The impact of rail transport on the prices of real estate: Empirical study of the Dutch housing market

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April 2005

Abstract:

In an efficient market, the levels of house prices reflect the values of the physical, accessibility and environmental features corresponding to the house. This paper focuses on the impact of railway accessibility feature on the residential houses prices. Stations are treated as transport access points with distance and frequency of train services components and potential places for negative externalities. Applying a cross sectional hedonic price model, we found railway stations as identified by frequency of train service has elasticity of close to 0.03 for houses up to a distance of 2 kilometres. Due to the spatial nature of the data we controlled for spatial effects by local dummies. Proximity to railway line as differing from proximity to station, explaining the noise effect, has a negative effect on prices. At the same time the immediate neighbourhood of the station is affected negatively due to externality of the station. Highway accessibility on the other hand shows slightly different effects on house prices, in that peak effects occur at 4-5 km from the highway entry/exit point. All other physical and neighbourhood variables as income level and population composition show expected effect on house prices.

JEL code: R14, R40

Key words: property value, railway station, accessibility, highway, railways, and hedonic pricing method.

1. INTRODUCTION

Hedonic pricing methods explain the value of real estate can be explained by the features of the property. Studies on real estate price mostly categorise the value bearing features of properties according to three dimensions namely physical, accessibly and environmental (Fujita 1989, Bowes and Ihlanfeldt 2001). In order to single out the accessibility effect of railway stations, in the literature, it is suggested that stations should be seen as nodes in a transport network and places in an area (Bertolini and Spit 1998). Based on this framework recent empirical studies treat the node feature and the place feature of a station separately. The former characteristic fully accounts for the accessibility effect which is generally positive. However the later feature (place in an area) can have positive and negative effect. Bowes and Ihlanfeldt (2001) in addition to the accessibility feature of a station pointed out the retail employment and crime that stations attract. By accounting for all the three categories of features this paper examines how railway accessibility, represented by railway stations proximity, affects the Dutch house price. There are three rail services in the Netherlands: light rail services (trams), heavy rail services (metro lines) and commuter rail services. The services of the first two are limited within the main cities. However commuter rails server inter-urban areas. This paper is interested in assessing the effect of proximity to the commuter railway stations on prices of residential houses. As a main accessibility competitor to the railway, highway accessibility is represented in our analysis by means of distance to points of highway entry and exits.

The accessibility and nuisance dual effect of a railway station is a function of distance between the station and the house under study. As the distance increases, the impact of both features on the house price declines. The level of accessibility provided by a railway station is measured by the quality of railway network the station is at, number of destinations that can be reached from the station, the frequency of services at the station and other departure station related facilities at the station. Stations with higher network quality, larger number of destinations and higher frequency of trains have a higher accessibility index and are expected to have a higher positive effect on the house prices. Railway stations at the same time pose localised negative environmental features.

The main question addressed in this paper would be "what is the impact of railway proximity and the level of services on value of properties." The data for the analysis in this paper includes the sales of residential properties in the Netherlands. For remaining close to the station commuter households are expected to be willing to pay higher prices for the same houses as compared to houses further away from the station. This is because, being close to the station means saving access time and cost to work and other opportunities that involve rail transport. Not only households locating close to railway stations benefit, but also business entities, for stations contribute to the accessibility for employees and visitors. Thus the value of a station can also be measured by the willingness of businesses to pay to remain close to the stations. These two values of station proximity can of course differ. This paper only covers residential house value sales. In a follow up paper we intend to cover the effect of railway station on commercial property values.

2. LITERATURE REVIEW

Land value theories have their root in the work of Von Thünen (1830), who tried to explain variations in farmland values. According to Von Thünen for agricultural lands of the same fertility, accessibility to the market place accounts for the value difference of these farmlands. In subsequent studies economists like Alonso and Muth refined this line of reasoning into bid-rent analysis (Alonso 1964 and Muth 1969). The basic idea behind the bid-rent model is that every agent is prepared to pay a certain amount of money depending on the location of the land. This leads in equilibrium to a rent gradient that declines with distance from the central business district (CBD) for sites that yield equal utility. Thus far in the analyses, the dominant factor explaining the difference between land (property) values was the accessibility as measured by the distance to the Central Business District (CBD) and the associated transportation costs. The physical characteristics of the land (fertility in the case of Thünen) were assumed given.

Thus the basic theory in real estate price can be put forward as follows: as a location becomes more attractive, due to certain characteristics, demand increases and thus the price. In most cases CBDs are the centres of many activities. Therefore, closeness to the CBD is considered an attractive quality that increases property prices. However investments in transport infrastructure reduce this demand friction to remaining close to the CBD to some degree (Fejarang 1994) by attracting households to settle around the stations. Properties close to the investment area also enjoy benefits from these investments. Being close to a transport facility increases the accessibility of the property and thus the value of the transport facility is capitalised on the property value. It may be expected that a price curve will have a negative slope; when we move away from the station, prices decrease.

The introduction of the hedonic pricing methodology by Rosen (1974) lead to an easier way of attributing effects to features comprising properties. Thus we observe the integration of physical, accessibility and environmental characteristics of the property in models trying to explain the difference in property values. For urban properties, the transport cost perspective (as a measure of accessibility) seems narrow, however. In successive studies, a more general concept of accessibility was introduced. The concept of accessibility thus encompasses all variables that contribute to the potential of opportunities of a location for interaction (Hansen 1959 and Martellato et al., 1998). Though a comprehensive definition of the concept of accessibility is available, the lack of data and appropriate measuring technique usually implies that simple measures are used. Thus, in the literature we see a focus on some factors only, especially a CBD oriented interaction related to employment and shopping. In most property value studies, the other trip purposes are missing from the model.

In this study on the impact of railway station accessibility, it is important to realize that accessibility can also be provided by other modes of transport. As Voith (1993) has pointed out, highway accessibility is an important competitor to rail accessibility. 'The presence of other facilities that increase accessibility like highways, sewer services and other facilities influence the impact area in the same fashion.' The benefits of these facilities and services are also capitalised into urban property values (Damm et al, 1980). Thus, to single out the effect of railway accessibility, other competing modes of accessibility need to be included along with it.

Apart from reasons of showing that railway investments do result in compact urbanisation, most studies in the area were conducted to provide evidence for the implementation of value capture schemes for financing of rail investments (Cervero and Susantono, 1999). This was based on the assertion the value of proximity to accessibility points is capitalised on the value of properties around these stations.

In general the empirical studies conducted in this area are diverse in methodology and focus. Although the functional forms can differ from study to study, the most common methodology encountered in the literature is hedonic pricing. However, no consistent relationship between proximity to railway stations and property values is recorded in the literature. Furthermore, the magnitudes of these effects can be minor or major. One of the earliest studies, Dewees (1976) analysed the relationship between travel costs by railway and residential property values. Dewees found that a subway station increases the site rent perpendicular to the facility within a one-third mile to the station. Similar findings confirmed that the distance of a plot of land from the nearest station has a statistically significant effect on the property value of the land (Damm et al, 1980). Consistent with these conclusions, Grass (1992) later found a direct relationship between the distance of the newly opened metro and residential property values. Some of the extensively studied metro stations in the U.S., though ranging from small to modest impact, show that properties close to the station have a higher value than properties farther away (Giuliano 1986; Bajic 1983; Voith 1991a). However there are studies, which have also found insignificant effects (Lee 1973; Gatzlaff and Smith 1993). On the other hand, contrary to the general assumption, Dornbusch (1975), Burkhart (1976) and Landis et al, (1995) traced a negative effect of station proximity. Evidence from other studies indicates little impact in the absence of favourable factors (Gordon and Richardson 1989; Guiliano 1986). For detailed documentation of the findings, we refer to (Vessali 1996; Smith 2001; NEORail 2001; CIP annual conference 2002; RICS 2002). In general, some studies indicate a decline in the historical impact of railway stations, on property values. This was attributed to improvements in accessibility, advances in telecommunications, computer networks, and other areas of technology that were said to make companies “footloose” in their location choices (Gatzlaff and Smith 1993).

The impact of railway station on the property values depends on several factors. First, railway stations differ from each other in terms of levels of service provided in terms of frequency, network connectivity, service coverage and the like. Thus it is natural to see stations to create differing impact levels on the value surrounding properties. The Meta analysis in Debrezion et al. (2004) reveals that railway stations differ in type and thus on their impact level. Commuter rail ways have higher impact on property value (Debrezion et al. 2003; Cervero and Duncan 2001; NEORail II 2001; Cervero 1984). Railway station at the same can differ in the level and quality of facilities they have. Stations with higher level and quality of facilities are expected to have greater impact on the surrounding properties. The presence and number of parking lots is one of the many station facilities that got attention in this area. Bowes and Ihlanfeldt (2001) found that stations with parking facilities have higher positive impact on property values. In addition the impact a railway station produces depends on its proximity to the CBD. Stations, which lie close to the CBD, produce greater positive impact on property value (Bowes and Ihlanfeldt 2001). In addition Gatzlaff and Smith (1993) claim that the variation in the findings of the empirical work is attributed to local factors in each city.

Second, railway stations affect residential and commercial properties differently. Most studies have treated the effect of railway on the different property types separately. That allows us somehow to explain the difference of railway effect on different property types. Generally it has been shown that the impact of railway stations is greater within short distance of the stations on commercial properties compared to residential ones. The larger part of the empirical literature on property value focuses on residential properties rather than commercial properties. Generally, it is claimed that the range of the impact area of railway stations is larger for residential properties, whereas the impact of a railway station on commercial properties is limited to immediately adjacent areas. In addition, there are claims that railway stations have a higher effect on commercial than on residential properties (Weinstein and Clower 1999; Cervero and Duncan 2001). This finding is in line with the assertion that railway stations - as focal, gathering points - attract commercial activities, which increase commercial property values. However, contrary to this assertion, Landis et al. (1995) determined a negative effect on commercial property values.

Third the impact of railway station on property value is subject to demographic segments. Income and social (racial) divisions are common. Proximity to a railway station is of higher value to low-income residential neighbourhoods than to high-income residential neighbourhoods (Nelson 1998; Bowes and Ihlanfeldt 2001). The reason is that low-income residents tend to rely on public transit and thus attach higher value to living close to the station. Because of the fact that reaching the railway station mostly depends on slow mode (waking and bicycle) the immediate locations are expected to have higher effects than locations further away. On the other hand the high population movement in the immediate location gives rise to the development of retail activities which leads to premiums on value of commercial properties but it may at the same time attract criminality (Bowes and Ihlanfeldt 2001). Bowes and Ihlanfeldt (2001) outlined that a significant relation was observed between stations and crime rates. However, no proximity variable shows a significant effect on retail employment. In this model, the immediate neighbourhood is affected by the negative impact of the station. Thus the most immediate properties (within a quarter of a mile of the station) were found to have an 18.7% lower value. Properties that are situated between one and three miles from the station, however, are more valuable than those further away. Though this study provides an important contribution, unexplained variations still remain.

3. DATA AND DESCRIPTIVES

(A) HOUSE CHARACTERISTICS

The data used in the analysis of this paper covers transactions in the Dutch residential housing market covering a period of seventeen years from 1985 to 2001. These transactions are recorded by the Dutch Brokers Association (NVM). Each of the sold houses is geo-coded to enable us compute the distanced to the railway stations and highway entry/exit points. Some houses are geo-coded at precise house level and the rest are geo-coded at six digit (e.g. 1234XX) post coded level, which is an area comprising few houses. Fairly the houses in the analysis extend over the whole country. The data set incorporates information related to price of the dwelling, characteristics of the dwelling and some environmental features. Apart from the house characteristics a number of accessibility and environmental features are linked. The land use data was acquired from the central office of statistics for the Netherlands (the CBS). This data set is available at the four-digit postal code level of the country. Moreover population related data are available at this level of aggregation. Income levels of the population in the post code area, the density and population composition particularly the share of foreigners in the area are used in our analysis. To account for the effect of central business area, employment accessibility index data was included which is aggregated at municipality level.. Other data sources include MNP-RIVM (The Environmental Planning Agency (MNP) of the National Institute for Public Health and the Environment (RIVM)) and the Dutch National Railway Company (NS).

In table 1 below some statistical descriptive on the three categories of factors affecting property value are given. Under the physical characteristics of the houses we use a large number of relevant items. Examples are area of the house (that includes the built up and non-built up part of the estate), age of the house, the number of room and number of bathrooms are given in the continuos variable form. The rest of the physical characteristics such as monument, gas heater, open fire place, garden and garage are represented by dummies to indicate that such features are present or not. The mean value for some of these features is given in the table 1.

The features under the accessibility category include distance to the railway station, frequency of trains (both with respect to the mostly chosen station for residents in the post code area and the nearest station to the house), the perpendicular distance to railway line and distance to the nearest highway entry/exit point. The distance to the railway line is aimed to capture the noise effect poised by railway. The distance to the highway entry/exit point is meant to take in to account the car-based accessibility.

Table 1: Descriptive statistics of house characteristics

	Minimum	Maximum	Mean	Std. Deviation
Dependent variable				
Transaction price in Euros	9076	5,558,800	123,130	95,830
Independent variables				
1. House features				
Surface area in sq. meters	1	100,000	380	1650
Building age in years	0	996	38	40
Total number of rooms	1	39	4.46	1.34
Number of bathrooms	0	4	0.87	0.58
Dummies				
Monument			0.009	
Gas heater			0.132	
Open fireplace			0.184	
Garage			0.322	
Garden			0.780	
2. accessibility features				
Distance to nearest railway station (m)	3	25,498	3,364	3350
Distance to chosen railway station (m)	10	35,643	4,245	4934
Frequency (trains per day)	22	788	271	216
Distance to highway entry/exit (m)	0	37,745	3,827	4564

The average distance to the mostly chosen station in the post code is is on average about 1 km longer that the average distance to the nearest railway station. That gives some indication that for many cases the mostly chosen station is not the nearest station. Thus, we will use the two distances in our analysis to show that an aggregate measure of railway accessibility is needed. Over the time period for the data set the price of houses has increased substantially from year to year. Figure 1 shows the average transaction price in each year. This increase can be attributed to combination of inflation and real value increase.

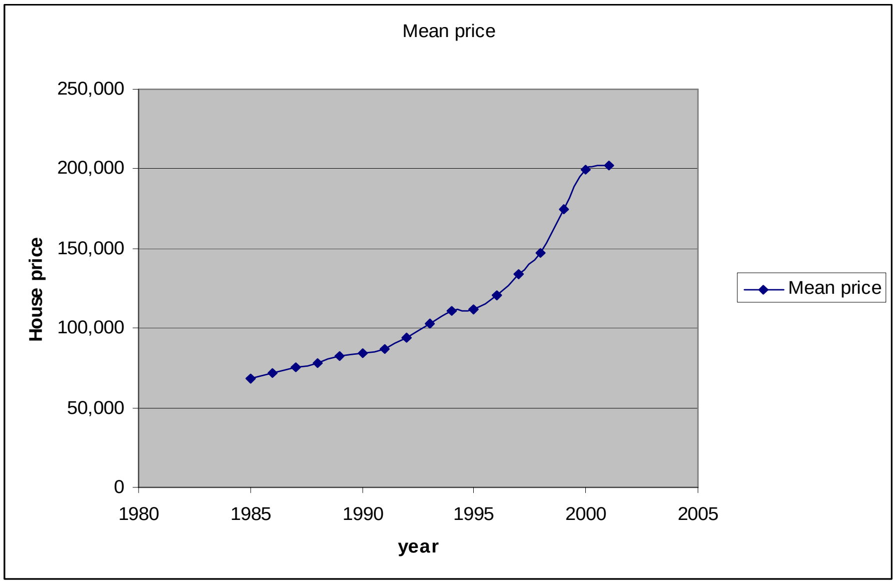

Figure 1: Mean price of houses per year

(B) RAILWAY STATION CHARACTERISTICS

The data of interest in this study concern the railway accessibility and associated noise or congestion effects. Railway accessibility in general terms means accessibility of railway station. Accessibility of railway station from the perspective of rail transport mostly accommodates two parts namely the station distance and the station services. The later part can be can be pure rail transport services like frequency of trains leaving the station per a period of time and network connectivity as determined by the number of destinations that can be reached with (out) transfer. In addition it can also include facilities that supplement railway transport. In the overall Dutch railway network there are about 360 stations. Our data allows us to use the mostly chosen station used as a departure station for households aggregated at the 4-digit post code level.

Table 2: descriptive statistics for the railway station characteristics

	No. stations	Minimum	Maximum	Mean	Std. Deviation
Rail service					
Frequency of trains per day		18	788	113	103
Destinations reached without a transfer		1	114	16	14
Destination reached with one transfer		8	246	87	53
Travel demand					
Total Passenger turnout per day		46	145,700	5,600	13,770
Station type					
Inter-city stations	64			0.18	
Station Facilities (dummies)					
Train taxi	109			0.30	
Bicycle stand	96			0.27	
Bicycle safe	264			0.74	
Bicycle rent	114			0.31	
Park and Ride	49			0.14	
Parking	326			0.91	
Taxi	163			0.45	
Car rent	1			0.00	
Luggage deposit	64			0.18	
International connection	22			0.06	

4. METHODOLOGY

In singling out the effect of one characteristic from a bunch of characteristics composing a property hedonic pricing technique has proved effective (Rosen 1974). The dependent variable in this analysis is the transaction price of residential houses and the logarithmic value of it for that matter. In line with the hedonic pricing technique we include a wide range of variables that we feel can explain the house prices. Among which are the physical characteristics of the houses, environmental and more importantly the accessibility variables that correspond to the house under analysis. Due to the wide range of time covered by the data set, temporal variables and to account for the spatial effect regional dummies are included. Our main focus in the analysis is the effect of station on the house prices as explained by the proximity to the station and the service quality of the station. Side by side, due to the undeniable competition exerted on railway by car based transport we also cover the effect of proximity to highway entry/exit points form the houses. In this paper we apply this technique to assess the impact of railway station proximity on property values.

Due to the fact that the data set covers a wide range of time and house prices have increased continuously during the last decade temporal effects are expected to play a role in explaining the variation in the sales price of houses. We capture these effects by half yearly dummies. These account for the inflation, real value changes and other temporal effects across.

CROSS-SECTIONAL MODEL

Even though the data include longer period, we could not organise our data in a panel structure because there were not many repeated sales over the time. Thus our data is organised in cross sectional pattern. We use two specifications for the distance effect. One is in terms of piece wise linear distance function, the other one makes use of transcendental logarithmic specification

(A) Semi logarithmic formulation based on piece-wise distance effect.
We start a semi logarithmic functional form represents the model and can be given as below.

$$Ln(\mathbf{P}) = B_0 + \mathbf{B}_1{}'\mathbf{X}_1 + \mathbf{B}_2{}'\mathbf{X}_2 + \ldots + \mathbf{B}_n{}'\mathbf{X}_n + \boldsymbol{\varepsilon} \qquad (1)$$

$\mathbf{P}$ is a vector of house prices, $\mathbf{X}_n$'s are matrices characteristics variables by categories. Included in our analysis are the variables listed in the appendix in table 1. The dependent variable is given in the natural logarithmic form; thus the values of the coefficients represent percentage change. Some of the variables are discrete represented by dummies, but some of them are continuous and most of the time given in the natural logarithmic form thus the coefficient indicate the elasticity for the variable. Distance to railway station and line and highway entry /exit points are represented by dummies for different distance categories. Thus our model takes the form

$$\begin{aligned}\ln(\mathbf{tranPrice}) = \alpha &+ \boldsymbol{\beta}_{\mathbf{HC}} \times \mathbf{HouseCh}r + \boldsymbol{\beta}_{\mathbf{dc}} \times \mathbf{Distcategrail} + \beta_{freq} \times \ln(FreqT)\\ &+ \boldsymbol{\beta}_{\mathbf{hw}} \times \mathbf{Distcateghway} + \boldsymbol{\beta}_{\mathbf{railline}} \times \mathbf{Drailline} + \boldsymbol{\beta}_{\mathbf{Neighb}} \times \mathbf{Neighb}\\ &+ \boldsymbol{\beta}_{\mathbf{Region}} \times \mathbf{Dregional} + \boldsymbol{\beta}_{\mathbf{time}} \times \mathbf{Dtime} + \boldsymbol{\varepsilon}\end{aligned}$$

(2)

$$\begin{aligned}\ln(\mathbf{tranPrice}) = \alpha &+ \boldsymbol{\beta}_{\mathbf{HC}} \times \mathbf{HouseCh}r + \boldsymbol{\beta}_{\mathbf{DC \otimes Freq}} \times \mathbf{Distcategrail} \otimes \ln(FreqT)\\ &+ \boldsymbol{\beta}_{\mathbf{hw}} \times \mathbf{Distcateghway} + \boldsymbol{\beta}_{\mathbf{railline}} \times \mathbf{Drailline} + \boldsymbol{\beta}_{\mathbf{Neighb}} \times \mathbf{Neighb} \qquad (3)\\ &+ \boldsymbol{\beta}_{\mathbf{Region}} \times \mathbf{Dregional} + \boldsymbol{\beta}_{\mathbf{time}} \times \mathbf{Dtime} + \boldsymbol{\varepsilon}\end{aligned}$$

Where **tranPrice** is the vector of transaction prices; **HouseChr** is a matrix of house characteristics including type of house, surface area, total number of rooms, number of bathrooms, presence of garage and garden for the house, presence of gas heater and fire place, monument, age of the building; **Distcategrail** a matrix of dummy variables representing the distance of the house from the mostly chosen railway station in the post code area. To see the smoothness of the effect we use a 500 meters range categories except in the two inner circle categories of the station which are 250 meters each. Thus we have 31 categories of distances up to 15,000 meter, where the rest area is taken as reference. *FreqT* is the frequency of trains at the mostly chosen station in the post-code area given in number of trains per day. **Distcateghway** is a matrix of dummies representing the distance category at which a highway entry/exit point is located. In the same fashion as the railway distance categories we have 31 distance categories for these variables as well. **Drailline** is a matrix of three dummy variables representing at which distance category the house is locating from the railway line. This is expected to account for the noise effect of trains. **Neighb** is a matrix of neighborhood characteristics including income and ratio of foreigners. It is given at the four-digit post code level. **Dregional** is a matrix of dummy variables representing to which municipality the house belongs. **Dtime** a matrix of time dummies representing the time of the transaction. $\boldsymbol{\varepsilon}$ is a vector of the error term.

Generally, the price house is expected to rise as the distance to the transport access points of station and highway entry/exit points declines. At the same time the influence of a station to the house prices is expected to increase with the increase in the service level provided by the station as given by frequency of trains and/or number of destinations directly served by the station. The two variables that indicate the service level provided by the station are highly correlated, thus we prefer only to include only one of the two in our estimation. We find the frequency variable more telling since it addresses waiting time aspect, an important dimension of generalized costs. In addition frequency is related to reliability since delays are less disturbing in the case of high frequency

(B) TRANSCENDENTAL LOGARITHMIC FORMULATION:

The transcendental logarithmic formulations generally produce smooth curves, showing the general approximation of effect. We accommodate the distance and frequency of trains in this transloging treatment.

$$\begin{aligned}\ln(\mathbf{tranPrice}) = {} & \alpha + \boldsymbol{\beta}_{\mathbf{HC}} \times \mathbf{HouseCh}r + \beta_d \times \ln Rail + \beta_{dSQ} \times (\ln Rail)^2 \\ & + \beta_{freq} \times \ln FreqT + \beta_{freqSQ} \times (\ln FreqT)^2 + \beta_d \times \ln Rail \times \ln FreqT \\ & + \beta_{hw} \times \ln highway + \boldsymbol{\beta}_{\mathbf{railline}} \times \mathbf{Drailline} + \boldsymbol{\beta}_{\mathbf{Neighb}} \times \mathbf{Neighb} \\ & + \boldsymbol{\beta}_{\mathbf{Region}} \times \mathbf{Dregional} + \boldsymbol{\beta}_{\mathbf{time}} \times \mathbf{Dtime} + \boldsymbol{\varepsilon}\end{aligned} \tag{4}$$

We also estimate a complete translog formulation including highway distance to the model as follows:

$$\begin{aligned}\ln(\mathbf{tranPrice}) = {} & \alpha + \boldsymbol{\beta}_{\mathbf{HC}} \times \mathbf{HouseCh}r + \beta_d \times \ln Rail + \beta_{dSQ} \times (\ln Rail)^2 + \beta_{freq} \times \ln(FreqT) \\ & + \beta_{freqSQ} \times (\ln FreqT)^2 + \beta_{hw} \times \ln highway + \beta_{hwSQ} \times (\ln highway)^2 \\ & + \beta_{CrossRailFreq} \times \ln Rail \times \ln FreqT + \beta_{Crossrailhighw} \times \ln Rail \times \ln highw \\ & + \beta_{CrossFreqHighw} \times \ln highw \times \ln FreqT + \boldsymbol{\beta}_{\mathbf{railline}} \times \mathbf{Drailline} + \boldsymbol{\beta}_{\mathbf{Neighb}} \times \mathbf{Neighb} \\ & + \boldsymbol{\beta}_{\mathbf{Region}} \times \mathbf{Dregional} + \boldsymbol{\beta}_{\mathbf{time}} \times \mathbf{Dtime} + \boldsymbol{\varepsilon}\end{aligned} \tag{5}$$

Where, *Rail* is the distance to the railway station in its continuous form; *highway* is the distance to the highway entry/exit point; the remaining vectors and variables are define above.

5. ESTIMATION RESULTS AND DISCUSSIONS

Based on the two functional formulations discussed above, we present two estimations for each. We have two references for the station namely the nearest railway station and the mostly chosen station in the neighbourhood represented by the four digit post code area. Intuitively the mostly chosen railway is expected to have stronger effect on the house price compared to the nearest station. In the final estimation reported in this paper we have included distance variable for the railways station, railway line and highway entry/ exit point and also to highway line. We have also included he frequency of trains as the stations, house characteristics, land use variables for the neighbourhood, temporal variable to represent the year of the transaction and regional variables at the municipality level. Highway distance variables, house features, land use variables except railway use, type of house, temporal variables-represented by yearly dummies, and municipality dummies.

The main focus of the estimation is to find the effect of station proximity and level of railway service explained by frequency of trains on the price of house. To trace these effects we estimated two families of estimation: the piecewise distance effect model and transcendental logarithmic model. The former is useful to show the effect of distance where as the later is found to be an efficient way to trace the effect of frequency of trains on house prices.

Table 3 gives the estimations based on the piecewise distance effect. The first two estimations correspond to the simple linear effect of piecewise distances and frequency of trains effect treated separately given by equation 2. The last two estimations are based on the model given by equation 3. It finds the effect of frequency of trains on house prices at each distance classes.

The semi log nature of the model in the piecewise distance models make the coefficients easy to interpret. Each coefficient for the distance categories in the first two estimations show the percentage effect on house pricesof distance to the station compared to houses locating beyond 15 km. Thus, we observe as big as 31% price difference for houses within 500m of the nearest station and houses beyond 15km for the station. This difference gets smaller for the case of a mostly chosen station effect where we encounter the peak house price to be between 250 and 500 metres. The general pattern of effect decline can be inferred form figures 2 and 3 below. Apart from some irregularities at distance category 7500 to 8000 metres we see a smooth decline in the effect of distance on house prices. The further we go out of the station the smaller the effect.

Table 3: Estimation of Railway station effect on house values: piecewise distance effect

Variable	Nearest Station		Chosen station		Cross distance-frequency of trains effect			
					Nearest Station		Chosen Station	
	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E
(Constant)	9.110***	(0.009)	8.929***	(0.009)	9.327***	(0.001)	9.369***	(0.008)
raildist250	0.313***	(0.006)	0.259***	(0.004)	0.048***	(0.001)	0.041***	(0.001)
raildist250_500	0.313***	(0.005)	0.265***	(0.003)	0.048***	(0.001)	0.043***	(0.001)
raildist500_1000	0.306***	(0.005)	0.251***	(0.003)	0.047***	(0.001)	0.041***	(0.001)
raildist1000_1500	0.300***	(0.005)	0.238***	(0.003)	0.046***	(0.001)	0.040***	(0.001)
raildist1500_2000	0.308***	(0.005)	0.238***	(0.003)	0.048***	(0.001)	0.041***	(0.001)
raildist2000_2500	0.290***	(0.005)	0.227***	(0.003)	0.044***	(0.001)	0.040***	(0.001)
raildist2500_3000	0.282***	(0.005)	0.199***	(0.003)	0.041***	(0.001)	0.036***	(0.001)
raildist3000_3500	0.272***	(0.005)	0.199***	(0.003)	0.040***	(0.001)	0.037***	(0.001)
raildist3500_4000	0.295***	(0.005)	0.196***	(0.003)	0.045***	(0.001)	0.037***	(0.001)
raildist4000_4500	0.280***	(0.005)	0.178***	(0.003)	0.041***	(0.001)	0.035***	(0.001)
raildist4500_5000	0.249***	(0.005)	0.158***	(0.003)	0.036***	(0.001)	0.032***	(0.001)
raildist5000_5500	0.236***	(0.005)	0.150***	(0.003)	0.033***	(0.001)	0.033***	(0.001)
raildist5500_6000	0.230***	(0.006)	0.131***	(0.004)	0.032***	(0.001)	0.030***	(0.001)
raildist6000_6500	0.224***	(0.006)	0.106***	(0.004)	0.031***	(0.001)	0.026***	(0.001)
raildist6500_7000	0.227***	(0.006)	0.104***	(0.004)	0.032***	(0.001)	0.027***	(0.001)
raildist7000_7500	0.200***	(0.006)	0.093***	(0.004)	0.027***	(0.001)	0.026***	(0.001)
raildist7500_8000	0.229***	(0.006)	0.006	(0.004)	0.033***	(0.001)	0.009***	(0.001)
raildist8000_8500	0.210***	(0.006)	0.062***	(0.004)	0.029***	(0.001)	0.020***	(0.001)
raildist8500_9000	0.259***	(0.006)	0.094***	(0.004)	0.039***	(0.001)	0.027***	(0.001)
raildist9000_9500	0.208***	(0.007)	0.102***	(0.004)	0.028***	(0.001)	0.029***	(0.001)
raildist9500_10000	0.175***	(0.007)	0.100***	(0.004)	0.023***	(0.001)	0.027***	(0.001)
raildist10000_10500	0.157***	(0.007)	0.044***	(0.005)	0.019***	(0.001)	0.018***	(0.001)
raildist10500_11000	0.066***	(0.007)	0.038***	(0.005)	0.001	(0.002)	0.016***	(0.001)
raildist11000_11500	0.038***	(0.008)	0.036***	(0.006)	-0.005***	(0.002)	0.015***	(0.001)
raildist11500_12000	0.032***	(0.008)	0.050***	(0.005)	-0.006***	(0.002)	0.021***	(0.001)
raildist12000_12500	0.039***	(0.009)	0.069***	(0.005)	-0.005***	(0.002)	0.026***	(0.001)
raildist12500_13000	0.021**	(0.009)	0.065***	(0.005)	-0.011***	(0.002)	0.023***	(0.001)
raildist13000_13500	0.008	(0.009)	0.047***	(0.005)	-0.013***	(0.002)	0.020***	(0.001)
raildist13500_14000	0.031***	(0.009)	0.032***	(0.005)	-0.007***	(0.002)	0.016***	(0.001)
raildist14000_14500	0.031***	(0.008)	0.058***	(0.005)	-0.003	(0.002)	0.020***	(0.001)
raildist14500_15000	0.032***	(0.009)	0.031***	(0.005)	-0.001	(0.001)	0.014***	(0.001)
Log (frequency)	0.032***	(0.001)	0.093***	(0.001)				
railline250	-0.050***	(0.001)	-0.054***	(0.001)	-0.049***	(0.001)	-0.046***	(0.001)
railline250_500	-0.038***	(0.001)	-0.041***	(0.001)	-0.037***	(0.001)	-0.036***	(0.001)
R square	0.825		0.827		0.825		0.825	

Linear regression model coefficients with standard errors of the estimates in parentheses

*** stands for a significance level of less than 1%

** stands for a significance level of less than 5%

* stands for a significance level of less than 10%

On the other land the separate effect of frequency of trains is given in elasticity form. A doubling of frequency of trains at the mostly chosen station has as high as 9% house price increase in the post code area compared to 3% for the case of the nearest railway station. This measure of frequency of trains' effect is crude since it does not allow for a differentiated effect between distance categories. Thus cross multiplying frequency with distance allows us to see the effect of change in frequency across distance categories. The last two columns of table 3 provide the estimation of the cross distance frequency effect. Doubling the frequency of trains in the nearest station result in as much as 5% price increase for houses locating up to 2kms. Doubling the frequency of the mostly chosen station on the other hand results in about 4% price increase for the same distance section.

A further refinement would be to estimate a hedonic price equation which combines equations 2 and 3 by incorporating both frequency (equation 2) and the cross product of frequency and the distance category dummies (equation 3). This leads to a doubling of the number of coefficients to be estimated, and it appears that the resulting distance decay patterns become rather unstable. A more promising approach for a detailed analysis of frequency effects on house prices is to use the translog form because its number of parameters is much smaller.

The estimation results for the tranlog function are presented in Table 4. The resulting patterns for the effect of frequency and distance are shown in Figure 4.

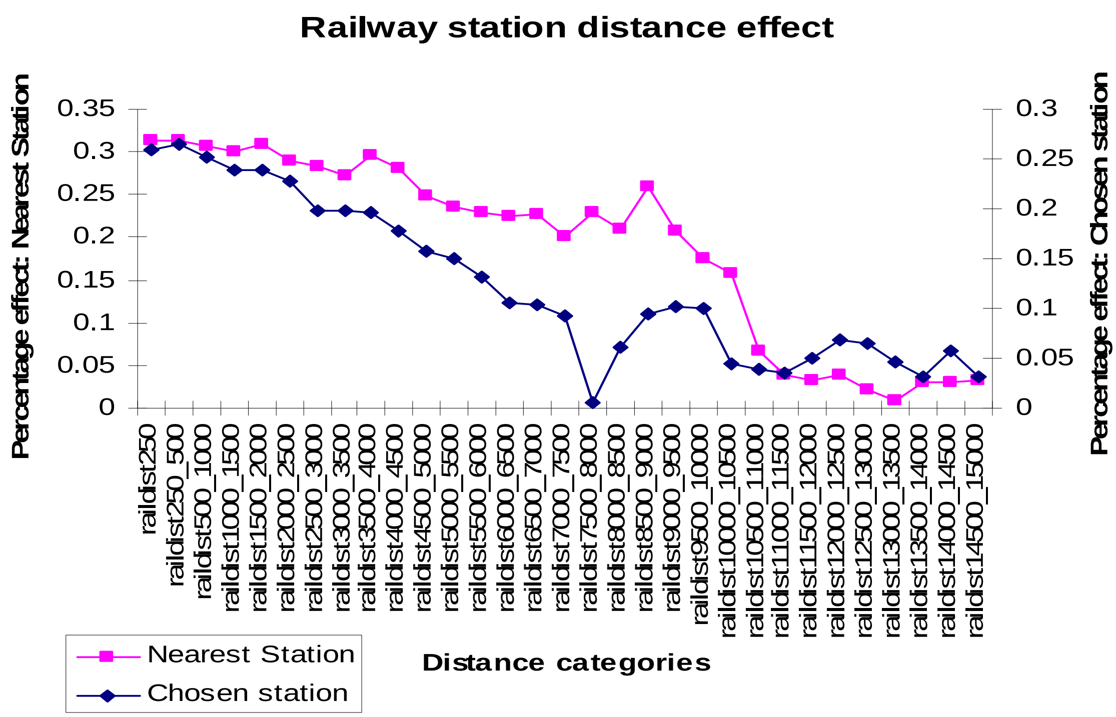

Fig 2: Effect railway station distance on house prices

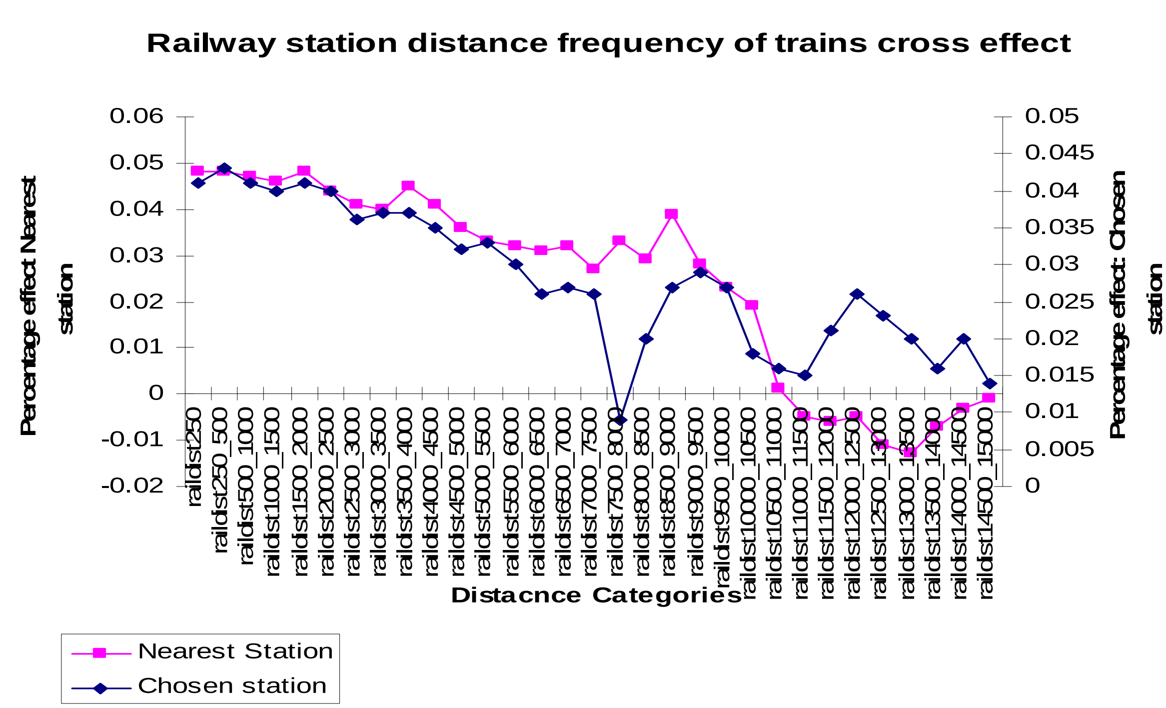

Fig 3: Railway station distance-frequency of trains cross effect on house prices

Table 4: Estimation of Railway station effect on house values: transcendental logarithmic formulation

	Nearest station	Chosen station	Near station	Chosen station
	Coefficient	Coefficient	Coefficient	Coefficient
(Constant)	9.018*** (0.045)	8.531*** (0.037)	9.848*** (0.071)	9.495*** (0.056)
Log (railways station dist)	0.192*** (0.007)	0.205*** (0.005)	0.226*** (0.009)	0.317*** (0.007)
Log (railways station dist) square	-0.019*** (0.000)	-0.024*** (0.000)	-0.017*** (0.000)	-0.025*** (0.0004)
Log (frequency)	0.030*** (0.011)	0.157*** (0.010)	-0.336*** (0.013)	-0.210*** (0.012)
Log (frequency) square	-0.007*** (0.001)	-0.020*** (0.001)	0.001 (0.001)	-0.009*** (0.001)
Log (highway dist)	0.014*** (0.001)	0.023*** (0.001)	0.009 (0.009)	-0.074*** (0.009)
Log (highway dist) square			-0.011*** (0.001)	-0.005*** (0.0005)
log (railway station dist)* log (frequency)	0.011*** (0.001)	0.019*** (0.001)	0.006*** (0.001)	0.010*** (0.0007)
Log (railway station dist)*log (highway dist)			-0.004*** (0.001)	-0.007*** (0.0006)
Log (frequency)*log (highway dist)			0.042*** (0.001)	0.042*** (0.0007)
railline250	-0.043*** (0.001)	-0.054*** (0.001)	-0.048*** (0.001)	-0.055*** (0.0013)
railline250_500	-0.036*** (0.001)	-0.046*** (0.001)	-0.041*** (0.001)	-0.046*** (0.0011)
Log surface area	0.181*** (0.001)	0.185*** (0.001)	0.181*** (0.001)	0.185*** (0.0006)
Building age	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.0000)
Log (number of rooms)	0.311*** (0.001)	0.310*** (0.001)	0.313*** (0.001)	0.311*** (0.0014)
Number of bathrooms	0.089*** (0.001)	0.088*** (0.001)	0.089*** (0.001)	0.088*** (0.0007)
Presence of Gas heater	-0.147*** (0.001)	-0.147*** (0.001)	-0.145*** (0.001)	-0.145*** (0.0011)
Presence of open fire place	0.066*** (0.001)	0.065*** (0.001)	0.066*** (0.001)	0.064*** (0.0010)
Presence of monument	0.304*** (0.004)	0.299*** (0.004)	0.286*** (0.004)	0.283*** (0.0037)
Presence of garage	0.116*** (0.001)	0.117*** (0.001)	0.116*** (0.001)	0.117*** (0.0009)
Presence of garden	0.024*** (0.001)	0.024*** (0.001)	0.024*** (0.001)	0.024*** (0.0012)
Other variables: not reported				
R square	**0.822**	**0.825**	**0.824**	**0.827**

Linear regression model coefficients with standard errors of the estimates in parentheses

*** stands for a significance level of less than 1%

** stands for a significance level of less than 5%

* stands for a significance level of less than 10%

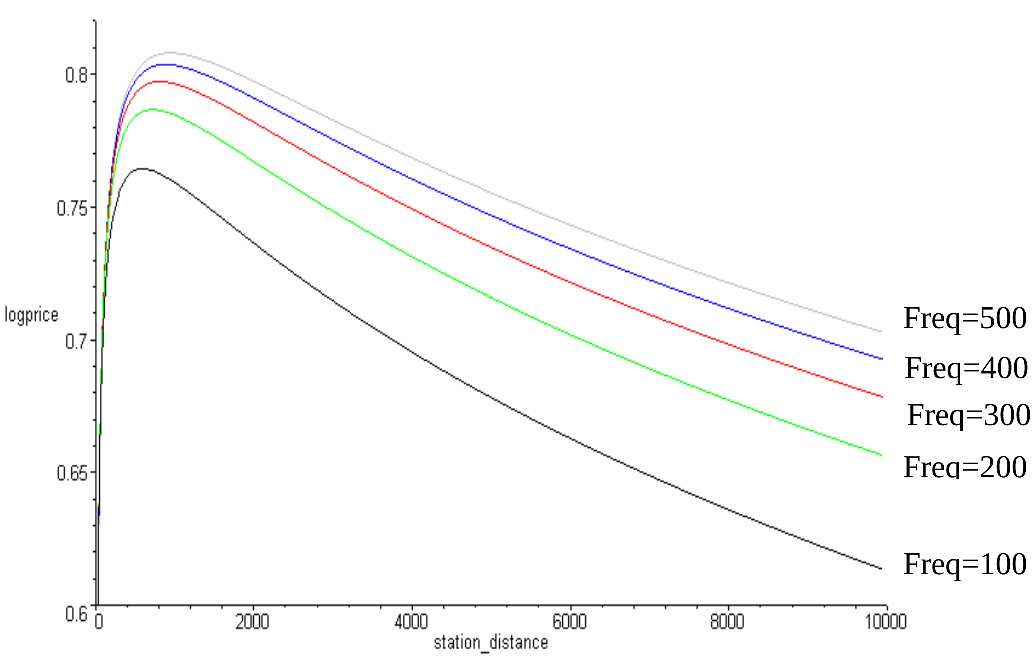

Figure 4: nearest station effect

On the Y-axis we have value of the log price determined as the combined effect of distance to the railway station and frequency in the transcendental logarithmic formulation given above. Figure 1 is based on the effect of nearest station given in column 1 of table 2. On the X-axis we have distance to the station (in this case to the nearest). The curves represent varying levels of frequency of trains at the stations. The lower curve corresponds to a frequency level of 100 trains per day whereas the outer curve corresponds to a frequency of 500 trains per day. The frequency interval between the curves is fixed to 100 trains per day to facilitate comparison on the effect of additional train. A simple look at the graph reveals there is a diminishing effect of increasing frequency of trains log price of houses. the general structure of the curves indicate the houses locating in adjacency to the stations sell lower that house locating some few hundreds of meters from the station.

Figure 2, below is based on the second column of table 2. It shows the effect of distance and frequency of train at the mostly chosen station on house prices. The general structure of the curves remains the same as curves based on the nearest station. The main difference between the two lays on the value of the total effect of distance and frequency of trains on house prices. The Chosen station results in a higher total effect compared to an effect produced by the nearest station. Besides we observe a shift in the location of the peak value for each of curves.

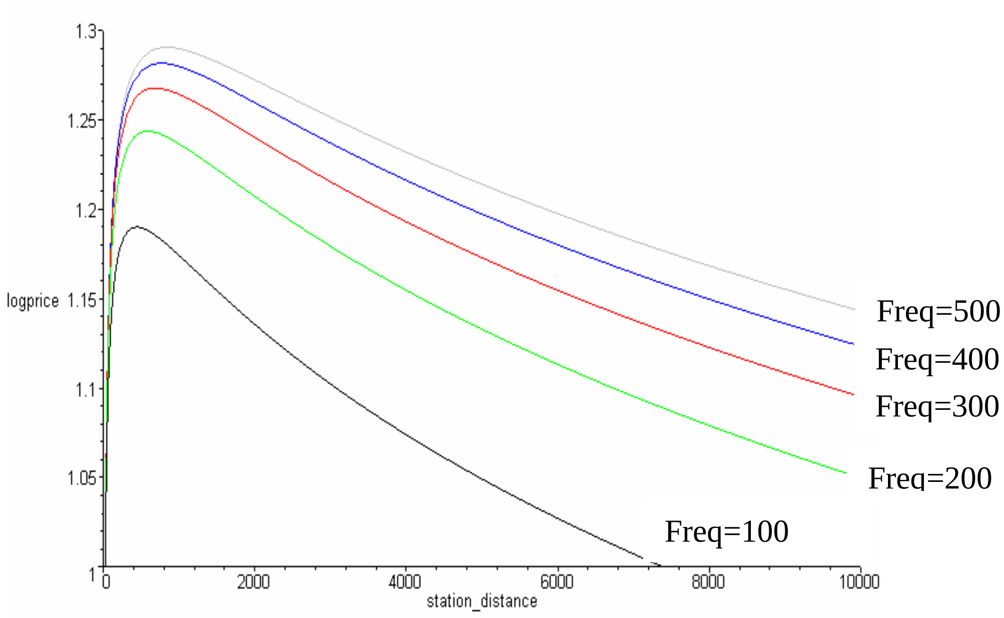

Figure 5: effect of distance frequency of trains based on the chosen station.

The use of the translog function is not so much that it gives a detailed treatment of the effect of distance: this can be done in a better way by the stepwise distance functions reported in Table 3. However, the translog model is better in dealing with the effect of frequency, in particular the extent to which frequency effects are different for houses close to stations and houses further away. Figure 4 shows that not only a low frequency leads to a lower house price, but also that for low frequencies the distance decay is faster. Other lessons told by this figure are that a doubling of frequency from 100 to 200 trains a day has an effect of about 3% on house prices (implying an elasticity of about 0.03) at a distance of 1000 meters, whereas this effect is about 5% at about 5 km and 6% at 10 km. This means the value additional frequency on house prices increases with distance. Another way in which Figure 1 can be interpreted is by considering a house at a distance of about 2300 meters from a station, having a frequency of 100 trains a day. A doubling of the number of trains would lead to a price increase of slightly more than 3 percent. This would bring the price at a level equal to that of a house at a distance of about 1000 meters at the low frequency level. Thus, according to market valuations, a doubling of frequency has a value that is about equal to a reduction of distance of about 1300 meters.

6. CONCLUSION

In this paper we consider the relationship between the prices of houses and railway accessibility through hedonic pricing model based on the Dutch residential house transaction in the years 1985 to 2001. The data set fairly extends across the country, thus can be assumed representative. Two functional formulations are applied. The first model treats distance in a piecewise fashion where as the second is based on continuous form. Both of them are aimed at focusing in estimation of impact of specific rail access feature. We treat the distance and service features separately. The service feature of rail assess in our case is explained by the frequency of train per day. The piece wise distance linear model is aims to explain the effect of distance on house price, where as the transcendental logarithmic function is meant to show the effect of frequency on house prices.

Based on the two treatment of the station namely the nearest and mostly chosen one we found significant effect for the impact of station distance and service on house prices. Thus, we observe as big as 31% price difference for houses within 500m of the nearest station and houses beyond 15km for the station. This difference gets smaller for the case of a mostly chosen station effect where we encounter the peak house price to be between 250 and 500 metres. The general pattern of effect decline can be inferred form figures 2 and 3 below. Apart from some irregularities at distance category 7500 to 8000 metres we see a smooth decline in the effect of distance on house prices. On the other land the separate effect of frequency of tells us on average doubling the frequency of trains at the mostly chosen station leads to 9% house price increase in the post code area as compared to 3% for the case of the nearest railway station. This measure of frequency of trains' effect is crude since it does not allow for a differentiated effect between distance categories. Allowing cross multiplied frequency with distance in the model gives us the effect of change in frequency across distance categories. Doubling the frequency of trains in the nearest station result in as much as 5% price increase for houses locating up to 2kms. Doubling the frequency of the mostly chosen station on the other hand results in about 4% price increase for the same distance section. A doubling of the number of trains would lead to a price increase of slightly more than 3 percent. This would bring the price at a level equal to that of a house at a distance of about 1000 meters at the low frequency level. Thus, according to market valuations, a doubling of frequency has a value that is about equal to a reduction of distance of about 1300 meters.

Based on the translog function we can efficiently infer the effect of additional frequency on house prices across distance. Doubling of frequency from 100 to 200 trains a day has an effect of about 3% on house prices (implying an elasticity of about 0.03) at a distance of 1000 meters, whereas this effect is about 5% at about 5 km and 6% at 10 km. This shows the value additional frequency on house prices increases with distance.

Acknowledgement

At this point we would like to take the opportunity to thanks different parties who contribute by providing useful data and insights. Rene van der Kruk provided us with useful data he used for his wet land study. The Dutch national Railway company were helpful at every stage by providing data and insightful ideas. People at the GEODAN were also helpful by geocoding the houses to make them ready for accessibility analysis and many others.

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