New German Highway Infrastructure and the Impacts on Residential Real Estate Prices

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Abstract: Germany's 1990 reunification necessitated highway connections between an underdeveloped region and a western country. The 2009/2013 German Autobahn highway A38 completion/additions alleviated congestion, enhanced connectivity, and increased pollution/noise. Using German residential real estate price data spanning 2007-2017, we find shorter drive times to the A38 raised prices; and direct proximity lowered prices. Our results exceed connectivity estimates of a German local roads study and some Western European highway studies, due to A38 newly linking the east/west of Germany. Our highway estimates are in the mid-range of German transit studies, implying German transit may impact real estate prices more than highways.

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Introduction and Background

Highway access has long been an essential component of the economies of thriving cities within Western countries, and in turn, their benefits and drawbacks are expected to be capitalized into real estate prices. Better highways make remote locations more accessible to jobs and therefore should enhance residential real estate prices nearby. On the other hand, there is additional noise and pollution that often accompany highway proximity, so in some cases the overall effect might be ambiguous.

There is an extensive literature demonstrating the relationships between residential real estate values and highway infrastructure. Across various countries and time periods, research typically indicates that for properties closer to the highways, the effects are small or sometimes negative. Moving slightly further away, the accessibility benefits are positive but further beyond a certain point they tend to dissipate.

While these effects tend to be well-known, Germany is a unique case study that has not been extensively explored. This is important because Germany was reunified in 1990 and the eastern part of the country was much less developed than the west. A highway connecting the east to the west would be expected to provide great opportunities for residents of the relatively under-developed east to access the west. This raises the question of whether the infrastructure impacts on real estate in the east are similar as those of other developed countries, and whether it makes sense to expand German highway infrastructure in a way that links the east with the west or restricting attention to one region only. Also, with constraints on overall funds for all types of infrastructure, it would be interesting to compare the potential real estate benefits from German transit studies with the benefits of the A38.

This study aims to estimate the potential benefits of proximity to segments of the A38 highway, and to determine whether these benefits are comparable to those in other developed countries and other infrastructure studies in Germany. The primary objectives of this paper are to test the hypotheses that access to a new highway in Germany led to higher residential real estate prices; and the associated negative effects such as noise and air pollution led to lower real estate prices. Our empirical setting allows us to disentangle connectivity and noise/pollution effects. We compare our estimates with the findings of studies of German transit impacts on house prices, as one way to generate potentially helpful information for policymakers who must choose how to spend limited public funds on all types of infrastructure. Finally, we explore how the real estate effects of a new highway in this unique geographical and historical context of Germany compare with other studies' estimates of highways impacts on house prices elsewhere in western Europe. This could provide some useful information for German policymakers on whether the house price benefits of highway infrastructure might be higher if a highway were exclusively in the west, or if it were to straddle the east and the west.

Recent research on real estate and highway infrastructure in other countries recognizes there may be significant relationships, and this can inform policy when new highway investments are being considered.[1] Germany's highways were originally designed in the 1930's to move military equipment, while 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] The benefits and drawbacks may be reflected in residential real estate prices near the highways.

One way to measure the value residents place on highway proximity and noise and air pollution is with a hedonic housing price model, as in Rosen (1974). Such an approach can help determine how real estate markets assign value to highway proximity. Two identification strategies that we explore here are the Lewbel (2012) instrumental variables (IV) approach that relies on heteroskedasticity; and separately, a quasi-difference-in-differences (diff-in-diff) approach. To our knowledge, the Lewbel (2012) IV approach has not been applied to address the question of how highway infrastructure impacts real estate prices. There is also little empirical evidence demonstrating the causal impacts of highways on residential real estate prices in Germany.

Collecting German real estate price data back to the initial construction (and/or the announcement) of the first highways in the 1930's or earlier is infeasible. In general, there is limited data available on residential German real estate prices; typically, the German data are available from 2007 onward. Even when considering only one more recent, specific highway infrastructure improvement, pre-announcement date real estate prices data are not available. We conjecture that the Lewbel (2012) IV approach is one way to address this problem. Unlike a difference-in-differences identification strategy, the Lewbel (2012) IV approach does not rely on a before vs. after analysis. But applying the Lewbel (2012) IV approach to study a relatively new highway can help one understand the impacts of this new highway on real estate.

The German A38, which was built in 2009 and expanded with additional interchanges through 2013, has been crucial in connecting specific parts of 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 corridor. This highway improvement was expected to

impact the values of real estate nearby. 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 onward. This discrete improvement in highway infrastructure in the East was expected to increase residential real estate prices as it would enable the east to become much more inhabitable, along with eased noise and congestion on nearby local roads that were previously relied upon but at a much slower travel speed.

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 Leipzig/Halle region 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 of about 12 km was in the West (Breitenworbis to Bleicherode, see Figure 2 for the route). Until the opening along this gap in December 2009, the traffic of the highway was directed on rural and county roads that are more or less parallel to the planned A38 (including the need to travel on the L2070 south to the L3080 west, in a very circuitous route). In addition to the increased travel time due

to the longer distance to reach the A38, these local roads were narrower and prevented high speed travel. These small roads still exist and go through villages and towns. Therefore, the residents who lived 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 instead had to drive on these alternative roads. Additionally, there might have been positive economic effects of the traffic since the drivers probably consume goods when they use the highway, because they could stop in these villages.

Besides the gaps that were closed at the A38 highway, it was also extended by new interchanges. On December 5th, 2012 the exit "Großwechsungen" (Figure 3) 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.

The completion of various sections of the A38 highway in 2009 provides the basis for analysis 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 that were built to connect with several segments of the A38. We focus our analysis on one of the alternative roads that were formerly used as primary driving routes between the east and west but were subsequently replaced by the A38; and on one A38 highway extension segment. We use a German dataset on owner-occupied real estate prices, based on properties listed for sale in Germany during the years 2007-2017.

We find prices are higher for those in shorter driving distance to this extension of the A38. On the other hand, after controlling for driving distance, properties that are close to the A38 extension ("as the crow flies") tend to have lower prices, which we attribute to traffic noise and congestion. We also find evidence that sales prices are lower for those in close proximity to the alternative road, which implies those neighborhoods perhaps became less desirable after the

opening of the new highway extensions. Negative economic effects seem to overcompensate positive effects due to less noise. We consider a set of robustness checks using different identification strategies (including both difference-in-differences and separately, an IV technique). For properties listed for sale, the most significant effects of the highway are evident when the quasi difference-in-differences treatment considered is post-2009, within 15 minutes driving of the nearest exit to the A38. The treatment effect of approximately 35%-38% is quite robust to various specifications for cross-sectional fixed effects. On the other hand, the IV estimates are statistically significant and in the same range while not significant smaller in proximity of less than 15 minutes driving time, which is also robust to alternative model specifications.

In the remainder of this paper, we first review the general literature on how proximity to highways may impact real estate values. We also discuss a small number of other recent studies of highways using German data, along with some studies on German transit and real estate prices. Then we provide an overview of the data and the econometric approaches 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 many studies of highway impacts for the U.S.[3] and for other countries. In the U.S., one notable example is Allen et al. (2015), who study Interstate 110 in Orlando, Florida. They find a 2.5% statistically significant discount in house prices for properties that are longer drive distance (in miles) from the highway, while houses next to the highway sell for 4% less than other houses. The Allen et al. (2015) drive distance estimate translates to approximately

1.5% per kilometer. Chernobai et al. (2011) consider Interstate 210 in the Los Angeles area, and find that nonlinear effects on property values are important, with low benefits to very close proximity but increasing benefits moving away up until a critical point, beyond which the benefits dissipate. They also find that there are essentially no "announcement" effects but most beneficial effects on property values occur very shortly after the opening of the highway.

In the broader European context, Levkovich et al. (2016) examine how house prices are impacted by newly constructed highways in the Netherlands, with a diff-in-diff approach as an identification strategy. For the new A50 highway, they find that house prices in their "treatment area" (within 10 km of the A50 after the completion of the highway) rose by approximately 5%. In our approach, we consider these types of tradeoffs in a somewhat similar manner, and in addition to our diff-in-diff approach, we also apply an IV approach that is not reliant on a specific event date.

There is literature providing evidence of German highways' impacts on other variables. For instance, in the context of 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 they 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. With a somewhat unique perspective of highways and real estate for Germany, Dorr and Gaebler (2020) use a difference-in-differences approach to consider how the BAB-20 highway in Mecklenburg-Western Pomerania impacts property taxes for municipalities within 10 km from the highway. They find that these "treated" municipalities have property taxes that are approximately 6.2% higher than the control group of municipalities. While higher

property taxes can imply higher value, this is not necessarily the case as some locations with better public services can have higher property tax rates but still have lower property values.

Liebelt et al. (2018) focus on the correlations between proximity to urban green space and house prices in Leipzig, Germany. While their primary 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 prices of houses fall by 0.39 Euros. 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. Leipzig is at 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. The Liebelt et al. (2018) estimates seem rather small; for a 133 square meter house that sells for approximately 200,000 Euros, their estimates for house prices imply a 1-kilometer decrease in distance to the municipal road leads to a 0.11% increase in price.

It could be helpful to policymakers to compare the real estate benefits of highway improvements with other alternative forms of transportation. Among studies of German real estate and transit, Brandt and Maennig (2012) find that proximity to rail and public transit in Hamburg has an overall effect of raising property list prices by 4.6%, while effect of proximity to underground stations is somewhat higher. But Ahlfeldt (2011) finds that rail station proximity has no significant effect on house prices in Berlin, possibly due to the drawbacks of noise and ease of access benefits offsetting each other.[4] In an earlier analysis, 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 Schulz and Werwatz (2004) do not distinguish between these different types of infrastructure in their analysis.

As one way to address the issue of how to allocate scarce resources for public infrastructure projects, it will be of interest for us to compare how the real estate impacts of a German highway measures up against similar impacts for transit based on other German studies. In addition, an interesting question we explore is how our house price impact estimates of a highway connecting an under-developed area in Germany to the western part of the country compares with similar effects of a highway in a European country that has been completely developed for much longer. Such comparisons could contribute valuable information to the debates on how to choose the locations of new infrastructure in Germany – i.e., completely within the western part of the country or by linking the west with the east.

Data

Figure 1 is a map of the location of the A38 in Germany and the average sales prices. 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[5]), which has coverage for all of Germany from 2007-2017. The actual coordinates of each property are available. Additional data (e.g., socio-economic neighborhood-

level data) on the 1km by 1km grid (regarding the European INSPIRE guideline) is available in which each property is located. Figures 2 and 3 demonstrate the two changes that we analyze in this study.

Drive times to the nearest A38 highway exits are based on actual latitude/longitude for each highway exit, and the latitude/longitude of each property. Drive times from each dwelling 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 property to the A38 are joined with the data for properties to the nearest exit of the A38. Figure 4 Panel A shows the A38, the locations of the homes for sale during our sample period, and the drive time (in meters) from each property to the nearest exit of the A38. Figure 4 Panel B shows the same homes with their "as-the-crow-flies" distance to the A38, which is a proxy for the extent of pollution exposure for each home.[6]

As additional control variables we take the average age of residents within the 1km² neighborhood of each individual property, from the RWI-GEO-GRID data set (RWI and microm 2018). A detailed data description is 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). It is important to note that while we use grid-level data for these age variables, the actual house price data is at the property-level.

For the quasi diff-in-diff analysis, we define the date of the treatment of each intervention, separately, by the month the respective part of the A38 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 (15 minutes) in the sales sample. Further, we have enough observations in the treatment group which is not the case for shorter driving times. 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.

The section of the A38 shown in Figure 2 (highlighted blue) was opened in December 2009, before which the B80 (highlighted in red) was used instead. 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 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 while their connection to the A38 is still there.

Figure 3 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, residents 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.

We restrict our analysis to the labor market areas that are covered by the changes in the A38. The overall development of real estate prices in this region is different to all Germany which is mainly driven by the big cities that experience even more pronounced price increases than the rest of Germany.

In the estimation sample between 2007-2017, there are 24 845 properties listed for sale, with an average log price per square meter of 6,8 Euros (Table 1). The average property is 44.1 years old[7] (where age is defined as difference between date of listing and date of construction completion), and approximately 20.5% of the properties are the first occupancy. The average lot size is 696 square meters, and 57.9% of the sales properties are single family houses.

Figure 1 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 throughout all of Germany, as well as near the A38. Prices are especially higher at both ends of the highway.

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. RWI-GEO-RED has information on the list price of individual properties for sale at a given point of time, between the years 2007-2017, for the entire country of Germany.[7]

Approach

We rely on an IV approach, as well as a difference-in-differences approach, as two separate ways to test the hypotheses on accessibility and noise effects of the A38. Using both of these approaches enables us to compare these A38 real estate impacts against a wide range of study results from various other countries and for transit in Germany. First, the IV approach developed by Lewbel (2012) is modelled as follows:

$$Y_{1i} = X_i'\beta + Y_{2i}\,\gamma + \varepsilon_{1i} \qquad \text{(i)}$$

$$Y_{2i} = X_i'\alpha + \varepsilon_{2i}\,, \qquad \text{(ii)}$$

For each empirical model (i.e., the model for properties near the "previous street" and the model for properties near the "highway extension"), we consider two alternative measures of distance. One of these is a continuous distance variable, and another is an indicator for within 2000m. In equations (i) and (ii) above, we define Y_{1i} as the house i price, Y_{2i} is a matrix with 2 elements, including the distance from house i to the "street", and distance from the house to the

A38 (or alternatively, an indicator variable for within 2000m); X_i is a vector of exogenous variables for house i (including a constant term), ε_{1i} and ε_{2i} are error terms for house i, and β, γ, and α are parameters to be estimated.

To provide some intuition, when Y_{2i} is the distance to the A38 from an individual property, one hypothesis is that we expect the distance to the A38 to impact newly listed house prices. But newly listed house prices have no impact on the distance to the A38 (since the decision of where to locate the A38 was already completed at the time of the sale listings of all the properties under consideration with the Lewbel approach). The equation (ii) implies a hypothesis that the location of the A38 relative to property i depends on the property i characteristics (i.e., the X's - bedrooms, bathrooms, age, etc.). Since in most if not all cases the property was built long before the location decision for the A38, those characteristics were in place before the A38, so perhaps the German government decided to build the A38 near "older" houses or houses with fewer bedrooms, bathrooms, etc. But the listing price in 2015, for instance, had no impact on the location of the A38 extension (for which the location decision was made earlier).

There are some assumptions behind the Lewbel (2012) approach. First:

$$\varepsilon_{1i} = cU_i + V_{1i} \qquad \text{(iii)}$$

$$\varepsilon_{2i} = U_i + V_{2i} \qquad \text{(iv)}$$

Here, U_i is an error term that is common to both equations, V_{1i} and V_{2i} are error terms specific to the Y_{1i} and Y_{2i} equations, respectively, and c is a non-zero constant. Lewbel (2012)

indicates the researcher should try to justify that these equations hold by using economic theory. In our case, we argue that air pollution and/or noise pollution - which are not easily measured accurately - impact the error term for Y_{1i} (house prices), and also impact the error term for Y_{2i} (distance to the A38 extension). When houses further away from the A38 are on the market, these houses tend to be exposed to less noise and air pollution due to their location far from the A38, so we expect distance and pollution to be negatively correlated.

The next Lewbel (2012) assumption is the following: U_i^2 is not correlated with Z (where Z is the X matrix, excluding the constant term). In other words, U_i is homoskedastic. To test this assumption, it is possible to use the ivhettest command in Stata (available from SSC). The ivhettest command is followed by a list of variables Z (which can be, for instance, all of the X's except for the constant term; or a subset of the X's excluding the constant term). If U_i^2 is not correlated with Z, then this assumption is satisfied. This tests the homoskedasticity of ε_1, so the null hypothesis is that there is homoskedasticity (that is, the p-value should be very large). If the researcher rejects the null of homoskedasticity (i.e., if the p-value is less than 0.05), it is indeterminant as to whether the assumption that U_i^2 is uncorrelated with Z is satisfied (in other words, this test result is inconclusive).

The final Lewbel (2012) assumption is that $(\varepsilon_{2i})^2$ is correlated with Z. This can be tested for the Y_{2i} equation with a Breusch and Pagan (1979) test for heteroskedasticity. The null hypothesis is homoskedasticity; this assumption is satisfied if a researcher rejects this hypothesis (i.e., if the p-value is less than or equal to 0.05).

We also explore a difference-in-differences approach. In that context, we expand the sales sample backward to 2007 (i.e., before the opening of the A38), and find that after the A38 opening prices were higher within short drive distances to the highway, on average.

But these effects are not as high as we are seeing with the Lewbel (2012) approach, perhaps because property owners already adjusted their prices immediately upon the announcement of the A38 construction; or, maybe a substantial part of the adjustment started at the time of the announcement so that much of the prices adjustment already happened by the time of the opening. Regardless, we have the reassuring finding of 2 separate pieces of evidence in support of the hypothesis that proximity to the A38 leads to higher house list prices - one from the Lewbel (2012) IV approach and another from the diff-in-diff.

Below, in equation (v), we present the quasi diff-in-diff model specifications for the highway extension (B80) and the previous street (B243), respectively. Specifically, for each of these quasi diff-in-diff robustness check to the Lewbel (2012) approach, we consider the following model in order to identify the treatment effect of the A38, for the highway extension (in Figure 3):

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

with listed price per square meter, Y_i, of the property i; X_i consists of the property characteristics of property i, $D_{A3\ ,i}$is an indicator variable taking value of 1 if property i is listed for sale after the completion of the part of the A38 near the B243 (in column 1 of Table 3) or the B80 extension off of the A38 (in column 2 of Table 3), = 0 otherwise; $D_{drivetime,i}$is an indicator variable taking value of 1 if property i is within a 15-minute drive to the nearest exit on the A38 extension, and 0 otherwise; $D_{close,i}$ being a dummy for proximity to the A38 ("as-the-crow flies" distance within 2000m), and $D_{street,i}$ is distance (as-the-crow-flies) from property i to the

"street". $D_{A38,i} * D_{drivetime,i}$ is the treatment effect variable taking value of 1 if property i is listed for sale after the completion date and is within a 15-minute drive to the nearest exit of the A38, and 0 otherwise; $D_{A38,i} * D_{close,i}$ is a treatment effect variable taking value of 1 if property i is listed for sale after completion and is within 2000m as-the-crow-flies distance to the nearest exit of the A38; $D_{A38,i} * D_{street,i}$ is a treatment effect for as-the-crow-flies distance between property i and the "street"; $\gamma_L + \gamma_t$ are location (labor market region or district) and year fixed effects, respectively; ε_i is an error term for property i 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, duet some residents using the A38 to commute further.

Results

First, we present the results from the Lewbel (2012) IV estimation approach. We run two separate sets of Lewbel (2012) IV estimations. These include one for the alternative streets (denoted in the tables as "Streets") that were used before the opening of the A38 segments nearby (shown in Figure 2); and one for the opening of the "extension" spurring off of the A38 shown in Figure 3 (and here the extension is denoted in the tables as "Streets"). The two sets of results for each estimation includes a near/far indicator variable (1= short drive time, i.e., less than 15 minutes to the road, =0 otherwise), and a continuous negative drive distance variable in seconds. Both specifications include month fixed effects. The first stage results are presented in Appendix Table A1 through A4. The fitted values of these first stage estimates are used in stage 2, to estimate equation (i) above. Results for the second stage Lewbel (2012) IV estimates of the alternative street and highway extension samples are presented in Table 2.

In Table 2, for properties in the vicinity of the alternative road B80 (i.e., the "previous street"), houses within 15 minutes driving time from the A38 had significantly higher prices (i.e., 35% higher) than for those houses beyond 15 minutes driving time from the A38. With a continuous specification, for every 1000 seconds (~16 mins) closer to the A38, prices were approximately 30% higher (and this was statistically significant).

For as-the-crow-flies distance, houses within 2000 meters of the B80 were considered "close" to the A38 (and the indicator = 1 for these properties). Properties that were 2000 meters or more away (as-the-crow-flies) from the nearest point on the A38 sold for approximately 28% more than houses that were within 2000 meters directly from the nearest point on the A38. This implies that short driving time to the A38 is an amenity while shorter Euclidean distance to the A38 is a disamenity. We also include a regressor for the distance to the (former) alternative road B80 in meters. Noise and pollution should be less after the opening of the highway. However, there could be economic effects of (truck) drivers. Similarly, when the indicator for proximity to the nearest street equals 1 (i.e., a property is within 2000 meters of the nearest street), the coefficient is negative and significant, implying proximity to the nearest street is a disamenity which is surprising since we expect positive effects due to less traffic. However, the remaining traffic can still be a disamenity. Also, the coefficient on continuous negative distance to the nearest street (in meters) is negative and significant, which reinforces our finding that properties further away from the alternative street are listed at higher prices.

The highway extension (which we denote in Table 2 as the "Street") – B243 – is a federal road (Bundesstrasse), but in this part of the road the B243 extension is quite similar as a highway. The "new" B243 extension connects the rest of the B243 to the A38. Prior to the construction of the extension of the B243, in order to travel from the B243 to the A38, drivers

would have to travel on the local roads L2070 south to the L3080 west, which is a much slower route. We use the Lewbel (2012) IV estimator to examine how proximity to the B243 extension, and the A38, impacts the house prices nearby. First stage results are again presented in an appendix (Table A1 through A4) and second stage results are in Table 2. First, houses "close" (within 2000m as-the-crow-flies distance) to the B243 extension have significantly lower list prices (i.e., 11% lower) than properties further away, while houses "close" to the A38 have a 31% lower price (which is also statistically significant). Properties that are within 15 minutes driving time to the A38 have significantly higher list prices (approximately 38% higher, ceteris paribus). Alternatively, in the continuous specification, for every 1000 seconds closer to the A38, properties are listed at 37% higher, ceteris paribus.

It may be important to consider nonlinear effects in benefits of the proximity to the highway. If the cutoffs for drive time to the A38 become smaller, fewer observations are in the treatment region, and the standard errors become larger. However, we can still observe positive treatment effects. Then as we expand the cutoff further out, the treatment effect coefficient becomes smaller and insignificant. This implies two important findings. First, our choice of a 15-minute cutoff for the treatment effect is appropriate. Second, there are nonlinear effects in the potential benefits of driving time proximity to the A38.

As discussed above, there are three assumptions underlying the Lewbel (2012) IV estimator. We discuss above the first assumption. Once again, we argue this assumption is satisfied because air pollution and/or noise pollution - which are not easily measured accurately - impacts the error term for Y_{1i} (house prices), and also impacts the error term for Y_{2i}. Recall that Y_{2i} is distance to the A38. The second assumption is that the common component of Y_{1i} and Y_{2i} equations error terms is homoscedastic. We implement the Pagan-Hall test in Stata to

evaluate the validity of this assumption in our models for the cases where Y_{2i} is the local street, and again where Y_{2i} is the extension. In both tests, the result is inconclusive (i.e., the p-value = 0.0000). Finally, heteroskedasticity should be present between ε_{1i} and Z and between ε_{2i} and Z. We use the Breusch-Pagan heteroskedasticity test and strongly reject the null hypothesis of homoskedasticity for both error terms. Thus, none of these assumptions are violated in our model (despite the assumption 2 being inconclusive).

For the quasi diff-in-diff results, we first examine whether there appear to be common trends in the data for the treated and control groups, before versus after the respective openings. We define one treatment group as those houses for sale that are within 15 minutes' drive time. The outcome variable is the log of sales price per square meter, respectively.
Figure 5 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 extension (the entire Germany trends are not shown but available upon request). 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.

Specifically, the trends (in Figure 5) appear to move in the same directions for treatment and control groups before the end of 2009, 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 A38 extension (i.e., the B243) do not show any clear pattern.

Next, we present the quasi difference-in-differences results for the neighborhoods near the previous street and the extension, in Table 3. The first column of Table 3 shows the alternative streets results, using all homes that were listed within the labor market regions in the area of the alternative street. One treatment was within 2000 meters (as-the-crow-flies distance) of the A38, after opening of the part of the A38 nearest to the street; another treatment effect was within 2000 meters distance (as-the-crow-flies distance) to the previous street, after the opening of the part of the A38 nearest to the street; and a third treatment effect is drive time to the A38 less than 15 minutes. Again, due to the locations of many properties very close or on the "street", it is not sensible to include a treatment effect for drive time to the street. The treatment effect for being close to the previous street after the opening of the nearest part of the A38 is insignificant, implying that these properties experienced no significant positive effect from reduced noise and pollution after the opening of the A38 segment. In contrast, the treatment effect for accessibility to the new segment of the A38 after its completion in December 2009 is positive and significant. Houses in short driving distance to the A38 experience 14% higher sales prices than houses more than 15 mins drive distance away. This implies greater accessibility to other parts of Germany due to the completion of this segment of the A38 is associated with higher house prices. The treatment effect for the direct (as-the-crow-flies) distance to the A38 is positive which was not expected, implying that the additional pollution and congestion from the A38 opening is not a significant detrimental effect. However, the estimated coefficient for the distance to the highway is negative during the whole observation period. This finding implies

that also before the opening property prices were reduced which can be driven by construction noise and anticipation.

For the highway extension sample in column 2 of Table 3, the treatment effect for houses within 2000 meters distance to the A38 (direct distance to A38 <2000m after the December 2012 completion) is significant and negative, so this confirms the hypothesis that Euclidean distance to the A38 is likely driven by pollution and noise. In other words, property prices are reduced due to noise and air pollution, within the critical location range. Additionally, there is a substantial positive treatment effect on housing prices due to accessibility to the A38 (approximately 14% higher property prices), indicating that home buyers likely value connectivity to the highway. The treatment effect from distance to the extension (denoted as "street" in Table 3) is also positive and significant (approximately 11% higher property prices, but the treatment effect from the A38 accessibility is higher than the treatment effect from the extension distance, ceteris paribus. This implies the connectivity from the A38's linkages with the rest of Germany is more valuable than the local benefits from the extension road.

To sum up, the results indicate that there are substantial positive effects on real estate prices of the better connectivity and accessibility with the A38. The findings in both empirical strategies are similar. The estimated effects in the Lewbel (2012) IV approach are larger. In contrast, noise and pollution (proxied by as-the-crow-flies' distance) from proximity to the A38 result in lower prices, but only in 2012 when the highway extension is opened.

Conclusion

We consider two different infrastructure improvements along the A38 highway in Germany – one that alleviates traffic on local streets, and another that develops an extension between the A38 and other local roads – and the associated impacts of these changes on

residential owner-occupied property prices. In our analysis, we use the Lewbel (2012) IV approach as an identification strategy in estimating the impact of this German highway on residential owner-occupied real estate prices. With this approach, we find higher prices when driving distance to the A38 is shorter. But properties that are close to the A38, using "as-the-crow-flies" distance after controlling for driving distance (i.e., accessibility), tend to have lower prices, likely due to noise and congestion.

We also estimate a set of quasi difference-in-differences models for the effects of proximity to highway extensions on prices. The results confirm our findings of the IV approach: The opening of the previously incomplete parts of the highway influence prices of those properties positively that are in short driving distance to the A38, while those in close Euclidean distance to the A38 are negatively impacted. The A38 highway completion as well as the extension to the A38 lead to increased sales prices for houses within 15 minutes' drive time to the A38. Buyers seem to value better infrastructure for commuting. The quasi diff-in-diff estimates of price increases are substantial, approximately 14 percent.

There are some notable differences between the accessibility benefit estimates from the Lewbel (2012) IV approach, and the quasi difference-in-differences results that we generate. Specifically, the former estimates are up to approximately double the size of the latter. We expect the Lewbel (2012) IV estimates to embody the full effect, while our quasi diff-in-diff estimates may not reflect announcement date benefits. Due to data limitations, the quasi diff-in-diff estimations focus on the pre- vs. post-completion date, but some of the benefits of the A38 highway improvements were likely realized at the time of the project announcements.

In comparing our findings to those of the A50 proximity by Levkovich et al. (2016) in the Netherlands, we find the benefits of proximity to the A38 highway to be much larger than the

A50 benefits (on the magnitude of 3 to 4 times larger). This may imply that connecting east and west parts of Europe through the A38 improvements could be contributing to a larger real estate capitalization effect than for a highway that is built exclusively within a currently developed area.

Second, our estimates for the A38 impacts on real estate prices in areas near Leipzig, Germany are approximately 10 times larger than those of Liebelt et al. (2018), who also consider the Leipzig area. But Liebelt et al. (2018) focus on local roads and highways, while our analysis is based on connections to the A38, which links up to the east and west of Germany.

In terms of comparison to results of highway studies in the U.S., our estimates are similar to those of the Orlando, Florida beltway study by Allen et al. (2015). Although a direct comparison between rural Florida and the east of Germany may be rough at best, this beltway also connects the highly developed area of Orlando with other parts of Florida that are less developed. Perhaps this analogy is one validation of our findings.

Finally, in comparing our drive time estimates on real estate prices with those from new transit in Germany, we note that our elasticity of roughly 1.7% is in the mid-range of some of the more recent German studies of transit impacts on real estate, between 0% and 4.6%. With such a broad range of elasticities for German transit, the choice between building more transit and new highway infrastructure, when a choice is necessary, should be very specific to the location of the proposed new transit infrastructure.

Several implications of this research are worth contemplating as policy makers in Germany and elsewhere (e.g., the U.S.) consider highway expansions. 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. But at the same time, the

tremendously better connectivity near the A38 manifests itself in the residential property values. Based on our results, the positive benefits of the accessibility to the A38 appear to outweigh the negative effects from the direct distance to the A38.

We have presented some evidence that a new highway can significantly and favorably impact property values (due to accessibility) in the years following the opening of the highway. In other respects, the opening of the highway can be detrimental to property values (from pollution and congestion). 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. It is evident that policy makers and urban planners should consider the real estate benefits of new highway infrastructure projects, in addition to other benefits (i.e., the more commonly considered travel time savings benefits), when weighing the decisions of how and whether to undertake these significant investments.

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

Number of Observations:	24,845			
Variable	**Mean**	**SD**	**Min**	**Max**
Log price per sq meter	6.843	0.630	4.069	12.429
Age of house	44.14	58.32	0	998
Age-squared	5348.9	23900.2	0	996004
First occupancy	0.205	0.404	0	1
Lot size	695.6	617.9	0	5000
Single family home	0.579	0.494	0	1
Semi-detached house	0.078	0.268	0	1
Row house	0.055	0.229	0	1
Facilities: simple	0.020	0.141	0	1
Facilities: normal	0.097	0.296	0	1
Facilities: sophisticated	0.145	0.352	0	1
Facilities: deluxe	0.004	0.060	0	1
Number of rooms: 1-2	0.455	0.498	0	1
Number of rooms: 3-4	0.167	0.373	0	1
Number of rooms: 5-6	0.072	0.258	0	1
Dummy: previous street/extension within 2000m	=0.014	0.117	0	1
Dummy within 2000m to A38	0.058	0.234	0	1
Dummy within 15min to A38	0.214	0.410	0	1
Years				
2007	0.079	0.270	0	1
2008	0.118	0.323	0	1
2009	0.132	0.338	0	1
2010	0.103	0.303	0	1
2011	0.081	0.272	0	1
2012	0.063	0.243	0	1
2013	0.075	0.263	0	1
2014	0.095	0.293	0	1
2015	0.080	0.271	0	1
2016	0.067	0.251	0	1
2017	0.107	0.310	0	1
Age of residents in neighborhood				
Share of kids (age < 18)	16.257	2.435	4.620	27.820
Share of young (18-29)	13.154	3.674	5.250	35.250
Share of elderly (60+)	27.765	4.850	7.160	44.620

Sources: RWI-GEO-RED and OpenStreetMap.

Table 2: Second Stage Regression Results for the Lewbel (2012) IV Approach; Driving Time and Distance to A38 are Instrumented

Dependent Variable: Ln of price per square meter	A38 Near Previous "Street" discrete treatment (<15 minutes)		A38 Near Previous "Street" continuous treatment (in -1000 seconds)		A38 Near Extension (i.e., "Street") discrete treatment (<15 minutes)		A38 Near Extension (i.e., "Street") continuous treatment (in -1000 seconds)	
Driving time A38 (<15 minutes)	0.3486	***			0.3769	***		
	(15.29)				(12.32)			
Driving time A38 (in -1000 seconds)			0.3003	***			0.3710	***
			(21.20)				(20.89)	
Distance A38 > 2000m	-0.2823	***			-0.3118	***		
	(-9.73)				(-8.28)			
Distance to A38 (in -1000m)			0.0161	***			0.0171	***
			(10.28)				(9.07)	
Distance to Street > 2000m	-0.1521	***			-0.1128	**		
	(-4.00)				(-2.18)			
Distance to Street (in 1000m)			-0.0109	***			-0.0124	***
			(-20.74)				(-19.81)	
Age	-0.0100	***	-0.0096	***	-0.0099	***	-0.0094	***
	(-71.64)		(-70.14)		(-53.15)		(-53.73)	
Age sq.	0.0000	***	0.0000	***	0.0000	***	0.0000	***
	(42.23)		(42.42)		(33.69)		(33.44)	
First occupancy	0.0861	***	0.0691	***	0.1155	***	0.0772	***
	(7.00)		(5.90)		(7.10)		(5.00)	
Lot size	0.0001	***	0.0001	***	0.0001	***	0.0001	***
	(12.40)		(13.50)		(9.44)		(10.75)	
Single house	0.0947	***	0.0890	***	0.1277	***	0.1330	***
	(10.24)		(10.16)		(10.40)		(11.55)	
Semi-detached house	0.2405	***	0.2113	***	0.3302	***	0.2941	***
	(15.22)		(14.15)		(15.62)		(14.83)	
Serial house	0.3940	***	0.3687	***	0.4968	***	0.4641	***
	(20.10)		(20.18)		(17.64)		(17.88)	
5-6 rooms	-0.0649	***	-0.0714	***	-0.1079	***	-0.1018	***
	(-7.03)		(-8.19)		(-8.61)		(-8.69)	
7-8 rooms	-0.1301	***	-0.1286	***	-0.1883	***	-0.1679	***
	(-10.75)		(-11.25)		(-11.53)		(-10.96)	
9-12 rooms	-0.1632	***	-0.1713	***	-0.1846	***	-0.1834	***
	(-10.14)		(-11.24)		(-8.99)		(-9.53)	
Facilities: simple	-0.2945	***	-0.2626	***	-0.2546	***	-0.2173	***
	(-11.78)		(-11.08)		(-7.82)		(-7.11)	
Facilities: normal	-0.0067		0.0004		0.0229		0.0266	*
	(-0.55)		(0.03)		(1.44)		(1.77)	
Facilities: sophisticated	0.1501	***	0.1300	***	0.1707	***	0.1373	***
	(13.40)		(12.29)		(11.90)		(10.25)	
Facilities: deluxe	0.4756	***	0.4722	***	0.4905	***	0.4792	***
	(8.69)		(9.14)		(7.68)		(8.01)	
month dummies	x		X		X		x	
Constant	7.1062	***	7.3634	***	7.0953	***	7.4029	***
	(327.91)		(320.04)		(285.76)		(276.91)	

R^2	0.4915		0.5052		0.5450		0.5651	
N	16 655				10 532			
Pagan-Hall (Chi²)	317.183	***	107.741	***	666.06	***	599.319	***
Underidentification test (Kleibergen-Paap rk LM statistic):	3965.82	***	6808.11	***	2753.71		2753.71	***
Weak identification test (Cragg-Donald Wald F statistic):	23.30	***	52.03		24.83		24.84	
Sargan statistic (overidentification of all instruments)	1625.534	***	5841.75	***	119.789	***	1666.758	***

*t-values in parentheses; * p<0.1, ** p<0.05, *** p<0.01.*

Table 3: Difference-in-Differences Regression Results – Houses for Sale

Dependent variable: ln(price per sqm)	**Properties Near Previous Street (B80) to the New Part of A38**	**Properties Near the A38 Extension (B243)**
Opening date t =	*Dec 2009*	*Dec 2012*
direct distance to A38 < 2000m	-0.109**	-0.036*
	(-4.26)	(-1.80)
treatment effect for direct distance to A38< 2000m after opening date t	0.067***	-0.078***
	(2.19)	(-2.70)
direct distance to street† (< 2000m) dummy	-0.194***	-0.191***
	(-5.15)	(-5.91)
treatment effect for direct distance to street† (< 2000m)	0.020	0.109**
	(0.41)	(2.02)
short drivetime to A38 (< 15 min)	-0.003	0.032***
	(-0.32)	(3.63)
treatment effect for short drive time to A38 (< 15 min)	0.137***	0.140***
	(9.90)	(9.06)
R^2	0.496	0.495
N	24,845	24,845
direct distance to A38 <2000m	1,446	1,446
direct distance to A38 < 2000m after date t	1,020	654
close to street†	337	345
close to street† after date t	243	141
close to A38	5,305	5,305
close to A38 after date t	3,231	1,900

Notes:
*t-values in parentheses; * p<0.1, ** p<0.05, *** p<0.01.*
Control variables (house characteristics, month and labor market area fixed effects, and age of residents in the neighborhood) are included in these regressions and their estimates are available upon request.

† "close to street" refers to the direct distance to the "previous street (B80)" for the results in column 1, and to the extension (B243) off of the A38 in column 2. Since many properties are on or very near the "street", we do not include a treatment effect for drive time to the "street".

Endnotes

[1] But this is not the way it always has been, particularly in Germany. For instance, 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).

[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.

[3] There are several studies focused on U.S. applications of highway impacts on employment, as well as U.S. studies focused on real estate impacts of highways. 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. Hicks (2014) find that there is no significant impact of the "Corridor G" highway on the productivity of rural firms, by approximately 1 percent per mile of the highway.

[4] In the U.S. context, McMillen and McDonald (2004) find the house price effects of properties sold within 1.5 miles of a new transit line in Chicago to be roughly in the range of 4% to 20% higher between the 3 years before and 3 years after completion of the stations. This is generally somewhat higher than the upper end of the German estimates for transit's impact on housing prices.

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

[6] While Levkovich (2016) use a cutoff of 300 meters from the highway for their cutoff as noisy locations, in our sample, based on anecdotal evidence, we use 2000 meters as the cutoff for noisy locations. This is because we have observed significant noise, firsthand, at up to 2000 meters from infrastructure in Germany. Also, in the more rural areas surrounding these parts of the A38, relatively few houses have been for sale within 300 meters of the extended segments of the A38. Also, Levkovich (2016) uses a complex "accessibility" measure in the part of their analysis that combines noise and accessibility, which makes it difficult to compare their noise estimates directly with ours.

[7] In the sales dataset, 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.

Figure 1: Location of the A38 and Average List Prices (Euros), Germany, 2007-17

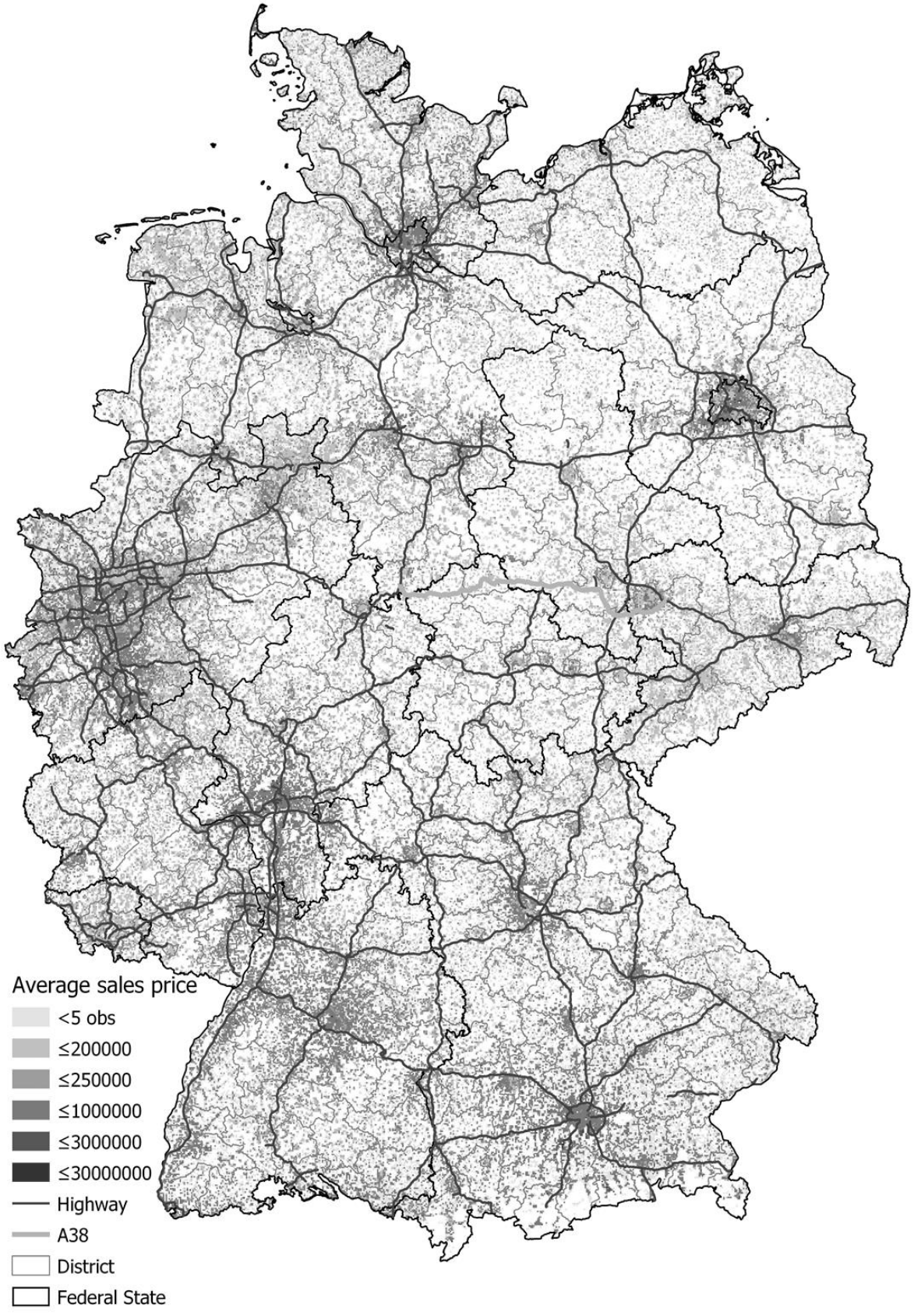


Figure 2: Highway A38 Completion and the "Previous Street"

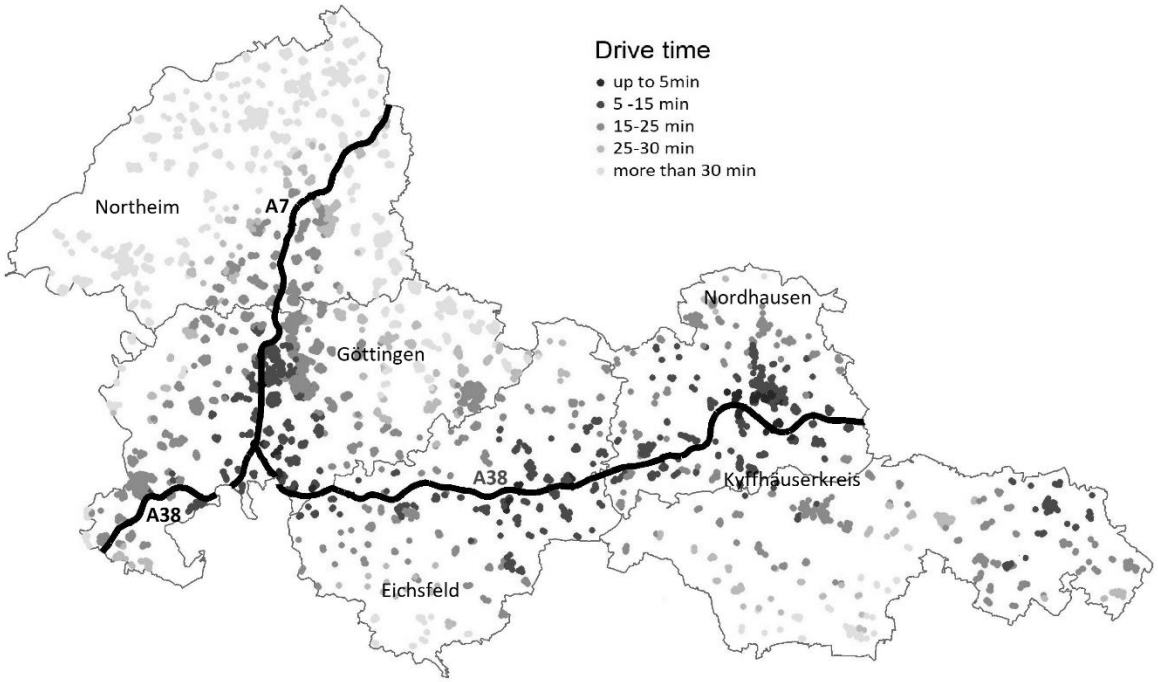
The black part of the A38 (i.e., the alternative road to the "previous street") was opened December 2009. The B80 (grey) was used before the opening (i.e., that is the "previous street" in Table 2, with 16,665 for sale properties nearby between 2007-2017).

Figure 3: Highway Extension Leading to the A38

The dark part of the B243 leading up to the A38 was opened in December 2012. It is a Bundesstrasse (federal road) but in this part is like a highway (there are 10,532 for sale properties between 2007-2017 nearby this extension).

Figure 4: Drive Times (Panel A) and Euclidean Distance (Panel B) to the A38 from Each Property for Sale (2007-2017)

Panel A



Panel B

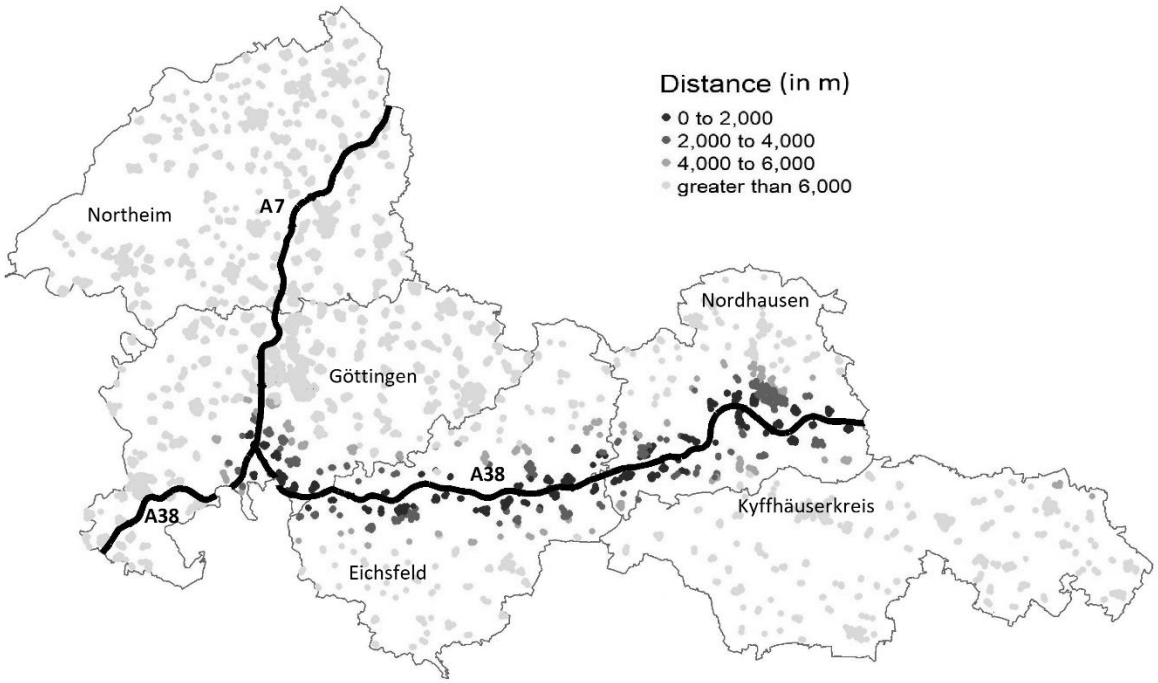
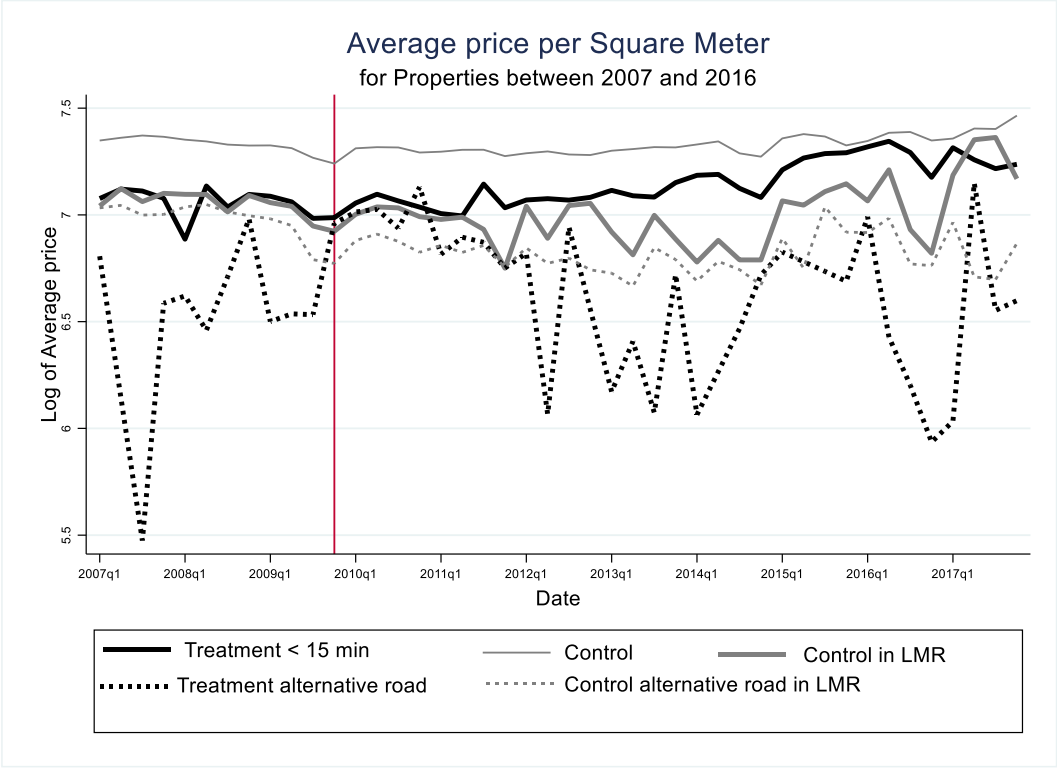
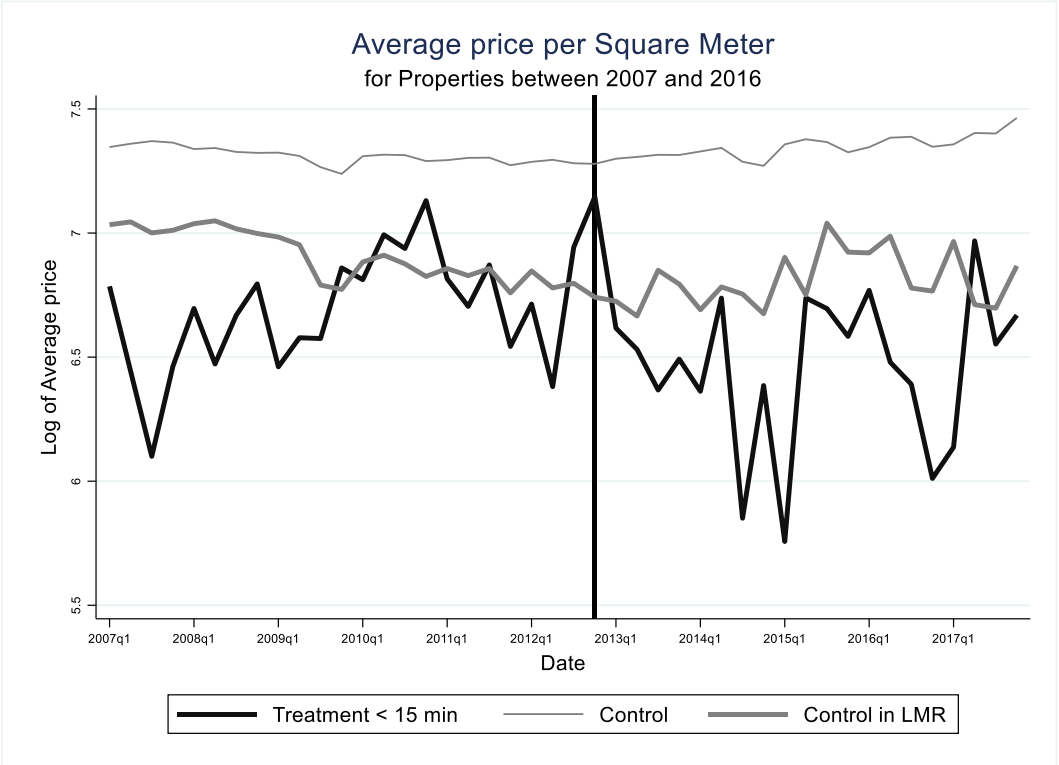


Figure 5: Common Trends for Previous Street (Panel A) and Highway Extension (Panel B)

Panel A - Previous Street



Panel B - Highway Extension



Source: RWI-GEO-RED, own calculation. LMR denotes “Labor Market Region”.