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

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Samenvatting

Dit paper bestudeert de invloed van een verandering van bereikbaarheid op huizenprijzen aan de hand van een natuurlijk experiment: de opening van de Westerscheldetunnel in 2003. De resultaten laten zien dat een toename van de bereikbaarheid met 1% gemiddeld 0,8% toename van de huizenprijzen teweegbrengt. Ongeveer de helft van dit effect wordt reeds meer dan een jaar vóór de opening van de tunnel gerealiseerd, het zogeheten anticipatie-effect. Daarnaast blijkt dat regio's verschillend reageren op een verandering van bereikbaarheid. Zo heeft de opening van de tunnel de huizenprijzen in Zeeuws-Vlaanderen nauwelijks beïnvloed, terwijl het effect voor Midden-Zeeland relatief sterk is. Tot slot onderstrepen de bevindingen het belang van de juiste reikwijdte van het (onderzoeks-)gebied waarin bereikbaarheidseffecten te verwachten zijn.

De bestaande literatuur biedt geen eenduidig antwoord op de vraag hoe bereikbaarheid van invloed is op huizenprijzen als gevolg van een aantal empirische problemen. Het natuurlijk experiment in deze studie biedt een uitgelezen kans om deze problemen grotendeels te omzeilen. Allereerst zorgde de opening van de tunnel, en daarmee het verdwijnen van de veerdiensten, voor een substantiële verandering van de bereikbaarheid (zowel positief als negatief). Ook lijkt het vaak voorkomende probleem van omgekeerde causaliteit een beperkte rol te spelen. De belangrijkste reden om de tunnel aan te leggen was immers een kostenbesparing en niet de economische ontwikkeling van de betrokken regio's. Ten slotte helpen de natuurlijke barrières in Zeeland bij het afschermen van externe ontwikkelingen die de resultaten zouden kunnen beïnvloeden.

Het effect van een verandering van bereikbaarheid op huizenprijzen wordt in dit onderzoek geschat met behulp van gedetailleerde data op postcodeniveau voor de periode tussen 1995 en 2013. Voor de huizenprijzen vindt een correctie plaats op basis van de karakteristieken van een woning (via de zogeheten hedonische prijsanalyse). Bereikbaarheid wordt gemeten door middel van het aantal bereikbare banen, gewogen met de reistijd voor woon-werkverkeer.

Executive summary

This paper studies the impact of accessibility on house prices, based on a natural experiment in the Netherlands: the opening of the Westerscheldetunnel in 2003. The results show that accessibility 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 accessibility effect already materializes more than one year before the opening of the tunnel. In addition, our analyses suggest substantial heterogeneity between regions. While the northern region is likely to experience positive effects, the southern region does not seem to respond to the improved accessibility at all.

Despite the theoretical arguments to expect spatial economic effects of changes in accessibility, there is little consensus in the empirical. One of the most salient reasons for the conflicting evidence is that studies in this field of research come across several empirical challenges. This paper aims to address these empirical issues by studying a natural experiment. The key aspect that makes the Westerscheldetunnel a novel piece of transport infrastructure is that it exerted a substantial impact on accessibility since the Westerschelde estuary hampers traffic flows towards the other bank by nature. Another key asset of this study is that reverse causality seems to be of minor concern. This is because the main reason to construct the tunnel was not to promote economic development, but to save on public costs as maintaining one tunnel would be cheaper than subsidizing two ferry lines. Finally, the relative remoteness of the region helps to limit the influence of external factors.

This study estimates the effect of a change in accessibility on house prices by using highly detailed data at the four-digit zip-code level for the period 1995-2013. When estimating this relation, we correct for variation in house characteristics by using hedonic control variables. Accessibility is measured as the number of accessible jobs, weighted by a travel time decay function.

1. Introduction

1.1 Accessibility and the relative attractiveness of regions

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 and amenities (Glaeser et al., 2001; Chen and Rosenthal, 2008). Improved accessibility, for instance as a result of new transport infrastructure, better enables people to work and live at a place that fits their skills and 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).

Despite the theoretical arguments to expect spatial economic effects of changes in accessibility, there is little 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 for 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). Finally, another strand of the literature identifies mainly 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 transport 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).

1.2 Research design

This paper aims to address these three issues by studying a natural experiment in the Netherlands: the Westerscheldetunnel, see Figure 1. The key aspect that makes the Westerscheldetunnel a novel piece of transport infrastructure is that it exerted a substantial impact on accessibility since 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 estuary right after the tunnel opened and the (slower) ferry services closed down, see Figure 2. The simultaneous abolishment of the ferries yields an even larger variation in accessibility due to the location of the tunnel: 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, see Figure 3

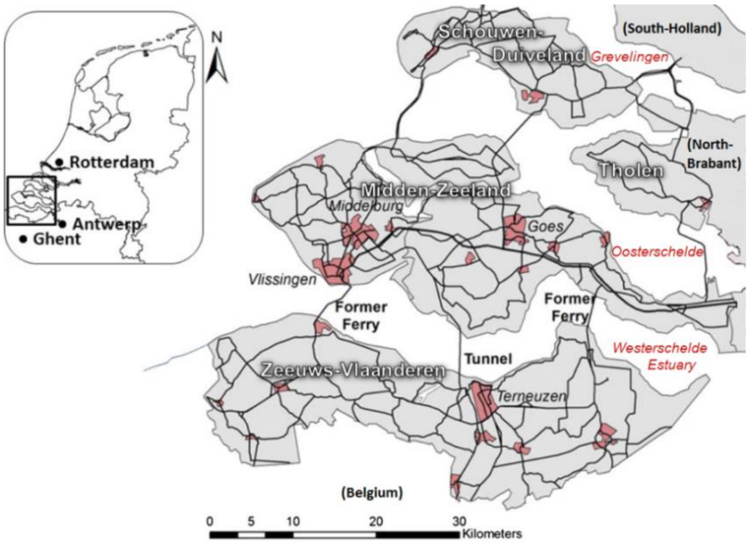

Figure 1. Location and detailed map of the province of Zeeland (source: Meijers et al. (2013), with slight adaptations)

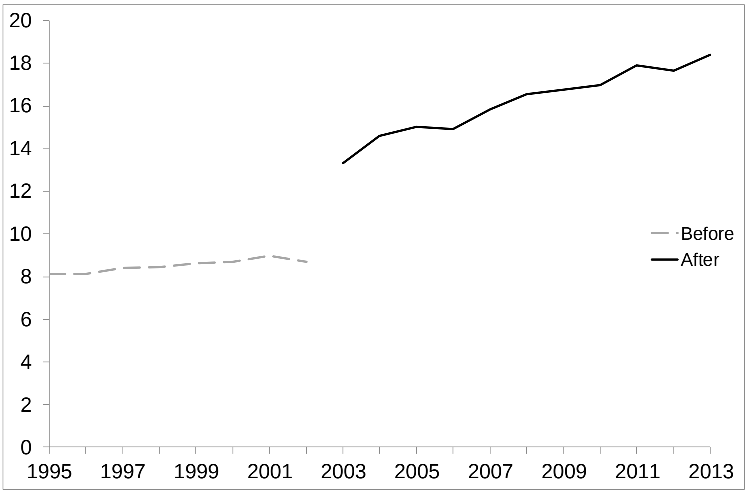

Figure 2. Traffic counts per working day across the Westerschelde estuary (thousands of vehicles) (source: Province of Zeeland)

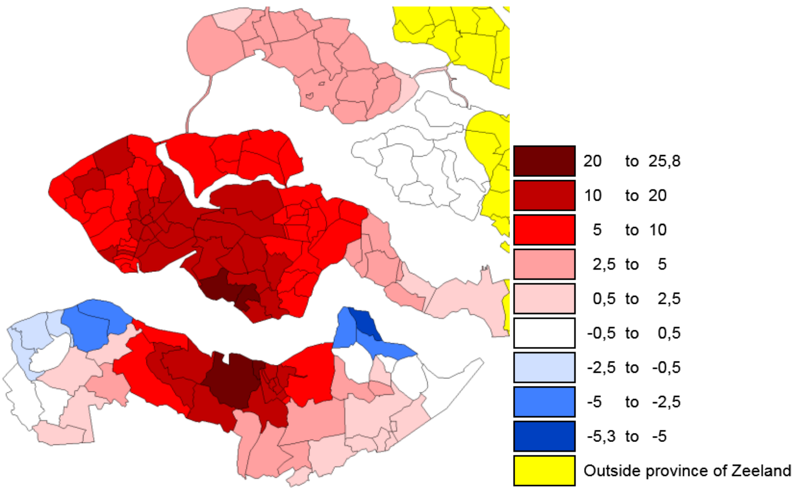

Figure 3. Percentage change in accessibility due to the opening of the tunnel[1]

[1] Accessibility is measured as the number of accessible jobs, weighted by a travel time decay function. A change in accessibility is expressed by ln(accessibility after March 2003/accessibility before March 2003).

Second, the predominant goal of constructing the tunnel was not to promote economic development. 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 borders in the area under scope helps to limit the influence of external developments.

The main goal of this paper is to estimate the effect of accessibility on house prices. We prefer house prices as our variable of interest because house prices are able to absorb demand shocks rather quickly. Other indicators, like population and employment growth, may be constrained by the pace of supply adjustment. Most importantly, when corrected for house characteristics using hedonic controls (Rosen, 1974), house prices can be used to evaluate residential land prices, which are a neat reflection of the relative attractiveness of regions. Hence, house prices function as an informative signal where (new) economic clusters will be formed.

Additionally, we will explore whether the impact of accessibility differs across regions. Accessibility shapes the economic activities of regions in a way that is often unclear ex ante; not all regions may end up being a winner (Krugman and Venables, 1995). Indeed, according to the New Economic Geography models, the net effect of improved accessibility consists of a trade-off between the positive effects of increased spatial economies of scale and the negative effects of increased competition (Krugman, 1991). Finally, we test several hypotheses on the timing of accessibility capitalization into house prices by allowing for anticipation and delayed response.

1.3 Summary of the results

The results show that accessibility 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 accessibility effect already materializes more than one year before the opening of the tunnel. We do not find evidence for delayed response: the accessibility benefits of the tunnel were entirely capitalized in the year following the opening. In addition, our analyses suggest substantial heterogeneity between regions. While the northern region is likely to experience positive effects, the southern region does not seem to respond to the improved accessibility at all. That is, the balance between the spatial economies of scale and increased competition appears to have been more favorable for the northern region.

2. Data collection and methodology

2.1 Data collection

As discussed in the introduction, this study examines the relation between accessibility and house prices, whereas the latter functions as an informative signal of the relative attractiveness of regions. To this end, we collected data on travel times and the spatial distribution of employment from the leading regional transport model in the Netherlands (NRM Zuid), and micro data on house prices from the administrative database of the Dutch Association of Real Estate Brokers and Experts (NVM).

In this paper, we define accessibility as the total number of accessible jobs, weighted by a travel time decay function. The idea behind this decay function is that jobs located further away get increasingly smaller weights, until the weight becomes zero for jobs located more than 90 minutes of travel time away (one way trip). This travel time decay function is graphically represented in Figure 4.

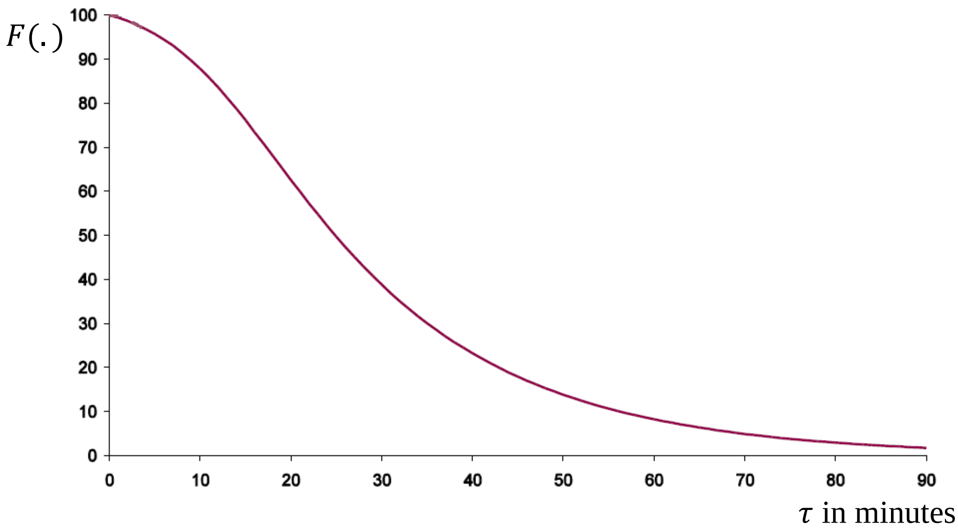

Figure 4. The empirically-based, Gaussian distance decay function (source: De Groot et al., 2010; with slight adaptations. The function resembles the share of the Dutch workforce that is willing to commute for **τ** minutes)

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. The model then 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 micro dataset from the NVM contains 38,948 house transactions, including the date of sale, transaction price and a variety of house characteristics (e.g. lot size, average floor height, maintenance status, housing type, parking lot, availability of a central heating system), 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.

2.2 Methodology

We identify the impact of a change in accessibility on house prices using zip code fixed effects and (hedonic) control variables for house characteristics (see Gibbons and Machins, 2005).[2] The aim of the zip code fixed effects is to curb endogeneity problems related to time-invariant zip code characteristics, whereas hedonic controls are included to correct for house characteristics that may vary across regions and over time. The hedonic controls are an important part of our identification strategy, because they reveal information about residential land prices and, hence, the (relative) attractiveness of regions.

In addition, we also employ zip code-specific linear time trends to avoid bias arising from time-variant factors. For instance, when regions with large accessibility gains have a downward house price trend and regions further away from the tunnel have an upward trend, our accessibility measure will be correlated to the error term yielding downward bias. Indeed, we find a correlation of -0.303 between the linear trend of house prices and

[2] Another strategy to identify the effect of an increase in accessibility on house prices is a difference-in-differences analysis (DiD). A DiD approach would be ineffective in this setting, because the accessibility shift has affected almost every region in the province of Zeeland (see Figure 2). This rules out the possibility of a proper control region that acts as a counterfactual. Control regions outside Zeeland involve serious doubts with regard to the common trend assumption underlying a DiD analysis.

accessibility increase at the zip code level, which is significantly different from zero at the one percent level. Hence, the change in accessibility would be endogenous when omitting the zip code-specific linear time trends.

Together, the zip code fixed effects, hedonic controls, zip code-specific linear time trends and the rather exogenous nature of the Westerscheldetunnel, give us confidence that the following regression specification is informative about the causal effect of accessibility on house prices:

$$\ln P_{iztm} = \alpha + \theta \ln A_{zt} + \gamma \boldsymbol{X}_i + \delta_y^I \boldsymbol{Y} + \delta_m^{II} \boldsymbol{M} + \delta_z^{III} \boldsymbol{Z} + \rho_z y_t + \varepsilon_{iztm}\,, \qquad (1)$$

where P_{iztm} denotes the house transaction price in dwelling i in zip code z, at year t, in month m.[3] A_{zt} indicates the accessibility for zip code z and year t with accessibility elasticity of house prices θ. $\boldsymbol{X}_i$ is a vector of hedonic control variables that represent house characteristics at the level of the individual house. $\boldsymbol{Y}$, $\boldsymbol{M}$ and $\boldsymbol{Z}$ are vectors of year, month and zip code fixed effects, with δ_y^I, δ_m^{II} and δ_z^{III} as their estimated coefficients. y_t is a linear scale variable that denotes the year of house sale ($y_{1995} = 1$, $y_{1996} = 2$ …) and its effect ρ_z differs per zip code z. ε_{iztm} is a random error term clustered at the zip code level.[4]

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)[5], we include an additional term:

$$\ln P_{iztm} = \alpha + \theta \ln A_{zt} + \theta_{ant} \boldsymbol{\omega}_t \ln\left(\frac{A_{z,after}}{A_{z,before}}\right) + \gamma \boldsymbol{X}_i + \delta_y^I \boldsymbol{Y} + \delta_m^{II} \boldsymbol{M} + \delta_z^{III} \boldsymbol{Z} + \rho_z y_t + \varepsilon_{iztm} \qquad (2)$$

The additional term in equation (2) reflects the relative change in accessibility due to the tunnel in zip code j (see 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 14). θ_{ant} measures the degree of capitalization in these years. Again, each of the four estimates in θ_{ant} can be interpreted as elasticity.[6]

One might also argue that θ increases over time. For instance, people and firms may gradually learn about the benefits of the tunnel. This delayed response hypothesis implies that θ, 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. An obvious way to test the delayed response hypothesis would be to include additional terms, equivalent to those used to test the anticipation hypothesis. However, this approach would be problematic: including an additional term for every year after the construction of the tunnel introduces the problem of multicollinearity since

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[3] We adopt a log-log specification because we expect the effect of accessibility on house prices to be proportional rather than additive. Also, this allows us to interpret the estimated coefficient as elasticity.

[4] 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).

[5] McDonald and Osuji (1995) assume that capitalization occurs from the moment the construction is announced. We cannot test this assumption since the announcement of the tunnel in 1995 coincides with the first year of our panel data.

[6] Equation (2) 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 analysis. 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_{ant} can be biased upwards or downwards depending on whether people overshoot or undershoot their expectations.

we also include a full set of year dummies and zip code-specific linear time trends. Therefore, we prefer the following strategy:

$$\hat{e}_{iztm} = \alpha + \theta_{del}\boldsymbol{\varphi}_t \ln\left(\frac{A_{z,after}}{A_{z,before}}\right) + u_{iztm} \quad (3)$$

where $\hat{e}_{ijtm}$ represents the residuals, as estimated by equation (2).[7] $\boldsymbol{\varphi}_t$ is a vector of dummies, where the first dummy indicates the period from the opening of the tunnel (on March 14) to the end of 2003. The remainder of $\boldsymbol{\varphi}_t$ denotes year dummies from 2004 to 2013. θ_{del} is a vector of estimates for the interaction effect between $\boldsymbol{\varphi}_t$ and accessibility change. u_{iztm} is a random error component. Standard errors are again clustered at the zip code level.

Finally, the impact of the tunnel may differ across regions. There are theoretical reasons to believe that a change in accessibility shapes the economic activities of regions in distinct and opposite ways (Krugman, 1991). The question whether the positive effect of increased spatial economies of scale (also known as the home market effect) or the negative effect of increased competition will dominate, cannot be answered ex ante. Instead, it should be determined empirically. To this end, we will estimate equations (1) and (2) 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 3).[8]

The methodological framework of this paper is summarized in Figure 5. Equation (1) assumes that the benefits of the tunnel fully capitalize right after the opening of the tunnel. Equation (2) (and (3)) assumes that capitalization already takes place before, not necessarily in a linear fashion. Note that equation (1) underestimates the impact of the tunnel if anticipation exists since it treats 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) and (2) will therefore yield similar results. By construction, the average effect for equation (3) is equal to that of equation (2). However, the slope of its line is not necessarily steeper in the anticipation period than in the period afterwards.

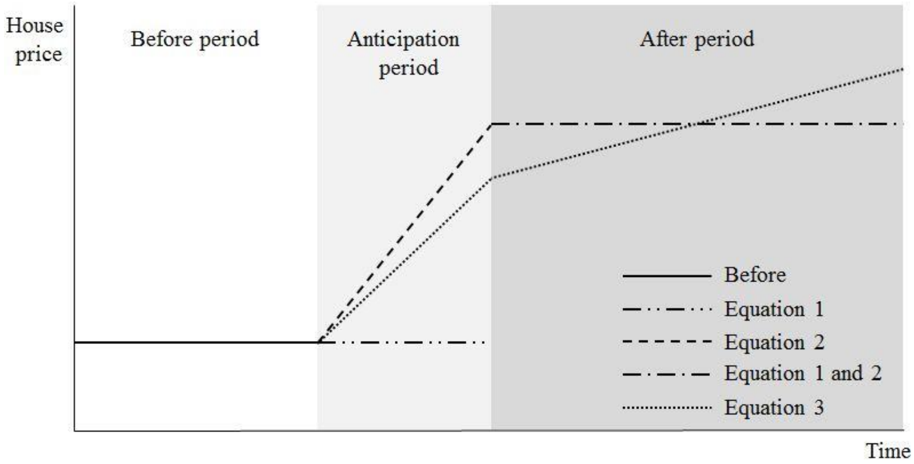

Figure 5. Methodological framework (for a zip code with an increase in accessibility)

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[7] We have experimented with the inclusion of 5-yearly or 3-yearly delayed response terms rather than delayed response terms for every year in Equation (1), which circumvents the problem of multicollinearity to some extent. The results that follow from this exercise are similar to those obtained from Equation (3).

[8] 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 Tholen and Schouwen-Duiveland do get their own interaction effect.

3. Results

3.1 Overall effect of accessibility on house prices

Table 1 shows the results for equation (1) and (2). Equation (1) yields a point estimate of 0.484; this implies that a 1% increase in accessibility leads to an increase in house prices of around 0.5%. However, the estimation results of equation (2) show that anticipation starts from 2002 and increases as the opening of the tunnel approaches.[9] The results also reveal that the accessibility elasticity of house prices based on equation (1) is probably an underestimate. When including anticipation terms, the effect accumulates to 0.8% for an accessibility gain of 1%. This is intuitive: if one ignores anticipation while it does exist, part of the accessibility effect is assigned to the pre-tunnel period, yielding a smaller difference between the before and after periods (see Figure 5).

Table 1. Effect of accessibility on house prices, equation (1) and (2)

	Equation (1)	Equation (2)
$\boldsymbol{\theta_{ant}\omega_{2000}}$		0.033
		(0.161)
$\boldsymbol{\theta_{ant}\omega_{2001}}$		-0.031
		(0.173)
$\boldsymbol{\theta_{ant}\omega_{2002}}$		0.427*
		(0.218)
$\boldsymbol{\theta_{ant}\omega_{2003}}$		0.599**
		(0.271)
$\boldsymbol{\theta}$	0.484***	0.790***
	(0.131)	(0.277)
N (#clusters / zip codes)	27,835 (146)	27,835 (146)
Within R^2	0.869	0.869

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 2 indicates the results for the incidence of delayed response, i.e. does θ_{del} in equation (3) increase over time? The θ_{del} variables are individually insignificant as well as jointly insignificant: $F(11, 145) = 0.76$. Therefore, we conclude that there is no evidence of delayed response: the benefits were fully capitalized into house prices in the year following the opening of the tunnel.

[9] A finer-grained measure using thirteen quarterly anticipation variables (for the first quarter of 2000 until the first quarter of 2003) indicates a smooth increase of house prices throughout this period.

Table 2. Delayed response effects, equation (3)

	Equation (3)
$\boldsymbol{\theta_{del}\varphi_{2003}}$	0.038
	(0.065)
$\boldsymbol{\theta_{del}\varphi_{2004}}$	-0.075
	(0.085)
$\boldsymbol{\theta_{del}\varphi_{2005}}$	-0.013
	(0.047)
$\boldsymbol{\theta_{del}\varphi_{2006}}$	-0.000
	(0.053)
$\boldsymbol{\theta_{del}\varphi_{2007}}$	0.027
	(0.055)
$\boldsymbol{\theta_{del}\varphi_{2008}}$	0.001
	(0.041)
$\boldsymbol{\theta_{del}\varphi_{2009}}$	0.012
	(0.050)
$\boldsymbol{\theta_{del}\varphi_{2010}}$	0.057
	(0.069)
$\boldsymbol{\theta_{del}\varphi_{2011}}$	0.060
	(0.069)
$\boldsymbol{\theta_{del}\varphi_{2012}}$	-0.028
	(0.054)
$\boldsymbol{\theta_{del}\varphi_{2013}}$	-0.031
	(0.078)
N (#clusters / zip codes)	27,835 (146)
R^2	0.0003

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). */**/*** denote significance at the ten, five and one percent level.

3.2 Differences across regions

To examine whether the northern region (Midden-Zeeland, Tholen and Schouwen-Duiveland) and the southern region (Zeeuws-Vlaanderen) have reacted similarly to a change in accessibility, we interact the accessibility measure with a dummy variable that equals one if the zip code is part of the southern region and zero otherwise ($D_{z,South}$).

Table 3 shows that the positive effect of accessibility on house prices is likely to be driven by the northern region. In this region, house prices increase by 1.5% for every 1% increase in accessibility. The southern region hardly experiences any observable effect with an insignificant accessibility elasticity of (1.497 - 1.317 =) 0.180. 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. On the other hand, it is in line with theoretical considerations arguing that a change in accessibility may affect regions in distinct and opposite ways, of which the net effect is often unclear ex ante.

Table 3. Effect of accessibility on house prices with regional interaction, equation (2)

	Baseline estimation	With regional interaction
$\theta_{ant}\omega_{2000}$	0.033	0.219
	(0.161)	(0.230)
$\theta_{ant}\omega_{2001}$	-0.031	0.279
	(0.173)	(0.221)
$\theta_{ant}\omega_{2002}$	0.423*	0.781***
	(0.218)	(0.236)
$\theta_{ant}\omega_{2003}$	0.599**	1.077***
	(0.271)	(0.273)
θ	0.790***	1.497***
	(0.277)	(0.257)
$\theta_{ant}\omega_{2000}D_{z,South}$		-0.363**
		(0.179)
$\theta_{ant}\omega_{2001}D_{z,South}$		-0.578***
		(0.163)
$\theta_{ant}\omega_{2002}D_{z,South}$		-0.661***
		(0.180)
$\theta_{ant}\omega_{2003}D_{z,South}$		-0.733***
		(0.240)
$\theta D_{z,South}$		-1.317***
		(0.202)
N (#clusters / zip codes)	27,835 (146)	27,835 (146)
Within R^2	0.869	0.870

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 6 displays the total effect of the tunnel in both regions, including delayed response as measured through equation (3). Note that the impact of accessibility on house prices is set to zero before 2000. One can observe that (actors in) the housing market already anticipated that the increase in house prices due to the tunnel would be larger in the northern region. After the period of anticipation, the house prices in the northern region show a small upward shift when the tunnel opens, and then they remain stable. In the southern region, the housing market expected a small increase in prices due to the tunnel, but this expectation turned out too optimistic when the tunnel was opened.

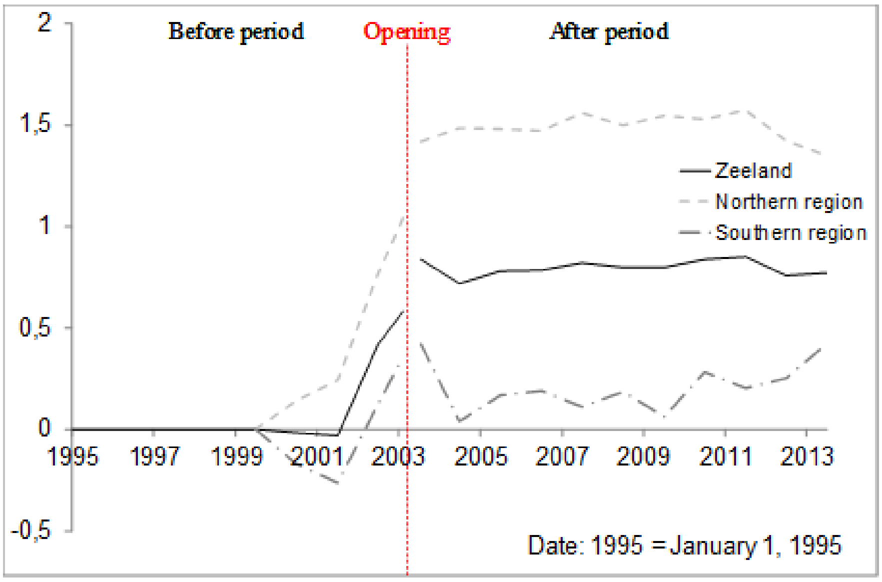

Figure 6. Effect of accessibility on house prices over time for both regions

To explore potential explanations for the regionally different responses to a change in accessibility, we have conducted several analyses. Most importantly, we analyzed whether zip codes with higher initial house price levels (mainly in the northern region) are more receptive to an increase in accessibility. To this end, we estimated the accessibility elasticity for each tertile and quartile of the zip code fixed effect. Results are presented in Table 4. It follows that the zip codes within the first tertile/quartile (with the lowest house prices) have shown a negative response to the change in accessibility though not all estimates are statistically significant. The zip codes within the other tertiles/quartiles have responded more strongly. In fact, it appears to be the case that the accessibility elasticity of house prices is higher for zip codes with a higher initial house price. Hence, the house price level in the initial situation may function as a proxy for how house prices will respond to a change in accessibility: the tunnel seems to have increased regional disparities in house prices.

Table 4. Effect of accessibility on house prices with tertile and quantile interaction, equation (2)

	With tertile interaction	With quartile interaction
$\boldsymbol{\theta_{ant}\omega_{2000}}$	-0.559*	-0.663
	(0.324)	(0.547)
$\boldsymbol{\theta_{ant}\omega_{2001}}$	-0.797**	-0.845*
	(0.313)	(0.470)
$\boldsymbol{\theta_{ant}\omega_{2002}}$	-0.355	-0.361
	(0.343)	(0.475)
$\boldsymbol{\theta_{ant}\omega_{2003}}$	-0.239	0.145
	(0.523)	(0.569)
$\boldsymbol{\theta}$	-0.589	-0.111
	(0.500)	(0.521)
$\boldsymbol{\theta_{ant}\omega_{2000}Q_2}$	0.625*	0.726
	(0.321)	(0.532)
$\boldsymbol{\theta_{ant}\omega_{2001}Q_2}$	0.755***	0.796*
	(0.270)	(0.435)
$\boldsymbol{\theta_{ant}\omega_{2002}Q_2}$	0.802***	0.726*
	(0.289)	(0.430)
$\boldsymbol{\theta_{ant}\omega_{2003}Q_2}$	0.893**	0.364
	(0.451)	(0.524)
$\boldsymbol{\theta Q_2}$	1.247***	0.606
	(0.440)	(0.476)
$\boldsymbol{\theta_{ant}\omega_{2000}Q_3}$	0.410	0.409
	(0.332)	(0.524)
$\boldsymbol{\theta_{ant}\omega_{2001}Q_3}$	0.721**	0.609
	(0.293)	(0.424)
$\boldsymbol{\theta_{ant}\omega_{2002}Q_3}$	0.639**	0.754*
	(0.280)	(0.410)
$\boldsymbol{\theta_{ant}\omega_{2003}Q_3}$	0.655	0.685
	(0.448)	(0.524)
$\boldsymbol{\theta Q_3}$	1.568***	1.186***
	(0.392)	(0.445)
$\boldsymbol{\theta_{ant}\omega_{2000}Q_4}$		0.828
		(0.520)
$\boldsymbol{\theta_{ant}\omega_{2001}Q_4}$		1.167***
		(0.430)
$\boldsymbol{\theta_{ant}\omega_{2002}Q_4}$		0.945**
		(0.407)
$\boldsymbol{\theta_{ant}\omega_{2003}Q_4}$		0.609
		(0.522)
$\boldsymbol{\theta Q_4}$		1.417***
		(436)
N (#clusters / zip codes)	27,835 (146)	27,835 (146)
Within R^2	0.869	0.870

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.

An alternative explanation for the regionally different response to a shift in accessibility is related to differences in education levels (Teulings et al., 2014). On average, the workforce is less well educated in the southern than in the northern region. To explore this hypothesis, we use cross-section data on educational attainment at the municipality level (Statistics Netherlands, 2014) and interact it with θ and θ_{ant}. 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 1.239. Other municipalities are characterized by an accessibility elasticity of 0.525. This suggests that accessibility is indeed more important to high educated than to low educated people. A final 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.[10]

4. Conclusions

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. Large variation in accessibility is a necessary condition to accurately measure the effect of accessibility on house prices. Nowadays, it is hard to find new transport infrastructure that generates such a shift in accessibility since most western countries already have a (very) dense transport network.

Our results indicate that the accessibility elasticity of house prices is equal to 0.8. Approximately half of the effect already materializes more than one year before the opening of the tunnel. We do not find evidence for delayed response, i.e. all accessibility benefits due to the tunnel were absorbed in house prices in the year the tunnel was opened. Moreover, our findings suggest that the impact of accessibility differs across regions. The northern region, with a more highly educated population and higher initial house prices, profited most from accessibility gains. On the other hand, the southern region did not respond at all to a change in accessibility in most specifications despite the fact that both regions are similar in terms of geography and economic development. This result does not necessarily contradict the predictions of the New Economic Geography model: the net effect of increased accessibility consists of a trade-off between increased spatial economies of scale and increased competition.

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, external developments in the area of research may affect the estimated relationship between house prices and accessibility. Nevertheless, the construction of the Westerscheldetunnel 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. We are therefore confident that the natural experiment of the

[10] Other possible explanations are found not to determine the differences in estimated coefficients such as zoning restrictions (limiting supply adjustments) in the northern region and a higher share of recreational housing and aged people in the southern region.

Westerscheldetunnel is informative about the causal effect of accessibility on house prices. Scholars, policy makers and tax payers all stand to gain from further insight in this relationship.

5. References

Angrist, J.D., and J.-S. Pischke, 2009. Mostly harmless econometrics: An empiricist's companion. Princeton: Princeton University Press.

Banister, D. and Y. Berechman, 2001. Transport investment and the promotion of economic growth. Journal of transport geography, 9(3), 209-218.

Baum-Snow, N., 2007. Did highways cause suburbanization? The Quarterly Journal of Economics, 122(2), 775-805.

Baum-Snow, N. and F. Ferreira, 2014. Causal inference in urban and regional economics. NBER Working Paper, 20535.

Cantos, P., M. Gumbau-Albert and J. Maudos, 2005. Transport infrastructures, spillover effects and regional growth: Evidence of the Spanish case. Transport reviews, 25(1), 25-50.

Chandra, A. and E. Thompson, 2000. Does public infrastructure affect economic activity? Evidence from the rural interstate highway system. Regional Science and Urban Economics, 30(4), 457-490.

Chen, Y., and S.S. Rosenthal. 2008. Local amenities and life-cycle migration: Do people move for jobs or fun? Journal of Urban Economics, 64(3), 519-537.

De Groot, H.L.F., G.A. Marlet, C.N. Teulings and W. Vermeulen, 2010. Stad en land [City and Countryside]. The Hague: CPB Netherlands Bureau of Economic Policy Analysis.

Duranton, G. and M.A. Turner, 2012. Urban growth and transportation. The Review of Economic Studies, 79(4), 1407-1440.

Fernald, J. G., 1999. Roads to prosperity? Assessing the link between public capital and productivity. American Economic Review, 619-638.

Garcia-López, M.Á., A. Holl and E. Viladecans-Marsal, 2015. Suburbanization and highways in Spain when the Romans and the Bourbons still shape its cities. Journal of Urban Economics, 85, 52-67.

Garcia-Mila, T., T.J. McGuire, and R.H. Porter, 1996. The effect of public capital in state-level production functions reconsidered. The Review of Economics and Statistics. 78(1), 177-180.

Gibbons, S and S. Machin, 2005. Valuing rail access using transport innovations. Journal of Urban Economics, 57(1), 148-169.

Glaeser, E. L., Kolko, J., & Saiz, A. 2001. Consumer city. Journal of economic geography, 1(1), 27-50.

Gutiérrez, J., A. Condeço-Melhorado and J.C. Martín, 2010. Using accessibility indicators and GIS to assess spatial spillovers of transport infrastructure investment. Journal of Transport Geography, 18(1), 141-152.

Haughwout, A.F., 1999. State infrastructure and the geography of employment. Growth and Change, 30(4), 549-566.

Haughwout, A.F., 2002. Public infrastructure investments, productivity and welfare in fixed geographic areas. Journal of Public Economics, 83(3), 405-428.

Jiwattanakulpaisarn, P., R.B. Noland, D.J. Graham and J.W. Polak, 2009. Highway infrastructure investment and county employment growth: A dynamic panel regression analysis. Journal of Regional Science, 49(2), 263-286.

Jiwattanakulpaisarn, P., R.B. Noland and D.J. Graham, 2011. Highway infrastructure and private output: evidence from static and dynamic production function models. Transportmetrica, 7(5), 347-367.

Klaiber, H. A. and V.K. Smith, 2010. Valuing incremental highway capacity in a network. NBER Working Paper, 15989.

Krugman, P. 1991. Increasing Returns and Economic Geography. The Journal of Political Economy, 99(3), 483-499.

Krugman, P.R. and A.J. Venables, 1995. Globalization and the Inequality of Nations. The Quarterly Journal of Economics. 110(4), 857-80.
Levkovich, O., J. Rouwendal and R. van Marwijk, 2015. The effects of highway development on housing prices. Transportation, DOI: 10.1007/s11116-015-9580-7.
McDonald, J.F. and C.I. Osuji, 1995. The effect of anticipated transportation improvement on residential land values. Regional Science and Urban Economics, 25, pp. 261-278.
Meijers, E., J. Hoekstra and M. Spaans, 2013. Fixed link, fixed effects? Housing market outcomes of new infrastructure development in the Dutch delta area. Geografisk Tidsskrift-Danish Journal of Geography, 113(1), 11-24.
Moreno, R. and E. López-Bazo, 2007. Returns to local and transport infrastructure under regional spillovers. International Regional Science Review, 30(1), 47-71.
Moulton, B. R., 1990. An illustration of a pitfall in estimating the effects of aggregate variables on micro units. The Review of Economics and Statistics, 334-338.
Ossokina, I.V. and G. Verweij, 2015.Urban traffic externalities: Quasi-experimental evidence from housing prices. Regional Science and Urban Economics, 55, 1-13.
Pereira, A.M., 2000. Is all public capital created equal? Review of Economics and Statistics, 82(3), 513-518.
Puga, D., 2010. The Magnitude and causes of agglomeration economies. Journal of Regional Science, 50(1), 203-219.
Redding, S. J. and M.A. Turner, 2014. Transportation costs and the spatial organization of economic activity. NBER Working Paper, 20235.
Rosen, S. (1974). Hedonic prices and implicit markets: product differentiation in pure competition. Journal of political economy, 82(1), 34-55.
Teulings, C.N., I.V. Ossokina, and H.L.F. de Groot, 2014. Welfare benefits of agglomeration and worker heterogeneity. CPB Discussion Paper, 289.