IATE cluster in relation to empirical covariate distribution.

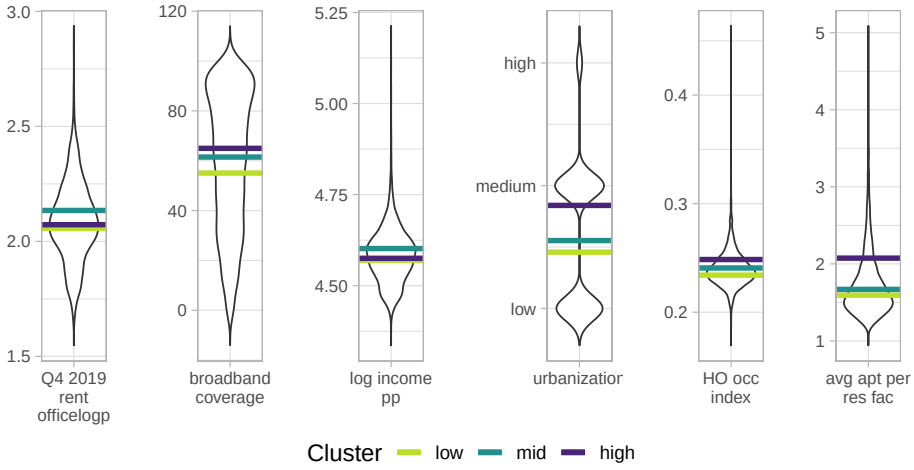



Figure 20: Characteristics of covariates by IATE cluster for office sales prices with short-time work incidence.
Notes: Average value of covariate in respective IATE cluster in relation to empirical covariate distribution.

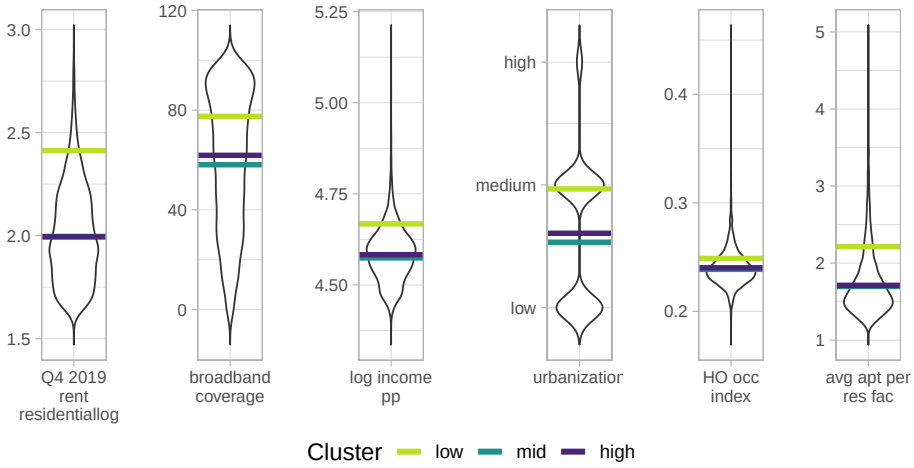



Figure 21: Characteristics of covariates by IATE cluster for residential rents with Covid incidence.
Notes: Average value of covariate in respective IATE cluster in relation to empirical covariate distribution.

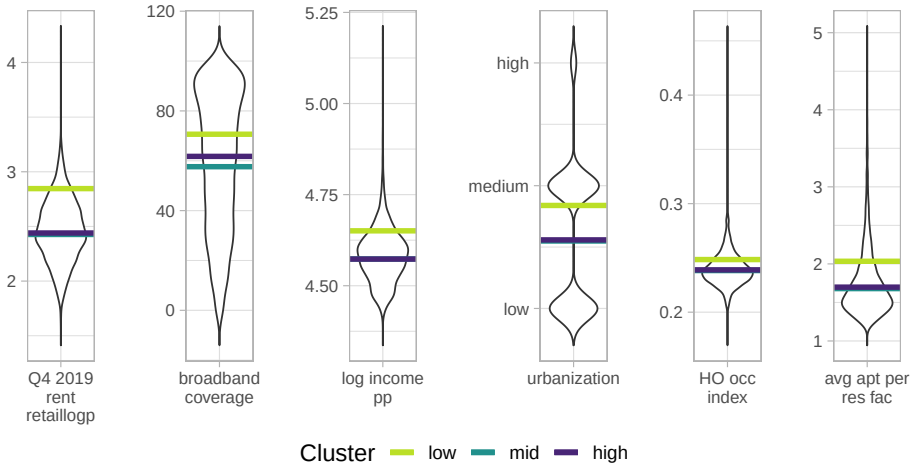



Figure 22: Characteristics of covariates by IATE cluster for retail rents with Covid incidence.
Notes: Average value of covariate in respective IATE cluster in relation to empirical covariate distribution.

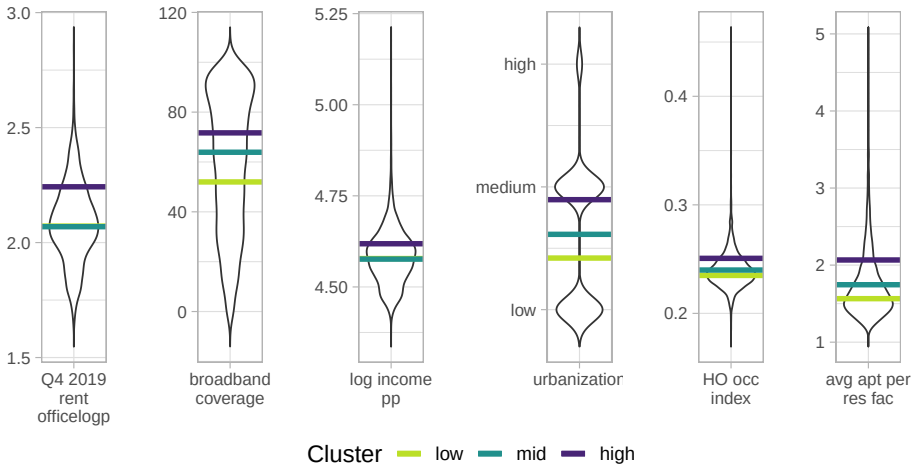



Figure 23: Characteristics of covariates by IATE cluster for office rents with Covid incidence.
Notes: Average value of covariate in respective IATE cluster in relation to empirical covariate distribution.

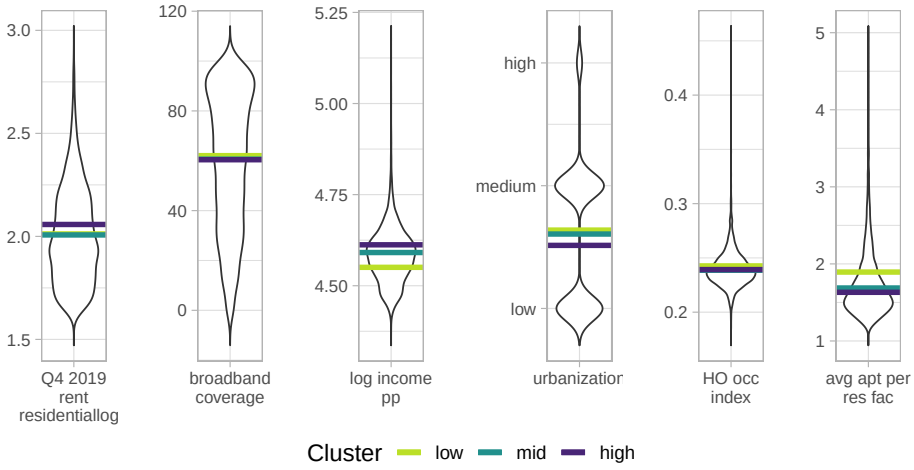



Figure 24: Characteristics of covariates by IATE cluster for residential sales prices with Covid incidence.
Notes: Average value of covariate in respective IATE cluster in relation to empirical covariate distribution.

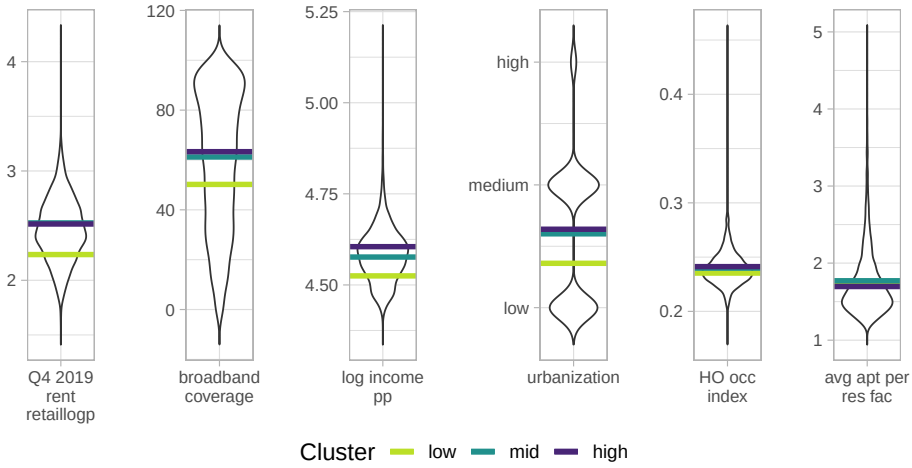



Figure 25: Characteristics of covariates by IATE cluster for retail sales prices with Covid incidence.
Notes: Average value of covariate in respective IATE cluster in relation to empirical covariate distribution.

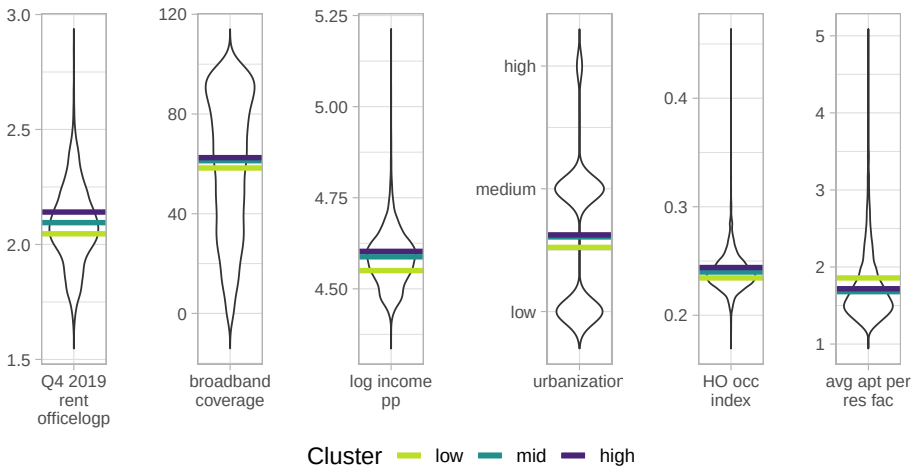



Figure 26: Characteristics of covariates by IATE cluster for office sales prices with Covid incidence.

Notes: Average value of covariate in respective IATE cluster in relation to empirical covariate distribution.