A New Highway in Germany and the Impacts on Real Estate Prices

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Abstract: How does a new highway in Germany impact residential real estate prices – both owner-occupied and rental properties? Construction of the A38 highway was completed in 2009 and expanded by additional interchanges at several points in time, through 2013. The highway connects the east and west of Germany. This dramatically alleviated congestion on nearby roads as well as enhanced connectivity for residents in the mainly rural areas. We consider a hedonic house price model with a quasi-difference-in-differences specification, to test the hypothesis that there are positive price effects on German real estate resulting from the highway completion and the associated relief of nearby road congestion. We control for potential negative effects due to additional noise and pollution, using direct distance (as the crow flies) to the nearest point on the highway. We use a German dataset on rental and owner-occupied real estate prices, for properties listed for sale and rent throughout Germany in the years 2007-2017. The treatment effects for houses and for apartments for rent are positive and significant, which implies that shorter distance to the highway leads to higher prices after the opening of the major highway (A38). The magnitudes of these treatment effects are larger for houses than for apartments. These results imply that the market capitalizes the new highway more strongly for sale properties than for rentals, perhaps because ownership implies a longer term commitment to staying in a property than renting. In other words, the present discounted value of the expected highway benefits over a relatively long time horizon are reflected quite strongly in owner occupied properties. For the changes in 2008 and 2009 we do not observe any significant effects of noise and pollution on prices while there are negative effects in 2012 and 2013. It appears likely that these disamenities became more prevalent in the most recent years.

Keywords: Real Estate Prices, Highways, Germany

JEL Codes: R3, R4

Introduction and History

Highway access has long been thought of as an essential component of the economies of thriving cities within Western countries. This is not the way it always has been. In the 1930's, Germany built a sophisticated highway network, primarily as a means to transport its military equipment and troops throughout the country and easily reach neighboring countries, and as a way to create construction jobs "partly to alleviate the serious unemployment problem among millions of hungry Germans" (Guthrie, 1949). Today, German highways are crucial for transporting goods, and for people commuting from rural areas to cities to access employment opportunities from their place of residence.[2]

One way to measure the value residents place on highway proximity is with a hedonic housing price model. Such an approach can help determine how real estate markets assign value to highway proximity, before versus after the completion of a highway. But unfortunately, there is little empirical evidence demonstrating the causal impacts of highways on residential real estate values in either the U.S. or Germany. This gap in the literature is due in large part to the lack of reliable property-level real estate price data extending back to the period when the highways were developed (early 1930's in Germany, and late 1940's in the U.S.).

There is a recent example of a new highway in Germany, the A38, which was built in 2009, and expanded with additional interchanges through 2013, and has been crucial in connecting East and West Germany. The A38 gives workers the opportunity to commute to Leipzig (in the East) or Gottingen (in the West), which are at the ends of the highway (see Figure 1 for the route of the road). It also enables firms to ship products more quickly along this

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[2] The German Autobahn system formed the model for the U.S. interstate highway system. When the U.S. General Dwight Eisenhower and the Allies conquered Germany at the end of World War II, the general was allegedly "impressed enough to come home and build our interstate highway system in response to what he'd seen" with Germany's highway system (Wilkinson, 1988). This U.S. interstate highway system has become an integral part of various aspects of the U.S. economy, and it is widely believed that highways have impacted real estate values.

corridor. This highway improvement was expected to impact the values of real estate nearby, after the completion of the A38, and possibly beforehand due to expectations of the future travel ease. This is an important part of the Autobahn because it enables people in the east to access job opportunities in the west and vice versa, among other benefits. Before reunification only very few border crossings between GDR and FRG were in operation. Therefore, there was a lack of connections between East and West Germany. Further, the former GDR invested nearly nothing in road infrastructure from the 1970s on.

The highway A38 is part of the "traffic project German union" (Verkehrsprojekt Deutsche Einheit). This project was implemented to improve the connection between East and West Germany as well as the quality of highways in the east. The aim of the highway A38 is, together with the A7 and A44, to connect the region Leipzig/Halle in the east with the Ruhr area in the west and to reduce the traffic on the A2. The different parts of the A38 highway were opened at different points of time. The last part was opened on December 22nd, 2009. However, additional motorway interchanges were opened in 2011 and 2012. The opening of the different parts of the highway did not follow from West to East, from East to West, or from the outside to the middle. Rather, it was opened piecewise so that there were still missing links in 2008. One of these gaps was about 22km in the East (Eisleben to Halle-Süd, see Figure 5 for the route) and one gap of about 12 km was in the West (Breitenworbis to Bleicherode, see Figure 6 for the route). Until the opening along these gaps in December 2008 and December 2009, respectively, the traffic of the highway was directed on rural and county roads that are more or less parallel to the planned A38.

These small roads still exist and go through villages and towns. Therefore, the residents very close to these roads were affected by a lot of noise and pollution due to the traffic, especially since many trucks already used the A38 and therefore had to drive on these alternative roads. Additionally, there can be positive economic effects of the traffic since the

drivers probably consume goods when they use the highway, because they can stop in these villages.

Besides the gaps closed at the A38 highway, it was also extended by new interchanges. On December 5th, 2012 the exit "Großwechsungen" (Figure 7) was opened that connects the A38 to the state road B243 that goes to the Northwest. Due to this connection, more villages and towns can be reached faster from the A38. On April 29th, 2013 the three-leg interchange to the highway A71 (Figure 8) was finished. The A71 goes to the south in the direction of Schweinfurt.

The completion of various sections of the A38 highway in 2009 provides the basis for a quasi-experiment that can identify the impacts of the highway on real estate prices, along with the effects on real estate prices of proximity to other new roads were built to connect with several segments of the A38. We use a German dataset on rental and owner-occupied real estate prices, based on properties listed for sale and rent throughout Germany in the years 2007-2017For properties that are listed for sale, the most significant effects of the highway are evident when the treatment considered is post-2009, within 15 minutes driving of the nearest exit to the A38. The treatment effect of approximately 11%-20% is quite robust to various specifications for cross-sectional fixed effects, and standard errors are clustered based on labor market commuting zones. For rental properties, the treatment effects are somewhat smaller, at approximately 10% or less, and in some specifications these treatment effects are insignificant. Also, the rentals treatment effect is significant for a drive time of approximately 5 minutes or less to the nearest exit of the A38. These results imply that the market capitalizes the expectation of the highway more strongly for owner-occupied properties than for rentals, perhaps because ownership implies a longer-term commitment to staying in a property than for renters. Nevertheless, the present discounted value of the expected highway benefits over a relatively long time horizon are reflected quite strongly in owner-occupied properties.

In the remainder of this paper, we review the literature on highways and how proximity to highways may impact real estate values. We also discuss other recent studies of highways using German data. Then we provide an overview of the data and the econometric approach to identifying the causal effects of the A38 highway on real estate prices in Germany, followed by a discussion of the results. A conclusion section summarizes the key findings and potential usefulness of the results for policy makers.

Literature Review

There are several studies focused on U.S. applications of highway impacts on employment, and a small number of U.S. studies focused on real estate impacts of highways. While data based on ImmobilienScout24 have been utilized extensively in real estate research, relatively few studies have been published on the German Autobahns' impacts on real estate prices.

U.S. highway studies have included Chandra and Thompson (2000), who examine the impacts of highways on economic development at the county level. They find that the impact of highways on industry varies, depending on which counties the highways pass through. While there are positive benefits from having a highway pass through the county, the nearby counties are worse off due to leaching of productive resources. Similarly, Baum-Snow (2007) uses information about the U.S. highway plans from the 1940's to assess how these plans affect employment and population in more recent years, using Metropolitan Statistical Area (MSA) level data. They find that population decreased by roughly 18 percent in MSAs where highways pass through the central city. Cohen and Morrison Paul (2007) is one study that examines the relationship between U.S. highways infrastructure and property values, and they find that additional highways infrastructure enhances the "shadow value" of buildings and structures in the manufacturing industry.

In the context of German highways, Möller and Zierer (2018) instrument the Autobahn networks using plans for the Autobahn from the 1930's and plans for rail networks from the 1800's, and observe positive causal effects of German highways on regional employment and wages. Specifically, they find that for a one standard deviation in the length of the Autobahn, both employment and the wage bill for local employees increased by around 3 percent during the period of 1994-2008.

There are several German housing price studies that utilize the RWI-GEO-RED dataset (that we use in this study), or other older data from sub-sections of Germany that is based on the platform ImmobilienScout24. Except for one of these studies, none of them consider the Autobahn (and that Autobahn study only examines correlations between proximity to the highways and residential real estate prices).

Bauer et al (2017) consider the natural experiment of a German nuclear power plant's sudden closing due to the Fukushima nuclear disaster, using the RWI-GEO-RED data. They find this sudden closure decreased real estate prices nearby by around 10% in the short-term.

There are some studies of German transportation infrastructure impacts on real estate prices (although only a small number of these use RWI-GEO-RED or similar). For instance, Schulz and Werwatz (2004) find that Berlin house prices are more than 26% lower if they are near a rail line, highway, or airport. But they do not distinguish between these different types of infrastructure in their analysis. Ahlfeldt (2011) finds that rail station proximity has no significant effect on house prices in Berlin.

Among studies of German real estate and transportation using ImmobilienScout24 data, there is Brandt and Maennig (2012). These authors find that proximity to rail and public transit in Hamburg has an overall effect of raising property list prices by 4.6%, while effects of proximity to underground stations is somewhat higher.

Liebelt et al (2018) examine the correlations between proximity to urban green space and house prices in Leipzig, Germany. While their main focus is on urban green space, they also include controls for distances from the nearest "large road" and "municipal road". For every meter further closer to the nearest large road, list price of houses fall by 0.39 Euros, and for rental apartments, for every meter closer to the nearest large road, rental prices fall by 0.001 Euro. But for "municipal roads" the signs are the opposite from large roads – the effect of being one meter closer to the nearest municipal road raises house prices by 0.22 Euros, while for apartments being one meter closer to a municipal road raises rental prices by 0.001 Euro. But their focus on Leipzig is the endpoint of the A38 on the eastern end of the highway, which is of direct interest to our study. However, their estimation approach implies correlation between proximity to the nearest large road and proximity to the nearest municipal road, but not causality. One of our major contributions is the focus on the quasi-experiment nature of the opening of the A38, in the broader context than in just one German city.

Approach and Data

Figure 1 is a map of the location of the A38. On the east side of the A38, it runs on the south end of Leipzig (former GDR), and moves west for approximately 100 km. The west side of the A38 terminates south of Gottingen and east of Kassel (former FRG). Before the opening of the A38, there were far fewer options for commuters to travel from the east to the west in this region of Germany. It is evident from this map that there are no viable alternative highways for driving between the east and west of this section of Germany.

For the real estate data, we use the property-level RWI-GEO-RED dataset (located and maintained by RWI[3]), which has coverage for all of Germany from 2007-2017. The actual coordinates of each property are not available, but location variables for each property are

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[3] http://en.rwi-essen.de/forschung-und-beratung/fdz-ruhr/datenangebot/

based on the centroid coordinates of the 1km by 1km grid in which each property is located. The lowest levels of aggregation available for locations of each property are these grids, due to the need to preserve confidentiality. Figures 2 and 3 demonstrate the numbers of houses and apartments in each grid throughout Germany during the sample period, with the location of the A38 highlighted in green. There is apparent density of both houses and apartments in Leipzig, as well as small pockets in various locations along the central portion of the A38. Slightly beyond the western end of the A38, the highway terminates approximately 15 km driving distance from both Kassel and Gottingen, which have substantial residential density of properties that were listed for sale and for rent between 2007 and 2017.

Drive times to the nearest A38 highway exits are based on actual latitude/longitude for each highway exit, and the latitude/longitude for the centroid of the grid in which each property is located. Drive times from each grid centroid to the actual location of the nearest exit of the A38 are obtained from OpenStreetMap. These drive time calculations are based on the average speed on the local motorways, e.g. on a motorway this would be 90 km per hour (defaults at OpenStreetMap). These drive times from each grid to the A38 are joined with the data for properties located in each grid, to get an approximate drive time from each property (i.e., the grid in which each property is located) to the nearest exit of the A38.

As additional control variables we take the age structure within the 1km² neighborhood from the RWI-GEO-GRID data set (RWI and microm 2018).A detailed data description can be found in Breidenbach and Eilers (2018). This data covers information on the population for all Germany for the years 2005 and 2009 to 2016. We define three age groups and their share at the whole population: kids (age 0 to 18), young age (18-29) and elderly (60 and above).

We define the date of the treatment each intervention, separately by the month the respective part was completed. For the driving time from each property to the nearest exit on the

A38, the most significant treatment effects occur for less than 900 seconds in the sales sample, and less than 300 seconds in the rental sample. Therefore, we define the sales treatment group as those properties that sold after the respective completion within 900 seconds (15 minutes) driving to the A38. For the rental sample, we define the treatment group as those properties within 300 seconds (5 minutes) drive to the A38 and rental listing after the respective completion. [4]

In the sales dataset, there are 4,341,107 observations, with an average log price per square meter of 7.312 Euros (Table 1). The average property is 36.4 years old[5] (where age is defined as difference between date of listing and date of construction completion), and approximately 15.8% of the properties are the first occupancy. The average lot size is 639 square meters, and 52.2% of the sales properties are single family houses. The federal state with the highest percentages of the sales is North Rhine-Westphalia (approximately 24.4%), followed by Lower Saxony (approximately 12.3%). Both 2008 and 2009 had about 11% of the total sales, followed by approximately 10% of the sales in 2010. The subsequent years each had about 9% or fewer of the total number of sales. Figure 4 is a map of the list prices for properties in Germany during the sample period of 2007-2017. There is substantial variation in the prices of houses near the A38, as well as throughout all of Germany.

There are 7,203,388 properties in the rental dataset, with an average log of rent of 1.929 Euros per square meter (Table 2). The average rental age is 46 years, and about 4.4% of the rentals are first occupancy. Approximately 34.3% of the rentals have a full kitchen included, while two-thirds of the rental properties have a balcony and 17.8% have a shared garden. The

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[4]

[5] In both the sales and rental datasets, a small number of properties have negative values for their age, which is attributable to their being listed before their construction is completed. Some of the oldest properties are over 1,000 years old, however these constitute only a small number of properties and given the age of many buildings in Europe dating back several hundred years, these age values are not completely surprising.

rentals are evenly spread out among the years, between 7% and 9% in each year, except for 2014 and 2015, which had approximately 12% and 11% of the rentals, respectively. North Rhine-Westphalia had about 26.7% of the rental listings, followed by Berlin (12.4%), Bavaria (11.7%), and Baden-Wurttemberg (10%).

Since the RWI-GEO-RED data available are individual properties listed for sale at various points in time, they do not comprise a panel dataset. Therefore, a variant of the difference-indifferences approach is used here (which we describe as a "quasi-difference-in-differences" approach). RWI-GEO-RED has information on the list price of properties for sale at a given point of time, between the years 2007-2017, for the entire country of Germany. For a detailed description of the data see Boelmann and Schaffner (2018). This dataset also has the rental asking price of properties during the same time period. Since it is not possible to know whether or not a property actually sold at the time of a prior listing, or whether it was simply removed from the market for a period of time and subsequently placed back on the market, it is necessary to consider only the most recent listing date and price. For rentals, we consider the same property address if it is listed multiple times, but only if the previous listing was listed at least 12 months before the current listing (due to the annual nature of many apartment leases).

There are several million property records in each of the rentals and sales property databases. Given these data, we consider the following model in order to identify the treatment effect:

$$\log(Y_i) = X_i\beta + D_{A38,i} + D_{drivetime,i} + D_{A38,i} * D_{drivetime,i} + \gamma_L + \gamma_t + \varepsilon_i \qquad \text{(i)}$$

where Y_i is the rental or sale price of the property i per square meter; X_i consists of the property characteristics of property i, $D_{A38,i}$ is an indicator variable taking value of 1 if property i is listed for sale or rent after the completion of the A38 (or its extensions), and 0 otherwise; $D_{drivetime,i}$ is

an indicator variable taking value of 1 if property i is within a k-minute drive to the nearest exit of

the A38, and 0 otherwise; $D_{A38,i} * D_{drivetime,i}$ is the treatment effect variable taking value of 1 if

property i is listed for sale after completion and is within a k-minute drive to the nearest exit of

the A38, and 0 otherwise; γ_L + γ_t are location (labor market region or district) and year fixed

effects, respectively; and ε_i is an error term for property we and is assumed to have a Normal

distribution with zero mean and constant variance and zero covariances across observations.

We cluster the standard errors based on labor market commuting zones to address potential

spillovers across these zones that may arise due to the fact that some residents are using the

A38 to commute further.

There are several alternative roads that were in use before the opening of various

sections of the A38. For instance, in Figure 5, the L172 and B180 (highlighted in red) were used

before the opening of the A38 blue part. There were trucks driving through small villages, and

the opening of this section of the A38 eliminated truck noise and some pollution. There were

some effects for residents living near this (and other alternative) road because of the benefit

from highway access as well as the additional benefit of fewer trucks in the villages after the

opening of this section of the A38. In the western part of Figure 5, there are reasonable

numbers of observations for the apartment rentals and houses for sale. After the opening of this

section of the A38, these properties are still similarly connected to the A38 compared with

before the completion of this section, but there is less noise.

The section of the A38 shown in Figure 6 (highlighted blue) was opened in December

2009, before which the B80 (highlighted in red) was used instead. Once again, there were many

trucks and cars that were using the B80, before the opening of the A38. Comparable to the first

section, after completion there is less noise due to reduced traffic for those living next to B80

while their connection to the A38 is still there.

Figure 7 shows the B243 (highlighted blue) that opened in December 2012, which connects to a section of the A38. Prior to the opening of the B243, people next to this local road had much less convenient access to the A38. There are several hundred real estate observations in our sample for this area.

Finally, the last part of the A71 that was built to connect with the A38 can be seen in Figure 8, highlighted in blue. For properties that were close to the A38, the nearest exit to the A38 was relatively far; subsequently the A71 enabled faster and easier access to the A38.

For these alternative roads, we estimate:

$$\log(Y_i) = X_i\beta + D_{A38,i} + D_{drivetime,i} + D_{A38,i} * D_{drivetime,i} + D_{alt,i} + D_{A38,i} * D_{alt,i} + \gamma_L + \gamma_t + \varepsilon_i$$

(ii)

with $D_{alt,i}$ being a dummy for near the alternative road (extension for setting 3&4). For alternative roads we choose the cutoff of 800m for houses. For apartments we take 800m for the first alternative road (shown in Figure 5) and 1200m for the second (shown in Figure 6), due to a limited number of observations being within 800m. For the extensions (shown in Figures 7 and 8), we use a cutoff of 1600m for rents and 2000m for sales.

Finally, we estimate:

$$\log(Y_i) = X_i\beta + D_{A38,i} + D_{drivetime,i} + D_{A38,i} * D_{drivetime,i} + D_{alt,i} + D_{A38,i} * D_{alt,i} + D_{close,i} + D_{A38,i} * D_{close,i} + \gamma_L + \gamma_t + \varepsilon_i$$

(iii)

with $D_{close,i}$ being a dummy for proximity to the A38 ("as-the-crow flies" distance) . The other variables are the same as above. In this last regression we bring together the effects of A38 for

all properties well connected, noise increase for those close to the highway, as well as better connectivity or less noise for all properties on the alternative routes.

Results

First, we examine whether there appear to be common trends in the data for the treated and control groups, separately for rentals and sales properties, before versus after the respective openings. We define the treatment group as those apartments for rent that are within 5 minutes' drive time and those houses for sale that are within 15 minutes' drive time, respectively. The outcome variable is the logarithm of rental price per square meter and sales price per square meter, respectively. Figure 9 demonstrates that the common trends assumption likely holds for the houses for sale within the same labor market region. The trend in other regions within Germany slightly differs especially for the extensions (lower panels). Prices in Germany are almost stable within the whole time period while they decrease in the treated labor market regions between 2007 and 2013. Therefore, we proceed by taking the same labor market regions as control groups. Figure 10 presents the trends for apartments for rent. Within this group the differences between all Germany and the labor market region are small. Rents in the treated regions are lower than in all Germany but the development is similar. Rents increase during the whole time period. However, the development in the regions with treatment seem to be more u-shaped especially before the respective treatment.

Specifically, for sales properties (Figure 9), the trends appear to move in same directions for treatment and control groups before the end of 2008 and 2009, respectively, although the treatment group exhibits somewhat wider volatility in periods when the control group experiences changes. In the short run (early 2009), both the treatment and control groups exhibit downward trends in the price (likely due to the economic crisis). In the long-run, the treatment group experiences steeper growth than the control group, after the treatment date, to

the extent where eventually the prices in the treatment group come close to completely catching up with the prices in the control group. This suggests that while there is a small, immediate treatment effect, the full impact of the new highway takes several years to show up in the sales data. The development around the extensions do not show any clear pattern.

For rental properties, the trends in the treatment and control groups seem similar pre-2009, and then there are several spikes in rental price per square meter due to small sample sizes. Both groups develop quite similarly. There does not seem to be a treatment effect. This descriptive illustration implies that the treatment effect (in the long-term) is likely greater for sales than the treatment effect for rentals.

Next we present the results for the streets and extensions, in Tables 3 and 4. The first column of Table 3 shows the results for the parallel road #1 for houses for sale, using all homes that were listed within the labor market regions in the area of the extension. The treatment was within 800 meters of the street formerly used as a link between the parts of the A38, after opening of the part of the A38 nearest to the street. The treatment effect for being close to the street after the opening of the nearest part of the A38 (treatment effect close to street) is negative and insignificant, implying that these properties experienced a negligible drop in noise and pollution due to completion of the highway. While we expected negative effects, it is possible that the negative effects as well as any positive economic effects can offset each other.

Further, sales prices are always higher in short driving distance to the A38 (close to A38) compared to the labor market region. It is possible that some buyers prefer the good connection to the highway. Finally, the time horizon for buyers is relatively long and due to anticipation, any effects are measurable. The results for parallel road #2 are quite similar.

However, we do observe significant price decreases for properties that are in close distance (15 min drive time) to the highway at the first construction point. This result is quite

surprising since these houses are better connected after the construction. The treatment effect for houses within 800 meters distance to the highway (direct distance to A38 < x after t treatment effect) is insignificant, so it is likely not driven by pollution. However, for the last part built (parallel road #2) there is a substantial positive effect (0.157) on housing prices indicating that home buyers likely value connectivity to the highway. This is also true for the extensions in 2013 and 2014 (0.193 and 0.101). The prices for houses within 15 minutes driving time to the highway increase substantially. For the extensions there is also a negative effect on sales prices for houses close to the highway (measured as the crow flies) of 0.195 and 0.121, respectively. Further, houses next to the first connected street experience price increases, probably due to the fact the increased connectivity.

Table 4 presents results for apartments for rent. The results are somewhat different between Tables 3 and 4. Again, noise and pollution do not appear to play a role for the properties close to the street after the opening of the nearby section of the A38 (i.e., they are all statistically insignificant in columns 1 and 2). The same is true for properties close by the new highway when controlling for distance as the crow flies (800m #1 and 1200m #2) to the A38 in the rental sample of all Germany apartments. However, for both additional parts, apartments with a driving distance of less than 5 minutes experience substantial increases (0.207 and 0.0594, respectively) in their rent. Connectivity is valued by the renters.

For the highway extensions there are not any significant effects of the highway on rental prices within a 5 minutes driving distance (columns 3 and 4). The only apparent improvement for those living next to the highway is the connection to the other roads. However, rental prices decrease near (within 2000m as the crow flies) the connected streets (extension #1) by 0.127 and next to the highway (extension #2) by 0.0503. These results may imply that the increased traffic leads to more noise and pollution and therefore lower rental prices.

To sum up, the results indicate that there are substantial positive effects of the better connection due to the highway on both rental and sales prices. In contrast, noise and pollution (proxied by as the crow flies' distance) do not result in lower prices in 2008 and 2009 while there are significant and negative effects in the more recent years 2012 and 2013.

Conclusion

In our analysis, we estimate quasi difference-in-differences models to determine the causal effects of proximity to highway extensions on real estate list prices in Germany. We observe that apartments and houses very close to the highway have lower list prices (both for sale and for rent). The opening of the previously missing parts of the highway influence prices of those properties positively that are in short driving distance while those in close air distance are not affected differently. Regarding the extensions to other roads we observe some significantly negative effects on housing prices close by the highway. For the new streets leading to the highway as well as the former alternative routes, there are not any significant differences. This can be because traffic has not changed much, and/or that noise and pollution are not valued. Another possible explanation is that positive economic effects as well as negative pollution effects cancel each other out. Positive effects could be attributed to trucks that pass the small villages and their drivers buying food etc.

The second completion as well as both extensions to the A38 lead to increased sales prices for houses within 15 minutes' drive time to the highway. Buyers seem to value better infrastructure for commuting. For rental apartments, the effect only occurs for the completions but not the extensions. Renters typically have a shorter time horizon in mind than buyers, so the capitalization of the positive effects are not as strong for renters as for buyers. Further, renters in those rural areas are mainly young people who grew up in the region or have a job close by.

They may value the extensions less than house buyers who come from bigger cities. The increases of sale prices are substantial, ranging between 11 and 21 percent.

Several implications of this research are worth contemplating as policy makers in Germany and elsewhere (e.g., the U.S.) consider highway expansions. First, the treatment effects for owner-occupied properties are larger than those for rentals. The A38 is likely a magnet that draws traffic away from the more rural roads, leaving less urban congestion and pollution, which is desirable from the perspective of residents. Perhaps these differences arise because renters typically expect to live in a property for less time than owner-occupiers of residential properties, so the present discounted value of future benefits could be reaped over a much longer time horizon.

Regardless of which property type benefits more, however, it is clear that a new highway can significantly and favorably impact property values in the years following the opening of the highway. Although there are relatively few causal real estate case studies of new highways being built, our findings have implications for other highway construction projects, such as those intended to reduce congestion and drive time on existing highways, both in Germany and internationally.

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Table 1
Descriptive Statistics - Residential Properties for Sale in Germany, 2007-2017

Variable	Obs	Mean	Std. Dev.	Min	Max
Log price per sq meter	4 341 107	7.312	0.553	1.265	17.71
Age	4 341 107	36.433	44.531	0	1014
Age-squared	4 341 107	3310.426	13641.550	0	1028196
First occupancy	4 341 107	0.158	0.365	0	1
Lot size	4 341 107	638.887	600.383	0	5000
Single family home	4 341 107	0.522	0.500	0	1
Semi-detached house	4 341 107	0.137	0.344	0	1
Row house	4 341 107	0.075	0.263	0	1
Facilities: simple	4 341 107	0.020	0.139	0	1
Facilities: normal	4 341 107	0.097	0.296	0	1
Facilities: sophisticated	4 341 107	0.167	0.373	0	1
Facilities: deluxe	4 341 107	0.014	0.118	0	1
Number of rooms: 1-2	4 341 107	0.483	0.500	0	1
Number of rooms: 3-4	4 341 107	0.152	0.359	0	1
Number of rooms: 5-6	4 341 107	0.059	0.236	0	1
Time	4 341 107	5.615	3.141	1	11
Time-squared	4 341 107	41.391	38.069	1	121
Dummy previous streets 1 within 800m	4 341 107	0.000	0.010	0	1
Treatment effect previous streets 1 within 800m	4 341 107	0.000	0.009	0	1
Dummy previous streets 2 within 800m	4 341 107	0.000	0.007	0	1
Treatment effect previous streets 2 within 800m	4 341 107	0.000	0.006	0	1
Dummy Extension 3 within 800m	4 341 107	0.000	0.003	0	1
Treatment effect extension 3 within 2000m	4 341 107	0.000	0.006	0	1
Dummy extension 4 within 2000m	4 341 107	0.000	0.012	0	1
Treatment effect extension 4 within 2000m	4 341 107	0.000	0.007	0	1
Dummy within 800m to A38	4 341 107	0.000	0.015	0	1
Dummy within 15min to A38	4 341 107	0.008	0.091	0	1
Federal State					
Schleswig-Holstein	4 341 107	0.054		0	1
Hamburg	4 341 107	0.012	0.109	0	1
Lower Saxony	4 341 107	0.123	0.329	0	1
Bremen	4 341 107	0.005	0.073	0	1
North Rhine-Westphalia	4 341 107	0.244	0.429	0	1
Hesse	4 341 107	0.090	0.287	0	1
Rhineland-Palatinate	4 341 107	0.088	0.283	0	1

Baden-Wurttemberg	4 341 107	0.112	0.316	0	1
Bavaria	4 341 107	0.111	0.314	0	1
Saarland	4 341 107	0.009	0.094	0	1
Berlin	4 341 107	0.026	0.160	0	1
Brandenburg	4 341 107	0.041	0.199	0	1
Mecklenburg-Western Pomerania	4 341 107	0.021	0.144	0	1
The Free State of Saxony	4 341 107	0.032	0.177	0	1
Saxony-Anhalt	4 341 107	0.017	0.131	0	1
The Free State of Thuringia	4 341 107	0.012	0.110	0	1
Years					
2007	4 341 107	0.094		0	1
2008	4 341 107	0.113	0.317	0	1
2009	4 341 107	0.117	0.322	0	1
2010	4 341 107	0.103	0.304	0	1
2011	4 341 107	0.089	0.285	0	1
2012	4 341 107	0.075	0.263	0	1
2013	4 341 107	0.086	0.280	0	1
2014	4 341 107	0.091	0.287	0	1
2015	4 341 107	0.084	0.277	0	1
2016	4 341 107	0.068	0.251	0	1
2017	4 341 107	0.080	0.271	0	1
Age structure of neighborhood					
Share of kids (age < 18)	4 341 107	0.0172	0.0248	0	1
Share of young (18-29)	4 341 107	0.0128	0.0247	0	0.525
Share of elderly (60+)	4 341 107	0.2672	0.0457	0	1

Sources: RWI-GEO-RED and OpenStreetMap.

Table 2
Descriptive Statistics for Residential Rental Properties in Germany, 2007-2017

Variable	Obs	Mean	Std. Dev.	Min	Max
Log price per sq meter	7 203 388	1.929	0.341	-1.187	11.16
Age	7 205 581	46.362	39.340	0	1017
Age-squared	7 205 581	3697.047	14349.680	0	1034289
First occupancy	7 205 581	0.044	0.205	0	1
Balcony at object	7 205 581	0.665	0.472	0	1
Garden	7 205 581	0.178	0.383	0	1
Kitchenette in object	7 205 581	0.343	0.475	0	1
Lot size	7 203 388	72.550	27.165	0.01	1000
Facilities: simple	7 205 581	0.007	0.083	0	1
Facilities: normal	7 205 581	0.218	0.413	0	1
Facilities: sophisticated	7 205 581	0.184	0.388	0	1
Facilities: deluxe	7 205 581	0.016	0.127	0	1
Number of rooms: 1-2	7 205 581	0.431	0.495	0	1
Number of rooms: 3-4	7 205 581	0.535	0.499	0	1
Number of rooms: 5-6	7 205 581	0.033	0.179	0	1
Number of rooms: 7-8	7 205 581	0.001	0.037	0	1
Dummy previous streets 1 within 800m	7 205 581	0.000	0.007	0	1
Treatment effect previous streets 1 within 800m	7 205 581	0.000	0.006	0	1
Dummy previous streets 2 within 1200m	7 205 581	0.000	0.004	0	1
Treatment effect previous streets 2 within 1200m	7 205 581	0.000	0.004	0	1
Dummy Extension 3 within 1200m	7 205 581	0.000	0.004	0	1
Treatment effect extension 3 within 1200m	7 205 581	0.000	0.003	0	1
Dummy extension 4 within 2000m	7 205 581	0.000	0.006	0	1
Treatment effect extension 4 within 2000m	7 205 581	0.000	0.004	0	1
Dummy within 800m to A38	7 205 581	0.000	0.010	0	1
Dummy within 5min to A38	7 205 581	0.000	0.016	0	1
Federal State					
Schleswig-Holstein	7 205 581	0.031		0	1
Hamburg	7 205 581	0.025	0.156	0	1
Lower Saxony	7 205 581	0.056	0.229	0	1
Bremen	7 205 581	0.007	0.085	0	1
North Rhine-Westphalia	7 205 581	0.267	0.442	0	1

Hesse	7 205 581	0.085	0.279	0	1
Rhineland-Palatinate	7 205 581	0.030	0.170	0	1
Baden-Wurttemberg	7 205 581	0.101	0.302	0	1
Bavaria	7 205 581	0.117	0.322	0	1
Saarland	7 205 581	0.002	0.046	0	1
Berlin	7 205 581	0.124	0.329	0	1
Brandenburg	7 205 581	0.022	0.145	0	1
Mecklenburg-Western Pomerania	7 205 581	0.010	0.099	0	1
The Free State of Saxony	7 205 581	0.081	0.274	0	1
Saxony-Anhalt	7 205 581	0.032	0.177	0	1
The Free State of Thuringia	7 205 581	0.010	0.100	0	1
Years					
2007	7 205 581	0.070		0	1
2008	7 205 581	0.073	0.261	0	1
2009	7 205 581	0.083	0.276	0	1
2010	7 205 581	0.092	0.290	0	1
2011	7 205 581	0.090	0.286	0	1
2012	7 205 581	0.086	0.280	0	1
2013	7 205 581	0.095	0.293	0	1
2014	7 205 581	0.124	0.330	0	1
2015	7 205 581	0.114	0.318	0	1
2016	7 205 581	0.088	0.283	0	1
2017	7 205 581	0.085	0.279	0	1
Age structure of neighborhood					
Share of kids (age < 18)	7 205 581	0.1569	0.0209	0	0.400
Share of young (18-29)	7 205 581	0.1573	0.0375	0	0.429
Share of elderly (60+)	7 205 581	0.2562	0.0551	0	1

Sources: RWI-GEO-RED and OpenStreetMap.

Table 3
Regression Results – Houses for sale

	previous street 1	previous street 2	extension 1	extension 2
X	*800m*	*800m*	*2000m*	*2000m*
t	*Dec 2008*	*Dec 2009*	*Dec 2012*	*Apr 13*
direct distance to A38 < x after t	0.0864	-0.389***	-0.384***	0.133***
	(0.45)	(-3.08)	(-7.48)	(2.44)
direct distance to A38 < x after t treatment effect	0.262	0.157	-0.195***	-0.121*
	(0.88)	(1.22)	(-3.43)	(-1.99)
close to street dummy	0.120	-0.540***	-0.170***	0.0660
	(1.17)	(-3.39)	(-4.63)	(0.74)
treatment effect close to street	-0.0997	-0.164	0.171***	0.0519
	(-0.69)	(-1.18)	(3.06)	(0.52)
close to A38	0.0591***	0.0122	0.0602***	0.0160*
	(3.54)	(1.01)	(5.97)	(1.86)
treatment effect close to A38	-0.0591***	0.157***	0.193***	0.101***
	(-3.22)	(10.60)	(11.62)	(7.59)
R²	0.4872	0.5029	0.5039	0.4989
N	20 090	24 845	24 845	24 235
direct distance to A38 <x	125	289	1 446	1 453
direct distance to A38 < x after t	114	191	654	653
close to street	393	216	345	580
close to street after	341	152	141	239
close to A38	7 028	5 305	5 305	8 365
close to A38 after t	5 909	3 231	1 900	3 545

Table 4
Regression Results – Apartments for rent

	previous street 1	previous street 2	extension 1	extension 2
X	*800m*	*1200m*	*2000m*	*2000m*
t	*Dec 2008*	*Dec 2009*	*Dec 2012*	*Apr 13*
direct distance to A38 < x	-0.0116	-0.44***	-0.219***	-0.0407
	(-0.18)	(-2.68)	(-6.11)	(-1.44)
direct distance to A38 < x treatment effect	-0.108	-0.147	0.0121	-0.0503**
	(-1.44)	(-0.97)	(0.23)	(-2.19)
close to street dummy	0.292***	0.364**	0.0824***	0.237***
	(6.32)	(1.98)	(2.77)	(4.42)
treatment effect close to street (< x)	-0.0733	0.139	-0.127***	0.0317
	(-1.22)	(0.71)	(-3.06)	(0.58)
close to A38	-0.159***	-0.0897***	-0.0249**	-0.00491
	(-4.45)	(-4.70)	(-2.33)	(-0.72)
treatment effect close to A38	0.207***	0.0594***	-0.0120	0.00725
	(5.64)	(2.93)	(-0.92)	(0.77)
R²	0.3125	0.5976	0.5977	0.3046
N	54 943	21 412	21 412	58 952
close to street	286	166	446	1 331
close to street after t	273	124	196	502
direct distance to A38 < x	322	124	226	241
direct distance to A38 < x after t	294	101	103	115
close to A38	623	1 128	1 128	1 670
close to A38 after t	600	1 000	662	793

Figure 1 Map of highway A 38
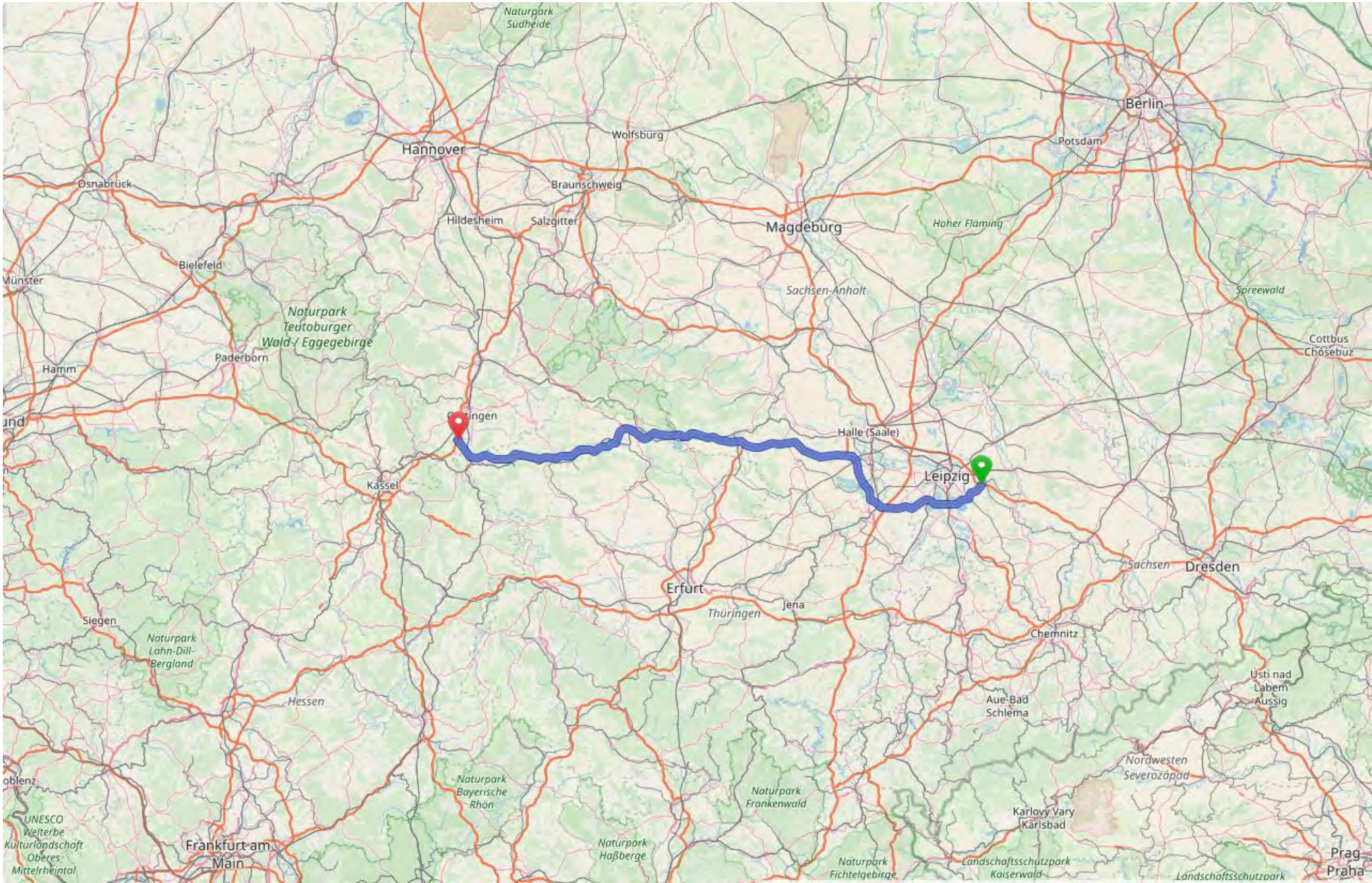
Source: Open Street Map1/1

Figure 2 Map of highway A 38 and Number of Observations for Sale
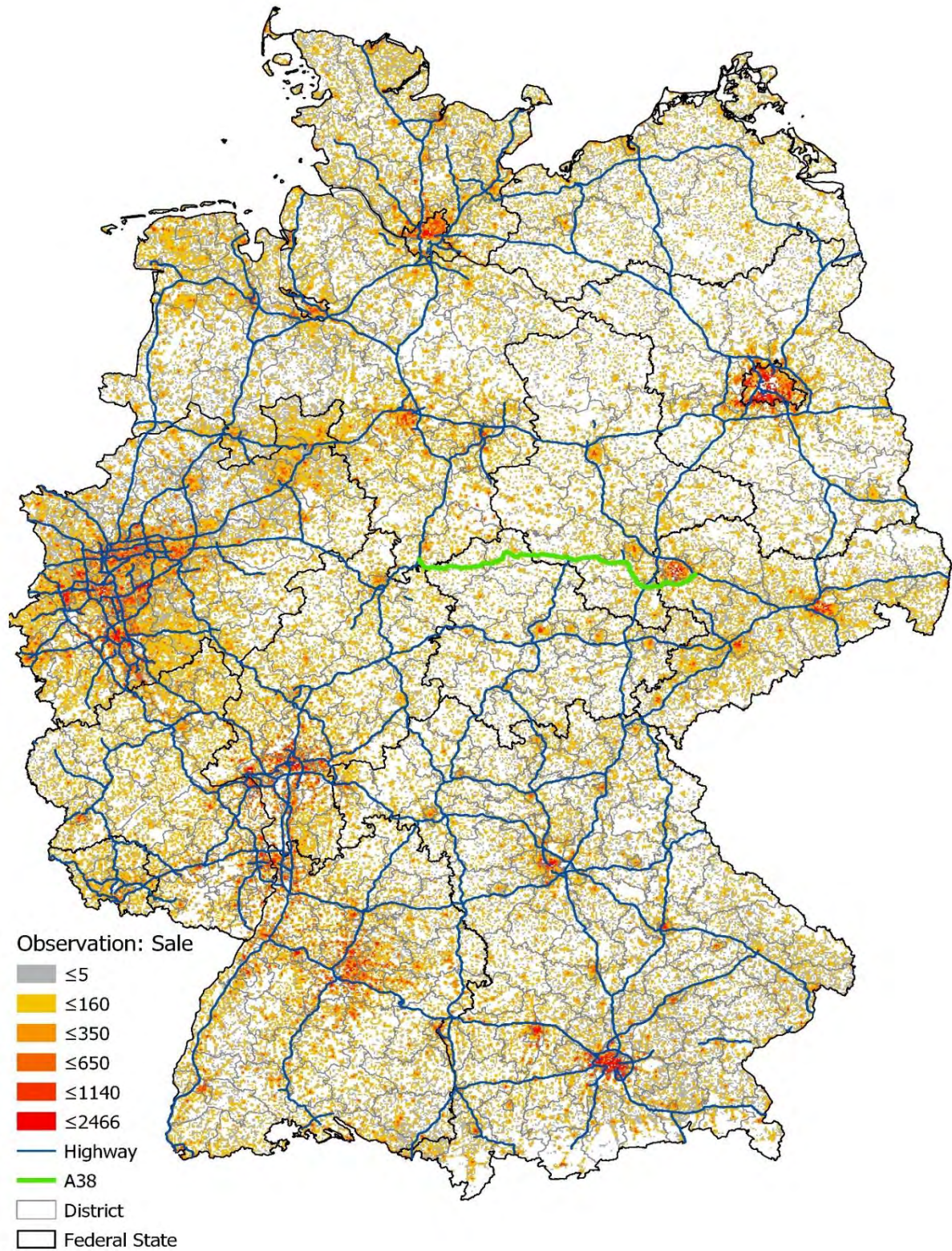
Figure 3 Map of highway A 38 and Number of Observations for Rent

Observation: Rent
- ≤5
- ≤100
- ≤300
- ≤600
- ≤1000
- ≤2393
- Highway
- A38
- District
- Federal State
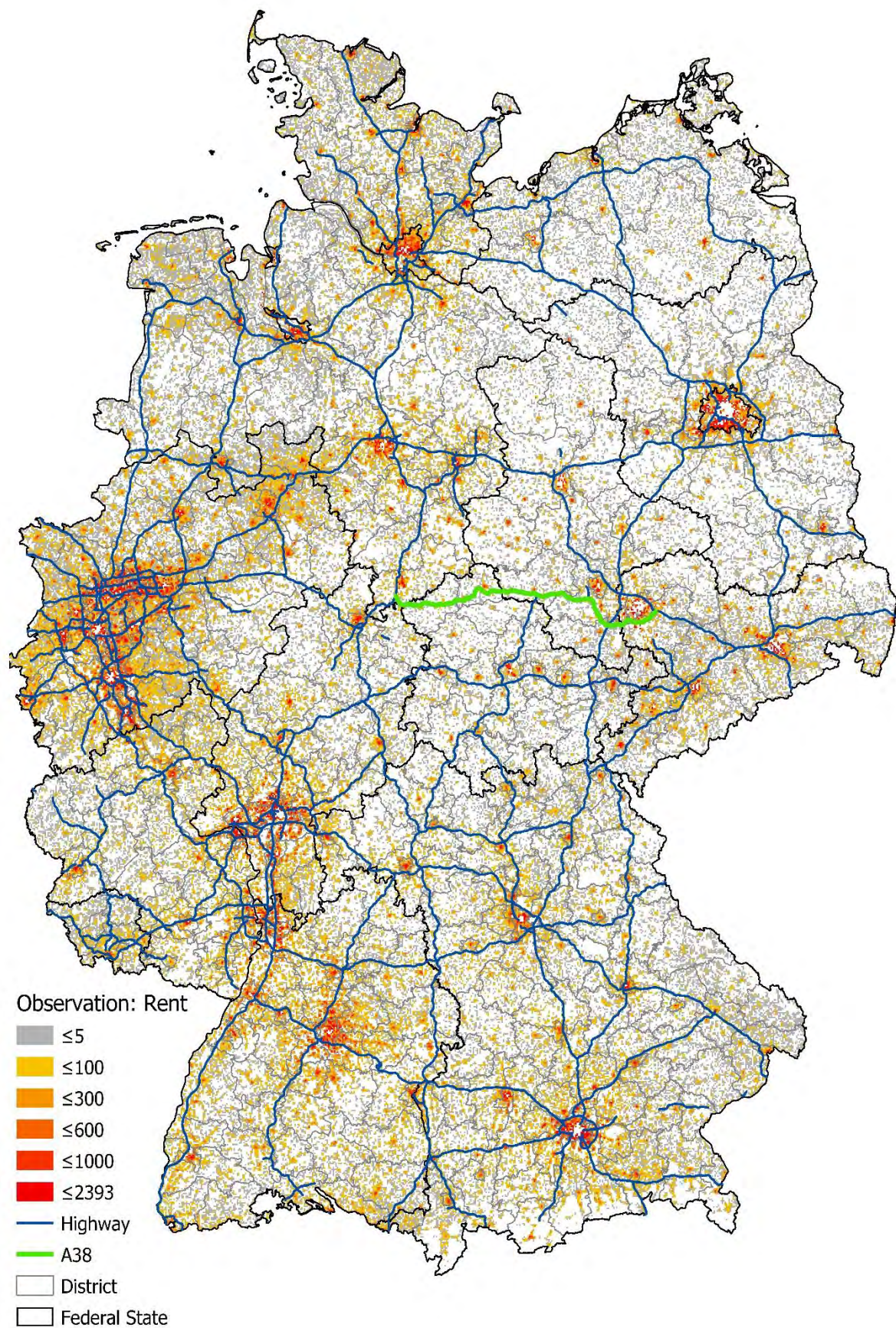
Figure 4: Average sales prices within Germany

Average sales price
- <5 obs
- ≤200000
- ≤250000
- ≤1000000
- ≤3000000
- ≤30000000
- Highway
- A38
- District
- Federal State
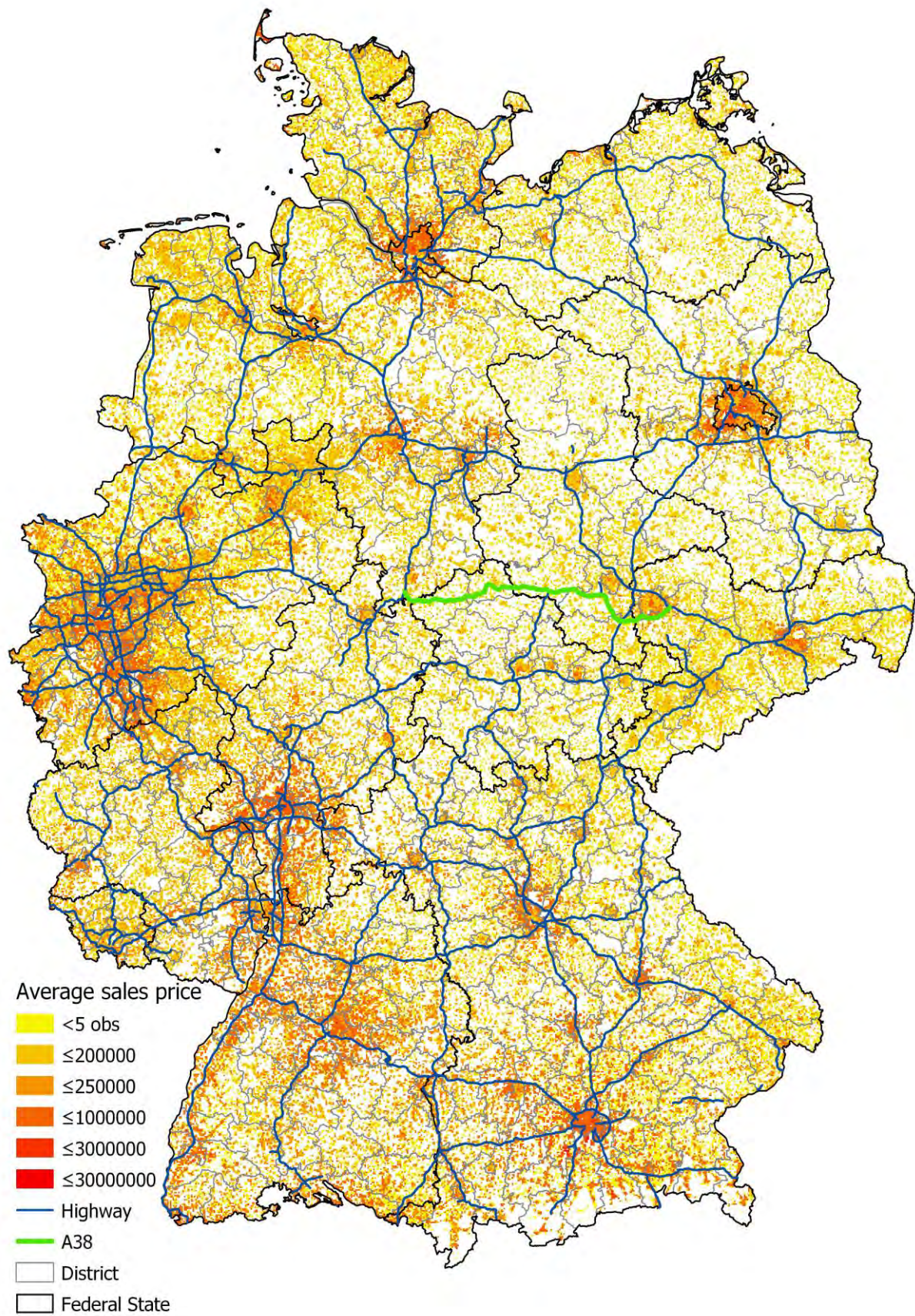
Figure 5: Highway completion #1
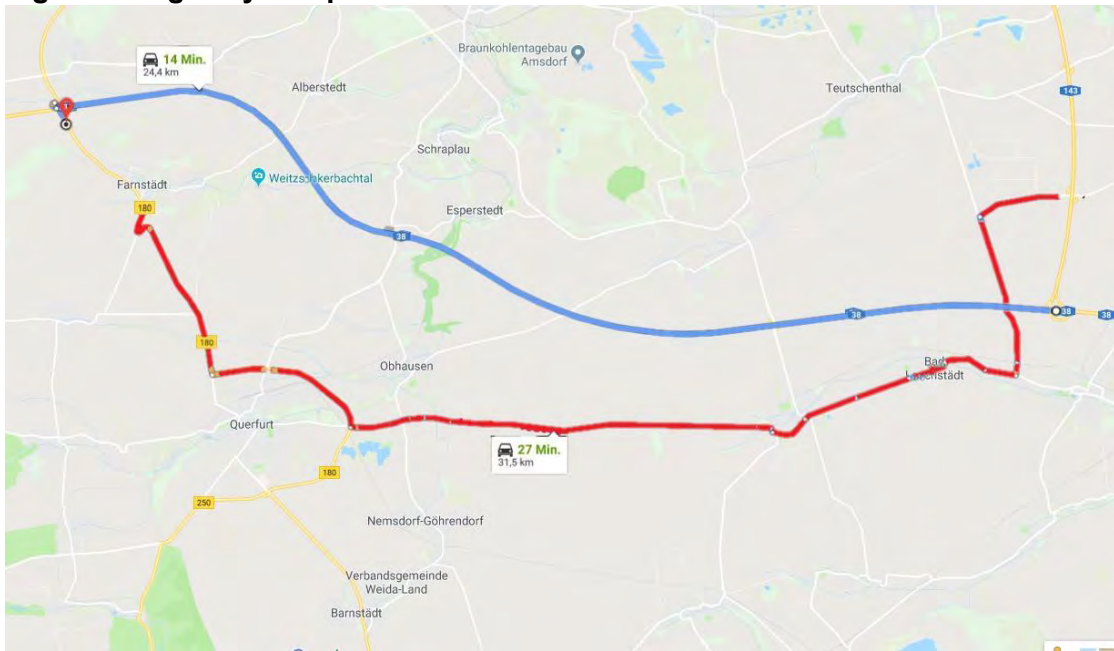
The blue colored part was opened December 2008 (22nd). The B180 and L172 (red route) were used before the opening.

Figure 6: Highway completion #2
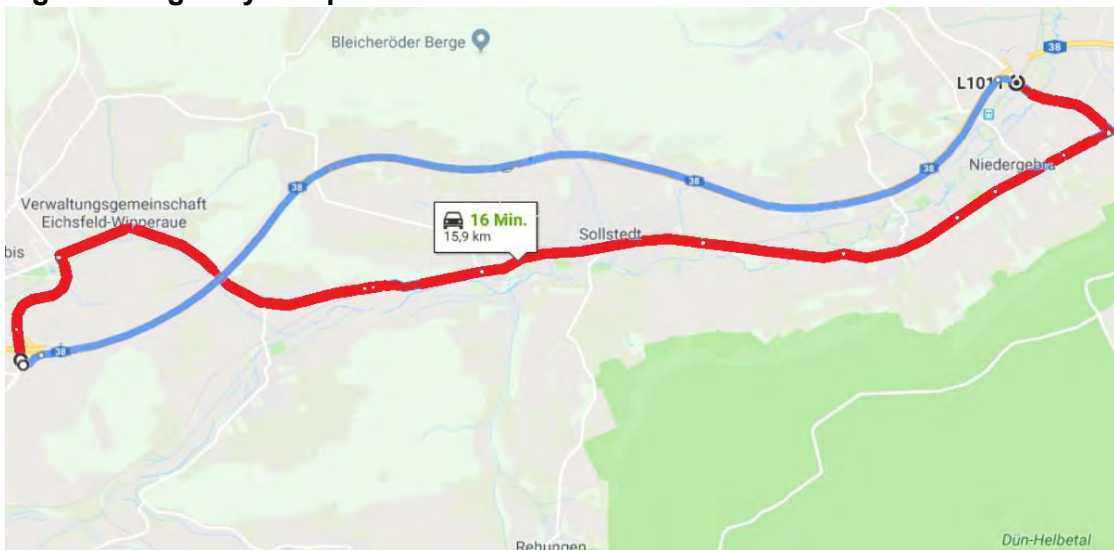
The blue colored part of the A38 was opened December 2009. The B80 (red route) was used before the opening.

Figure 7: Extension #1

The blue colored part of the B343 to the A38 was opened in Dec2012. It is a Bundesstrasse but in this part like a highway.

Figure 8: Extension #2
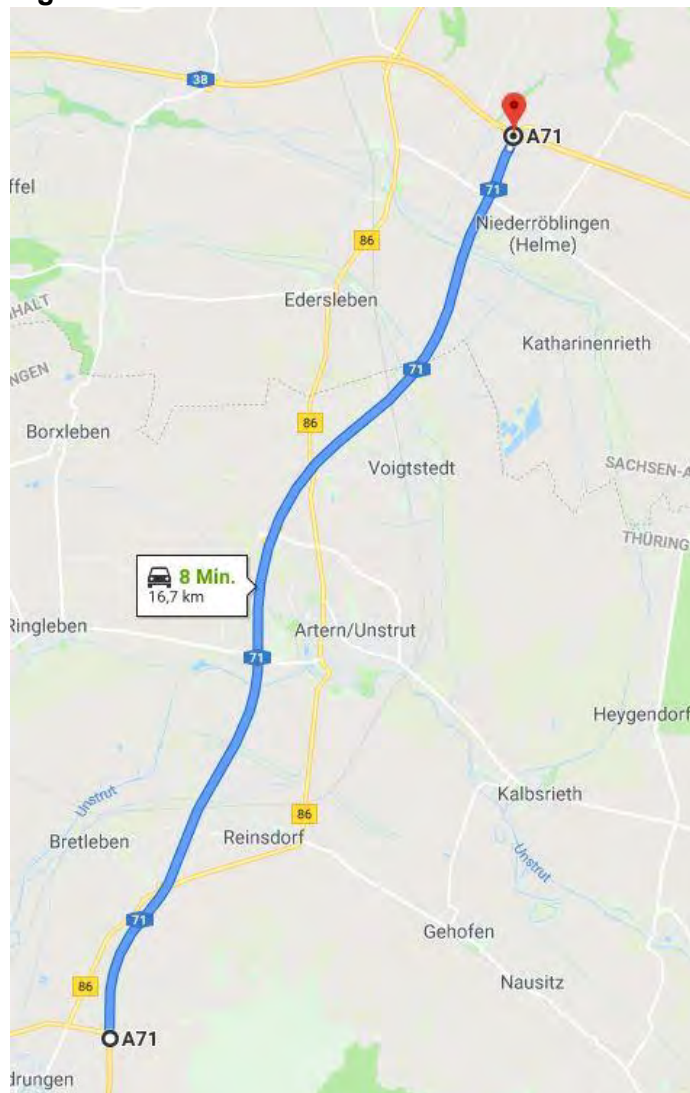
The last change was the Autobahndreieck Südharz. This last part (blue) of the A71 was built to connect it to the A38.

Figure 9　　　　　　**Mean price for houses for sale**
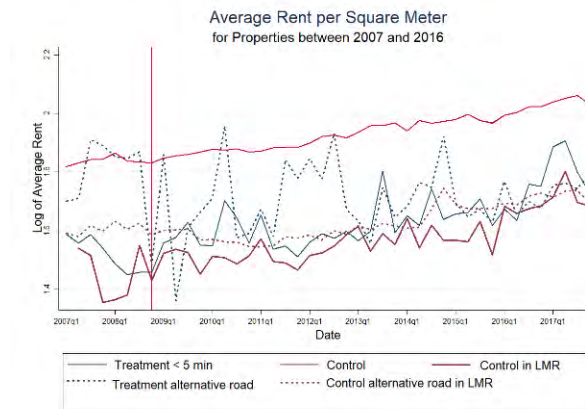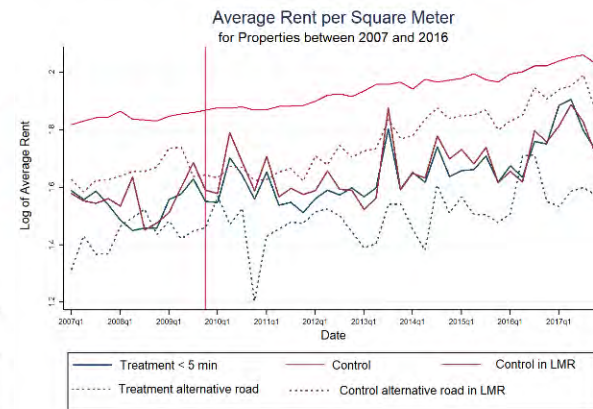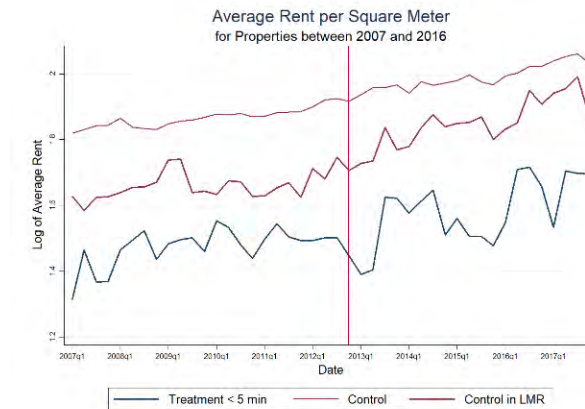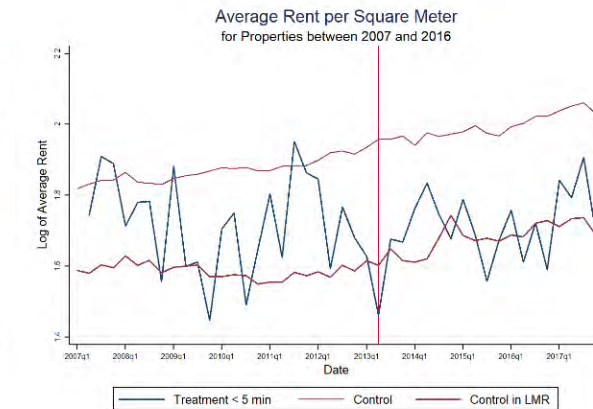
Road #1
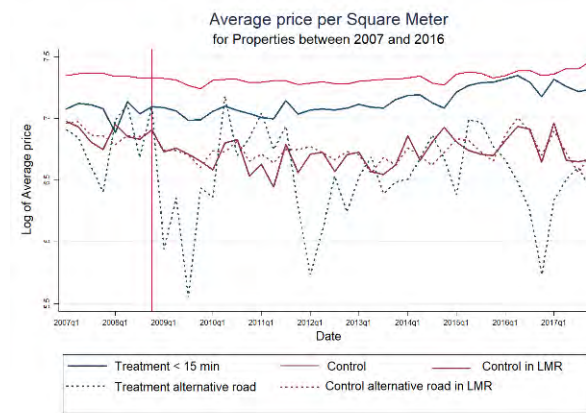
Road #2
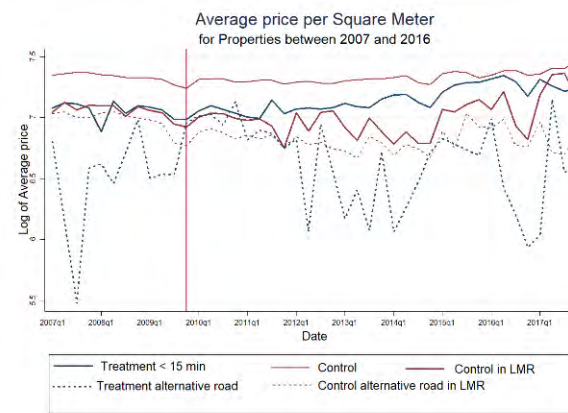
Extension #1
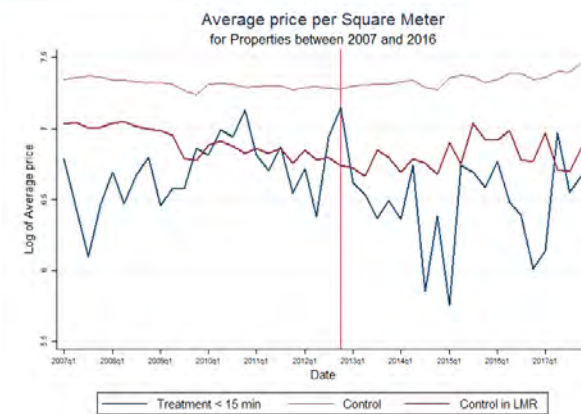
Extension #2

Source: RWI-GEO-RED, own calculation.

Figure 10   Mean rent for apartments for rent

Road #1

Road #2

Extension #1

Extension #2

Source: RWI-GEO-RED, own calculation.