How large are road traffic externalities in the city?

The highway tunneling in Maastricht, the Netherlands

Joep Tijm
j.tijm@cpb.nl

Thomas Michielsen
t.o.michielsen@cpb.nl

Raoul van Maarseveen
raoul.vanmaarseveen@nek.uu.se

Peter Zwaneveld
p.j.zwaneveld@cpb.nl

4th April 2018

Abstract

Infrastructure projects are increasingly aiming to improve liveability, in particular in urban areas. We analyse a specific case in which an existing highway in an urban area was moved underground in order to improve intercity traffic flows and to reduce traffic externalities. As travel times within the city hardly changed, this allows for a clean identification of the value of traffic externalities. We find that the liveability benefits of such integrated infrastructure are substantial relative to the construction costs. Each halving of distance to the tunneled segment is associated with 3.5% more appreciation in house prices since the start of the project.

1 Introduction

Traditionally, the most important aim of infrastructure has been the reduction of travel time. However, liveability and efficient use of space are becoming increasingly important aspects of new infrastructure developments, especially in urban areas (see for example Badland et al. (2014)). The purpose of this study is to analyse the value that housing consumers attach to improvements in liveability as a result of such infrastructure investments. We analyse one such case, namely the moving of the A2 highway in Maastricht, a medium sized town in the Netherlands, from above the surface into a tunnel underneath the city. Similar highway relocations have recently taken place or are being planned in other cities such as Amsterdam, Antwerp, Dallas, Denver, Hamburg, Madrid, San Francisco and Seattle.

Our main contribution is twofold. First, our case study allows a clean identification of liveability improvements because travel time only decreases for ongoing traffic, so that the travel reduction benefits do not vary much within the project city, whereas the liveability benefits are concentrated near the new tunnel. Separating accessibility and liveability effect has often been challenging in existing literature. Second, we add to a nascent literature on the effects of infrastructure relocation projects in urban areas (Chang et al. 2014; Seo et al. 2014; Ahlfeldt et al. 2016), which are becoming increasingly important.

To measure the improvements in liveability, we perform a hedonic pricing analysis on house prices in the project municipality. We compare the trend in house prices near the relocated highway segment to the price trend in other parts of the municipality, controlling for house characteristics. In doing so, we find that each halving of the distance to the now tunnelled highway segment is associated with a price increase of 3.5%, as a result of the decrease in traffic externalities.

2 Related literature

The effects of noise and air pollution resulting on house prices have been extensively studied using the hedonic method (Smith and Huang 1995; Chay and Greenstone 2005; Boes and Nesch 2011), which can be traced back to Court (1939) and Rosen (1974). A clean identification of the liveability effects of road and rail infrastructure is difficult however. Some papers look at the house price effects of new construction (see e.g. Levkovich et al. (2016) and the meta-analysis in Debrezion et al. (2007)), but cannot disentangle accessibility and externality effects. Other studies use direct road noise or pollution data (Day et al. 2007; Andersson et al. 2010; Brandt and Maennig 2011), but without quasi-experimental variation in the level of externalities, the results may be influenced by unobserved correlations with other neighbourhood characteristics.

Little research so far has analysed the case in which infrastructure relocation coincides with the development of the public space or in which investments in infrastructure leave the accessibility largely unchanged, but reduces the externality. Such studies can mitigate the concerns in the previous paragraph. Most prominently, Ossokina and Verweij (2015) analyse the effect of traffic externalities on housing prices in an urban area of The Hague. Their identification is based on the construction of a new ring-road, which significantly reduces traffic volume along former commuting routes, but crucially leaves the local accessibility largely unaffected. By comparing houses along the former commuting routes with houses in the same neighbourhood but without commuting routes close by, they identify the effect of car traffic on house prices. By using a fixed effects model at the postal code (6-digit) level, they find that a negative relation between traffic externalities and house prices. For areas where traffic density was already high, reductions in externalities are valued stronger compared to areas with lower initial traffic density.

Another paper that separates accessibility and nuisance is Ahlfeldt et al. (2016). They evaluate the effects of metro line A in Berlin, both in the period when it was built, around 1900, and contemporarily. The line is part elevated and part underground. The elevated and underground stations provide the same accessibility benefits, but noise is higher on the elevated stretches. The authors use noise data by source from 2007 to capture local variation in rail noise. A 10 db increase in noise decreases house prices by 1%. Ahlfeldt et al. (2016) find that the accessibility and nuisance effects are underestimated by 40% and 80% respectively if they are not conditioned on each other.

Because the tunnel that we study has only recently opened, our analysis captures the anticipation effect in the housing market. Several papers find evidence that a large part of the benefits of infrastructure projects capitalizes into housing prices shortly after the opening. A study by Hoogendoorn et al. (2017) based on the same data as our study reports that half of the accessibility benefits of a new tunnel in the South-West of the Netherlands are capitalized more than a year before the opening of the tunnel, and all benefits were absorbed in the year of opening. Ahlfeldt et al. 2016 find significant anticipation effects for rail noise in the year after the concession of the metro line was granted; 6 years before the opening. Levkovich et al. 2016 also find that anticipation effects accounted for more than half of the total effect for two recent highway extensions in the Netherlands.

3 Methods

3.1 Case description

Since 1960 the A2 highway has run right through the city of Maastricht in a North-South direction. As a result of the dense traffic on the A2, 37,000 and 69,000 houses exceeded the norms for NO2 and PM10 exposure respectively in 1997 (Oranjewoud 2006).[1] In the 1990's, ideas to build a tunnel started circulating among (local) politicians and inhabitants of the city. In 2002, the Dutch parliament agreed with the idea of constructing a tunnel to lead traffic under a large part of the city. Eight years later, the minister of Infrastructure and the Environment officially signed the proposed plans. Preparatory works started in 2010, the actual tunneling started in 2012 and the first parts of the tunnel opened in December 2016.[2] The tunnel has two tubes: an upper one for local traffic, and a lower one for ongoing traffic. In 2017 and 2018, a rectangular-shaped park will be placed on top of the tunnel.[3] As part of a broader redevelopment of the area,

[1] These transgressions were forecasted to disappear after the underground relocation.

[2] A resident along the tunneled segment used to be unable to use her balcony or sleep with the window open, and was experiencing significant noise from 6am in the morning. The morning when the tunnel opened, "only two cars came by". https://nos.nl/artikel/2148593-a2-tunnel-onder-maastricht-open-nog-even-wennen.html

[3] http://www.a2maastricht.nl/

residential and commercial real estate will be developed until 2026.

Figure 1 shows the project area in Maastricht. From the South-East, the A2 highway enters the city and proceeds in a northerly direction. The roughly 2 kilometer long tunnel segment is drawn in red. The former A2 highway was located right on top of the new tunnel. The highway leaves the city in the North-East. The (historical) centre of the city is located on the western side of the Meuse river where the name Maastricht is written on the map.

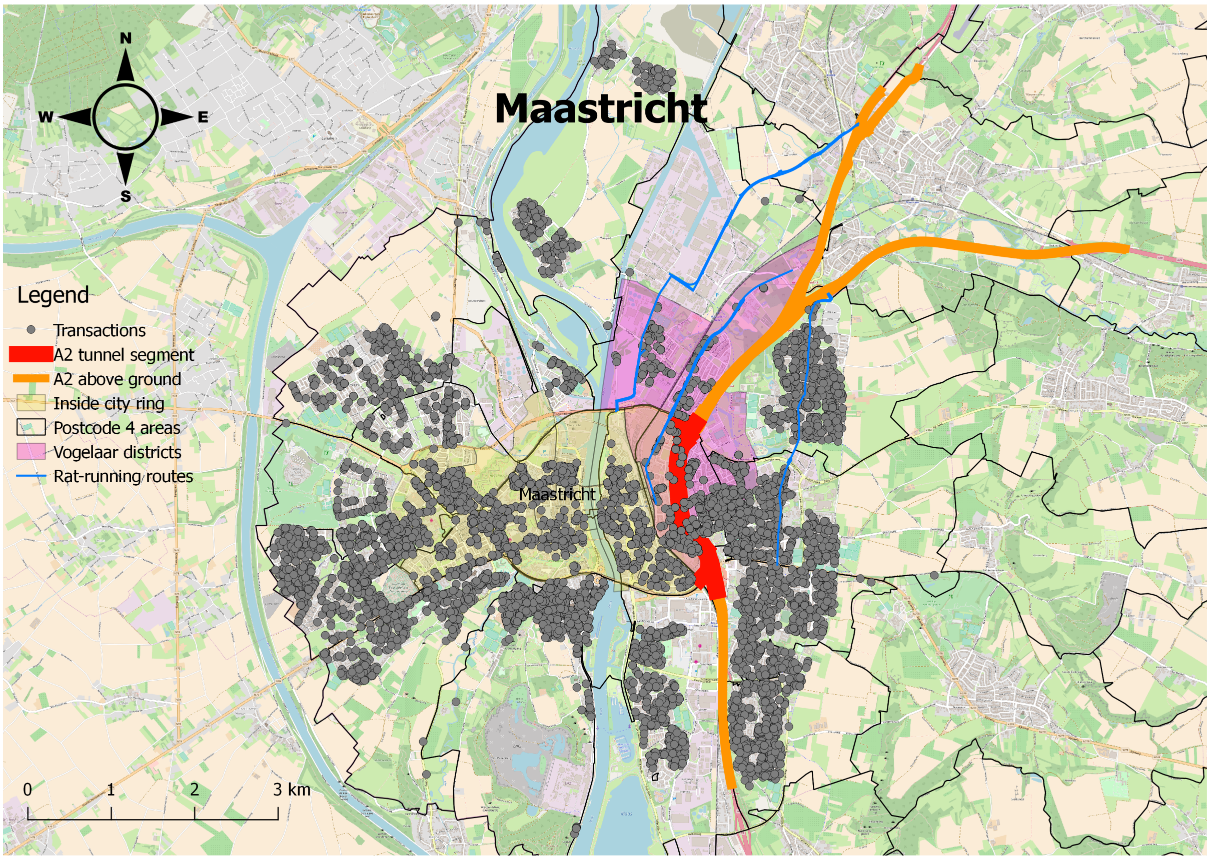

Figure 1: Map of Maastricht showing the locations of all observed transactions

The main improvements in terms of traffic time are for ongoing traffic, according to the official exploratory study (Oranjewoud 2006). The old situation was characterized by traffic lights at the north and south entrance of the A2 highway to the city, which were important choke points. Moreover, ongoing traffic was limited to 50km/h in the area that is now tunneled, as opposed to 100km/h after the relocation.

Inhabitants of Maastricht benefit from the improved traffic flow at the north and south entrance to the city when they use the A2 to travel north or south to areas outside Maastricht, or when they travel to a local destination using the city ring road, which intersects the A2 at these former choke points. The former benefit accrues to inhabitants in all areas of Maastricht more or less equally, and should therefore not affect relative changes in house prices within Maastricht. The latter benefit might be more important for inhabitants living east of the A2 - since the city centre is in the west, they are more likely to use the ring road for intra-city trips.

In the old situation people were able to cross the highway from east to west and vice versa at various traffic light intersections along the now-tunneled segment. In the new situation, the green space that will be realised after deconstruction of the old highway will also contain roads connecting east and west, without traffic lights. While the highway relocation thus removes a barrier between the two parts of the city, the travel time for crossing the A2 between the north and south choke points is not much affected.[4] The environmental impact report states that even at the tunnel entries and exits the air quality will improve compared to the original situation (Dotinga 2010). We therefore expect the liveability benefits to be positive along the entire tunneled stretch, and not exhibit large changes near the entries and exits.

We perform several robustness checks to verify that house price appreciations near the project are not driven by improved travel times for trips within Maastricht. To address the concern that houses east of the A2 benefit from lower travel times en route to the city center when crossing the now-tunneled segment, we perform a robustness analysis in which we only analyze transactions to the west of the A2. To account for the possibility that houses outside the city ring profit from improved traffic flow on the city ring for intra-city trips, we conduct a sensitivity analysis excluding transactions outside the city ring. In addition, we drop four streets in which rat-running used to be an issue according to the official exploratory study (Oranjewoud 2006).

Maastricht is a medium size city in the south of the Netherlands. The A2 highway project is by far the largest infrastructural project taking place in the city at the moment. Part of the project area was involved in a large national urban revitalization scheme, in which 40 disadvantaged neighbourhoods in the Netherlands received approximately €1500 per household in investments between 2007 and 2012, largely in the social housing stock.[5] One of these 40 so-called Vogelaar neighbourhoods is Maastricht North-East, which is indicated in purple in Figure 1. The evidence on the effectiveness of this revitalization scheme is mixed. Permentier et al. (2013) conclude that the scheme was largely ineffective, but Koster and Van Ommeren (2017) report a positive influence on house prices. In a robustness analysis, we exclude transactions in the Vogelaar districts.

3.2 Econometric model

In order to examine how house prices are affected by the relocation of the highway, we estimate a hedonic equation of house prices. The main variable of interest is the distance to the highway interacted with time variables. One would expect that houses close to the highway should appreciate in value over time relative to houses further away if there is a positive anticipation effect, and may temporarily decrease due to construction-related nuisance. We estimate the net effect of these two effects. The model is specified as follows:

$$\begin{aligned} \ln P_{ijt} = \alpha + \beta_0 \ln Distance_i + \beta_1 \ln Distance_i * YearGroup_t \\ + \beta_2 X_{it} + \gamma_1 L_i + \gamma_2 I_t + \varepsilon_{ijt} \end{aligned} \tag{1}$$

[4] The official exploratory study remarks that "the traffic structure of the eastern flank of Maastricht is not substantially changed. There is no effect on the accessibility of the western part of Maastricht."

[5] This figure is an estimation; it is difficult to determine the exact amount (Permentier et al. 2013; Geurts 2014). The social housing stock is rental only and does not figure in our transaction data.

where $\ln P_{ijt}$ is the natural logarithm of the price of house i in postal code area j in period t. β_0 measures the effect of log distance to the new highway tunnel on the log of house price in the baseline period. We have chosen a log-log specification as air and noise pollution effects decrease with distance more than linearly. We refer to this as the logarithmic specification in the table captions.

β_1 is the coefficient vector of interest and measures the interaction effect between the log distance to the tunnel and two-year group dummies so we can see how the relocation's effect varies over time. β_2 measures the effect of house characteristics. γ_1 are the location effects, including the postal code fixed effects, and γ_2 captures yearly effects such as changes in the business cycle.[6] Variations in the sale price due to unobserved house attributes or idiosyncrasies end up in the error term ε_{it}.

The postcode fixed effects L_j control for unobserved neighbourhood characteristics. We estimate (1) for two spatial units. In our preferred specification, we use postal code 4 level (PC4) fixed effects, which are district or neighbourhood sized and contain about 4000 persons each. As a sensitivity analysis, we also estimate (1) with PC6 code fixed effects - one side of a street or one block of houses. These finer fixed effects can deal with smaller-scale time-invariant differences in neighbourhood attractiveness, but restrict the information we can use for estimating the effect of proximity to the highway to within-block differences in distance. As a benchmark, we also run an OLS regression without geographic fixed effects.

We expect a positive relationship β_0 between distance to the tunnel and house prices in the original situation since houses closer to the highway faced more externalities than houses at larger distances. The start of the tunnel construction in 2012 was announced in November 2010, which is why we hypothesize 2010 to be the first year in which anticipation effects may show up.[7] According to our hypothesis, the interaction terms should become negative for later year groups, indicating that houses at lower distances to the tunnel become more attractive over time.

We also run the model with distance band dummies instead of the continuous variable to verify whether the effect in (1) is driven by the log-log functional form. We will interact the distance dummies with same the year group dummies that we used in (1). This way we measure the average increase of house prices within the specified distance per period, compared to houses further than 2km away from the highway. This model is similar in all other ways and is specified as:

$$\begin{aligned} \ln P_{ijt} = \alpha + \beta_0 DistanceDummies_i + \beta_1 DistanceDummies_i * YearGroup_t \\ + \beta_2 X_{it} + \gamma_1 L_i + \gamma_3 I_t + \varepsilon_{ijt} \end{aligned} \tag{2}$$

3.3 Data

We use housing transaction data from the Dutch Association of Real Estate Brokers and Experts (NVM). Our dataset contains all transactions brokered by NVM members between 1985 and September 2017. The NVM members' national market share

[6] We also include month-of-sale fixed effects to capture seasonality in the housing market.

[7] We also looked at earlier years but did not find any anticipation effects in the period 2000-2009 and decided to not interact them in our final regressions. Instead they are now part of the baseline period.

in Limburg, the province that includes Maastricht, rose from 24,6% in 1995 to 53,8% in 2016. We consider our data representative for the local housing market.[8]

Our dataset includes 9243 transactions in Maastricht, 581 of which took place in 2016, the last full year that we include. The city of Maastricht consists of 18 PC4 areas for which we have on average 31.9 transactions in 2016 with a minimum of 3 and a maximum of 67. The 1677 PC6 areas contain on average 0.3 transactions in 2016 with a minimum of 0 and a maximum of 6.

Other than transaction prices, the dataset contains a number of characteristics for each sold house that are relevant for prices. Table 3.3 presents summary statistics. The average sale price in Maastricht was €240 thousand with a standard deviation of €128 thousand. All prices in our dataset are in euros of 2015. The distance variable is the Euclidean distance measured in meters for each house using GIS software. Descriptions of all variables are included in appendix Table A.1.

Figure 2: Upper left: being Transaction price and Distance to the tunnel in meters for observations ≤1km before 2010, Upper right: Transaction price and distance to the non-tunnelled highway parts in meters for observations ≤1km before 2010, Bottom: Average transaction prices over time.

Figure 2 shows the relations between transaction prices and distance to the highway before 2010. From panel A one can see an increase in prices for transactions further away

[8]The national market share rose from 57,1% in 1995 to 82,6% in 2016.

Table 1: Descriptive statistics

	Mean	Median	Max	Min	SD
Dependent variable and main independent variable:					
Transaction price (2015 €)	241030.4	207483.8	1747870	36881.51	128591
Distance tunnel (m)	2013.44	1762.17	4907.36	13.48	1300.23
Structural attributes:					
Building period	5.32	5	9	1	2.14
Floor space (m^2)	127.59	120	490	26	50.87
Apartment	0.33	0	1	0	0.47
Terraced	0.33	0	1	0	0.47
Corner house	0.09	0	1	0	0.29
Semi detached	0.18	0	1	0	0.39
N Floors	2.54	3	6	1	1.04
N Rooms	4.68	5	25	0	2.41
Balcony	0.22	0	1	0	0.42
Monument	0.00	0	1	0	0.07
Parking	0.44	0	1	0	0.50
Maintenance inside	6.77	7	9	1	1.28
Maintenance outside	6.89	7	9	1	1.08
Locational attributes:					
Distance non-tunneled highway (m)	2055.40	1605.24	5297.69	98.22	1429.71
Within 300m of rail station	0.10	0	1	0	0.30
Distance centre (m)	1903.33	1871.85	5277.36	1.08	964.34
Distance centre (m) $*$ linear time trend					
Time:					
Year	2005.87	2006	2017	1985	7.22

Table showing descriptive statistics for all included variables. We have constructed Distance tunnel, Distance non-tunneled highway, Rail and Distance centre ourselves using GIS, all other variables were available in the NVM dataset. All variables are in level values. N = 9243.

from the tunnel in the first kilometer. This indicates that before 2010, houses closer to the tunnel segment were less attractive. The same goes for panel B where the transaction prices have been plotted against distance to parts of the highway that are not tunneled. We also find an increase in house prices at higher distances for observations that lie within the first kilometer from the highway. The last panel, C shows that there is considerable variation in transaction prices over the years. House prices increased sharply during the nineties, and came down during the post-2008 crisis on the Dutch housing market.

In Figure A.1 in the Appendix, we show that the positive correlation between distance to the tunnel and house prices is also apparent when we look at quality-adjusted prices.

Table 2: Logarithmic specification

	OLS	PC4 FE	PC6 FE
Ln Distance Tunnel	0.009**	0.010	-0.011
	(0.004)	(0.008)	(0.046)
Ln Distance Tunnel ∗ 2010-11	0.003	0.004	-0.001
	(0.009)	(0.009)	(0.008)
Ln Distance Tunnel ∗ 2012-13	-0.019*	-0.007	-0.009
	(0.011)	(0.010)	(0.009)
Ln Distance Tunnel ∗ 2014-15	-0.016**	-0.013*	-0.010
	(0.008)	(0.007)	(0.007)
Ln Distance Tunnel ∗ 2016-17	-0.038***	-0.034***	-0.037***
	(0.008)	(0.008)	(0.007)
Housing attributes	Yes	Yes	Yes
Location attributes	Yes	Yes	No
Year dummies	Yes	Yes	Yes
N	9243	9243	9243
Adjusted R^2	0.805	0.843	0.906

Note: Dependent variable is the natural logarithm of transaction prices. (1) is a baseline OLS regression, (2) is a PC4 code fixed effects model and (3) is a PC6 code fixed effects model. Heteroskedasticity robust standard errors in parentheses. ** p < 0.10, ** p < 0.5, *** p < 0.01*

4 Results

We begin by estimating the basic model (1), of which the results are shown in Table 2. In our preferred specification using PC4 fixed effects (the second column in Table 2), each halving of the distance to the tunnel increases house prices by 3.5% in the two years around the opening (2016-2017), compared to the pre-2010 period. For example, a house at 300m from the tunnel appreciated in value by 3.5% between 2010 and 2016-2017 compared to a similar house at 600m. We find no significant effects for years before 2016, although the point estimates in 2014-2015 move in the same direction. The estimates are of similar magnitude when we use fixed effects for smaller areas (column 3). Contrary to expectations, the distance to the tunnel has no significant effect in the baseline period: before the relocation works started, houses close to the highway were not significantly cheaper than houses further away. We do find a negative effect of the surface highway on house prices when we estimate the effect on between-postcode as well as within-postcode differences in distance (first column), but those estimates do not control for unobserved neighbourhood characteristics.

When we use a distance-band specification for the influence of distance, we again find that the relocation increases house prices. Table 3 shows that with PC4 fixed effects, houses within 500m of the tunnel appreciated 7.1% more in value between 2010 and 2016-2017 than similar houses more than 2km from the tunnel. We find weaker results between

Table 3: PC4 FE Difference-in-difference model

	0-0.5km	0.5-1km	1-2km
Base	-0.149***	-0.098***	-0.071***
	(0.019)	(0.015)	(0.011)
2010-2011	0.030	-0.069***	0.012
	(0.026)	(0.021)	(0.020)
2012-2013	0.030	0.030	0.083***
	(0.026)	(0.022)	(0.020)
2014-2015	0.051**	0.007	0.049***
	(0.021)	(0.020)	(0.016)
2016-2017	0.071***	0.042**	0.100***
	(0.026)	(0.019)	(0.015)
N	9243	9243	9243
Adjusted R^2		0.845	

Note: Dependent variable is the natural logarithm of transaction prices. The coefficients are the effect of being within a certain distance from the tunnel within a specified time period compared to houses at more than 2km away from the tunnel. Heteroskedasticity robust standard errors in parentheses. Housing attributes, Location attributes and Year dummies have been included in the regression. ** $p < 0.10$, ** $p < 0.5$, *** $p < 0.01$*

500m and 1km, but - surprisingly - larger effects for houses between 1 and 2km (10.0% more appreciation). These results are consistent with those in the OLS and PC6 FE models (see Table D.4 in the appendix). We also find in this specification with distance bands, that before 2010, houses within a given PC4 that are closer to the tunnel, were substantially cheaper than comparable houses further than 2km from the tunnel (7.1% to 14.9%). Indicating that these houses suffered more from highway externalities.

Because of the curious results in the last column of Table 3, we perform a robustness analysis in which we move houses between 1 and 2km to the control group in the appendix (Table D.2, left half). All coefficients in the inner two distance bands then attenuate to zero with some 5%-points. These results suggest that houses in the 1-2km band experienced an increase in value between 2010 and 2016-2017, conditional on factors we control for, that drives both the large effects in the last column of Table 3 and the smaller estimates for the inner two bands in the appendix, through their effect on the average appreciation in the control group. We verify this hypothesis with an additional regression in which we drop all houses between 1-2km of the tunnel (right half of Table D.2). The coefficients for the inner two distance bands are then similar to Table 3.

To further pinpoint what drives these changes in coefficients, we run two more regressions: one in which we drop houses situated between 1 and 2km west of the tunnel, and one in which we remove observations between 1 and 2km east of the tunnel (Table D.3). We find no clear indication that the large effect of the tunnel in the 1-2km band is driven by asymmetric developments on the western and eastern side of the tunnel.

If we multiply the percentage effects on house prices with the number of houses in the distance bands within 1 km, the total increase in house values within 1km between 2010 and 2016-2017 amounts to €220 mln.[9]

We see two explanations for our main finding that the tunnel has a positive effect in 2016-2017 but not earlier. First, as the works progress, more of the construction nuisance becomes sunk and thus no longer relevant for house prices. Second, the waiting period before home owners can experience the decrease in noise and air pollution gets shorter over time.

4.1 Sensitivity analyses

The appendix contains a set of robustness analysis with respect to equation (1). Firstly, the effects of the tunnel in 2016-2017 are robust in three additional analyses in which we exclude houses in areas that we identified in section 3.1 as potentially benefitting from larger-than-average reductions in travel times: houses east of the A2, houses outside the city ring and housing along streets that were popular rat-running routes. The base coefficient of distance to the tunneled segment varies only slightly in these analyses but always remains significant at the 99% level. Secondly, the effect of the tunnel also does not change when we exclude the 'Vogelaar' districts that received urban revitalization investments. Thirdly, we verify that the results hold up in the subsample of houses closer to the tunnel than to the non-tunneled segment, to address the concern that the main estimates are distorted by houses which are close to the tunnel, but still experience nuisance after the project because they are even closer to a non-tunneled part of the A2.

Fourthly, we decompose the effects for individual years (Table D.1), and perform a robustness analysis in which we only include houses within 1km, 2km or 3km from the tunnel (Table D.5), because distance to the tunnel might not matter as fmuch for houses further away. The results are robust for the subsample within 1km, but we find no significant effect in the intermediate subsamples. We suspect that the houses between 1 and 2 km from the tunnel drive the non-result in this last sensitivity analysis, as in the specification with distance bands. This conjecture accords with an eyeball plot that shows a relatively large increase in observed transaction prices between 1-2km in 2016-2017.

5 Conclusion

We analysed how a reduction in traffic externalities influences house prices, by studying the underground relocation of a highway in Maastricht that left local travel times largely unaffected. We find evidence that house prices start to increase even before the project

[9] In 2017, there were 7526 houses within 500 meter of the tunnel and 10647 houses between 500 and 100 meter. The average transaction prices within these bands between 2010 and 2017 were €198 thousand and €257 thousand, respectively.

is completed and the externalities disappeared, indicating that home buyers anticipate future benefits when they purchase their house.

Our preferred specification estimates that for two otherwise identical houses in the period 2016 to 2017, the house half the distance to the tunnel appreciated 3.5% more compared to before 2010. The effects are largest within 1 kilometer. Our results are mostly robust to changes in specification.

We find positive effects in the year before the tunnel opened, indicating that people do indeed value the outlook of improved liveability in the near future. Our findings suggest that highway tunneling projects may be worthwhile in other cities as well. Though such projects are not worthwhile purely on the grounds of reducing externalities, the liveability gains are sizeable both compared to the total construction costs (€ 890 mln) and the anticipated travel time and reliability gains (€ 930 mln).[10]

This study was limited in the sense that we only looked at housing transactions. The prices of commercial property may also have experienced increases as a result of the reduction in externalities. Another limitation is that we cannot be certain that we have measured the full ex-post valuation of the increase in liveability, since the project was only recently completed. Future research may also use additional data. When the next wave of the noise monitor of the National Institute for Public Health and the Environment is released, it will be possible to condition the estimates on changes in noise pollution. In the longer term, one could look at the health effects of the relocation on nearby residents.

References

Ahlfeldt, G. M., Nitsch, V. and Wendland, N. (2016). *Ease vs. noise: On the conflicting effects of transportation infrastructure*. CESifo Working Paper Series No. 6058.

Andersson, H., Jonsson, L. and Ögren, M. (2010). 'Property Prices and Exposure to Multiple Noise Sources: Hedonic Regression with Road and Railway Noise'. In: *Environmental and Resource Economics* 45.1, pp. 73–89. ISSN: 1573-1502.

Badland, H., Whitzman, C., Lowe, M., Davern, M., Aye, L., Butterworth, I., Hes, D. and Giles-Corti, B. (2014). 'Urban liveability: emerging lessons from Australia for exploring the potential for indicators to measure the social determinants of health'. In: *Social science & medicine* 111, pp. 64–73.

Boes, S. and Nesch, S. (2011). 'Quasi-experimental evidence on the effect of aircraft noise on apartment rents'. In: *Journal of Urban Economics* 69.2, pp. 196 –204. ISSN: 0094-1190.

Brandt, S. and Maennig, W. (2011). 'Road noise exposure and residential property prices: Evidence from Hamburg'. In: *Transportation Research Part D: Transport and Environment* 16.1, pp. 23 –30. ISSN: 1361-9209.

Chang, J. S., Han, S., Jung, D. and Kim, D. (2014). 'Benefits of rerouting railways to tunnels in urban areas: a case study of the Yongsan line in Seoul'. In: *International Journal of Urban Sciences* 18.3, pp. 404–415. eprint: https://doi.org/10.1080/12265934.2014.934270.

[10]This number is from the ex-ante social cost benefit analysis ECORYS (2006), corrected for inflation between 2005 and 2015.

Chay, K. and Greenstone, M. (2005). 'Does Air Quality Matter? Evidence from the Housing Market'. In: *Journal of Political Economy* 113.2, pp. 376–424. ISSN: 00223808, 1537534X.
Court, A. T. (1939). *Hedonic price indexes with automotive examples.* The Dynamics of Automobile Demand. New York: General Motors.
Day, B., Bateman, I. and Lake, I. (2007). 'Beyond implicit prices: recovering theoretically consistent and transferable values for noise avoidance from a hedonic property price model'. In: *Environmental and Resource Economics* 37.1, pp. 211–232.
Debrezion, G., Pels, E. and Rietveld, P. (2007). 'The Impact of Railway Stations on Residential and Commercial Property Value: A Meta-analysis'. In: *The Journal of Real Estate Finance and Economics* 35.2, pp. 161–180. ISSN: 1573-045X.
Dotinga, F. (2010). *A2 Passage Maastricht.* MilieuEffectRapport [Environmental impact report]. Projectbureau A2 Maastricht and Avenue2.
ECORYS (2006). *Kengetallen Kosten-Batenanalyse project A2-Maastricht.*
Geurts, B. (2014). 'Evaluatie van ruimtelijk beleid is een vak apart'. In: *Soort zoekt soort; Clustering en sociaal-economische scheidslijnen in Nederland.* Ed. by J. Bakens, H. L. de Groot, P. Mulder and C.-J. Pen. Platform31, pp. 145–32.
Hoogendoorn, S., Gemeren, J. van, Verstraten, P. and Folmer, K. (2017). 'House prices and accessibility: Evidence from a natural experiment in transport infrastructure'. In: *Journal of Economic Geography.*
Koster, H. R. and Van Ommeren, J. (2017). *Place-based policies and the housing market.* Tech. rep. Tinbergen Institute.
Levkovich, O., Rouwendal, J. and Marwijk, R. (2016). 'The effects of highway development on housing prices'. In: *Transportation* 43.2, pp. 379–405.
Oranjewoud (2006). *Één plan voor stad en snelweg, Onderzoek alternatieven en varianten A2-passage Maastricht.* Tech. rep.
Ossokina, I. V. and Verweij, G. (2015). 'Urban traffic externalities: Quasi-experimental evidence from housing prices'. In: *Regional Science and Urban Economics* 55, pp. 1–13.
Permentier, M., Kullberg, J. and Van Noije, L. (2013). *Werk aan de wijk; Een quasi-experimentele evaluatie van het krachtwijkenbeleid.* Tech. rep. Sociaal en Cultureel Planbureau.
Rosen, S. (1974). 'Hedonic prices and implicit markets: product differentiation in pure competition'. In: *Journal of Political Economy* 82.1, pp. 34–55.
Seo, K., Golub, A. and Kuby, M. (2014). 'Combined impacts of highways and light rail transit on residential property values: a spatial hedonic price model for Phoenix, Arizona'. In: *Journal of Transport Geography* 41, pp. 53 –62. ISSN: 0966-6923.
Smith, V. K. and Huang, J.-C. (1995). 'Can Markets Value Air Quality? A Meta-Analysis of Hedonic Property Value Models'. In: *Journal of Political Economy* 103.1, pp. 209–227. ISSN: 00223808, 1537534X.

6 Appendix

6.1 Variable description

Table A.1 provides a description of the variables we use in the econometric analyses.

Table A.1: Variables with descriptions included in the case study

Variable	Description
Dependent variable and main independent variable:	
Ln Transaction price (€)	Ln of the transaction price in 2015 Euro
Ln Distance tunnel (m)	Ln of the distance to the tunnel segment of the highway in meters
Structural attributes:	
Building period	Building period, 1500–≥2001 divided in 9 unequally sized periods
Ln Floor space (m^2)	Ln of the number of square meters of floor space
N Floors	Number of floors
N Rooms	Number of rooms
Apartment	Apartment dummy
Terraced	Terraced dummy
Corner house	Corner house dummy
Semi detached	Semi detached dummy
Balcony	Balcony dummy
Monument	Monument dummy
Parking	Parking space dummy
Maintenance inside	Score for maintenance ranging from 1 to 9
Maintenance outside	Score for maintenance ranging from 1 to 9
Locational attributes:	
Ln Distance non-tunneled highway (m)	Ln of the distance to non-tunneled highway segments in the urban area measured in meters
Rail	Dummy for being within 300m of a railway
Ln Distance centre (m)	Ln of the distance to the centre measured in meters
Macro effects:	
Year	Year dummy

6.2 Quality-adjusted prices and distance to tunnel

The descriptive relation between house prices and distance to the tunnel in Figure 2 may be partly driven by differences in house quality between neighbourhoods close to the tunnel and further away. We already noted in section 3.1 that the immediate vincinity of the tunnel contains some disadvantaged areas. We therefore also present the relation from Figure 2 for quality-adjusted prices. We use the coefficient estimates from equation (1) to calculate the price of each house $\hat{P}_{ijt}$ as if it had average house characteristics $\bar{X} = \frac{1}{N}\sum_{i,t} X_{it}$:

$$\begin{aligned}\hat{P}_{ijt} = \exp\big(&\alpha + \beta_0 \ln Distance_i + \beta_1 \ln Distance_i * YearGroup_t \\ &+\beta_2\bar{X} + \gamma_1 L_i + \gamma_2 I_t + \varepsilon_{ijt}\big)\, oster\end{aligned} \tag{3}$$

Figure A.1 shows that the relation between house prices and distance to the tunnel is still increasing when we correct for housing characteristics, although the pattern is more volatile. The quality adjustment is relatively large for houses very close to the tunnel.

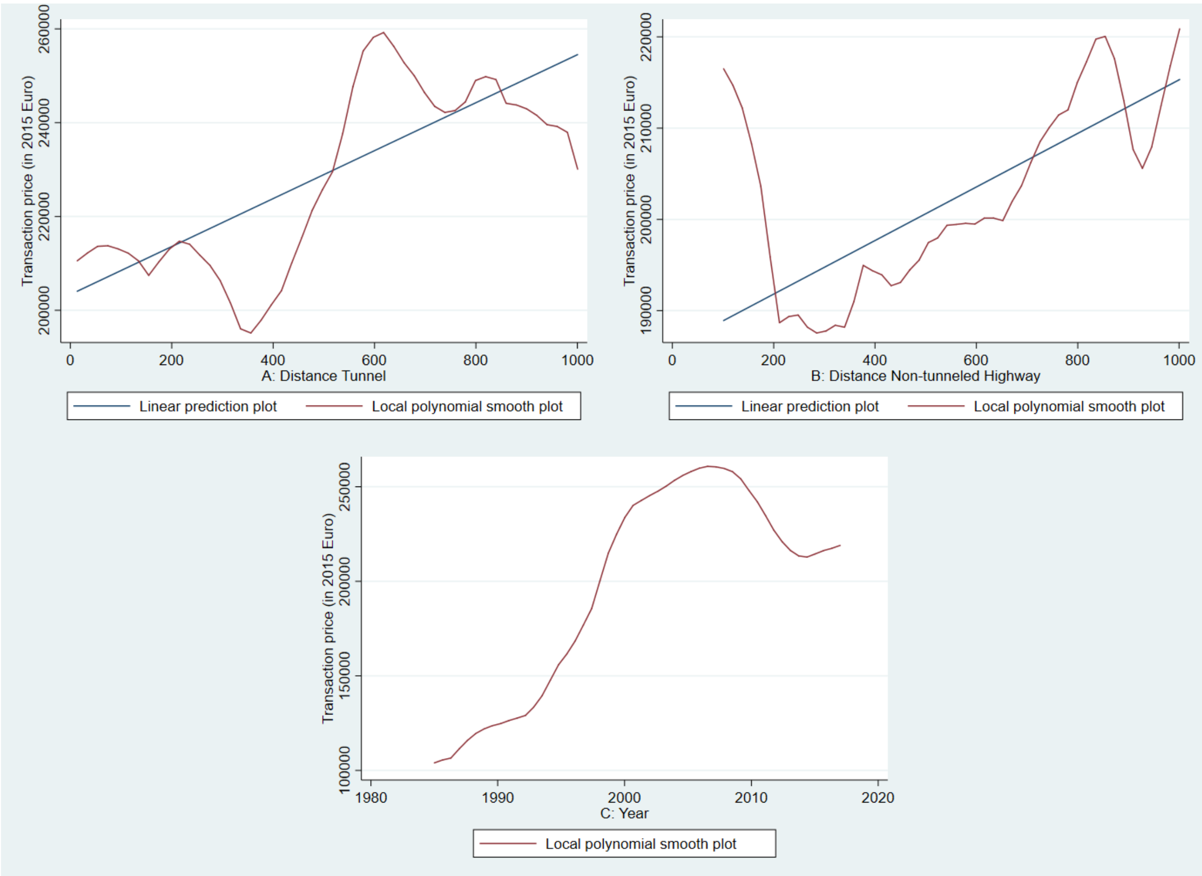

Figure A.1: Upper left: being Quality-adjusted prices and Distance to the tunnel in meters for observations ≤1km before 2010, Upper right: Quality-adjusted prices and distance to the non-tunnelled highway parts in meters for observations ≤1km before 2010, Bottom: Average quality-adjusted prices over time.

6.3 Sensitivity to travel times within Maastricht

This section contains the sensitivity analyses in which we exclude houses that potentially benefit from improved travel times for trips within Maastricht. If these sensitivity checks yield different outcomes than the main results in section 4, our estimates might not reflect only the liveability benefits of the A2 tunnel, but also include a travel time effect.

In Tables B.1, B.2 and B.3, we re-estimate equation (1). When we restrict the analysis to houses west of the A2 (Table B.1), the main coefficient of interest (Ln Distance Tunnel 16-17) is 1 percentage point smaller in absolute value than in the main specification, but still negative and significant. When we restrict the analysis to houses inside the city ring (Table B.2), the effect of distance to the tunnel in 2016-2017 is about 1 percentage point larger than in the main specification. The results when we exclude the rat-running streets (Table B.3) are almost identical to those in Table 2, which might be related to the small number of excluded transactions (153) along these streets.

Table B.1: Logarithmic specification, only houses west of the A2

	OLS	PC4 FE	PC6 FE
Ln Distance Tunnel	-0.032***	-0.024*	0.021
	(0.007)	(0.013)	(0.079)
Ln Distance Tunnel ∗ 2010-11	0.001	0.011	-0.004
	(0.011)	(0.011)	(0.011)
Ln Distance Tunnel ∗ 2012-13	-0.036***	-0.012	-0.009
	(0.013)	(0.011)	(0.010)
Ln Distance Tunnel ∗ 2014-15	-0.020*	-0.003	-0.007
	(0.011)	(0.009)	(0.009)
Ln Distance Tunnel ∗ 2016-17	-0.042***	-0.027***	-0.043***
	(0.011)	(0.010)	(0.009)
Housing attributes	Yes	Yes	Yes
Location attributes	Yes	Yes	No
Year dummies	Yes	Yes	Yes
N	6531	6531	6531
Adjusted R^2	0.800	0.843	0.904

Note: Transacted houses east of the A2 are excluded. Dependent variable is the natural logarithm of transaction prices. (1) is a baseline OLS regression, (2) is a PC4 code fixed effects model and (3) is a PC6 code fixed effects model. Heteroskedasticity robust standard errors in parentheses. * *p < 0.10, ** p < 0.5, *** p < 0.01*

The baseline coefficient on distance to the tunnel is smaller and even significantly negative in Tables B.1 and B.2 than in Table 2. Since most of the houses close to the tunnel in these subsamples are also close to the river and the railway station, the baseline coefficient might now pick up some of the amenity benefits of these areas. This should not influence the validity of the coefficients of interest however.

6.4 Sensitivity to urban revitalization investments

Table C.1 shows the results of equation (1) on the subsample that excludes the Vogelaar districts that received urban revitalization investments. The coefficients on the effect of the tunnel in 2016 and 2017 are similar to the main results.

6.5 Sensitivity to nuisance from non-tunneled segment

We control for distance to the non-tunneled highway segment in all our analyses, but one might be concerned that the benefit of the tunnel might be sizeably lower for houses that are closer to the non-tunneled part of the highway than to the tunnel, because the most relevant (closest) part of the highway for these houses is still above ground after

Table B.2: Logarithmic specification, only houses inside the city ring

	OLS	PC4 FE	PC6 FE
Ln Distance Tunnel	-0.045***	-0.046**	-0.051
	(0.011)	(0.019)	(0.108)
Ln Distance Tunnel ∗ 2010-11	-0.017	0.002	-0.005
	(0.015)	(0.014)	(0.016)
Ln Distance Tunnel ∗ 2012-13	-0.020	-0.010	0.007
	(0.017)	(0.015)	(0.015)
Ln Distance Tunnel ∗ 2014-15	-0.044***	-0.025*	-0.001
	(0.014)	(0.013)	(0.011)
Ln Distance Tunnel ∗ 2016-17	-0.058***	-0.047***	-0.042***
	(0.014)	(0.013)	(0.012)
Housing attributes	Yes	Yes	Yes
Location attributes	Yes	Yes	No
Year dummies	Yes	Yes	Yes
N	2525	2525	2525
Adjusted R^2	0.827	0.839	0.893

Note: Transacted houses outside the city ring are excluded. Dependent variable is the natural logarithm of transaction prices. (1) is a baseline OLS regression, (2) is a PC4 code fixed effects model and (3) is a PC6 code fixed effects model. Heteroskedasticity robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.5$, *** $p < 0.01$

Table B.3: Logarithmic specification, rat-running streets excluded

	OLS	PC4 FE	PC6 FE
Ln Distance Tunnel	0.010***	0.010***	-0.024
	(0.004)	(0.004)	(0.047)
Ln Distance Tunnel $*$ 2010-11	0.005	0.005	-0.002
	(0.009)	(0.009)	(0.008)
Ln Distance Tunnel $*$ 2012-13	-0.020*	-0.020*	-0.010
	(0.011)	(0.011)	(0.009)
Ln Distance Tunnel $*$ 2014-15	-0.014*	-0.014*	-0.010
	(0.008)	(0.008)	(0.007)
Ln Distance Tunnel $*$ 2016-17	-0.037***	-0.037***	-0.036***
	(0.009)	(0.009)	(0.007)
Housing attributes	Yes	Yes	Yes
Location attributes	Yes	Yes	No
Year dummies	Yes	Yes	Yes
N	9090	9090	9090
Adjusted R^2	0.806	0.806	0.907

Note: Transacted houses along the Meerssenerweg, Willem Alexanderweg, Ambyerstraat and Fregatweg are excluded. Dependent variable is the natural logarithm of transaction prices. (1) is a baseline OLS regression, (2) is a PC4 code fixed effects model and (3) is a PC6 code fixed effects model. Heteroskedasticity robust standard errors in parentheses. * *$p < 0.10$, ** $p < 0.5$, *** $p < 0.01$*

Table C.1: Logarithmic specification, Vogelaar districts excluded

	OLS	PC4 FE	PC6 FE
Ln Distance Tunnel	-0.017***	0.035***	0.036
	(0.005)	(0.010)	(0.065)
Ln Distance Tunnel ∗ 2010-11	0.014	0.021*	-0.008
	(0.012)	(0.011)	(0.010)
Ln Distance Tunnel ∗ 2012-13	-0.047***	-0.029***	-0.039***
	(0.012)	(0.011)	(0.011)
Ln Distance Tunnel ∗ 2014-15	-0.016*	-0.016*	-0.021***
	(0.010)	(0.008)	(0.008)
Ln Distance Tunnel ∗ 2016-17	-0.040***	-0.036***	-0.049***
	(0.010)	(0.009)	(0.009)
Housing attributes	Yes	Yes	Yes
Location attributes	Yes	Yes	No
Year dummies	Yes	Yes	Yes
N	8339	8339	8339
Adjusted R^2	0.805	0.844	0.906

Note: Transacted houses in Vogelaar districts are excluded. Dependent variable is the natural logarithm of transaction prices. (1) is a baseline OLS regression, (2) is a PC4 code fixed effects model and (3) is a PC6 code fixed effects model. Heteroskedasticity robust standard errors in parentheses. ** $p < 0.10$, ** $p < 0.5$, *** $p < 0.01$*

Table C.2: Logarithmic specification, exclude houses closer to non-tunneled segment than to tunnel

	OLS	PC4 FE	PC6 FE
Ln Distance Tunnel	0.006	-0.043***	-0.071
	(0.006)	(0.011)	(0.052)
Ln Distance Tunnel $*$ 2010-11	-0.010	-0.002	-0.009
	(0.009)	(0.009)	(0.009)
Ln Distance Tunnel $*$ 2012-13	-0.017	-0.009	-0.009
	(0.011)	(0.010)	(0.009)
Ln Distance Tunnel $*$ 2014-15	-0.018**	-0.013*	-0.011
	(0.008)	(0.007)	(0.007)
Ln Distance Tunnel $*$ 2016-17	-0.036***	-0.033***	-0.039***
	(0.009)	(0.008)	(0.007)
Housing attributes	Yes	Yes	Yes
Location attributes	Yes	Yes	No
Year dummies	Yes	Yes	Yes
N	7023	7023	7023
Adjusted R^2	0.804	0.844	0.904

Note: Transacted houses that are closer to the non-tunneled segment than to the tunnel are excluded. Dependent variable is the natural logarithm of transaction prices. (1) is a baseline OLS regression, (2) is a PC4 code fixed effects model and (3) is a PC6 code fixed effects model. Heteroskedasticity robust standard errors in parentheses. *$*$ $p < 0.10$, $**$ $p < 0.5$, $***$ $p < 0.01$*

completion of the project. To see whether these houses influence our estimates, we run a regression in which we exclude them. Table C.2 shows the results, which are of similar magnitude to the main text.

6.6 Sensitivity to alternative subsamples and fixed effects

When we estimate equation (1) with interaction terms for each individual year, the overall pattern of the effect of the tunnel on house prices is similar to Table 2. Interestingly, the coefficient on the interaction term for 2016 is larger than 2017.

Tables D.2 and D.3 show how the results of equation (2) change when we exclude the distance band between 1 and 2 km. Houses in this distance band received a larger benefit from the tunnel than houses closer by according to the baseline results of (2), whereas one would expect the benefits of the tunnel to decline monotonically with distance. When we no longer include a separate distance band for houses between 1 and 2 km, these houses move to the control group (Table D.2, left half). The coefficients on the shorter distance bands now reflect the additional appreciation within these bands vis a vis houses further than 1 km from the tunnel. In the main text, these coefficients indicated the appreciation

Table D.1: Logarithmic specification with interaction terms for individual years

	OLS	PC4 FE	PC6 FE
Ln Distance Tunnel	0.009**	0.010	-0.011
	(0.004)	(0.008)	(0.046)
Ln Distance Tunnel 2010	0.002	-0.000	0.001
	(0.011)	(0.011)	(0.011)
Ln Distance Tunnel 2011	0.005	0.009	-0.005
	(0.014)	(0.013)	(0.012)
Ln Distance Tunnel 2012	-0.017	-0.009	-0.007
	(0.014)	(0.012)	(0.011)
Ln Distance Tunnel 2013	-0.023	-0.005	-0.012
	(0.016)	(0.014)	(0.013)
Ln Distance Tunnel 2014	-0.015	-0.013	-0.014
	(0.010)	(0.010)	(0.008)
Ln Distance Tunnel 2015	-0.016	-0.012	-0.006
	(0.011)	(0.010)	(0.009)
Ln Distance Tunnel 2016	-0.048***	-0.043***	-0.042***
	(0.011)	(0.010)	(0.009)
Ln Distance Tunnel 2017	-0.025**	-0.023**	-0.031***
	(0.012)	(0.011)	(0.009)
Housing attributes	Yes	Yes	Yes
Location attributes	Yes	Yes	No
Year dummies	Yes	Yes	Yes
N	9243	9243	9243
Adjusted R^2	0.805	0.843	0.906

Note: Dependent variable is the natural logarithm of transaction prices. (1) is a baseline OLS regression, (2) is a PC4 code fixed effects model and (3) is a PC6 code fixed effects model. Heteroskedasticity robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.5$, *** $p < 0.01$

Table D.2: PC4 FE Difference-in-difference model, fewer distance bands

	Full sample		Exclude houses between 1-2 km	
	0-0.5km	0.5-1km	0-0.5km	0.5-1km
Base	-0.084***	-0.035***	-0.154***	-0.102***
	(0.015)	(0.010)	(0.030)	(0.027)
2010-2011	0.026	-0.071***	0.026	-0.079***
	(0.025)	(0.019)	(0.026)	(0.022)
2012-2013	-0.006	-0.005	0.037	0.028
	(0.025)	(0.021)	(0.026)	(0.022)
2014-2015	0.029	-0.015	0.050**	0.002
	(0.020)	(0.019)	(0.020)	(0.020)
2016-2017	0.031	0.003	0.072***	0.037*
	(0.025)	(0.019)	(0.025)	(0.020)
N	9243	9243	6508	6508
Adjusted R^2	0.843	0.843	0.843	0.843

Note: Dependent variable is the natural logarithm of transaction prices. The coefficients are the effect of being within a certain distance from the tunnel within a specified time period compared to houses at more than 1km away from the tunnel. Heteroskedasticity robust standard errors in parentheses. Housing attributes, Location attributes and Year dummies have been included in the regression. ** $p < 0.10$, ** $p < 0.5$, *** $p < 0.01$*

compared to house more than 2km from the tunnel.

In the left half of Table D.2, the effects of the tunnel are no longer significant. When we exclude houses between 1 and 2km rather than moving them to the control group (right half), we find that the tunnel has a comparable effect to Table 3 in the main text. We interpret these findings that both the anomalously large effect of the tunnel in the 1-2km band in the main text, as well as the non-result in the left half of Table D.2 are driven by an increase in the value of houses within this distance band - conditional on the other variables we control for.

An eyeball plot of transaction prices per distance band indeed shows a relatively strong increase in prices in the 1-2km distance band in 2016-2017 (Figure D.1).

We explore whether the large coefficient estimate for the 1-2km band is driven primarily by houses within 1-2km on the west side of the tunnel, or by properties within 1-2km on the east side. We do this by sequentially excluding only those houses which are within 1 and 2 km on the eastern side of the tunnel (Table D.3, left half), and excluding only the houses within 1 and 2 km on the western side (right half). The coefficients on the interaction terms are a bit smaller in the right half of the Table than in the left half, but the differences are not large. We thus find no evidence that the large effect of the tunnel in the 1-2km band is driven by asymmetric developments on the western and eastern side of the tunnel.

Table D.4 shows the results of equation (2) without postal code fixed effects (left half), and with postal code effects for smaller areas (right half). Without fixed effects,

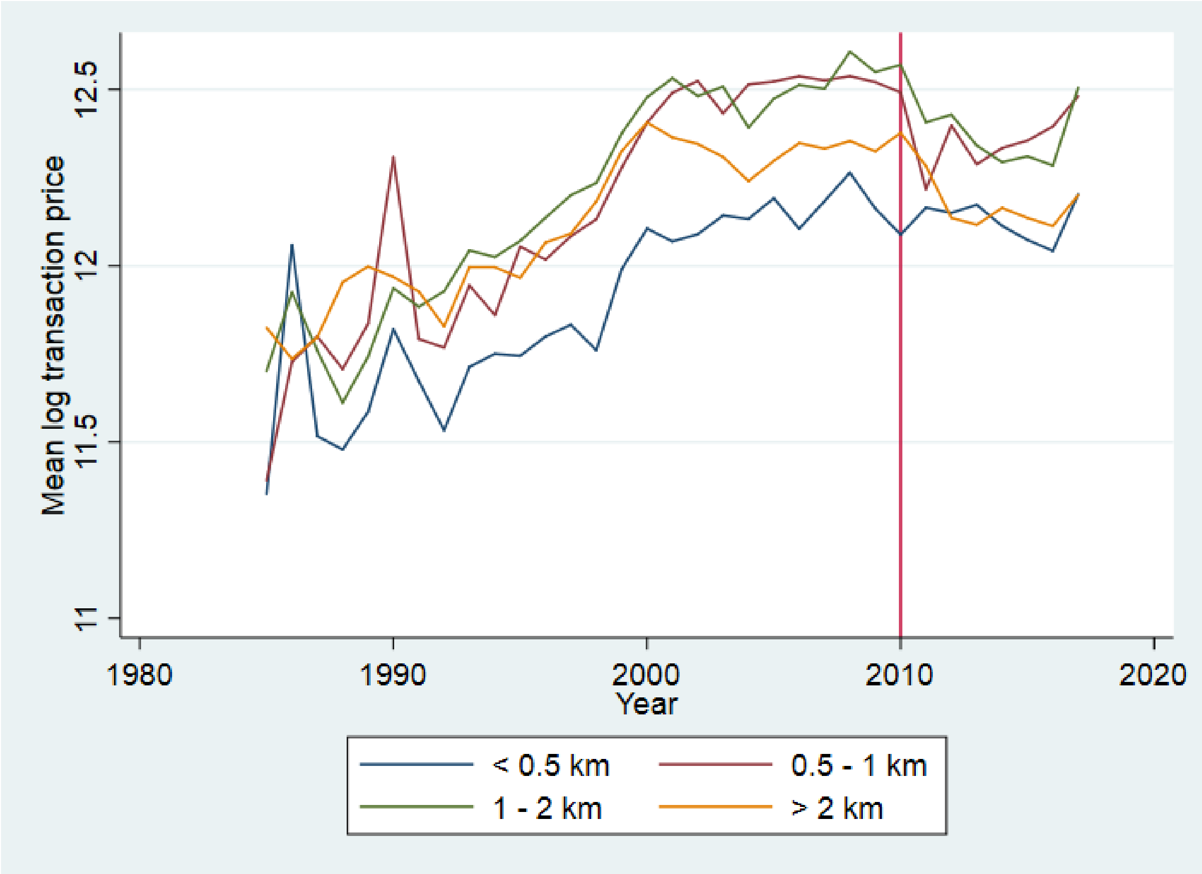

Figure D.1: Observed mean log transaction prices per distance band

the base coefficients on the distance bands are larger in de OLS specification than in Table 3. The OLS results also display an earlier effect of the tunnel than our preferred specification with PC4 fixed effects. The results with PC6 fixed effects are similar to the preferred specification, with the exception of the positive and significant coefficients for the 0.5-1km and 1-2km distance bands in 2012-2013.

Lastly, Table D.5 shows how the results of the log-log specification (1) change when we use smaller subsamples of houses closer to the tunnel. Postulating a logarithmic effect of distance to the tunnel has the advantage of a single, easy-to-interpret coefficient, but the results are potentially sensitive to a distance cutoff for the estimation sample. If this distance cutoff is too generous, this could attenuate the estimated effect of the tunnel. In the main analysis, the cutoff is given by the municipality borders of Maastricht. The Table shows that the results are stronger than in the main analysis we use a 1 km cutoff, weaker with a 3km cutoff and zero with a 2km cutoff. The results with the 2km cutoff are likely to have the same cause as the large coefficient estimate for the 1-2km band in the distance band specification (2).

Table D.3: PC4 FE Difference-in-difference model, fewer distance bands, subsamples

	No houses 1-2km east of tunnel		No houses 1-2km west of tunnel	
	0-0.5km	0.5-1km	0-0.5km	0.5-1km
Base	-0.122***	-0.071***	-0.101***	-0.051***
	(0.029)	(0.026)	(0.016)	(0.010)
2010-2011	0.023	-0.068***	0.034	-0.076***
	(0.025)	(0.020)	(0.025)	(0.020)
2012-2013	0.017	0.016	0.011	0.006
	(0.026)	(0.022)	(0.026)	(0.021)
2014-2015	0.044**	-0.001	0.038*	-0.009
	(0.020)	(0.020)	(0.020)	(0.019)
2016-2017	0.056**	0.026	0.045*	0.013
	(0.025)	(0.019)	(0.025)	(0.019)
N	7471	7471	8280	8280
Adjusted R^2	0.842	0.842	0.845	0.845

Note: Dependent variable is the natural logarithm of transaction prices. The coefficients are the effect of being within a certain distance from the tunnel within a specified time period compared to houses at more than 1km away from the tunnel. Heteroskedasticity robust standard errors in parentheses. Housing attributes, Location attributes and Year dummies have been included in the regression. ** $p < 0.10$, ** $p < 0.5$, *** $p < 0.01$*

Table D.4: OLS & PC6 FE Difference-in-difference model

	OLS Distance bands			PC6 FE Distance bands		
	0-0.5km	0.5-1km	1-2km	0-0.5km	0.5-1km	1-2km
Base	-0.040***	0.039***	0.046***	-0.139***	-0.120***	-0.067**
	(0.012)	(0.010)	(0.009)	(0.049)	(0.040)	(0.028)
2010-2011	0.018	-0.039*	0.021	0.015	-0.027	0.032*
	(0.027)	(0.023)	(0.023)	(0.024)	(0.021)	(0.018)
2012-2013	0.054*	0.069***	0.097***	0.009	0.047**	0.049**
	(0.027)	(0.024)	(0.023)	(0.025)	(0.020)	(0.019)
2014-2015	0.051**	0.019	0.048***	0.030	0.004	0.041***
	(0.022)	(0.022)	(0.018)	(0.020)	(0.018)	(0.014)
2016-2017	0.059**	0.046**	0.102***	0.069***	0.047**	0.083***
	(0.026)	(0.021)	(0.017)	(0.020)	(0.019)	(0.014)
N	9243	9243	9243	9243	9243	9243
Adjusted R^2		0.809		0.906	0.906	0.906

Note: Dependent variable is the natural logarithm of transaction prices. The coefficients are the additional price growth of a house in the specified distance band compared to a house more than 2km away from the tunnel, relative to the pre-2010 period. Heteroskedasticity robust standard errors in parentheses. Housing attributes, Location attributes and Year dummies have been included in the OLS regression, Housing attributes and Year dummies have been included in the PC6 FE regression. ** $p < 0.10$, ** $p < 0.5$, *** $p < 0.01$*

Table D.5: Logarithmic specification, subsamples within 1km, 2km and 3km

	1km			2km			3km		
	OLS	PC4 FE	PC6 FE	OLS	PC4 FE	PC6 FE	OLS	PC4 FE	PC6 FE
Ln Distance Tunnel	0.036***	0.010	-0.082	0.030***	0.013	-0.047	0.012***	0.016*	-0.017
	(0.007)	(0.011)	(0.051)	(0.005)	(0.009)	(0.047)	(0.004)	(0.008)	(0.046)
Ln Distance Tunnel $*$ 2010-11	-0.034*	-0.042**	-0.019	0.011	0.005	0.018	0.010	0.009	0.015
	(0.019)	(0.020)	(0.021)	(0.013)	(0.013)	(0.013)	(0.012)	(0.011)	(0.011)
Ln Distance Tunnel $*$ 2012-13	0.029	0.025	0.055***	0.042***	0.041***	0.029**	0.015	0.015	0.014
	(0.023)	(0.024)	(0.019)	(0.015)	(0.015)	(0.014)	(0.014)	(0.013)	(0.012)
Ln Distance Tunnel $*$ 2014-15	-0.003	-0.007	0.000	0.015	0.012	0.017*	0.001	0.001	0.010
	(0.019)	(0.019)	(0.016)	(0.012)	(0.012)	(0.010)	(0.010)	(0.009)	(0.008)
Ln Distance Tunnel $*$ 2016-17	-0.041**	-0.044**	-0.030*	-0.000	-0.000	0.001	-0.021*	-0.019*	-0.008
	(0.019)	(0.019)	(0.017)	(0.013)	(0.013)	(0.010)	(0.011)	(0.010)	(0.009)
Housing attributes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Location attributes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2551	2551	2551	5286	5286	5286	6822	6822	6822
Adjusted R^2	0.827	0.829	0.896	0.817	0.836	0.903	0.802	0.836	0.901

Note: Dependent variable is the natural logarithm of transaction prices. We drop observations further than 1, 2 or 3km of the tunnel segment of the highway, respectively. We run a baseline OLS regression, a PC4 code fixed effects model and a PC6 code fixed effects model. Heteroskedasticity robust standard errors in parentheses. ** $p < 0.10$, ** $p < 0.5$, *** $p < 0.01$*