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House prices and accessibility: Evidence from a natural experiment in transport infrastructure

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Abstract
This paper studies the impact of accessibility on house prices, based on a natural experiment in the Netherlands: the Westerscheldetunnel. We exploit the fact that the opening of the tunnel caused a substantial shift in accessibility for people and firms in the connected regions. Our results indicate that the elasticity between house prices and accessibility is equal to 0.8. We also find support for the idea of anticipation: about half of the accessibility effect already materializes more than one year before the opening of the tunnel. Moreover, our analyses suggest that the impact of accessibility differs across regions.

Keywords: House prices; accessibility; natural experiment; hedonic approach; transport infrastructure
JEL classification: R2, R4

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1. Introduction

A key ingredient in the location decision of people and firms is accessibility. The location decision of people is mainly based on the accessibility of jobs (Alonso, 1964; Brueckner, 1987) and amenities (Glaeser et al., 2001). Improved accessibility, for instance as a result of new transport infrastructure, better enables people to work at a place that fits their skills and live at a spot that matches their needs (Teulings et al., 2014). For firms, accessibility lowers transportation costs and fosters agglomeration economies through *matching*, *sharing* and *learning* (Puga, 2010). Together, these factors often lead to clustering in economic centers (Krugman and Venables, 1995).[2] Hence, accessibility shapes economic activities and development.

Despite the theoretical arguments to expect spatial economic effects of changes in accessibility, there is few consensus in the empirical literature (e.g. Gutiérrez et al., 2010). Some studies find evidence that transport infrastructure affects employment (Haughwout, 1999; Duranton and Turner, 2012), productivity (Pereira, 2000; Cantos et al., 2005), house prices (Gibbons and Machin, 2005; Klaiber and Smith, 2010; Levkovich et al., 2015) and population (Baum-Snow, 2007; Garcia-Lopez et al., 2015). However, other studies report insignificant effects on the same measures (on employment: e.g. Jiwattanakulpaisarn et al., 2009; on productivity: e.g. Garcia-Mila et al., 1996), or find that the impact of accessibility is negligible (Haughwout, 2002; Jiwattanakulpaisarn et al., 2011). Moreover, a third strand of the literature identifies a redistribution of economic activities due to changes in accessibility (Chandra and Thompson, 2000; Moreno and López-Bazo, 2007; Redding and Turner, 2014).

One of the most salient reasons for the conflicting evidence is that studies in this field of research come across several empirical challenges. First, to obtain an observable impact of infrastructure, one needs to analyze a sufficiently large change in accessibility. This is problematic since substantial increases in accessibility are rare, given the existing dense network of roads and railways in most western countries (Fernald, 1999; Banister and Berechman, 2001). Second, changes in accessibility are seldom exogenous (Duranton and Turner, 2012; Redding and Turner, 2014). It often remains unclear whether economic development results from improved infrastructure or the other way around. Particularly, investments in transport infrastructure are usually targeted to benefit areas with high or low economic growth (Garcia-López et al., 2015). This introduces the problem of reverse causality. Finally, the estimated relationship between spatial economic effects and changes in accessibility is frequently confounded by external developments in the area of research (Duranton and Turner, 2012; Baum-Snow and Ferreira, 2014).

This paper aims to address these issues by studying a case that qualifies as a natural experiment in the Netherlands: the Westerscheldetunnel. The key contribution of this paper is that the opening of tunnel exerted a substantial impact on accessibility, because the Westerschelde estuary hampers traffic flows towards the other bank by nature. This is clearly illustrated by the 50% increase of the number of vehicles that crossed the Westerschelde right after the tunnel opened and the ferry services closed down. The simultaneous abolishment of the ferries yields an even larger variation in accessibility due to the location of their former route: the ferries used to run on the east and west side of the estuary, while the tunnel is located in the center. This allows us to exploit both positive and negative changes in accessibility. Second, the predominant goal of constructing the tunnel was not to promote economic development. Rather, the main goal was to save on public costs as maintaining one tunnel would be cheaper than subsidizing two ferry lines. This makes the construction of the tunnel a rather exogenous event compared to the bulk of investments in transport infrastructure. Third, the existence of natural

[2] On the other hand, accessibility might also bring disadvantages. For instance, more competitors will increase prices for non-transportable production factors like land. This induces an outflow from the center to peripheral locations from where one can now service more customers. The relative importance of these centrifugal and centripetal forces may differ between types of firms (Graham, 2007; Combes et al., 2011; Desmet and Fafchamps, 2005; Glaeser and Kohlhase, 2004).

borders in the Dutch province of Zeeland helps to limit the influence of external developments in the area under scope.

The main goal of this paper is to estimate the effect of accessibility on house prices. To this end, this study employs detailed panel data at the zip code level for the period between 1995 and 2013 (the tunnel was opened in 2003). We also test several hypotheses on the timing of accessibility capitalization into house prices, by allowing for anticipation and delayed response. Moreover, we explore whether the impact of accessibility differs across regions. Finally, we examine the robustness of our results to data selection and methodological choices, also to help explain the mixed findings presented in the literature.

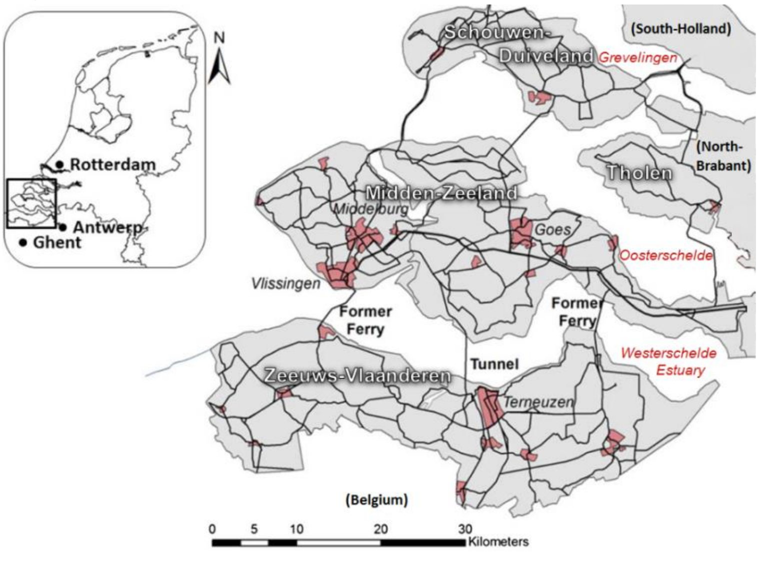
The results show that the Westerscheldetunnel positively and significantly affects house prices. On average, a 1% increase in accessibility leads to an 0.8% increase in house prices. Furthermore, about half of the effect already materializes more than one year before the opening of the tunnel. We also find weak evidence for delayed response: the (remaining) benefits of the tunnel were not entirely capitalized right after the opening. In addition, our analyses suggest substantial heterogeneity between regions. While the northern region is likely to experience positive effects from the opening of the tunnel, the southern region does not seem to respond to the improved accessibility at all. This is a rather intriguing result since both regions are not too different from one another in terms of geography and economic development.

The remainder of this paper is structured as follows. Section 2 describes the natural experiment that we study. Section 3 presents the data and methodology. Section 4 reports our results, including a variety of sensitivity analyses. Section 5 concludes.

2. Natural experiment

This paper focuses on the Dutch province of Zeeland, located in the far south-western part of the Netherlands (see Figure 1). The province covers almost 3000 square kilometers and accommodates around 380,000 inhabitants (Statistics Netherlands, 2014). It consists mostly of islands and peninsulas in a delta area, and is bordered by Belgium to the South. Due to its geography, Zeeland is relatively isolated from the rest of the Netherlands, even though the Euclidian distance to the large cities of Rotterdam, Antwerp and Ghent is small. The relative isolation of Zeeland helps to limit the influence of developments outside the research area.

Figure 1 Location and detailed map of Zeeland

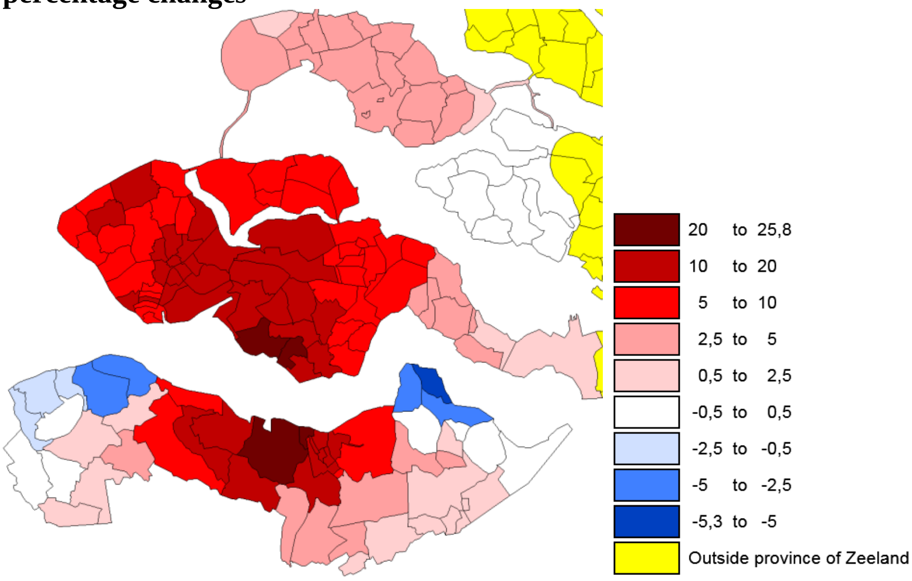


Source: Meijers et al. (2013), with slight adaptations.

The province of Zeeland is generally perceived as part of the periphery of the Netherlands. The number of accessible jobs is relatively low (Meijers et al., 2013) and the population density is low relative to the rest of the Netherlands (OECD, 2014). Zeeland is also relatively aged (Statistics Netherlands, 2014) and has a low population growth, urbanization rate and education level (OECD, 2014). Still, GDP per capita and productivity rank medium, whereas its unemployment rate is the lowest in the Netherlands (OECD, 2014).

The Westerscheldetunnel was opened on the 14th of March 2003.[3] It connects Midden-Zeeland in the North to Zeeuws-Vlaanderen in the South. Before the opening of the tunnel, traffic had to use one of the ferry services. An alternative option was to drive through another tunnel near Antwerp in Belgium to cross the Westerschelde estuary (not on the map in Figure 1). Both ferries, one in the west and the other in the eastern part of Zeeland, were closed down on the day the tunnel opened. Hence, the simultaneous opening of the tunnel and abolishment of the ferries redirected trans-Westerschelde traffic from the outskirts towards the middle of the province. The changes in accessibility were particularly significant for the geographical center of both Midden-Zeeland and Zeeuws-Vlaanderen, and the outskirts of Zeeuws-Vlaanderen (see Figure 2). Other regions in Zeeland, such as Schouwen-Duiveland and Tholen, remained largely unaffected.

Figure 2 Accessibility change due to the opening of the tunnel and the abolishment of the ferries, percentage changes

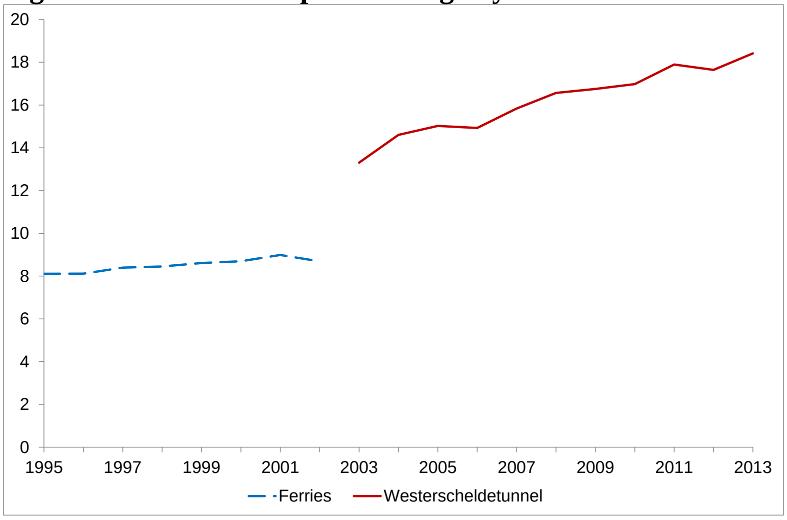


Accessibility is measured as the number of accessible jobs, weighted by a generalized Gaussian distance decay function. A change in accessibility is expressed by ln(accessibility after March 2003/accessibility before March 2003).

The time to cross the Westerschelde by ferry (including waiting time) was just under half an hour, while the tunnel can take cars across the estuary in five minutes. Traffic count numbers are illustrative for the substantial change in accessibility. In the first year after the opening of the tunnel, the number of vehicles that crossed the Westerschelde per working day increased by 50% and it has continued to rise by another 45% in the years afterwards (see Figure 3). However, not all origin-destination combinations have experienced a travel time gain. For instance, mimicking the former route of the ferry by car through the tunnel now takes double the amount of time as before. This novel feature allows us to exploit positive as well as negative changes in accessibility.

[3] The final decision to construct the tunnel was made in September 1995, whereas the actual construction started in November 1997. Nowadays, there still exists a small ferry service in the western part of Zeeland, mainly for recreational use and restricted to pedestrians and cyclists.

Figure 3 Traffic counts per working day across the Westerschelde estuary, thousands of vehicles



Source: Province of Zeeland.

Furthermore, public cost savings were the dominant consideration at the time of decision (e.g. Louw et al., 2013; Priemus and Hoekstra, 2001). Another, more subordinate goal was to promote safety on the Westerschelde estuary since the ferry lines were crossing the busy shipping lane to the international port of Antwerp. From an technical perspective, the project was also expected to deepen engineers' knowledge on tunnel construction in soft clay ground. Consequently, the construction of the tunnel can be qualified as a rather exogenous event (not related to economic development), which allows us the opportunity to estimate the causal effect of accessibility on house prices.

Nevertheless, as with any investment in transport infrastructure, the decision where to locate the tunnel was not completely random. The central route was chosen in order to connect the industrial areas of Terneuzen (in the southern region) and Middelburg/Vlissingen (in the northern region), and to improve the access of Ghent (Belgium) to the international port of Rotterdam. In what follows, we will correct for possible bias as a result of time-(in)variant sources.

3. Methodology and data

3.1 Identification strategy

In line with Gibbons and Machin (2005), we identify the impact of a change in accessibility on (hedonic) house prices using a zip code fixed effects regression:[4]

$$\ln P_{ijt} = \alpha + \theta_1 \ln A_{jt} + \beta_j \ln L_i + \gamma \boldsymbol{X}_{it} + \delta^I \boldsymbol{Y}_t + \delta^{II} \boldsymbol{M}_t + \delta^{III} \boldsymbol{Z}_j + \varepsilon_{ijt}\,, \quad (1)$$

where P_{ijt} denotes the house transaction price in dwelling i in zip code j, at date t. A_{jt} indicates the accessibility for zip code j and date t with accessibility elasticity of house prices θ_1. L_i is the lot size of the dwelling; its effect on house price β_j is allowed to vary over zip codes. $\boldsymbol{X}_{it}$ is a vector of hedonic control variables that represent house characteristics (see Appendix A.2 for details). $\boldsymbol{Y}_t$, $\boldsymbol{M}_t$ and $\boldsymbol{Z}_j$ are vectors of year, month and zip code fixed effects, with δ^I, δ^{II} and δ^{III} as their estimated coefficients. ε_{ijt} is a random error term clustered at the zip code level.[5]

[4] We adopt a log-log specification rather than a (log-)linear form (Osland, 2010; Iacono and Levinson, 2011; Levkovich et al., 2015).

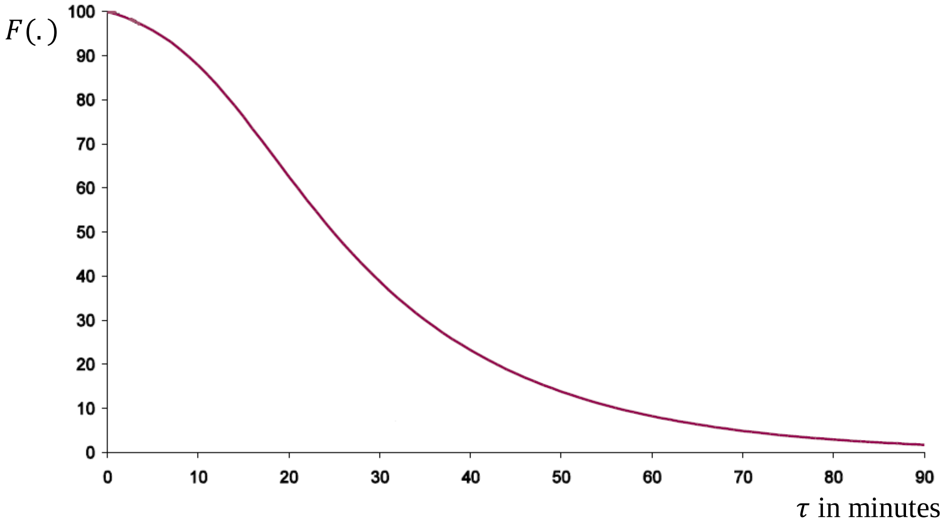
[5] Clustered error terms correct for the spatial autocorrelation (Angrist and Pischke, 2009) that arises because accessibility is measured at the zip code level, while house prices are measured at the level of the individual house (Moulton, 1990).

The potential accessibility framework that we employ in equation (1) focuses on the *possibility* to access 'economic mass', a collective term for jobs, people and amenities (e.g. Van Wee et al., 2001; Gutiérrez et al., 2010).[6] The general equation for potential accessibility equals:

$$A_{jt} = \sum_{d=1}^{D} E_d F(\tau_{jdt})$$

where d is an index that relates to destinations that one can travel to from zip code j. The zip code area j itself is also part of the set of D feasible destinations. E_d captures the economic mass in destination d at the date the tunnel was opened; we measure this using the number of jobs.[7] τ_{jdt} describes the travel time required to reach destination d from zip code j at date t. Travel time is then used as input for our generalized Gaussian distance decay function $0 \leq F(.) \leq 100\%$, based on De Groot et al.'s (2010) estimates for the Netherlands (see Figure 4).[8] The idea is that jobs located further away from home get increasingly smaller weights, until the weight becomes zero in the limit for jobs located more than 90 minutes of travel time away (one way trip).

Figure 4 Generalized Gaussian distance decay function



Source: De Groot et al. (2010), with slight adaptations. The function resembles the share of the Dutch workforce that is willing to commute for τ minutes.

Equation (1) may exhibit bias if the house price trend is not uniform across the research area. For instance, when regions with large accessibility gains have an upward house price trend (conditional on the general house price trend captured by the dummies) and regions further away from the tunnel have a downward trend, A_{jt} will be correlated to the error term yielding upward bias. These time variant differences between regions can be controlled for by linear zip code-specific year trends (Allers and Vermeulen, 2013), as expressed in equation (2):

$$\ln P_{ijt} = \alpha + \theta_1 \ln A_{jt} + \beta_j \ln L_i + \gamma \boldsymbol{X}_{it} + \delta^{I} \boldsymbol{Y}_t + \delta^{II} \boldsymbol{M}_t + \delta^{III} \boldsymbol{Z}_j + \rho_j y_t + \varepsilon_{ijt} \quad (2)$$

[6] Other (utility-based) measures use *actual*, revealed behavior to operationalize accessibility. Similar results are obtained if we employ this concept of accessibility (see sensitivity analyses).
[7] E_d is not allowed to vary over time since relocation of economic mass may be a generative effect of the tunnel and should therefore be absorbed by the house prices (rather than controlling for it in the accessibility measure).
[8] The impedance function is slightly different from the commonly used function $F(.) = 1/\tau$ (Gutiérrez et al., 2010; Levkovich et al., 2015). This function dictates that doubling the travel time corresponds to halving the weight. Our empirically-based decay function declines less sharply in the lower part of the travel time distribution, and more sharply in the right tail. Intuitively, a job at 10 minutes away gets a weight less than twice that of a job at a distance of 20 minutes, while one job at 40 minutes travel time counts more than two jobs that are 80 minutes away.

where y_t is a linear scale variable that denotes the year of house sale ($y_{1995} = 1$, $y_{1996} = 2$ ...). Its effect ρ_j differs per zip code j.

To allow for anticipation effects, i.e. future accessibility benefits that already capitalize in house prices before the opening of the tunnel (McDonald and Osuji, 1995)[9], we include an additional term:

$$\ln P_{ijt} = \alpha + \theta_1 \ln A_{jt} + \theta_2 \boldsymbol{\omega}_t \ln\left(\frac{A_{j,after}}{A_{j,before}}\right) + \beta_j \ln L_i + \gamma \boldsymbol{X}_{it} + \delta^I \boldsymbol{Y}_t + \delta^{II} \boldsymbol{M}_t + \delta^{III} \boldsymbol{Z}_j + \rho_j y_t + \varepsilon_{ij} \quad (3)$$

The additional term in equation (3) reflects the relative change in accessibility due to the tunnel in zip code j, in line with Ossokina and Verweij (2015). If people anticipate an accessibility gain, house prices will start to respond to this before March 2003. $\boldsymbol{\omega}_t$ is a vector of four dummy variables that equal one for respectively 2000, 2001, 2002 and 2003 (before March). θ_2 then measures the degree of capitalization in these years. Again, each of the four estimates in θ_2 can be interpreted as elasticity.

Equation (3) implicitly assumes that people have a proper idea about the magnitude of accessibility changes due to the tunnel, before it actually opens. This assumption is necessary to test for anticipation effects when there is no valid control group to perform a difference-in-differences analyses (e.g. Levkovich et al., 2015). It is safe to assume that people will predict the sign of the change correctly, but one can debate to what extent they anticipate the magnitude of the change. If anticipation capabilities are poor, θ_2 can be biased upwards or downwards depending on whether people overshoot or undershoot their expectations.

One might also argue that θ_1 increases over time. For instance, people and firms may gradually learn about the benefits of the tunnel. This delayed response hypothesis implies that θ_1, which estimates the *average* house price effect of a change in accessibility, overestimates the effect in the first years after the opening of the tunnel, and underestimates it for later years. In that case, the delayed response effect shows up in the error term. This can be tested empirically by the following OLS regression with standard errors clustered at the zip code level:

$$\hat{e}_{ijt} = \alpha + \delta \boldsymbol{Y}_t + \varphi \boldsymbol{y}_t * \ln\left(\frac{A_{j,after}}{A_{j,before}}\right) + u_{ijt} \quad (4)$$

where $\hat{e}_{ijt}$ represents the residuals, as estimated by equation (3). $\boldsymbol{Y}_t$ is a vector of year dummies with coefficient δ. $\boldsymbol{y}_t$ is a vector of dummies, where the first dummy indicates the period from the opening of the tunnel (in March) to the end of 2003. The remainder of $\boldsymbol{y}_t$ denotes year dummies from 2004 to 2013. φ is a vector of estimates for the interaction effect between $\boldsymbol{y}_t$ and accessibility change. Hence, if there is delayed response φ should be below zero in 2003 and increasing afterwards. u_{ijt} is a random error component.

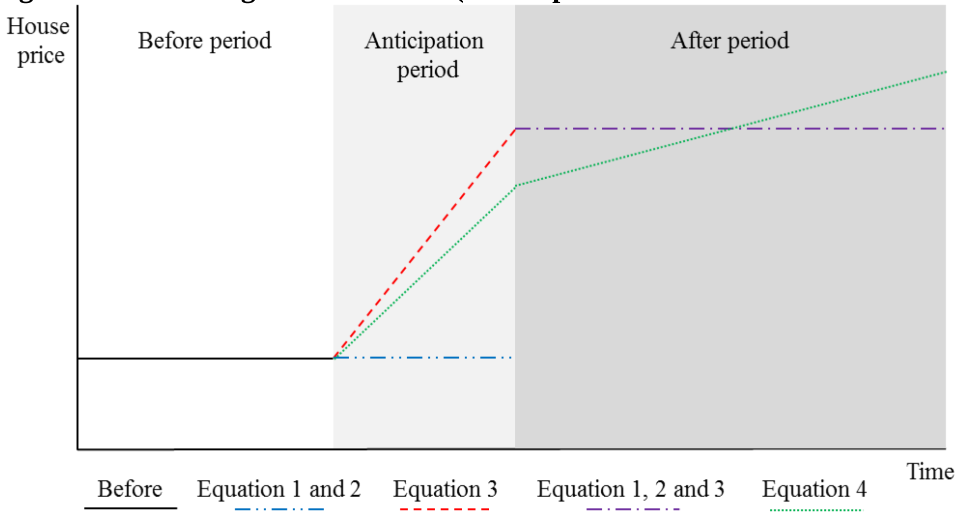
The impact of the tunnel may differ across regions (e.g. Meijers et al., 2013). For instance, there could be a core-periphery effect, which allows the center to benefit more from the opening of the tunnel than the periphery (Krugman and Venables, 1995). To this end, we will estimate equations (3) and (4) including an interaction effect with a region dummy that equals one for observations located to the South of the Westerschelde estuary (Zeeuws-Vlaanderen), and zero otherwise (the northern region). The effect of the tunnel in the northern region is dominated by Midden-Zeeland (see Figure 2).[10]

[9] McDonald and Osuji (1995) assume that capitalization occurs from the moment the construction is announced. We cannot accurately test this assumption since the announcement of the tunnel in 1995 coincides with the first year of our panel data. Arguably, we choose 2000 as the first year that anticipation effects may take place. In what follows, we show that anticipation is unlikely to occur before 2002.

[10] The other two regions, Tholen and Schouwen-Duiveland, do not get their own interaction effect due to the fact that these regions lack sufficient observations and variation in accessibility to obtain a reliable estimate, particularly in Tholen. Similar results (for Zeeuws-Vlaanderen and Midden-Zeeland) are obtained if all regions have their own interaction effect.

The methodological framework of this paper is summarized in Figure 5. Equations (1) and (2) assume that the benefits of the tunnel fully capitalize right after the opening of the tunnel. Equation (3) (and (4)) assumes that capitalization already takes place before, not necessarily in a linear fashion. Note that equations (1) and (2) underestimate the impact of the tunnel if anticipation exists since they count the anticipation period as part of the 'before period', reducing the before-after difference. If the anticipation period is deleted from the sample, equations (1), (2) and (3) will therefore yield the same results. By construction, the average effect for equation (4) is equal to that of equation (3). However, the slope of its line is not necessarily steeper in the anticipation period than in the period afterwards.

Figure 5 Methodological framework (for a zip code with an increase in accessibility)



The larger the accessibility increase, the steeper the slope of the lines and the higher the shift. The figure for a zip code with a decrease in accessibility is the mirror image.

3.2 Accessibility data

Our data on travel time and economic mass (employment) stem from the input database of the leading regional transport model in the Netherlands (NRM Zuid). The model is widely applied for benefit-cost analyses and audited on a regular basis to ensure accuracy. The input database combines observational data from several sources, such as the LISA employment database that registers all jobs in the Netherlands at the local level. Our dataset reports data on 3300 areas, both Dutch and foreign, including the travel time between all of these areas.

The NRM Zuid model is also able to create a counterfactual travel time matrix: the travel times that apply to the situation before the opening of the tunnel. To this end, we erase the tunnel and corresponding on-ramps from the transport network in the model and reintroduce the ferry services. Then, the model calculates the counterfactual behavior of road users in terms of destination and route choice, based on the new generalized travel costs and revealed preference in the model's base traffic network. The counterfactual network and road user behavior together determine the counterfactual travel time matrix.

The 3300 areas in the NRM Zuid model are smaller than zip codes. Therefore, we aggregate these areas to (the size of) zip codes using weighted averages of the number of commuting trips in an area.[11] This results in 934 zip codes with data on accessibility before and after the opening of the tunnel, of which 153 are located in the province of Zeeland. The change in accessibility for these 153 zip codes is shown in Figure 2.

[11] Alternatively, the number of households in an area can be used as a weight. In practice, the difference is negligible since the correlation between the number of commuting trips and the number of households is close to one.

Table 1 presents the descriptive statistics of accessibility and the substantial shift caused by the tunnel. The largest increase in accessibility is more than 25%, while other regions experience a decrease of about 5%. These percentages correspond to approximately 46,000 extra jobs and 9,000 fewer jobs accessible, respectively. The average zip code in Zeeland was able to access almost 12,000 extra jobs. In the southern region of Zeeuws-Vlaanderen, potential accessibility is highest before the opening of the tunnel due to the proximity of Antwerp and Ghent in Belgium.[12] On average, the northern region of Midden-Zeeland encounters the largest increase in accessibility. Nevertheless, Zeeuws-Vlaanderen shows the largest variation in accessibility (as indicated by the standard deviation).

Table 1 Descriptive statistics of accessibility

Region	# zip codes	Mean accessibility before tunnel, # jobs	Mean increase in accessibility	Minimum increase in accessibility	Maximum increase in accessibility	SD of percentage accessibility increase
Zeeland	153	176,706	6.80%	- 5.22%	25.80%	5.78%
Northern region	102	165,170	7.92%	0.04%	25.80%	4.88%
Zeeuws-Vlaanderen	51	199,778	4.55%	- 5.22%	22.96%	6.72%

3.3 House price data

We use micro data on house prices from the administrative database of the Dutch Association of Real Estate Brokers and Experts (NVM). Almost half of the real estate brokers in the province of Zeeland is a member of the NVM. In total, the dataset contains 38,948 house transactions, including the date of sale, transaction price and a variety of house characteristics (see Appendix A.2 for an overview), for the period between 1985 and 2013. 27,835 observations in 146 zip codes remain after removing incomplete observations and restricting the sample to 1995 and onwards (due to representativeness concerns with regard to the data before 1995).[13] Appendix A.1 describes this procedure in more detail. Table 2 provides the number of house transactions and transaction prices on a year-to-year basis.

Table 2 Number of house transactions and transaction prices per year in Zeeland (by NVM enlisted real estate brokers)

Year	Number of transactions	Mean transaction price in euro	SD of transaction price in euro	Minimum transaction price in euro	Maximum transaction price in euro
1995	715	89,162	42,163	22,689	298,587
1996	940	95,010	53,172	22,689	589,914
1997	1,093	97,546	49,282	24,958	492,352
1998	1,153	107,876	56,537	24,958	621,679
1999	1,355	119,974	63,756	29,496	544,536
2000	1,488	132,292	75,161	22,689	689,746
2001	1,820	144,000	81,704	22,689	703,360
2002	1,780	166,530	88,144	25,000	699,100
2003	1,738	184,712	94,189	33,000	706,024
Without tunnel	323	174,808	91,242	44,111	612,603
With tunnel	1,415	186,973	94,735	33,000	706,024
2004	1,750	192,345	102,339	31,000	710,000
2005	2,006	203,978	101,348	32,000	710,000
2006	2,014	214,108	109,557	35,000	710,000
2007	1,948	215,164	107,386	32,500	700,000
2008	1,622	212,806	105,167	34,000	687,500
2009	1,230	199,326	98,559	37,500	710,000
2010	1,219	204,557	102,455	47,500	700,000
2011	1,192	200,287	101,494	34,000	710,000

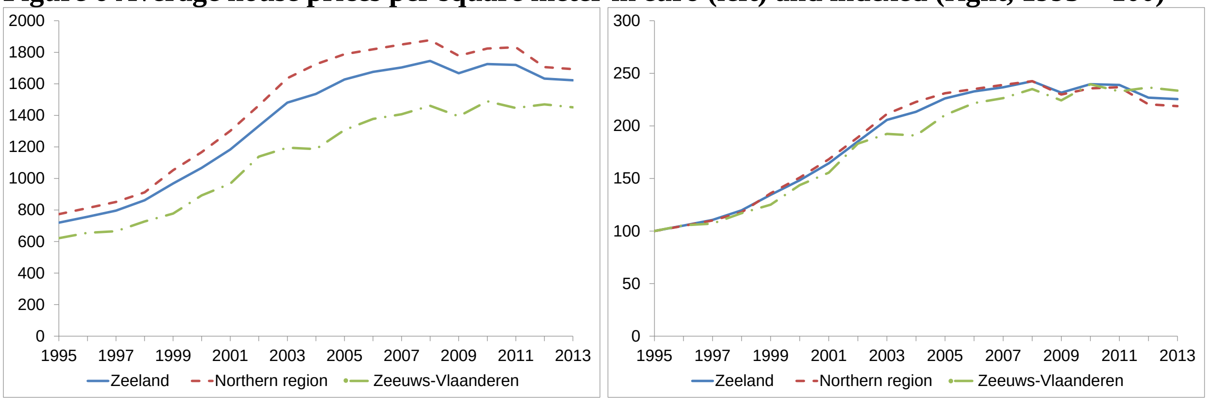
[12] The fact that Zeeuws-Vlaanderen has a higher initial accessibility level than Midden-Zeeland does not imply that this region is the economic center of Zeeland. In fact, the opposite is argued more often (e.g. Meijers et al., 2012). Teulings et al. (2014) consider the two regions as being equally peripheral. Without jobs in Belgium, Zeeuws-Vlaanderen would only have 34,291 jobs accessible on average, which is far less than its current population of about 100,000 inhabitants.

[13] 7 zip codes are removed due to insufficient observations (<10 during the whole period). Similar results are obtained if we use a different threshold for the minimum number of house transactions in a zip code (see Appendix A.4).

2012	1,388	192,464	103,022	29,000	700,000
2013	1,384	190,129	99,167	22,500	675,000
Whole sample	27,835	173,446	100,330	22,500	710,000

Figure 6 shows the development of average house prices per square meter for the northern region and the southern region (Zeeuws-Vlaanderen). The graph indicates a steady increase in average yearly house prices per square meter over the years, until the crisis (from 2008 onwards). House prices in the North are about 25% higher than in Zeeuws-Vlaanderen. There are no systematic differences in the trend across regions before the opening of the tunnel in 2003. However, from 2003 onwards Zeeuws-Vlaanderen appears to lag a bit behind the northern region. This may be related to the fact that the average accessibility increase in Zeeuws-Vlaanderen was lower, or because Zeeuws-Vlaanderen responds less strongly to an increase in accessibility. We will test this more formally in Section 4.

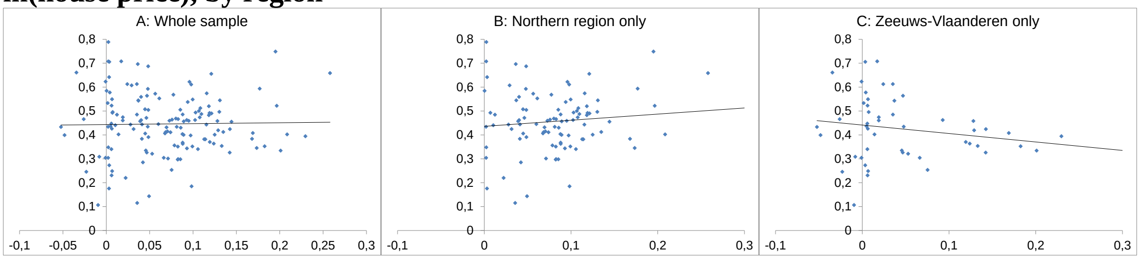
Figure 6 Average house prices per square meter in euro (left) and indexed (right, 1995 = 100)



3.4 A first impression of the house price-accessibility relationship

Figure 7 presents the relationship between (raw) house price growth and accessibility change at the zip code level. Panel A indicates that there is no relationship for the whole sample. However, once we split up the sample in the northern and southern region (panel B and C), a weak relationship between accessibility and house price changes emerges. This relationship turns out positive for the northern region and negative for the southern region (Zeeuws-Vlaanderen), in line with Meijers et al. (2013).

Figure 7 Scatterplot of accessibility change due to the tunnel (x-axis) and average change in ln(house price), by region



Accessibility change is measured as the natural logarithm of potential accessibility after the tunnel minus the natural logarithm of potential accessibility before the tunnel. The average change in house prices is measured as the average house price per square meter after the tunnel minus the average house price per square meter before the tunnel (in natural logarithms). Each zip code equals one observation.

4 Results

4.1 Main findings

Table 3 shows the results for equations (1) and (2), without anticipation effects. Equation (1), that does not include zip code-specific linear trends, yields an insignificant estimate for the impact of accessibility on house prices. However, equation (2) estimates that a 1% increase in accessibility leads to an increase in house prices of 0.498%. This finding suggests a downward bias in the estimate of equation (1). Indeed, regions that experienced a smaller increase in accessibility, were characterized by a stronger upward trend in house prices.[14]

Table 3 Effect of (ln) accessibility on (ln) house prices, equations (1) and (2)

	Equation (1)	Equation (2)
Ln (accessibility)	-0.044 (0.073)	0.498*** (0.133)
Zip code-specific linear trends	No	Yes
N (#clusters / zip codes)	27,835 (146)	27,835 (146)
Within R^2	0.8700	0.8728

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects, month fixed effects and hedonic controls for house characteristics are included. */**/*** denote significance at the ten, five and one percent level.*

Anticipation effects and delayed response

Table 4 presents the results for equation (3). Anticipation starts from 2002 and increases as the opening of the tunnel approaches. In 2002, house prices rose by 0.420% for every 1% (expected) increase in accessibility. House prices further increased to 0.583% between January and March 2003.[15] The results also reveal that the accessibility elasticity of house prices based on equation (2) in Table 3 is possibly an underestimate. In Table 4 the elasticity accumulates to a maximum of 0.792% for an accessibility gain of 1%. The higher elasticity is intuitive: if one ignores anticipation while it does exist, the 'before' house prices are higher on average and thus more close to the 'after' house prices (see Figure 5).

Table 4 Effect of (ln) accessibility on (ln) house prices with anticipation, equation (3)

Ln (anticipated increase in accessibility, 2000)	-0.015	(0.145)
Ln (anticipated increase in accessibility, 2001)	-0.030	(0.160)
Ln (anticipated increase in accessibility, 2002)	0.420**	(0.212)
Ln (anticipated increase in accessibility, 2003)	0.583**	(0.270)
Ln (accessibility)	0.792***	(0.276)
N (#clusters / zip codes)	27,835	(146)
Within R^2		0.8730

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects, month fixed effects and hedonic controls for house characteristics are included, as well as zip code specific linear time trends. */**/*** denote significance at the ten, five and one percent level.*

Table 5 indicates the results for the occurrence of delayed response, i.e. does φ in equation (4) increase over time? This effect is not obvious from the data. All φ variables are insignificant (except for 2004). In 2003, the residuals are also not below zero as hypothesized, but above. Nevertheless, the observed pattern roughly corresponds to the one predicted by equation (4). Moreover, the combined effect of φ from 2003 onwards is jointly significant. Therefore, we conclude that there is weak evidence of delayed response.

[14] The correlation between the (conditional) linear trend of house prices and accessibility change is -0.326 and significantly different from zero (at the one percent level).
[15] A finer-grained measure using five quarterly anticipation variables (for the first quarter of 2002 until the first quarter of 2003) indicates a smooth increase of house prices throughout this period (see Appendix A.3).

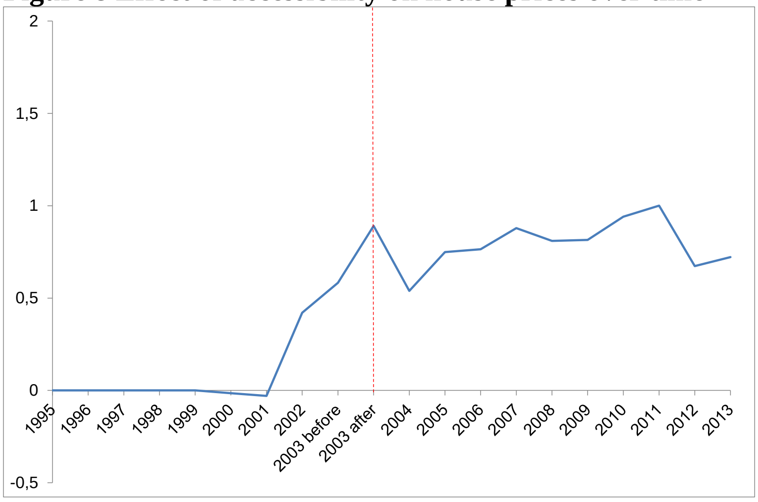
Table 5 Delayed response effects, equation (4)

φ 2003	0.098	(0.086)
φ 2004	-0.253*	(0.144)
φ 2005	-0.044	(0.068)
φ 2006	-0.028	(0.100)
φ 2007	0.086	(0.099)
φ 2008	0.017	(0.078)
φ 2009	0.022	(0.093)
φ 2010	0.149	(0.119)
φ 2011	0.208	(0.130)
φ 2012	-0.119	(0.107)
φ 2013	-0.071	(0.181)
N (#clusters / zip codes)	27,835 (146)	
R^2	0.0009	

*Estimates are based on an OLS-regression using the residuals of equation (3) as dependent variable. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects are included. */**/*** denote significance at the ten, five and one percent level.*

The total effect of accessibility on house prices over time is illustrated in Figure 8, a combination of equation (3) and (4). Note that the impact of accessibility on house prices is set to zero before 2000. The tunnel benefits already start to capitalize into house prices more than one year before the opening of the tunnel. Initially, the effect of the tunnel appears to be an overshoot by the housing market. After 2003, its impact on house prices slowly though steadily rises until 2012.

Figure 8 Effect of accessibility on house prices over time



Differences across regions

Table 6 shows that the positive effect of accessibility on house prices is likely to be driven by the northern region. Here, house prices increase by 1.485% for every 1% increase in accessibility. The southern region (Zeeuws-Vlaanderen) hardly experiences any observable effect with an insignificant accessibility elasticity of 1.485 - 1.282 = 0.203%. A similar pattern holds for the anticipation effects. Hence, our analyses indicate substantial heterogeneity between regions. This is a rather intriguing result since both regions are not too different from one another in terms of geography and economic development. Furthermore, this result suggests that the impact of accessibility is dependent on the research area of interest, in line with the heterogeneous results in the literature.[16]

[16] Meijers et al. (2013) also find differences across regions in their analysis of the Westerscheldetunnel, but establish a negative effect for the southern region. For a different area of the Netherlands, Levkovich et al. (2015) estimate the accessibility elasticity of house prices to be about 1.76, using inhabitants as their measure of economic mass. Franklin and Waddell (2003) find that the elasticity depends on the sector under scope, based on data from the district of Washington. The highest elasticity is found for the commercial sector (0.96). Other sectors (university, industry and education) are characterized by an elasticity close to or

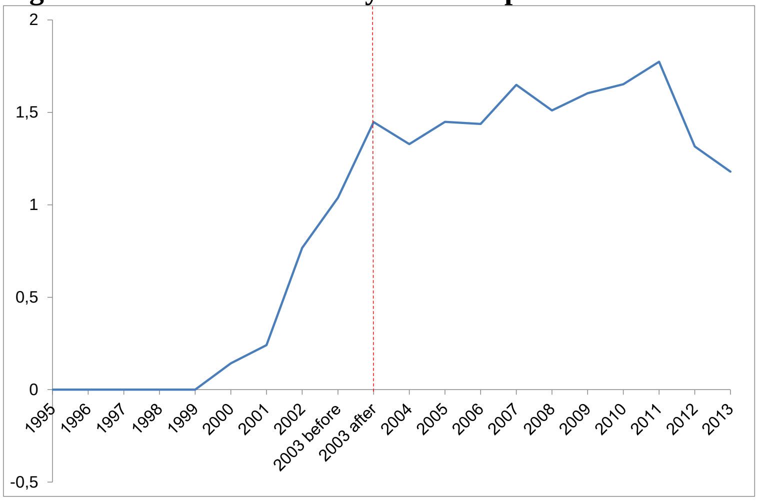
Table 6 Effect of (ln) accessibility on (ln) house prices with regional interaction, equation (3)

	Without regional interaction	With regional interaction
Ln (anticipated increase in accessibility, 2000)	-0.015 (0.145)	0.143 (0.211)
Ln (anticipated increase in accessibility, 2001)	-0.030 (0.160)	0.241 (0.214)
Ln (anticipated increase in accessibility, 2002)	0.420** (0.212)	0.767*** (0.230)
Ln (anticipated increase in accessibility, 2003)	0.583** (0.270)	1.038*** (0.272)
Ln (accessibility)	0.792*** (0.276)	1.485*** (0.258)
Ln (anticipated increase in accessibility, 2000) * dummy region Zeeuws-Vlaanderen		-0.313* (0.168)
Ln (anticipated increase in accessibility, 2001) * dummy region Zeeuws-Vlaanderen		-0.506*** (0.157)
Ln (anticipated increase in accessibility, 2002) * dummy region Zeeuws-Vlaanderen		-0.642*** (0.173)
Ln (anticipated increase in accessibility, 2003) * dummy region Zeeuws-Vlaanderen		-0.681*** (0.234)
Ln (accessibility)*dummy region Zeeuws-Vlaanderen		-1.282*** (0.202)
N (#clusters / zip codes)	27,835 (146)	27,835 (146)
Within R^2	0.8730	0.8736

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects, month fixed effects and hedonic controls for house characteristics are included, as well as zip code specific linear time trends. */**/*** denote significance at the ten, five and one percent level.*

Figure 9 displays the total effect of the tunnel in the northern region, including delayed response as measured through equation (4). Again, a weak pattern of delayed response can be observed (see Appendix A.5 for the underlying φ variables). In this case, overshooting in the first year after the opening of the tunnel is less present.

Figure 9 Effect of accessibility on house prices over time in the northern region



The differences in estimated coefficients between regions in Table 6 may be related to differences in education levels (see Teulings et al., 2014): the workforce is less well educated in Zeeuws-Vlaanderen than in the northern region, on average. In order to explore this hypothesis, we use cross-section data on educational attainment at the municipal level (Statistics Netherlands, 2014), and interact it with accessibility. The results show that the accessibility elasticity of house prices in highly educated municipalities (at least 25% has a university degree, and at most 25% without intermediate vocational education) is 1.251. Other municipalities are characterized by an elasticity of 0.523. This suggests that accessibility is indeed more important to high educated than to low educated people.

sometimes even below zero. Iacono and Levinson (2011) conclude for the district of Minnesota that the elasticity equals 0.138, on average. Finally, evidence from Norway suggests an elasticity of 0.186 (Osland, 2010).

An alternative explanation for the regionally different impact may be that the southern region has a higher housing vacancy rate than the northern region, which facilitates housing market adjustment to demand shocks in the southern region through other channels than prices.[17]

4.2 Sensitivity analyses

In this section, we explore the robustness of our main findings to: (i) including regionally different house price trends, (ii) using a different accessibility framework, and (iii) adopting different data selection criteria.

4.2.1 Regionally different house price trends

To allow for a different house price trend per region, we add to equation (3) an interaction term between the vector of year dummies and region (see Levkovich et al., 2015; Ossokina and Verweij, 2015). This captures unobservable characteristics in a region that might be correlated with the accessibility measure.

Table 7 shows that inclusion of the interaction term has a downward effect on the main estimate (an accessibility elasticity of 0.563 rather than 0.792). Nevertheless, the new estimate is still well within the confidence interval of the main specification, estimated in Table 4.

Table 7 Effect of (ln) accessibility on (ln) house prices with regionally different house price trends, equation (3)

	No region-specific year dummies	With region-specific year dummies
Ln (anticipated increase in accessibility, 2000)	-0.015 (0.145)	-0.081 (0.132)
Ln (anticipated increase in accessibility, 2001)	-0.030 (0.160)	-0.120 (0.127)
Ln (anticipated increase in accessibility, 2002)	0.420** (0.212)	0.303* (0.180)
Ln (anticipated increase in accessibility, 2003)	0.583** (0.270)	0.390* (0.211)
Ln (accessibility)	0.792*** (0.276)	0.563*** (0.185)
N (#clusters / zip codes)	27,835 (146)	27,835 (146)
Within R^2	0.8730	0.8746

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects (per region for the right hand column), month fixed effects and hedonic controls for house characteristics are included, as well as zip code specific linear time trends. */**/*** denote significance at the ten, five and one percent level.*

Table 8 suggests that, if we also include regional interaction, the previously obtained differences across regions are less robust than the main effect. In fact, this specification predicts that the southern region (Zeeuws-Vlaanderen) may profit even more than the northern region, although the difference between the elasticities of the two regions is insignificant.

Table 8 Effect of (ln) accessibility on (ln) house prices with regional interaction and regionally different house price trends, equation (3)

	No region-specific year dummies	With region-specific year dummies
Ln (anticipated increase in accessibility, 2000)	0.143 (0.211)	-0.325 (0.308)
Ln (anticipated increase in accessibility, 2001)	0.241 (0.214)	-0.609* (0.284)
Ln (anticipated increase in accessibility, 2002)	0.767*** (0.230)	-0.245 (0.285)
Ln (anticipated increase in accessibility, 2003)	1.038*** (0.272)	-0.164 (0.341)
Ln (accessibility)	1.485*** (0.258)	0.177 (0.314)
Ln (anticipated increase in accessibility, 2000) * dummy region Zeeuws-Vlaanderen	-0.313* (0.168)	0.397 (0.328)
Ln (anticipated increase in accessibility, 2001) * dummy region Zeeuws-Vlaanderen	-0.506*** (0.157)	0.751** 0.296)
Ln (anticipated increase in accessibility, 2002) * dummy region Zeeuws-Vlaanderen	-0.642*** (0.173)	0.817** (0.347)
Ln (anticipated increase in accessibility, 2003) * dummy region Zeeuws-Vlaanderen	-0.681*** (0.234)	0.980** (0.417)
Ln (accessibility)*dummy region Zeeuws-Vlaanderen	-1.282*** (0.202)	0.600 (0.379)

[17] Other possible explanations are found not to determine the differences in estimated coefficients: zoning restrictions (limiting supply adjustments) in the North, a higher share of recreational housing and a higher share of aged people in the South.

N (#clusters / zip codes)	27,835 (146)	27,835 (146)
Within R^2	0.8736	0.8748

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects (per region for the right hand column), month fixed effects and hedonic controls for house characteristics are included, as well as zip code specific linear time trends. */**/*** denote significance at the ten, five and one percent level.*

4.2.2 Accessibility framework

This subsection explores the sensitivity of our main findings to a different accessibility framework, measuring utility-based rather than potential accessibility.[18] The difference between the two is that the former is based on *revealed* travel behavior, while the latter focuses on the *possibility* to access economic mass. Our utility-based measure employs so-called logsums to operationalize accessibility (see De Jong et al., 2007 for a literature review and the theoretical underpinnings of this accessibility measure). Logsums are a standard accessibility indicator of the NRM Zuid model. Two logsum indicators are available for each of the 3300 zones: one for the base traffic network and one for the counterfactual state (before the opening of the tunnel).

Note that the logsum *levels* have no interpretation, and percentage changes do not reveal actual information either. This implies that logsums cannot be used in our preferred log-log setting. Logsum *absolute differences* (cross-sectional or temporal), however, do convey information. Therefore, we rely on a log-linear framework that includes logsum accessibility as our independent variable. In a fixed effects regression, this boils down to exploiting the absolute temporal change in logsum accessibility (LGS):

$$\ln P_{ijt} = \alpha + \theta_1 LGS_{jt} + \theta_2 \boldsymbol{\omega}_t (LGS_{j,before} - LGS_{j,after}) + \beta_j \ln L_i + \gamma \boldsymbol{X}_{it} + \delta^I \boldsymbol{Y}_t + \delta^{II} \boldsymbol{M}_t + \delta^{III} \boldsymbol{Z}_j + \rho_j y_t + \varepsilon_{ijt}, \quad (5)$$

where $LGS_{jt} = LGS_{j,before}$ for $t <$ March 2003, and $LGS_{jt} = LGS_{j,after}$ otherwise. The other variables are as in equation (3).

Table 9 indicates that the logsum accessibility measure is not significantly related to house prices. The main reason for the difference with the potential accessibility measure is that the logsums predict a strong impact of the tunnel for the southern region, while the northern region experiences hardly any effect (see Figure 10). This means that the model predicts that the tunnel alters actual travel behavior in the southern region, and much less so in the northern region.[19] Consequently, the variation in the logsum accessibility measure is dominated by zip codes in the South, and the estimates in Table 9 will closely resemble the effect of the tunnel predicted for the southern region in Table 6. Indeed, adding a regional interaction term to equation (5) confirms an insignificant effect for the southern region and again a positive and significant effect for the northern region (see Table 10).

Table 9 Effect of accessibility on (ln) house prices with different accessibility measures, equations (3) and (5)

	Potential accessibility in ln	Logsum accessibility in levels
Anticipated increase in accessibility, 2000	-0.015 (0.145)	-0.499 (0.324)
Anticipated increase in accessibility, 2001	-0.030 (0.160)	-0.682* (0.396)
Anticipated increase in accessibility, 2002	0.420** (0.212)	-0.224 (0.760)
Anticipated increase in accessibility, 2003	0.583** (0.270)	0.119 (1.141)
Accessibility	0.792*** (0.276)	-0.221 (0.955)
N (# clusters)	27,835 (146)	27,835 (146)
Within R^2	0.8730	0.8726

[18] The correlation between the potential and utility-based measure of accessibility at the zip code level is 0.65 and significantly different from zero.

[19] This idea seems to be rejected by data: commuting flows from the northern to the southern region increased more strongly since the opening of the tunnel than the other way around (Louw et al., 2013). The same holds for migration flows (Statistics Netherlands, 2014).

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects, month fixed effects and hedonic controls for house characteristics are included, as well as zip code specific linear time trends. */**/*** denote significance at the ten, five and one percent level.*

Figure 10 Density plot of logsum accessibility change by region

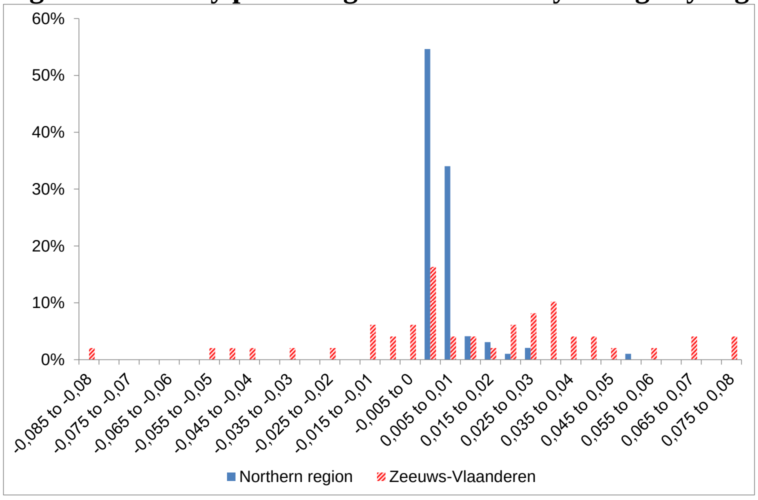


Table 10 Effect of accessibility on (ln) house prices with regional interaction and different accessibility measures, equations (3) and (5)

	Potential accessibility in ln	Logsum accessibility in levels
Anticipated increase in accessibility, 2000	0.143 (0.211)	5.042** (2.335)
Anticipated increase in accessibility, 2001	0.241 (0.214)	6.143*** (1.771)
Anticipated increase in accessibility, 2002	0.767*** (0.230)	11.514*** (2.497)
Anticipated increase in accessibility, 2003	1.038*** (0.272)	11.987*** (3.172)
Accessibility	1.485*** (0.258)	18.064*** (3.408)
Anticipated increase in accessibility, 2000 * dummy region Zeeuws-Vlaanderen	-0.313* (0.168)	-5.361** (2.263)
Anticipated increase in accessibility, 2001 * dummy region Zeeuws-Vlaanderen	-0.506*** (0.157)	-6.597*** (1.657)
Anticipated increase in accessibility, 2002 * dummy region Zeeuws-Vlaanderen	-0.642*** (0.173)	-11.390*** (2.191)
Anticipated increase in accessibility, 2003 * dummy region Zeeuws-Vlaanderen	-0.681*** (0.234)	-11.241*** (2.827)
Accessibility * dummy region Zeeuws-Vlaanderen	-1.282*** (0.202)	-17.860*** (3.094)
N (# clusters)	27,835 (146)	27,835 (146)
Within R^2	0.8736	0.8734

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects, month fixed effects and hedonic controls for house characteristics are included, as well as zip code specific linear time trends. */**/*** denote significance at the ten, five and one percent level.*

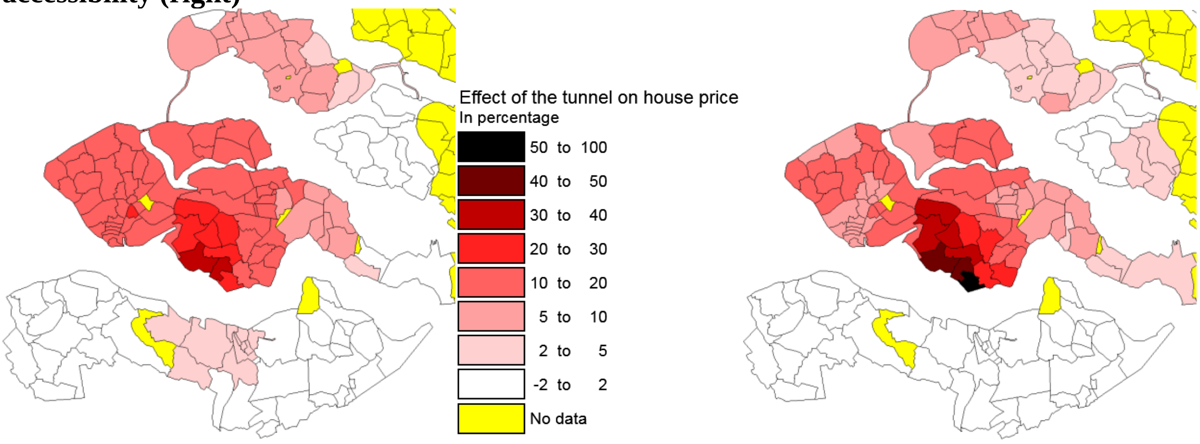
One can compare the effect sizes of the potential and logsum accessibility estimates by calculating the total effect of the tunnel on house prices, as in equation (6):

$$\frac{d\ln P_{ijt}}{dT} = \frac{d\ln P_{ijt}}{d(\text{Accessibility measure})} * \frac{d(\text{Accessibility measure})}{dT} \quad (6)$$

The effect of the tunnel (*dT)* on the accessibility measure employed (potential accessibility or logsum accessibility) times the estimated effect of this accessibility measure on house prices is equal to the effect of the tunnel on the log of house prices. This holds for both accessibility measures. Hence, equation (6) circumvents that $\frac{d\ln P_{ijt}}{d(\text{Accessibility measure})}$ (shown for both measures in Table 9 and 10) is not comparable across measures. $\frac{d \ln P_{ijt}}{dT}$ can be interpreted as the impact of the tunnel on house prices in percentage terms.

Figure 11 displays this effect per zip code for the potential and logsum accessibility measure. The (unweighted) average effect in Midden-Zeeland is very similar (14.7% versus 14.1%, respectively). The impact of the tunnel on the three other regions (Zeeuws-Vlaanderen, Schouwen-Duiveland and Tholen) is small for both measures. Therefore, we conclude that our findings for the impact on house prices of a change in accessibility are rather insensitive to using different accessibility frameworks.

Figure 11 Comparison of the total effect of the tunnel: potential accessibility (left) versus logsum accessibility (right)



4.2.3 Data selection criteria

In this subsection, we discuss the influence of different data selection criteria on our main findings. Particularly, we identify the impact of excluding foreign data (to measure economic mass) and a restricted data period.

Foreign data

Suppose that our dataset would be restricted to the Netherlands only, for instance because data about Belgium is unavailable or perceived as irrelevant due to substantial border effects (e.g. Knowles and Matthiessen, 2006).[20] In that case, the average potential accessibility before the opening of the tunnel shrinks by 53,4%. In addition, the largest accessibility increase at the zip code level in the southern region (Zeeuws-Vlaanderen) is no longer 25.8%, but 118.1% (about 5 times larger). On the other hand, the largest increase in the northern region shrinks from 29.4% to 11.4% (on average about two times smaller in the North) since the economic mass in Belgium is no longer taken into account. Note that the intraregional differences in accessibility are hardly affected by deleting foreign data.

Table 11 presents the results for this exercise. Without data for Belgium, accessibility appears to affect house prices negatively (weakly significant), i.e. a 1% increase in accessibility now deteriorates housing value by 0.132% on average. The estimated pattern of anticipation is also puzzling at first glance. However, again the main reason for these findings is that the accessibility measure inflates the importance of the southern region (as with the logsum accessibility measure).

[20] One could argue that destinations in Belgium are irrelevant to Zeeland since only 9% of the workers living in the southern region (Zeeuws-Vlaanderen) commute to Belgium, even though 90% of the potentially accessible jobs are located there (Marlet et al., 2014). However, this perspective denies that people may value the *possibility* to work in Belgium. Moreover, potential accessibility does not only capture jobs, but also takes amenities and other economic activity in Belgium into account.

Table 11 Effect of (ln) accessibility on (ln) house prices without foreign data, equation (3)

	With foreign data	Without foreign data
Ln (anticipated increase in accessibility, 2000)	-0.015 (0.145)	-0.082***(0.030)
Ln (anticipated increase in accessibility, 2001)	-0.030 (0.160)	-0.122***(0.030)
Ln (anticipated increase in accessibility, 2002)	0.420** (0.212)	-0.080 (0.052)
Ln (anticipated increase in accessibility, 2003)	0.583** (0.270)	-0.100 (0.070)
Ln (accessibility)	0.792*** (0.276)	-0.132* (0.068)
N (#clusters / zip codes)	27,835 (146)	27,835 (146)
Within R^2	0.8730	0.8727

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects, month fixed effects and hedonic controls for house characteristics are included, as well as zip code specific linear time trends. */**/*** denote significance at the ten, five and one percent level.*

Table 12 shows the same regression though including a regional interaction term. For the southern region, we observe no effect. The impact of accessibility on house prices in the northern region is now approximately twice as large as in Table 6. This is intuitive: after all, the accessibility change in the North is roughly twice as small and intraregional differences remain very similar without foreign data. Nevertheless, an accessibility elasticity of 2.575 can be qualified as fairly high. This emphasizes the importance of including data from abroad or neighboring districts, especially when studying border regions.

Table 12 Effect of (ln) accessibility on (ln) house prices with regional interaction and without foreign data, equation (3)

	With foreign data	Without foreign data
Ln (anticipated increase in accessibility, 2000)	0.143 (0.211)	-0.107 (0.410)
Ln (anticipated increase in accessibility, 2001)	0.241 (0.214)	0.068 (0.441)
Ln (anticipated increase in accessibility, 2002)	0.767*** (0.230)	1.162** (0.486)
Ln (anticipated increase in accessibility, 2003)	1.038*** (0.272)	1.736*** (0.563)
Ln (accessibility)	1.485*** (0.258)	2.575*** (0.533)
Ln (anticipated increase in accessibility, 2000) * dummy region Zeeuws-Vlaanderen	-0.313* (0.168)	0.023 (0.388)
Ln (anticipated increase in accessibility, 2001) * dummy region Zeeuws-Vlaanderen	-0.506*** (0.157)	-0.179 (0.414)
Ln (anticipated increase in accessibility, 2002) * dummy region Zeeuws-Vlaanderen	-0.642*** (0.173)	-1.168*** (0.444)
Ln (anticipated increase in accessibility, 2003) * dummy region Zeeuws-Vlaanderen	-0.681*** (0.234)	-1.675*** (0.518)
Ln (accessibility)*dummy region Zeeuws-Vlaanderen	-1.282*** (0.202)	-2.557*** (0.486)
N (#clusters / zip codes)	27,835 (146)	27,835 (146)
Within R^2	0.8736	0.8737

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects, month fixed effects and hedonic controls for house characteristics are included, as well as zip code specific linear time trends. */**/*** denote significance at the ten, five and one percent level.*

Sample period

To test whether the available data period affects our main findings, we restrict our sample to specific sub periods. Table 13 report the results for this exercise using equation (3) and without including the insignificant anticipation years of 2000 and 2001 to avoid collinearity with the zip code specific linear time trends. The impact of accessibility on house prices turns out to be rather insensitive to the sample period of interest. That is, the coefficients for the different sub periods by and large fluctuate within the confidence intervals of the main specification (1995-2013).

Table 13 Effect of (ln) accessibility on (ln) house prices for different time periods, equation (3)

	1995-2013	1995-2007	1995-2005	1998-2013	1998-2007	1998-2005
Anticipation 2002	0.433** (0.168)	0.526***(0.136)	0.558***(0.146)	0.408***(0.150)	0.445***(0.140)	0.458***(0.167)
Anticipation 2003	0.599***(0.216)	0.797***(0.162)	0.853***(0.176)	0.571***(0.209)	0.690***(0.178)	0.761***(0.225)
Ln (accessibility)	0.810***(0.213)	0.877***(0.151)	0.906***(0.165)	0.747***(0.212)	0.717***(0.170)	0.741***(0.220)
N (# clusters)	27,835 (146)	19,800 (146)	15,838 (146)	25,087 (146)	17,052 (146)	13,090 (146)
Within R^2	0.8730	0.8856	0.8828	0.8547	0.8686	0.8670

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects, month fixed effects and hedonic controls for house characteristics are included, as well as zip code specific linear time trends. */**/*** denote significance at the ten, five and one percent level.*

Table 14 shows the results for the same exercise, while including a regional interaction term. Here, the distribution of the treatment effect across regions is less robust. Especially when the crisis years from 2008 onwards are deleted, the northern (southern) region tends to profit less (more) from the opening of the tunnel. Nevertheless, the effect size always remains smaller for the southern region than for the northern region (though not always significant).

Table 14 Effect of (ln) accessibility on (ln) house prices for different time periods with regional interaction, equation (3)

	1995-2013	1995-2007	1995-2005	1998-2013	1998-2007	1998-2005
Anticipation 2002	0.666***(0.177)	0.527***(0.162)	0.511***(0.180)	0.570***(0.161)	0.471***(0.163)	0.445** (0.197)
Anticipation 2003	0.922***(0.220)	0.801***(0.220)	0.804***(0.244)	0.857***(0.216)	0.758***(0.218)	0.785***(0.273)
Ln (accessibility)	1.346***(0.189)	1.044***(0.199)	1.043***(0.223)	1.291***(0.188)	0.983***(0.194)	0.956***(0.253)
Anticipation 2002 *	-0.411***	-0.013	0.071	-0.287**	-0.064	0.002
Zeeuws-Vlaanderen	(0.139)	(0.141)	(0.160)	(0.134)	(0.142)	(0.180)
Anticipation 2003 *	-0.432**	0.079	0.182	-0.338	-0.023	0.046
Zeeuws-Vlaanderen	(0.211)	(0.221)	(0.248)	(0.208)	(0.226)	(0.291)
Ln (accessibility) *	-0.967***	-0.308	-0.254	-0.981***	-0.497**	-0.406
Zeeuws-Vlaanderen	(0.161)	(0.188)	(0.203)	(0.164)	(0.204)	(0.260)
N (# clusters)	27,835 (146)	19,800 (146)	15,838 (146)	25,087 (146)	17,052 (146)	13,090 (146)
Within R^2	0.8730	0.8856	0.8828	0.8547	0.8686	0.8670

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects, month fixed effects and hedonic controls for house characteristics are included, as well as zip code specific linear time trends. */**/*** denote significance at the ten, five and one percent level.*

5 Conclusion and discussion

This paper studies the impact of accessibility on house prices, based on a natural experiment in the Netherlands: the Westerscheldetunnel. We exploit the novel opportunity that the opening of the tunnel (and the simultaneous abolishment of the ferry services) caused a substantial shift in accessibility for people and firms in the connected regions, positively as well as negatively.

Our results indicate that the accessibility elasticity of house prices is equal to 0.8. Approximately half of this effect already materializes more than one year before the opening of the tunnel. We also find weak evidence for delayed response, i.e. house prices kept increasing slowly over time as a response to the change in accessibility due to the tunnel. Moreover, our findings suggest that the impact of accessibility differs across regions, in line with the heterogeneous results found in the literature. Finally, the results are rather robust to a variety of sensitivity analyses.

Several limitations pertain to the natural experiment that we study. Most importantly, the decision where to locate the tunnel was not entirely random (as with any investment in transport infrastructure). In addition, possible external developments in the area of research may influence the estimated relationship between house prices and accessibility. Nevertheless, the construction of the tunnel itself can be qualified as a rather exogenous event since the main goal was to save on public costs instead of promoting economic development. Furthermore, our identification strategy (that corrects for potential bias as a result of time-(in)variant sources) and the existence of natural borders in the Dutch province of Zeeland, help to limit the influence of external developments in the area under scope. All in all, we are therefore confident that the natural experiment of the Westerscheldetunnel is informative about the causal effect of accessibility on house prices.

Two lessons remain for future research on the spatial economic effects of changes in accessibility. First, it is important to assess the impact of accessibility by region. If region A dominates region B in terms of accessibility variation, our results show that region A is likely to have a too large weight in the overall effect. Second, the scope of the research area is crucial to estimate the accessibility elasticity correctly. This emphasizes the relevance of including data from abroad or neighboring districts, especially when studying border regions. Scholars, policy makers and tax payers all stand to gain from further progress in this research agenda.

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Appendix

A.1 Housing data selection process

The initial dataset has been cleared to remove incomplete observations. One may think of houses with undisclosed selling price or with unknown lot size. In addition, we have deleted apartments as well as a few houses that have been sold more than 5 times during the period between 1985 and 2013. Table A1 summarizes our data selection procedure in sequential order.

Table A1 Housing data selection process and number of observations

Selection criteria (a)	Number of observations
1. Initial dataset (1985-2013)	38,948
2. Remove cases with zero living area	
3. Remove cases with zero lot size	
4. Remove cases with lot size outside 0.1 and 99.9 percentiles	
5. Remove cases with average floor height outside 0.1 and 99.9 percentiles	
6. Remove cases with unknown transaction price	
7. Remove cases with transaction price outside 0.5 and 99.5 percentiles	
8. Remove cases with no information on parking facilities	
9. Remove data on apartments	
10. Remove cases with unknown dwelling type	
11. Remove cases with unknown maintenance status	
12. Remove cases with no information on the presence of central heating	
13. Remove cases with unknown year of construction	
14. Remove dwellings that have been sold more than 5 times	
15. Remove zip codes with less than 15 observations in 1985 – 2013	31,573
16. Remove years before 1995 (due to representativeness concerns)	27,835

(a) Some numbers in the table are missing due to confidentiality of the NVM dataset. These numbers can be obtained upon request.

A.2 Characteristics of houses

This paper uses several hedonic house characteristics from the NVM dataset (see Table A2). Table A3 shows the average values and standard errors of the scale variables, and the effect of these variables (in ln) on house prices (in ln), following equation (3) without regional interaction. The other hedonic variables and their effects are described in Table A4. Finally, Table A5 presents (the effects of) the non-hedonic control variables that we include in our analyses.

Table A2 Hedonic variables by type

Variable	Type
Lot size (m^2)	Scale variable
Living area (m^2)	Scale variable
Average floor height (m)	Scale variable
Maintenance status	Factor variable
Housing type	Factor variable
Parking lot	Factor variable
Period of construction	Factor variable
Central heating system	Dummy variable

Table A3 Descriptive statistics of house characteristics (scale variables) and their effects on house prices

Description	Average	Standard deviation	Effect on ln (house prices), equation 3
Lot size in m^2	476.96	1410.63	0.048*** to 0.375*** (a)
Living area in m^2	122.19	40.25	0.566*** (0.017)
Average floor height in m (volume in m^3 divided by living area in m^2)	3.08	0.38	0.426*** (0.020)

(a) This effect is allowed to vary over zip codes to account for differences in land prices per zip code: a higher elasticity to lot size implies a higher land price (De Groot et al., 2012). The table shows the minimum and maximum value of the elasticity.
//*** denote significance at the ten, five and one percent level. Standard errors in parentheses.*

Table A4 Descriptive statistics of house characteristics (factor and dummy variables) and their effects on house prices

Variable	Category	Share in dataset (%)	Effect on ln (house prices), equation 3
Maintenance status	Bad	0.38	(reference)
	Bad – mediocre	0.16	0.205*** (0.064)
	Mediocre	1.86	0.179*** (0.034)
	Mediocre – reasonable	0.47	0.263*** (0.038)
	Reasonable	11.17	0.325*** (0.032)
	Reasonable – good	4.03	0.388*** (0.034)
	Good	73.12	0.486*** (0.033)
	Good – excellent	0.97	0.553*** (0.035)
	Excellent	7.85	0.571*** (0.034)
Housing type	Row house	36.00	-0.190*** (0.013)
	Semi-detached house	2.30	-0.129*** (0.013)
	Corner house	16.98	-0.179*** (0.012)
	Duplex house	18.05	-0.093*** (0.009)
	Detached house	26.68	(reference)
Parking lot	No parking place	55.62	(reference)
	Parking place on the street	1.57	0.020 (0.014)
	Carport	1.99	0.051*** (0.010)
	Single garage	36.63	0.080*** (0.006)
	Carport and garage	0.79	0.083*** (0.011)
	At least a double garage	3.39	0.092*** (0.010)
Period of construction	Before 1906	8.70	-0.115*** (0.016)
	Between 1906 en 1930	13.63	-0.167*** (0.015)
	Between 1931 and 1944	6.52	-0.169*** (0.017)
	Between 1945 and 1959	10.50	-0.169*** (0.012)
	Between 1960 and 1970	15.63	-0.152*** (0.011)
	Between 1971 and 1980	21.24	-0.116*** (0.013)
	Between 1981 and 1990	10.12	-0.054*** (0.013)
	Between 1991 and 2000	11.03	(reference)
	2000 and later	2.63	0.019 (0.013)
Central heating system	No	12.64	(reference)
	Yes	87.36	0.099*** (0.007)

//*** denote significance at the ten, five and one percent level. Standard errors in parentheses.*

Table A5 Descriptive statistics of non-hedonic control variables and their effects on house prices

Variable	Year/month	Share in dataset (%)	Effect on ln (house prices), equation 3
Year of transaction	1995	2.57	(reference)
	1996	3.38	0.080*** (0.009)
	1997	3.93	0.123*** (0.010)
	1998	4.14	0.180*** (0.012)
	1999	4.87	0.306*** (0.014)
	2000	5.35	0.410*** (0.017)
	2001	6.54	0.496*** (0.017)
	2002	6.39	0.572*** (0.016)
	2003	6.24	0.625*** (0.016)
	2004	6.29	0.666*** (0.015)
	2005	7.21	0.714*** (0.013)
	2006	7.24	0.740*** (0.012)
	2007	7.00	0.761*** (0.011)
	2008	5.83	0.773*** (0.011)
	2009	4.42	0.725*** (0.010)
	2010	4.38	0.724*** (0.011)
	2011	4.28	0.706*** (0.012)
	2012	4.99	0.653*** (0.014)
	2013	4.97	0.621*** (0.016)
Month of transaction	January	6.96	(reference)
	February	7.89	0.007 (0.006)
	March	8.58	0.013** (0.006)
	April	8.43	0.023*** (0.006)
	May	8.54	0.029*** (0.005)
	June	8.60	0.021*** (0.005)
	July	8.81	0.034*** (0.006)
	August	8.32	0.030*** (0.005)
	September	8.53	0.036*** (0.006)
	October	9.30	0.037*** (0.005)
	November	8.37	0.037*** (0.006)
	December	7.66	0.041*** (0.005)
Zip code specific linear time trends (146 variables: 1995=1, 1996=2 …)			-0.024*** to 0.030*** (a)
Constant			-2.801 (3.300)

*(a) This effect varies over zip codes; the table shows the minimum and maximum value of the elasticity. */**/*** denote significance at the ten, five and one percent level. Standard errors in parentheses.*

A.3 Anticipation effects per quarter

Table A6 reports the results for equation (3) when we employ anticipation variables for the 1st quarter of 2002 until the 1st quarter of 2003, instead of using yearly anticipation variables. Anticipation turns significant in the second quarter of 2002, and increases towards the last quarter of 2002. Compared to the previous quarter, there is no additional anticipation effect in the first quarter of 2003.

Table A6 Effect of (ln) accessibility on (ln) house prices with anticipation per quarter, equation (3)

	Base (10 transactions)
Ln (anticipated increase in accessibility, 2002q1)	0.233 (0.178)
Ln (anticipated increase in accessibility, 2002q2)	0.363** (0.172)
Ln (anticipated increase in accessibility, 2002q3)	0.479*** (0.183)
Ln (anticipated increase in accessibility, 2002q4)	0.592*** (0.200)
Ln (anticipated increase in accessibility, 2003)	0.589*** (0.216)
Ln (accessibility)	0.810*** (0.213)
N (#clusters / zip codes)	27,835 (146)
Within R^2	0.8730

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects, month fixed effects and hedonic controls for house characteristics are included, as well as zip code specific linear time trends. */**/*** denote significance at the ten, five and one percent level.*

A.4 Sensitivity to the minimum number of house transactions per zip code

Table A7 shows that adjusting the minimum number of house transactions yields similar results as the main specification. Hence, the currently employed minimum of 13 transactions per zip code seems to be sufficient to run the analyses accurately. The estimations are even more robust if we add a regional interaction dummy (see Table A8).

Table A7 Effect of (ln) accessibility on (ln) house prices with different minimum number of house transactions per zip code, equation (3)

	Base (13 transactions)		50 transactions		100 transactions	
Ln (anticipated increase in accessibility, 2000)	-0.015	(0.145)	-0.046	(0.152)	-0.072	(0.140)
Ln (anticipated increase in accessibility, 2001)	-0.030	(0.160)	-0.023	(0.166)	-0.056	(0.168)
Ln (anticipated increase in accessibility, 2002)	0.420**	(0.212)	0.438**	(0.218)	0.366	(0.238)
Ln (anticipated increase in accessibility, 2003)	0.583**	(0.270)	0.553*	(0.281)	0.390	(0.317)
Ln (accessibility)	0.792***	(0.276)	0.785***	(0.290)	0.661**	(0.324)
N (#clusters / zip codes)	27,835 (146)		26,456 (105)		24,272 (75)	
Within R^2	0.8730		0.8725		0.8746	

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects, month fixed effects and hedonic controls for house characteristics are included, as well as zip code specific linear time trends. */**/*** denote significance at the ten, five and one percent level.*

Table A8 Effect of (ln) accessibility on (ln) house prices with different minimum number of house transactions per zip code, equation (3) with regional interaction

	Base (13 transactions)		50 transactions		100 transactions	
Ln (anticipated increase in accessibility, 2000)	0.143	(0.211)	0.107	(0.223)	0.040	(0.211)
Ln (anticipated increase in accessibility, 2001)	0.241	(0.214)	0.251	(0.221)	0.221	(0.235)
Ln (anticipated increase in accessibility, 2002)	0.767***	(0.230)	0.794***	(0.236)	0.725***	(0.266)
Ln (anticipated increase in accessibility, 2003)	1.038***	(0.272)	1.007***	(0.283)	0.874***	(0.323)
Ln (accessibility)	1.485***	(0.258)	1.501***	(0.271)	1.459***	(0.321)
Ln (anticipated increase in accessibility, 2000) * dummy region Zeeuws-Vlaanderen	-0.313*	(0.168)	-0.293*	(0.172)	-0.202	(0.160)
Ln (anticipated increase in accessibility, 2001) * dummy region Zeeuws-Vlaanderen	-0.506***	(0.157)	-0.489***	(0.160)	-0.429***	(0.163)
Ln (anticipated increase in accessibility, 2002) * dummy region Zeeuws-Vlaanderen	-0.642***	(0.173)	-0.632***	(0.172)	-0.554***	(0.174)
Ln (anticipated increase in accessibility, 2003) * dummy region Zeeuws-Vlaanderen	-0.681***	(0.234)	-0.631***	(0.234)	-0.532**	(0.240)
Ln (accessibility) * dummy region Zeeuws-Vlaanderen	-1.282***	(0.202)	-1.274***	(0.204)	-1.241***	(0.216)
N (#clusters / zip codes)	27,835 (146)		26,456 (105)		24,272 (75)	
Within R^2	0.8736		0.8732		0.8752	

*All results are based on zip code fixed effects regressions. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects, month fixed effects and hedonic controls for house characteristics are included, as well as zip code specific linear time trends. */**/*** denote significance at the ten, five and one percent level.*

A.5 Delayed response with regional interaction, for the northern region

Table A9 shows the results of equation (4) for the northern region with a regional interaction dummy included. Note that the average effect for Zeeuws-Vlaanderen was insignificant. The results reveal an upward sloping pattern of the $\boldsymbol{\varphi}$ variables over time until 2012. The estimates are jointly significant. We conclude that there is weak evidence for delayed response.

Table A9 Testing delayed response: do residuals increase over time in more accessible locations, equation (4) with regional interaction

$\boldsymbol{\varphi}$ 2003	-0.038	(0.093)
$\boldsymbol{\varphi}$ 2004	-0.157	(0.166)
$\boldsymbol{\varphi}$ 2005	-0.036	(0.088)
$\boldsymbol{\varphi}$ 2006	-0.048	(0.107)
$\boldsymbol{\varphi}$ 2007	0.164*	(0.091)
$\boldsymbol{\varphi}$ 2008	0.026	(0.090)
$\boldsymbol{\varphi}$ 2009	0.119	(0.090)
$\boldsymbol{\varphi}$ 2010	0.167	(0.122)
$\boldsymbol{\varphi}$ 2011	0.289**	(0.122)
$\boldsymbol{\varphi}$ 2012	-0.170	(0,130)
$\boldsymbol{\varphi}$ 2013	-0.306*	(0.164)
N (#clusters / zip codes)	27,835	(146)
R^2		0.0022

*Estimates are based on an OLS-regression using the residuals of equation (3) with regional interaction as dependent variable. Standard errors are clustered at the zip code level (in parentheses). Year fixed effects are included as well as interactions between φ and a dummy for the southern region. */**/*** denote significance at the ten, five and one percent level.*

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