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**The Impact of Industrial Sites on Residential Property Values: A hedonic pricing analysis from the Netherlands**

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Keywords:	industrial sites, negative externalities, hedonic pricing



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3 The Impact of Industrial Sites on Residential Property Values  
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5 A hedonic pricing analysis from the Netherlands  
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3 Abstract  
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5 Industrial sites cause several negative externalities. In order to quantify these negative effects,  
6 we estimate the impact of distance to industrial sites on residential property values. We use data  
7 on houses sold in the Randstad region and in the Province of North-Brabant (both located in the  
8 Netherlands) in the year 2005, together with data on the characteristics of industrial sites in the  
9 same regions and period. The distance to an industrial site exhibits a statistically significant  
10 negative effect on the value of residential properties. However, the effect is largely localized  
11 within a relatively short distance from the nearest industrial site.  
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24 Keywords: Industrial sites, Negative externalities, Hedonic pricing  
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29 JEL classifications: O18, R30, R52  
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## INTRODUCTION

The results of Dutch policies aimed at providing an adequate supply of industrial land are mixed. In accordance with the spatial policy objectives, industrial sites have become the main location for supplying industrial land. Slowly but steadily, both the amount and share of employment on industrial sites are rising. Industrial sites are now a favourable place to settle for many firms (Louw and Bontekoning, 2007), and can be considered important contributors to the (local) economy: such sites occupy about 2 per cent of the total area of the Netherlands, and account for about one-third of the national output (Louw *et al.*, 2007). However, the recent planning debates about Dutch industrial sites have focused strongly on the quality of industrial sites (Louw *et al.*, 2004). Concerns have been raised about the possible negative external effects of industrial activities on other firms, on nature, and particularly on households (Schoor, 2001; Needham and Louw, 2003; Louw *et al.*, 2004; Blaauw, 2007). Although the development of industrial sites in the Netherlands is based on the mono-functional policy concept of separating industry and housing, residents may still be affected by industrial sites because of a multitude of perceived disamenities, such as noise, traffic, congestion, air pollution and obstruction of view.

This study contributes to the planning debate by elaborating on the implications of the presence of industrial sites on their immediate vicinity, distinguishing between various types of industrial sites.<sup>1</sup>

It aims to measure the negative externalities generated by industrial sites, and to obtain insight into the scope of these externalities. By means of a hedonic pricing analysis of residential property transactions, we identify the impact – *ceteris paribus* – of the distance to industrial sites on property transaction prices. Furthermore, we look into the implications of the characteristics of an industrial site on the magnitude of its impact by differentiating according to the size of the industrial site concerned. Many existing studies dealing with the topic of negative externalities

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3 generated by industrial sites consider a specific, tightly framed, study area comprising a  
4 restricted number of industrial sites. These studies arrive at a multitude of outcomes referring to  
5 a variety of specific cases.<sup>2</sup> In this respect, our study deviates from this literature by employing a  
6 more general approach: we analyse a comprehensive sample of industrial sites and identify the  
7 effects of these sites on neighbouring house prices in the Randstad region and in the Province of  
8 North-Brabant (both in the Netherlands).  
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10  
11 The paper is organized as follows. We start with a discussion of the literature on negative  
12 externalities originating from industrial facilities and hedonic pricing. The Dutch (policy) context  
13 with regard to the negative external effects of industrial sites is reviewed subsequently. We then  
14 continue with a presentation of the characteristics of the data set underlying our analysis and the  
15 research setup, followed by a discussion of the econometric model and the estimation results.  
16  
17 The paper concludes with a summary and discussion of policy implications.  
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## 20 21 22 LITERATURE REVIEW 23

24  
25 Farber (1998) provides a survey of the literature on the impact of undesirable facilities on house  
26 values due to perceived disamenities. Such concerns range from worries about health risks to  
27 those about the public image of the community. They can manifest themselves in property  
28 markets, since it is most likely that people are willing to pay more to reside in locations further  
29 located from perceived disamenities. The survey confirms that undesirable facilities (e.g.  
30 landfills, waste sites, hazardous manufacturing facilities) reduce property values in their  
31 immediate vicinity. These adverse effects diminish with distance, resulting in increased property  
32 values as distance from these sites increases. Moreover, these adverse property value effects  
33 appear to be relatively localized. Other examples can be found in a number of studies which have  
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3 shown effects on property values caused by proximity to a contaminated site. These studies (e.g.  
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5 Smolen *et al.*, 1991; Mendelsohn *et al.*, 1992) have reported adverse impacts on values, ranging  
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7 from as low as 0.24 per cent to as high as 25 per cent, depending on the extent of pollution and  
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9 the location of the property. In view of the Dutch situation, Visser and van Dam (2006) have  
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11 analysed the housing market in the Netherlands as a whole and have focused on, among other  
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13 things, the contribution of environmental characteristics to house price variation. By taking into  
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15 account various characteristics within the immediate vicinity (50 metres) of the dwelling  
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17 concerned (e.g. presence of parks, open space and industrial land, nature and quality of  
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19 buildings, social status of the neighbourhood, distance to services, and infrastructure), they  
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21 conclude that property value is positively affected by the quality of its vicinity in terms of the  
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23 availability of amenities. For instance, houses located in low-density, leafy neighbourhoods, are  
24  
25 valued significantly higher than houses in high-density areas with a lack of parks and open space.  
26  
27 Conversely, disamenities, such as the presence of industrial land and proximity to a highway,  
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29 affect the prices negatively. These findings suggest that effects generated by (dis)amenities  
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31 operate especially on a local scale, which confirms the notion that impact decreases with  
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33 distance. These outcomes are confirmed by the more detailed studies concerning the Dutch  
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35 situation of Rouwendal and van der Straaten (2008), Dekkers and Van der Straaten (2008) and  
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37 Debrezion *et al.* (2006). The first of these studies shows that, in three major Dutch cities  
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39 (Amsterdam, Rotterdam, and The Hague), parks and public gardens within the immediate  
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41 vicinity of houses increase their value. Considering the three investigated cities, the city of  
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43 Amsterdam has the highest price per square metres of floor area, which is in line with the tight  
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45 housing market situation in Amsterdam and the fact that the average floor area is the smallest in  
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47 Amsterdam. However, the willingness-to-pay for open space appears to be lowest in Amsterdam.  
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3 This finding is caused by the relatively low average quality of the different parks and public  
4 gardens in Amsterdam, compared with those in Rotterdam and The Hague. It shows that, as well  
5 as vicinity, the quality of the amenity matters. The second study investigates the effect of aircraft  
6 noise on house prices in the highly urbanized area around Amsterdam Airport. Controlling for  
7 multiple sources of traffic noise, air traffic yields the largest price impact, followed by railway  
8 traffic, and road traffic. Finally, the third study analyses the effect of the accessibility provided  
9 by Dutch railway stations on residential house prices. It shows that house prices decrease with  
10 distance from a railway station, revealing the positive effect of proximity. This effect is enhanced  
11 by the increased frequency of train services at a station. Hence, these three studies provide  
12 insights into the efficiency of public policy in terms of optimal open space provision, aircraft  
13 noise reduction measures, and railway station accessibility, respectively.  
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29 As the existing literature has mainly focussed on cataloguing the adverse effects on  
30 property values, less is known about the magnitude with which the property values may increase  
31 following a clean-up or regeneration of a site. Exceptions are Dale *et al.* (1999) and McComb  
32 (2004) who report that property values around the sites under investigation appeared to be lower  
33 before the clean-up or regeneration. However, after the clean-up, the prices consistently  
34 rebounded, although in the areas closest to the site and the poorest neighbourhoods prices  
35 rebounded more slowly. These studies underline that taking into account specific properties of  
36 sites may increase the accurateness of predicting the impact effects.  
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48 The previously mentioned studies are useful to demonstrate the nature and intensity of  
49 the impact of local forms of land use. Generally, they are based on revealed preference methods  
50 to observe what individuals really pay or require in compensation for living in the vicinity of  
51 sites that generate negative externalities (Farber, 1998). Hedonic pricing methods are helpful to  
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3 identify the impact of the various externalities (Rosen, 1974). Hedonic prices are defined as the  
4 implicit prices of attributes, which are revealed to economic agents from observed prices of  
5 differentiated products and the specific amounts of characteristics associated with them. More  
6 specifically, in hedonic price analysis, house prices are regressed on a vector of inherent  
7 attributes. A hedonic equation helps to explain house prices in terms of the house's own  
8 characteristics, such as the type of dwelling, age, floor area, neighbourhood characteristics and  
9 job accessibility. Each of these attributes is assumed to be implicitly priced. The real-estate  
10 literature is replete with hedonic pricing models estimating the willingness-to-pay for housing  
11 characteristics (e.g. Linneman, 1981; Palmquist, 2005). In addition, there has been a growing  
12 literature that uses the hedonic pricing model to measure the impact of environmental amenities  
13 and disamenities on real-estate values (e.g. Kohlhase, 1991, Hite *et al.*, 2001, Kiel and Zabel,  
14 2001; Kaufman and Cloutier, 2006).

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32 However, hedonic pricing methods have some limitations (Farber, 1998; Kiel and Zabel,  
33 2001). First, property markets may not be in equilibrium when the impact of the undesirable  
34 facility is estimated. This is why it would be preferable to use data on house sales over a  
35 sufficiently long period of time. Second, there is an inherent problem in statistically identifying  
36 the willingness-to-pay to avoid a disamenity. The effects of sorting in property markets play a  
37 strong role in residential location decisions. Those people who are most willing to accept a  
38 disamenity, or who have limited housing options because of income or discrimination, locate  
39 adjacent to a disamenity. As a consequence, property value differentials will underestimate the  
40 disamenity effect for the general population. Third, to the extent that the adverse activity may be  
41 locally job-enhancing, adjacent house values could be elevated because of the effect of a  
42 reduction of transportation costs. Despite these limitations which are important to bear in mind  
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3 when interpreting results from hedonic pricing models, the model is very suitable to identify the  
4 scope of negative externalities generated by industrial sites as it can reveal the effect of distance  
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6 to industrial sites on residential property values.  
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## 10 11 12 THE DUTCH CONTEXT

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14 As in many Western countries, post-war spatial planning in the Netherlands has been dominated  
15 by mono-functional approaches. This has resulted in core spatial functions, such as housing,  
16 industry, farming, or shopping, being allocated to rather large-scale areas, often separated by  
17 'buffers of open space'. However, several studies and the proliferation of 'mixed land use'  
18 approaches have revealed the limitations of mono-functional land use (Legendijk, 2001; Vreeker  
19 *et al.*, 2004). Whereas concepts of mixed land use aim to reduce urban sprawl and to promote  
20 spatial and environmental quality, the mono-functional approach presents a rather space-  
21 consuming form of land use which also tends to be inferior in terms of spatial quality. This  
22 notion is to a great extent reflected by the Dutch case of the provision of industrial sites, which is  
23 characterized by an abundant availability of industrial land and an associated decline of spatial  
24 quality (Gordijn *et al.*, 2007).  
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41 In the Netherlands, local authorities are the main suppliers of building land, whether for  
42 housing or industry. On account of their statutory planning and land policy powers, they can plan  
43 and develop industrial sites<sup>3,4</sup> or facilitate enterprise zones. Therefore, the role of private agents  
44 in the supply of industrial land has always been limited; approximately 74 per cent of the total  
45 area of industrial land is supplied by local authorities (Segeren *et al.*, 2005). Local authorities  
46 consider the provision of industrial sites as a key instrument of their economic policy. In  
47 accordance with their task and responsibility as a provider of industrial land, local authorities  
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3 ensure that there is always a minimum amount of industrial land available for immediate sale to  
4 interested companies. Over the last decade, this approach has resulted in a yearly average  
5 disposal of 1,038 hectares of industrial sites. The stock of industrial sites in the Netherlands  
6 increased from 3,203 formal industrial sites in 1995 to 3,605 sites in 2006. In terms of land area,  
7 this represents an increase from 78,886 hectares to 94,560 hectares (Arcadis and Stec Groep,  
8 2007). It implies a rise of industrial land area from 1.3 per cent to 2.7 per cent as share of the  
9 total area of the Netherlands. Given the growth rate of land designated for housing (8.0 per cent  
10 in the period 1993 to 2000), we can infer that the area of industrial land has risen substantially by  
11 12.9 per cent in the same period (Gordijn *et al.*, 2007).

12  
13 An important side-effect of the ample provision of industrial land, besides a shrinking  
14 quantity of open space, is the degradation of environment and landscape. This refers not only to  
15 the obstructing consequences of the disposal of new industrial land but also to its contribution to  
16 the process of the ageing of existing industrial sites. According to the Dutch Industrial Sites  
17 Database (Arcadis and Stec Groep, 2007), 29 per cent of the total number of industrial sites  
18 (1,052 sites) were considered as 'out-dated' in 2006. These sites have substantial vacancies in the  
19 building stock and poorly maintained public spaces. Attracted by the favourable assets of  
20 recently serviced land, well-performing companies decide to move to newly developed industrial  
21 sites. As a result, this outflow of well-performing firms generates unused industrial premises and  
22 substitution by marginal firms which creates a downward spiral of attractiveness of older  
23 industrial sites concerned (Louw and Bontekoning, 2007).

24  
25 In conclusion, the 'buffers' of open space are under pressure in the Netherlands. This  
26 involves a gradual diminishing of the distance of housing and other functions from industrial  
27 sites. Accordingly, the present policy of mono-functional planning, and the interplay between  
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3 distance and perceived negative externalities, provides us with relevant background with regard  
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5 to the impact of negative externalities originating from industrial sites, to which we now turn in  
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7 the remainder of this paper.  
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#### 10 11 12 DATA SET AND RESEARCH SET UP 13

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15 The data used originate from two sources: industrial site data were collected from the Dutch  
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17 Industrial Sites Database (IBIS), and property data from the Dutch Association of Real Estate  
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19 Agents (NVM). The selected data refer to the Randstad region<sup>5</sup> and to the Province of North-  
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21 Brabant in the Netherlands in the year 2005. The data collected on industrial sites and houses are  
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23 all geo-referenced, which enables us to link these sets by using GIS (see the detailed map in Fig.  
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29 Since the Randstad region and the Province of North-Brabant are jointly responsible for  
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31 generating 51 per cent of the total Dutch GDP, these regions are considered as the economic  
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33 core-regions of the Netherlands. Respectively, 41 per cent and 15 per cent of the Dutch  
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35 population reside in the Randstad region and North-Brabant (Statistics Netherlands, 2008). The  
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37 regions studied contain a considerable amount of the national stock of industrial sites. We added  
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39 a 500 metres buffer zone to the initial study area to incorporate possible effects generated by  
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41 industrial sites located just outside the examined region. Hence, we obtained a sample containing  
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43 information on 1,201 industrial sites,<sup>6</sup> acquired from the Dutch Industrial Sites Database (IBIS).  
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45 These sites cover 26,703 hectares of industrial land. Fig. 1 shows the spatial distribution of the  
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47 industrial sites in our sample.  
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55 <INSERT FIGURE 1 AROUND HERE>  
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6 The IBIS database provides an inventory of formal industrial sites<sup>7</sup> containing information on  
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8 numerous characteristics of the industrial sites concerned, of which the variables 'location' and  
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10 'type of industrial site' are the most relevant for the purpose of this paper. Regarding the variable  
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12 'type of site', the IBIS data set distinguishes five categories of industrial sites: 'heavy-industry',  
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14 'sea-harbour', 'miscellaneous', 'high-tech', and 'transport'. This typology of industrial sites is  
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16 associated with the nature of an industrial site;<sup>8</sup> it proxies the quality of the industrial sites  
17  
18 concerned (Arcadis and Stec Groep, 2007). However, the typology has a serious drawback in  
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20 terms of its ability to distinguish between types of sites. In 2006, 60 per cent of the total area of  
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22 industrial land in the Netherlands (in hectares) was classified as 'miscellaneous'. The categories  
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24 'heavy-industry', 'sea-harbour', 'high-tech', and 'transport' represent, respectively, 10 per cent,  
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26 18 per cent, 4 per cent and 4 per cent of the area. The remaining 4 per cent of industrial land has  
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28 been categorized as 'unknown' (Arcadis and Stec Groep, 2007). We deal with this drawback by  
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30 categorizing industrial sites in two classes which proxy the nature of an industrial site. 'Heavy  
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32 industrial sites' are sites which were originally classified as heavy-industry, sea-harbour, and  
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34 transport sites, as these types of sites are assumed to generate substantial nuisance in terms of  
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36 noise, traffic, congestion and pollution. The category 'regular sites' comprises miscellaneous and  
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38 high-tech sites. These sites are expected to create less nuisance than 'heavy sites'. In our sample,  
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40 61 sites are categorized as 'heavy' and 1,140 sites as 'regular', covering, respectively, 728 and  
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42 25,975 hectares of industrial land.  
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51 The data regarding residential property values include information on all houses sold by  
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53 NVM real-estate-agents<sup>9</sup> in the Randstad and North-Brabant in the year 2005. We removed all  
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55 observations referring to a house with a volume of less than 100 m<sup>3</sup>, a floor area of less than 40  
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3 m<sup>2</sup> or a transaction price exceeding 1 million euros. Furthermore, the upper and lower 0.5 per  
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5 cent of the transaction values of the remaining observations were excluded (for a similar  
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7 approach, see Rouwendal and van der Straaten, 2008). This leaves a sample containing  
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9 information on 70,684 dwellings within the defined area.  
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13 Furthermore, additional geographical information on important control variables, such as  
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15 the ethnic composition and population density of the neighbourhood, location of highway exits  
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17 and railway stations, and distance-to-jobs, was acquired from, respectively, Statistics  
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19 Netherlands (CBS), the National Road Database (NWB), the Dutch Railways (NS) and the  
20  
21 Netherlands Institute for Spatial Research (RPB)/Land Use Scanner.<sup>10</sup>  
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25 Building on the hedonic valuation methodology, and allowing for its limitations, as  
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27 described in the literature review, we assume that residential property values are a function of  
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29 structural, neighbourhood, and industrial site variables.<sup>11</sup> The structural variables are the physical  
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31 characteristics or attributes of the residential property, and include the numerical variables ‘floor  
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33 area’ and ‘volume’. Categorical variables indicate the presence of central heating, garage and  
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35 garden, the period of construction and the type of house. The latter incorporates four basic  
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37 architectural house styles: detached, semi-detached, terraced house, and apartment.  
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41 The neighbourhood variables cover the characteristics of the area in which the property is  
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43 located, such as socioeconomic factors, status of the area, ease of accessibility and labour market  
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45 characteristics. We include the ethnic composition (fraction of ethnic minorities) and the  
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47 population-density of the 4-digit ZIP-code area in which the dwelling is located. Additionally, a  
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49 regional dummy is included to indicate the region (Randstad or North-Brabant) in which the  
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51 dwelling of interest is located. We control for the ease of accessibility in two ways. First, we  
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53 employ the ease of accessibility by road, operationalized by the road distance (metres) from each  
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3 property to the nearest highway exit. Second, we employ the ease of accessibility by railway,  
4 operationalized by the straight-line distance (metres) from each property to the nearest railway  
5 station. Allowing for the positive effects associated with the provision of local employment by  
6 the industrial site concerned, which may elevate adjacent house values, we include the minimum  
7 distance (circle radius in metres) within which a total of 100,000 jobs can be reached. This  
8 measure is a proxy for job opportunities in the vicinity of the house.  
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17 Industrial site variables refer to the perceived impact of the industrial sites that are  
18 present. This variable encompasses the characteristics of the industrial sites which are located in  
19 the vicinity of the properties concerned. The location of an industrial site, vis-à-vis residential  
20 properties, is specified by the distance from the approximate centre of a residential property to  
21 the nearest industrial site. In this respect, we include the straight-line distances in metres from  
22 each residential property to the closest point on the boundary of the industrial site. A dummy  
23 variable is included to indicate the category (heavy or regular) to which this nearest industrial  
24 site belongs. Furthermore, we assume that the size of an industrial site matters in explaining its  
25 impact on property values. Thus, we also control for the gross area<sup>12</sup> in hectares of the industrial  
26 sites concerned. Finally, since the data set also contains information about the date of house  
27 transactions, we include monthly dummies to capture the effects of the seasonality of the housing  
28 market. Appendix A reports the variable names, their sources, definitions and some descriptive  
29 statistics.  
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3 THE ECONOMETRIC MODEL  
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6 A formal way of describing the hedonic price function is as follows:  
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$$P_j = f(S_1, \dots, S_K; N_1, \dots, N_L; I_1, \dots, I_M; D_1, \dots, D_N), \quad (1)$$

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16 where houses are identified by the subscript  $j$ ;  $P_j$  is house transaction price; and  $f$  relates the  
17 transaction price to structural ( $S$ ) and neighbourhood ( $N$ ) characteristics of the property, and the  
18 characteristics of the industrial sites ( $I$ ) concerned. Since the effect of distance to industrial sites on  
19 property transaction prices is our variable of key interest ( $D$ ), we distinguish this variable  
20 explicitly. It assumes a housing market in equilibrium, meaning that all individuals have made  
21 their utility-maximizing choices, given the prices of alternative housing locations. For individual  
22  $i$  living in house  $j$ , the utility is given by (see Rosen, 1974):  
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$$u_i = u(x; S_1, \dots, S_K; N_1, \dots, N_L; I_1, \dots, I_M; D_1, \dots, D_N), \quad (2)$$

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40 which is assumed to be strictly concave.  $x$  is all other goods consumed. Set the price of  $x$  equal to  
41 1 and measure the me of individual  $i$ ,  $y_i$ , in terms of units of  $x$ . This gives the following budget  
42 constraint:  
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$$y_i = P_j(S_1, \dots, S_K; N_1, \dots, N_L; I_1, \dots, I_M; D_1, \dots, D_N) + x. \quad (3)$$

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54 The maximization of utility, subject to the budget constraint, requires choosing  $x$  and  
55  $(S_1, \dots, S_K; N_1, \dots, N_L; I_1, \dots, I_M; D_1, \dots, D_N)$  to satisfy the budget and the first-order conditions. So,  
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partial differentiation with respect to, for example, an industrial site attribute  $M$  gives the marginal implicit price for that attribute  $\partial P_j / \partial I_M$ .

Economic theory provides little guidance regarding choice of functional form for the hedonic price function (Deaton and Hoehn, 2004; Neupane and Gustavson, 2008). The double natural log specification is widely employed for model estimation (Freeman, 1993), largely motivated by the fact that it allows for a simple interpretation of estimated coefficients as elasticities. However, in order to describe the pattern of distance-decay, we measure the effect of distance on house prices by using distance dummies, i.e. a less restrictive functional form, instead of employing the natural log of distance. We use distance categories with a 250 metre range to enable us to examine the effect in a detailed way (see Debrezion *et al.*, 2006). Endogenous determination of the cut-off distance by running models with different cut-off distances results in a distance of 2,250 metres to the nearest industrial site, beyond which house prices are no longer significantly affected by negative externalities generated by the industrial sites concerned.<sup>13</sup> As a consequence, the piecewise specification of distance renders nine categories up to 2,250 metres. In the empirical application, the transaction price of a house  $j$  is modelled as follows:

$$\ln P_j = \alpha + \sum_{k=1}^{15} \beta_k S_{j,k} + \sum_{l=1}^6 \gamma_l N_{j,l} + \sum_{m=1}^2 \delta_m I_{j,m} + \sum_{n=1}^9 \xi_n D\_dum_{j,n} + \varepsilon_j, \quad (4)$$

where all variables are defined as in Equation (1).  $\alpha$  is a constant, and  $\beta$ ,  $\gamma$ ,  $\delta$  and  $\zeta$  are coefficients to be estimated. The variables of structural, neighbourhood, industrial site characteristics, and the distance-to-site variable for property  $j$  are, respectively, indexed by  $k$ ,  $l$ ,  $m$  and  $n$ . In accordance with most of the previous literature, Equation (4) is estimated by ordinary

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3 least squares (OLS). White's heteroskedastic consistent covariance matrix is used to correct the  
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6 estimated errors for unknown forms of heteroskedasticity.  
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8 In our model in its simple and basic form, we assume that house prices rise with  
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10 increasing distance to the nearest industrial site. More specifically, the sign and the magnitude of  
11  
12 estimated coefficients of the separate distance dummies are, respectively, expected to be negative  
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14 and decreasing at a decreasing rate as distance between the site and the property increases (i.e.  
15  
16 the coefficients under consideration express the price differentials between the distance category  
17  
18 concerned and the reference group).<sup>14</sup> Furthermore, *ceteris paribus*, an increase in house prices is  
19  
20 hypothesized to result from increases in floor area and housing volume. Increases in the age of  
21  
22 the dwelling are hypothesized to cause a decline in house values. The price effect associated with  
23  
24 the style of housing (i.e. detached, semi-detached, terraced, or apartment) is uncertain, given that  
25  
26 the model controls for floor area and volume. Specific assets of a house, such as the presence of  
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28 central heating, garage and garden, are expected to have a positive price effect. Neighbourhood  
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30 measures associated with status, such as ethnical composition and population density, are  
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32 expected to influence house prices negatively, as has been shown by, amongst others, Rouwendal  
33  
34 and van der Straaten (2008). Considering the distance to jobs, we hypothesize a negative effect  
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36 on house prices. Increased remoteness of households to areas of employment increases the costs  
37  
38 of commuting. The associated expenditures will be capitalized into property values. Following  
39  
40 Debrezion *et al.* (2006), we suppose that the effect of increasing distance to highway exits and  
41  
42 railway stations on house prices is negative. Increased proximity causes positive effects in terms  
43  
44 of accessibility which are assumed to exceed the negative effects, such as inherent traffic  
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46 nuisance. Since the Randstad is the economic core region of the Netherlands, dwellings located  
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48 in this region are hypothesized to sell at a higher price than dwellings in North-Brabant. The  
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3 remainder of the variables which are associated with the perceived impact proceeding from  
4 present industrial sites on house prices, e.g. the size of the industrial site, and heavy sites  
5 compared with regular sites, are hypothesized to affect house prices negatively.  
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## 10 11 12 13 EMPIRICAL RESULTS

### 14 15 The basic results

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20 The basic estimation results are shown in Table 1. The majority of the results are highly  
21 statistically significant (at the 1 per cent significance level) and consistent with our hypotheses,<sup>15</sup>  
22 including those for the distance-to-site dummies. Looking at the industrial site characteristics  
23 size and type of site, we see that the corresponding estimated parameters have a negative and  
24 positive sign, respectively. On the one hand, this confirms our hypothesis that the larger an  
25 industrial site, the more inconvenience it generates. On the other hand, the effect of heavy sites  
26 on their immediate vicinity has significantly less impact than that of regular sites, which is  
27 remarkable since the heavy-industry sites are defined as industrial sites on which it is intended to  
28 establish highly undesirable effects in terms of environmental nuisance. A possible explanation  
29 for this unexpected finding is the relatively small occurrence of sites denoted as 'heavy' in our  
30 data set. It may also stem from an omitted variable bias (for example, lot sizes close to heavy  
31 sites being relatively large).  
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49 Considering distance, we find, consistent with our expectations, that increased distance  
50 from industrial sites increases house prices. *Ceteris paribus*, houses located within 250 metres of  
51 an industrial site are predicted to sell at 14.9 per cent less than houses located beyond a distance  
52 of 2,250 metres from such a site (the reference group). The estimated relationship, employing the  
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linear piecewise distance specification and a given set of characteristics, is shown in Fig. 2. The figure illustrates the value of the representative property<sup>16</sup> as a function of the distance-to-site dummy (keeping all other variables constant).

< INSERT TABLE 1 AROUND HERE >

<INSERT FIGURE 2 AROUND HERE>

In Fig. 2, the depicted pattern suggests a logistic shape, representing the (partial) relationship between the distance to the closest industrial site and house prices. We therefore proceed by replacing the piecewise specification of distance with a logistic functional form of distance. More specifically, we estimate the following model using nonlinear squares (NLS):

$$\ln P_j = \alpha + \sum_{k=1}^{15} \beta_k S_{j,k} + \sum_{l=1}^6 \gamma_l N_{j,l} + \sum_{m=1}^2 \delta_m I_{j,m} + \eta_1 \frac{e^{\eta_2 + \eta_3 \ln(D_j)}}{1 + e^{\eta_2 + \eta_3 \ln(D_j)}} + \varepsilon_j, \quad (5)$$

where all variables are defined as in Equation (1). Because of the transformation into the logistic specification for distance, we estimate three parameters,  $\eta_1$ ,  $\eta_2$  and  $\eta_3$ , which together characterize the partial relationship between distance and the house price. More specifically, the maximum variation of house prices as a function of distance to the nearest industrial site is captured by parameter  $\eta_1$ . Furthermore, the relationship is upward sloping if  $\eta_1 \cdot \eta_3 > 0$ , and the point of inflection (viz. the distance at which the curve is steepest, and thus beyond which the effect of the presence of the industrial site gradually diminishes) can be derived as:

$$D_j^* = \left( \frac{\eta_3 - 1}{e^{\eta_2} (1 + \eta_3)} \right)^{1/\eta_3}. \quad (6)$$

The point of inflection thus decreases with increasing values of  $\eta_3$ . We refer to Appendix B for technical details.

The results of the estimation are presented in Table 2. Since the other estimated coefficients remain generally unchanged, we only report the outcomes referring to the effect of distance from an industrial site on house prices.

<INSERT TABLE 2 AROUND HERE>

With reference to the goodness-of-fit and the parsimony of the preceding models, examination of corresponding criteria does not point to one of the models being clearly preferred over the other.<sup>17</sup> However, given the advantages with respect to interpretation and presentation, we decide to use the more parsimonious model to characterize the relationship between distance to industrial site and house prices. On that account, a detailed look at the employed logistic functional form of the house prices as a function of the minimum distance of a house to its nearest industrial site gives us more precise information about the nature of the distance decay of the negative externalities which are generated by the industrial sites. The partial relationship between house prices and distance to the nearest industrial site can be represented as:

$$P(D_j) = 0.169 \frac{e^{-18.445 + 2.516 \ln(D_j)}}{1 + e^{-18.445 + 2.516 \ln(D_j)}} = \frac{0.169 e^{-18.445} D_j^{2.516}}{1 + e^{-18.445} D_j^{2.516}}. \quad (7)$$

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3 Moreover, from Equation 6 the point of inflection ( $D_j^*$ ) can be derived. It appears that up to  
4 distance of 1,093 metres, the house prices are increasing at an increasing rate, whereas the house  
5 prices are increasing at a decreasing rate beyond this distance. We have depicted this relationship  
6 graphically in Fig. 3. It illustrates the value of the representative property given a change in the  
7 distance-to-site variable, holding the other variables constant.  
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18 <INSERT FIGURE 3 AROUND HERE>  
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22 The revealed shape of the curve in Fig. 3 is in accordance with our expectations. It illustrates that  
23 the impact of negative externalities generated by industrial sites is largely localized. Increasing  
24 distance leads to a gradually diminishing increase of house prices.  
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32 A more detailed look at industrial site size  
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37 In view of the estimation results of Equation (5), we infer that the nature of the distance-decay of  
38 negative externalities generated by industrial sites is largely localized. Amongst other things, we  
39 have seen that the point of inflection is at 1,093 metres. However, we have neglected the  
40 potential relevance of the interplay between the effect of distance and another relevant industrial  
41 site characteristic, such as the gross area of the site.  
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49 The value of the estimated coefficient of the gross area of the nearest industrial site,  
50 irrespective of which model we use, equals  $-0.012$  (statistically significant at the 1 per cent  
51 level). This implies that an increase of 1 per cent of the gross area of the nearest industrial site  
52 decreases house price by 0.012 per cent. However, it is plausible to contend that the effect of the  
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3 increase of site area on house prices modifies with increasing distance from the site concerned.  
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5 We therefore allow for interaction effects between gross site area and distance to the nearest site.  
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7 Interaction of these parameters with industrial site acreage will result in a change of the nature of  
8  
9 the distance decay, in that it becomes conditional on site acreage. However, sequential regression  
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11 model runs (NLS) for separate ‘site size-distance’ interaction terms, and all three site size-  
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13 distance interaction terms together, only yield statistically significant estimates (at the 5 per cent  
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15 level) for the model which controls for  $\eta_1 \cdot \text{LnGrossarea}$  ( $\varphi_1$ ).<sup>18</sup> This model is specified as follows,  
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18 where all variables are defined as in Equation (5):  
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$$\begin{aligned}
 \text{Ln}P_j = & \alpha + \sum_{k=1}^{15} \beta_k S_{j,k} + \sum_{l=1}^6 \gamma_l N_{j,l} + \sum_{m=1}^2 \delta_m I_{j,m} + \eta_1 \frac{e^{\eta_2 + \eta_3 \text{Ln}(D_j)}}{1 + e^{\eta_2 + \eta_3 \text{Ln}(D_j)}} \\
 & + \varphi_1 (\eta_1 \cdot \text{LnGrossArea}_j) \frac{e^{\eta_2 + \eta_3 \text{Ln}(D_j)}}{1 + e^{\eta_2 + \eta_3 \text{Ln}(D_j)}} + \varepsilon. \quad (8)
 \end{aligned}$$

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37 The results of the estimation are presented in Table 3. We only report the outcomes referring to  
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39 the effects of site size, distance from an industrial site, and the corresponding interaction effect  
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41 on house prices.  
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52 The estimated interaction coefficient ( $\varphi_1$ ) indicates that the effect of distance on house prices,  
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54 referring to the range, rises with increasing site size. In other words, an increase of 1 per cent  
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56 gross area of the industrial site concerned elevates the accompanying distance effect by 0.008 per  
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3 cent, *ceteris paribus*. This effect is illustrated graphically in Fig. 4. We have depicted the price  
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5 gradients of representative properties whose nearest industrial sites have a gross area of 1  
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7 hectare, 25 hectares and 50 hectares, given a change in the distance-to-site variable. As well as  
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9 observing that the overall price-level of houses located near ‘small’ industrial sites exceeds the  
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11 price level of ‘larger’ sites, we also observe that the range or variation of the house prices  
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13 increases as the size of the nearest industrial site increases. Furthermore, the relationship  
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15 between site size and distance to the site appears to be nonlinear, in the sense that the effect of  
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17 size change is relatively larger for ‘small’ sites than for ‘large’ sites.  
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25 <INSERT FIGURE 4 AROUND HERE>  
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### 29 Robustness analysis 30 31 32 33

34 The results so far show that the findings concerning the marginal effect of the presence of an  
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36 industrial site on house prices, as measured by distance-to-site, are robust to the employed  
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38 functional forms, viz. the piecewise and logistic specification of distance. In accordance with our  
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40 findings concerning goodness-of-fit and parsimony of the model, we prefer to use the logistic  
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42 functional form. In order to test the robustness of our results, we replicated the corresponding  
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44 regression model employing different subsets of the original data, and, finally, we have added  
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46 municipality dummies to the basic model to examine whether the results are sensitive to potential  
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48 unobserved local circumstances.  
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53 First, we conducted model runs for four different subsamples comprising houses which  
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55 are located, respectively, within 500, 1,000, 1,500 and 2,000 metres from the nearest industrial  
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3 site. The regression estimates are strongly in line with the findings discussed before: they  
4 confirm that there is a lack of variation in house prices within short distance from an industrial  
5 site, and, conversely, that expanding the sample sizes leads to a rise of house prices variation  
6 across distance as, amongst others, represented by an increasing parameter  $\eta_1$ .<sup>19</sup>  
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13 Second, we examined the sensitivity of the empirical results to regional specifications by  
14 dividing the transaction data into two subsamples, viz. the Randstad and the Province of North-  
15 Brabant, respectively.<sup>20</sup> The model run for the Randstad sample yields coefficients which are  
16 fully consistent with the general findings, regarding sign as well as the statistical significance of  
17 the estimated effects. However, the impact of the presence of an industrial site on house prices  
18 appears to be more pronounced in the Randstad region than in the entire area of examination, in  
19 the sense that house prices are increasing at a faster rate as the distance to the nearest industrial  
20 site increases. For the sake of comprehensibility, these outcomes have been displayed graphically  
21 (see Fig. 5). Conversely, the results for North-Brabant with regard to distance yield statistically  
22 insignificant outcomes. Displaying the corresponding transaction price gradient reveals a  
23 relationship between distance and house price which exhibits a logarithmic form.<sup>21</sup> In North-  
24 Brabant the effect of industrial site presence on house prices is, apparently, manifested within a  
25 relatively short distance of the site concerned. To get more insight into this regional anomaly, we  
26 have conducted additional model runs for the Province of North-Brabant and the Randstad  
27 separately, explicitly accounting for the nature of industrial sites in terms of type and size.<sup>22</sup> The  
28 outcomes turned out to be consistent with the aforementioned findings. In North-Brabant,  
29 beyond a distance of approximately 750 metres there is no discernible impact of distance to the  
30 closest site on house prices, irrespective of type and size of the industrial site. Concerning the  
31 Randstad, the revealed partial relationship between distance to industrial site and house prices  
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3 features a logistic shape. Given that we have controlled for the industrial site characteristics of  
4 the investigated regions, the functioning of regional housing markets thus seems to differ  
5 considerably. Likewise, replicating the preceding regressions using the piecewise distance  
6 specification instead of the logistic distance specification yields consistent results, indicating that  
7 the employed model is sensitive to geographical considerations.<sup>23</sup>  
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18 <INSERT FIGURE 5 AROUND HERE>  
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22 Finally, estimating the basic model with the inclusion of 219 municipality dummies, each  
23 corresponding to the municipality in which the dwelling concerned is located (taking the  
24 municipality of Amsterdam as reference group), yields outcomes which are qualitatively as well  
25 as quantitatively comparable to those obtained with the basic logistic specification (see Table 4).  
26  
27 Considering the estimated partial relationship between distance to industrial site and house  
28 prices, the parameter  $\eta_1$ , which captures the maximum variation of house prices as a function of  
29 distance to the nearest industrial site, slightly increases from 0.169 to 0.186. Furthermore, by  
30 using Equation (7) the point of inflection is at 1,133 metres (instead of at 1,093 metres). The  
31 remainder of the estimated coefficients are also consistent with the basic model estimates.  
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33 Hence, we may infer that the revealed effect of distance-to-site on house prices is robust, in the  
34 sense that its nature is hardly affected by potential unobserved heterogeneity, stemming from  
35 specific local circumstances.  
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## CONCLUSION

The main aim of this paper was to study the impact of the presence of industrial sites on their immediate vicinity. Applying a hedonic pricing model, we valued the negative externalities generated by activities located on industrial sites in the Randstad region and the Province of North-Brabant (both in the Netherlands), in the year 2005. The effect of these negative externalities is proxied by estimation of the distance-decay of house prices in the vicinity of industrial sites. In accordance with previous hedonic pricing studies, our results clearly show that the presence of an industrial site has a statistically significant negative effect on the value of residential properties: house prices rise with increasing distance to the nearest industrial site. However, in contrast to previous hedonic pricing studies that we know of, we employ a logistic functional form to reveal the nature of the effect of distance-to-site on house prices. This leads to a relationship between distance and residential property prices which is best described as 'dichotomous': relatively close to a site, negative externalities have a strong negative effect on house prices which convexly decreases up to a certain distance. Beyond this point, in our case 1,093 metres, the negative effect on house prices concavely decreases till it fades out with increasing distance. Furthermore, we find that the effect of site size intervenes with the effect of distance on house prices, in the sense that this interactive effect affects the maximum variation of the distance effect: the larger the site, the larger the range of houses which are affected by the presence of the industrial site concerned.

Our outcomes demonstrate that the impact of negative externalities is largely localized, implying that the perception of the spatial quality of the neighbourhood is affected by the presence of an industrial site, and to a certain extent by the size of an industrial site. In addition, our study may provide spatial planners with more insight into setting zoning guidelines in order

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3 to decrease potential inconvenience resulting from the presence of an industrial site. We have to  
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5 be careful, however, in deriving inferences with regard to the latter, as our study only employs  
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7 the revealed preferences of house buyers in the vicinity. In view of this, we should take into  
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9 account that our approach is sensitive to sorting of individuals driven by variation in the  
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11 willingness-to-accept a disamenity. This may be manifested by underestimation of the distance-  
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13 to-site effect within a short distance of an industrial site. Our results, furthermore, neglect the  
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15 preferences of other stakeholders, for instance employees of the firms located on the sites or the  
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17 visitors to these firms, who may attach different values to the impact of industrial sites. Another  
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19 possible shortcoming is the variation across regions. As we obtained substantially different  
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21 parameters regarding the effects of distance on house price for the Randstad and North-Brabant  
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23 subsets, it reduces the general applicability of the method. This regional sensitivity may be of  
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25 special importance for policy makers.  
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32 In conclusion, the findings of this paper provide insight into the extent of negative  
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34 externalities involved with location of certain industrial activities on a specific site. The observed  
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36 impacts address the notion of the spatial quality of an industrial site. Despite some caveats, they  
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38 provide useful information that can help with prioritizing and assessing spatial planning  
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40 approaches.  
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## APPENDIX A

This Appendix contains definitions, sources and descriptive statistics for the variables used in the empirical analysis.

Variable	Description	Source	Mean	Standard Deviation
Price	Transaction price in the year 2005 in euros	NVM	254,522.33	141,377.12
<b>Structural characteristics</b>				
Floor area	Size of living area of the house (m <sup>2</sup> )	NVM	120.24	49.51
Volume	Volume of the house (m <sup>3</sup> )	NVM	353.28	220.34
Detached	Dummy variable: equals 1 if the house is detached	NVM	0.08	0.27
Semi-detached	Dummy variable: equals 1 if the house is semi-detached	NVM	0.10	0.31
Terraced	Dummy variable: equals 1 if the house is a terraced house	NVM	0.46	0.50
Apartment	Dummy variable: equals 1 if the house is an apartment	NVM	0.36	0.48
Before 1906	Dummy variable: equals 1 if the house was built before 1906	NVM	0.06	0.24
1906-1930	Dummy variable: equals 1 if the house was built in the period 1906-1930	NVM	0.14	0.34
1931-1944	Dummy variable: equals 1 if the house was built in the period 1931-1944	NVM	0.09	0.28
1945-1959	Dummy variable: equals 1 if the house was built in the period 1945-1959	NVM	0.08	0.26
1960-1970	Dummy variable: equals 1 if the house was built in the period 1960-1970	NVM	0.15	0.36
1971-1980	Dummy variable: equals 1 if the house was built in the period 1971-1980	NVM	0.15	0.36
1981-1990	Dummy variable: equals 1 if the house has been built in the period 1981-1990	NVM	0.14	0.35
After 1990	Dummy variable: equals 1 if the house was built after 1990	NVM	0.20	0.40
Central heating	Dummy variable: equals 1 if the house has central heating	NVM	0.92	0.27
Garage	Dummy variable: equals 1 if the house has a garage	NVM	0.20	0.40
Garden	Dummy variable: equals 1 if the house has a garden	NVM	0.56	0.50
<b>Neighbourhood characteristics</b>				
Ethnic minorities	Fraction of inhabitants of non-western origin in the ZIP-code area (4-digit) of the house	CBS	0.12	0.11
Population-density	Number inhabitants per km <sup>2</sup> in the postcode area (4-digit) of the house	CBS	5,361.07	3,935.07
Distance to highway exit	Distance, by road, from the house to the nearest highway exit (in metres)	NWB	3,993.81	2,548.18
Distance to railway station	Straight-line distance from the house to the	NS	3,142.00	3,279.79

	nearest railway station (in metres)			
Job accessibility	Minimum distance (circle radius) within which a total of 100,000 jobs can be reached (in metres)	RPB/LS	8,492.26	4,511.54
North-Brabant	Dummy variable: equals one if the house is located in the Province of North-Brabant	NVM	0.27	0.44
<b>Industrial site characteristics</b>				
Distance to industrial site	Straight-line distance from the house to the boundary of the nearest industrial site (in metres)	IBIS	784.39	606.72
Gross area	Gross area of the nearest industrial site (in hectares)	IBIS	34.02	58.45
Regular industrial site	Dummy variable: equals 1 if the nearest industrial site concerns a miscellaneous or high-tech site	IBIS	0.93	0.27
Heavy industrial site	Dummy variable: equals 1 if the nearest industrial site concerns a heavy industry site, sea harbour or transport site	IBIS	0.07	0.27

Notes: The abbreviations stand for: CBS - Statistics Netherlands; IBIS - Dutch Industrial Sites Database; LS - Land Use Scanner; NS - Dutch Railways; NVM - Dutch Association of Real Estate Agents; NWB - National Road Database; RPB - Netherlands Institute for Spatial Research. The sample size is 70,864 observations.

## APPENDIX B

This Appendix derives the characteristics of the logistic specification for the partial relationship between house prices and distance to the closest industrial sit. We start from the basic function:

$$F(D_j) = \eta_1 \frac{e^{\eta_2 + \eta_3 \ln D_j}}{1 + e^{\eta_2 + \eta_3 \ln D_j}} = \frac{\eta_1 e^{\eta_2} D_j^{\eta_3}}{1 + e^{\eta_2} D_j^{\eta_3}}. \quad (\text{B.1})$$

The first-order derivative of this function ( $F$ ) with respect to distance ( $D$ ) equals:

$$F'(D_j) = \frac{\eta_1 \eta_3 e^{\eta_2} D_j^{\eta_3 - 1}}{(1 + e^{\eta_2} D_j^{\eta_3})^2}, \text{ so } F'(D_j) > 0 \text{ if } \eta_1 \cdot \eta_3 > 0. \quad (\text{B.2})$$

The second-order derivative equals:

$$F''(D_j) = \frac{(1 + e^{\eta_2} D_j^{\eta_3}) D_j^{\eta_3 - 1} e^{\eta_2} \eta_3 \eta_1}{(1 + e^{\eta_2} D_j^{\eta_3})^4},$$

$$\text{so } F''(D_j) = 0 \text{ if } D_j^* = \left( \frac{\eta_3 - 1}{e^{\eta_2} (1 + \eta_3)} \right)^{1/\eta_3}. \quad (\text{B.3})$$

For  $0 < D_j < D_j^*$ ,  $F(D_j)$  is an increasing convex function of  $D_j$ , if  $\eta_3 > 0$ . For  $D_j^* < D_j < \infty$ ,  $F(D_j)$  is an increasing concave function of  $D_j$ , if  $\eta_3 > 0$ .

## NOTES

<sup>1</sup> Five categories of industrial sites have been defined: 'heavy-industry', 'sea-harbour', 'miscellaneous', 'high-tech', and 'transport'. This typology of industrial sites, as defined by IBIS, is associated with the nature of the industrial site concerned.

<sup>2</sup> See, for example, Zeiss (1999) who analyses the results of 69 studies dealing with the negative effects of industrial facilities on their direct vicinity.

<sup>3</sup> In general, an industrial site can be considered as a collective location for the establishment of firms (Bak, 1985).

<sup>4</sup> Sites that are designated exclusively for offices are not covered by this definition.

<sup>5</sup> The Randstad region comprises the following areas: the Province of North-Holland (excluding Alkmaar and surrounding area and the northern part of North-Holland) and the Provinces of South-Holland and Utrecht. We refer to Rietveld and Wagtenonk (2004) for more details about regional definitions.

<sup>6</sup> The examined area originally comprised 1,718 industrial sites. Information on the 'type of industrial site' is only available for 1,201 sites. We eliminated from the sample those houses that are closest to an industrial site but for which no information on the type of industrial site is available.

<sup>7</sup> An industrial site is defined as 'a location which the land-use plans deem suitable for activities in the branches of commerce, manufacturing, commercial services, industry, and whose original design is larger than one hectare'.

<sup>8</sup> Heavy-industry sites are industrial sites on which it is intended to establish highly undesirable facilities in terms of environmental nuisance (e.g. landfills, demolition dumps, waste sites, hazardous manufacturing facilities, etc.). Sea-harbours comprise large-scale sites featuring freight

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4 facilities for maritime shipping activities. Miscellaneous sites are commonly seen as regular  
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6 industrial sites which include a large variety of activities (ranging from small to medium  
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8 polluting activities), on the condition that these sites may not be categorized as high-tech or  
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10 transport. High-tech sites are sites which are developed for high-tech production activities and  
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12 R&D-activities. Transport is characterized by a dominant presence of logistics and wholesale  
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14 activities.  
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19 <sup>9</sup> NVM real-estate agents deal with approximately 70 per cent of all property transactions in the  
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21 Netherlands.  
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24 <sup>10</sup> These data sets have been provided by SPINLab, VU University Amsterdam.  
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27 <sup>11</sup> Rents are controlled in the Netherlands, implying that their values are determined by a  
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29 restricted system of points that highly disregards neighbourhood characteristics. We therefore do  
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31 not take into account rented housing in our analysis.  
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34 <sup>12</sup> Gross area is defined as the total area designated as the industrial site, including the area which  
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36 is used for infrastructure, water, green space and other forms of public open space.  
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39 <sup>13</sup> Details are available on request.  
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42 <sup>14</sup> Our results may be biased due to a possibly negative correlation between distance to the  
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44 industrial sites and distance to, for example, public goods provided in the city centre. This  
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46 problem becomes more severe if many industrial sites are located in the urban fringe. This bias is  
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48 likely to be limited in our case because (i) our sample comprises both inner-city industrial sites  
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50 and fringe sites (e.g. greenfield sites); and (ii) we control in our empirical analysis for a range of  
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52 characteristics of city-centres that may positively affect house prices, thus reducing the bias due  
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54 to an omitted variable (viz. distance to 'goods' typically provided in city centres such as railway  
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<sup>15</sup> Concerning the impact of the age of the dwelling on house prices, alternative models have been estimated by applying a linear and a quadratic specification for the year of the transaction. The estimated coefficients are consistent with the general findings, regarding sign as well as statistical significance of the estimated effects. Details are available on request.

<sup>16</sup> The representative property is defined as the hypothetical property for which all explanatory variables (viz. attributes of the property), except for the distance to the industrial site, are set at their respective means.

<sup>17</sup> The adjusted  $R^2$  of both models is 0.774. The Akaike's Information Criterion (AIC) for the respective models equals  $-0.251$  for the piecewise model, and  $-0.250$  for the logistic model. The model with a lower AIC is typically preferred.

<sup>18</sup> The estimation results of the other models which are related to the interaction between site size and distance are available on request.

<sup>19</sup> Sampling along the spatial dimensions concerned creates data sets consisting of the following number of observations:  $<500$ :  $N=27,711$ ;  $<1,000$ :  $N=50,660$ ;  $<1,500$ :  $N=62,485$ ;  $<2,000$ :  $N=67,600$ . The estimation results related to this sensitivity analysis are available on request.

<sup>20</sup> Sampling along the regional dimensions concerned creates data sets consisting of the following number of observations: Randstad:  $N=51,689$ ; North-Brabant:  $N=18,995$ .

<sup>21</sup> This has been confirmed by running an alternative regression (OLS) using the natural logarithm of distance. The regression yields statistically significant estimates of the log of distance (at the 1 per cent significance level). Estimation results are available on request.

<sup>22</sup> The additional models comprise four basic regression runs per region for different compositions of the samples: a sample with only small sites ( $<35$  ha.), a sample with only large

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sites (>35 ha.), and samples with only heavy and non-heavy sites, respectively. The estimation results are available on request.

<sup>23</sup> The estimation results are available on request.

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Table 1. Estimation results of the hedonic price function for the Randstad and North-Brabant in 2005 using a piecewise specification of distance

Variable	Coefficient	t-statistic
Constant	9.649***	(260.4)
Structural characteristics ( $S_k$ )		
Ln Floor area (m <sup>2</sup> )	0.391***	(29.1)
Ln Volume (m <sup>3</sup> )	0.407***	(29.4)
Detached	0.275***	(46.0)
Semi-detached	0.128***	(27.4)
Terraced	-0.022***	(-7.0)
Year of construction (<1906)	-0.008*	(-1.7)
Year of construction (1906-1930)	-0.086***	(-24.2)
Year of construction (1931-1944)	-0.126***	(-32.1)
Year of construction (1945-1959)	-0.157***	(-42.9)
Year of construction (1960-1970)	-0.175***	(-71.6)
Year of construction (1971-1980)	-0.155***	(-65.8)
Year of construction (1981-1990)	-0.099***	(-41.7)
Central heating	0.081***	(21.9)
Garage	0.094***	(36.0)
Garden	-0.000	(-0.0)
Neighbourhood characteristics ( $N_l$ )		
Ethnic minorities (fraction population)	-0.644***	(65.3)
Ln Population-density (inhabitants per km <sup>2</sup> )	-0.021***	(-16.2)
Ln Distance to 100,000 jobs (in metres)	-0.096***	(-51.4)
Ln Distance to highway exit (in metres)	-0.019***	(-12.7)
Ln Distance to railway station (in metres)	-0.012***	(-13.0)
North-Brabant regional dummy	-0.137***	(-72.9)
Industrial site characterises ( $I_m$ )		
Ln Gross area of nearest industrial site	-0.012***	(-19.1)
Heavy industrial site dummy	0.117***	(30.6)
Distance ( $D_n$ )		
0-250	-0.149***	(-21.4)
250-500	-0.139***	(-20.1)
500-750	-0.122***	(-17.5)
750-1000	-0.109***	(-15.5)
1000-1250	-0.103***	(-14.2)
1250-1500	-0.087***	(-11.5)
1500-1750	-0.051***	(-6.3)
1750-2000	-0.034***	(-3.9)
2000-2250	-0.004	(-0.4)
Adjusted $R^2$	0.774	
Number of observations	70,684	

Notes: The equation also contains month of sale (full estimation results are available on request); White  $t$ -values are given in parentheses; \*\*\* Significant at the 1% level; \* Significant at the 10% level.



Table 2. Estimation results of the hedonic price function for the Randstad and North-Brabant in 2005 using a logistic specification of distance

Variable	Coefficient	t-statistic
Constant	9.506***	(261.7)
Distance ( $D_j$ )		
$\eta_1$	0.169***	(8.8)
$\eta_2$	-18.445***	(-10.7)
$\eta_3$	2.516***	(9.6)
Adjusted $R^2$	0.774	
Number of observations	70,684	

Notes: Only the estimation results referring to the effect of distance are reported (full estimation results are available on request); White t-values are given in parentheses; \*\*\* Significant at the 1% level.

Table 3. Estimation results of the hedonic price function for the Randstad and North-Brabant in 2005, using a logistic specification of distance: the interaction effect between distance and industrial site size

Variable	Coefficient	t-statistic
Constant	9.511 <sup>***</sup>	(261.7)
Size of nearest industrial site Ln Gross area	-0.013 <sup>***</sup>	(15.6)
Distance		
$\eta_1$	0.147 <sup>***</sup>	(7.5)
$\eta_2$	-17.700 <sup>***</sup>	(-10.6)
$\eta_3$	2.419 <sup>***</sup>	(9.4)
Interaction distance and size		
$\phi_1$	0.008 <sup>**</sup>	(2.3)
Adjusted $R^2$	0.774	
Number of observations	70,684	

Notes: Only the estimation results referring to the (interaction) effects of distance are reported (full estimation results are available on request); White  $t$ -values are given in parentheses; \*\*\* Significant at the 1% level; \*\* Significant at the 5% level.

Table 4. Estimation results of the hedonic price function for the Randstad and North-Brabant in 2005, including municipality dummies

Variable	Coefficient	<i>t</i> -statistic
Constant	9.510 <sup>***</sup>	(232.6)
Distance ( $D_j$ )		
$\eta_1$	0.186 <sup>***</sup>	(2.7)
$\eta_2$	-13.006 <sup>***</sup>	(-8.0)
$\eta_3$	1.653 <sup>***</sup>	(5.8)
Adjusted $R^2$	0.839	
Number of observations	70,684	

Notes: Only the estimation results referring to the effect of distance are reported (full estimation results are available on request); White *t*-values are given in parentheses; \*\*\* Significant at the 1% level.

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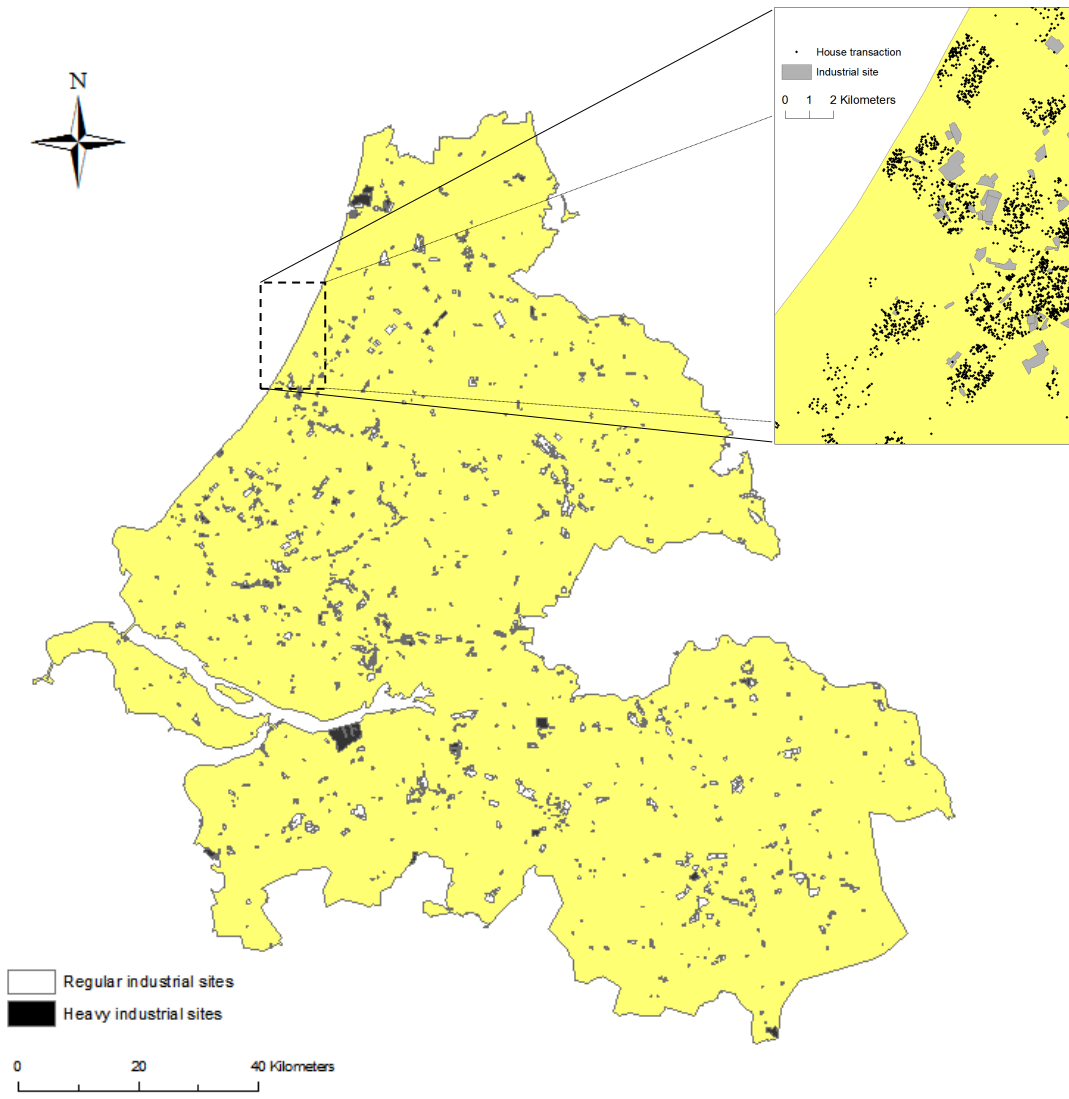


Fig. 1. Distribution of industrial sites in the Randstad and North-Brabant, 2005

Source: Dutch Industrial Sites Database (IBIS)

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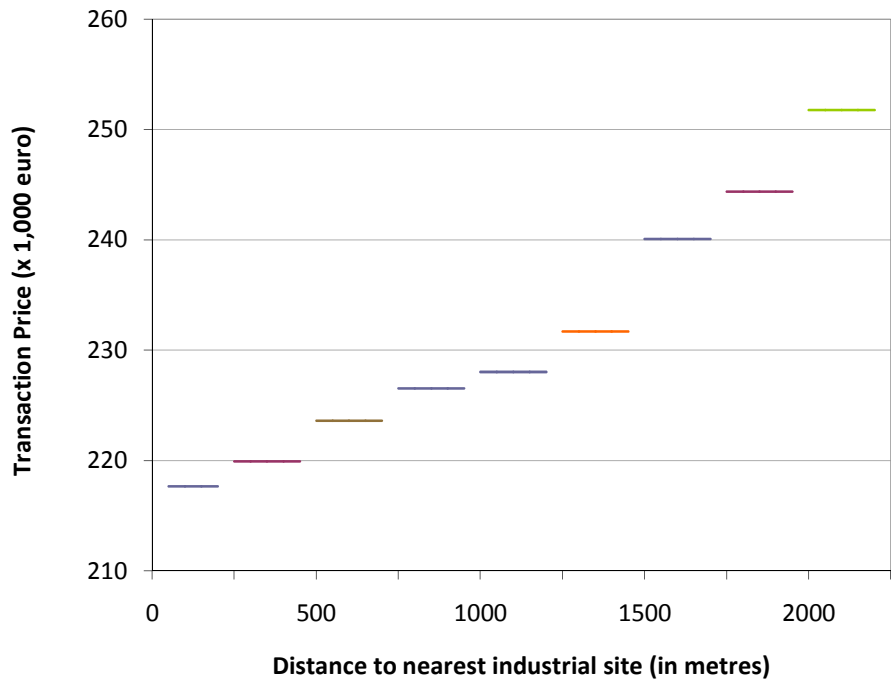


Fig. 2. Transaction price gradient function for a representative property

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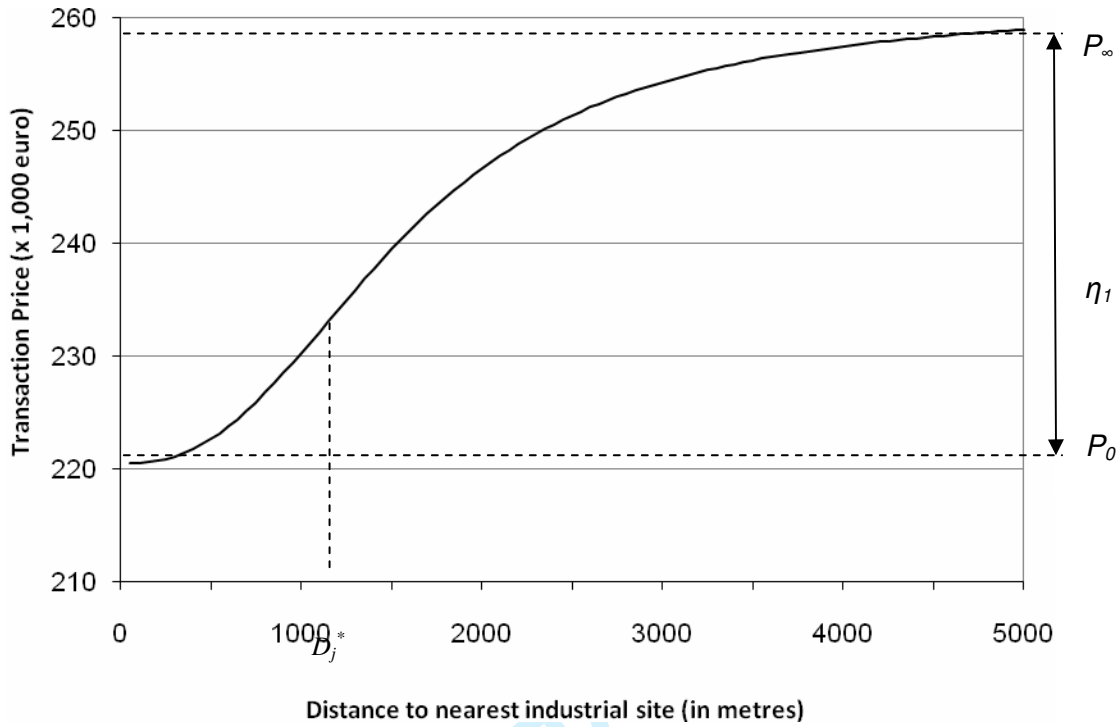


Fig. 3. Transaction price gradient function for a representative property

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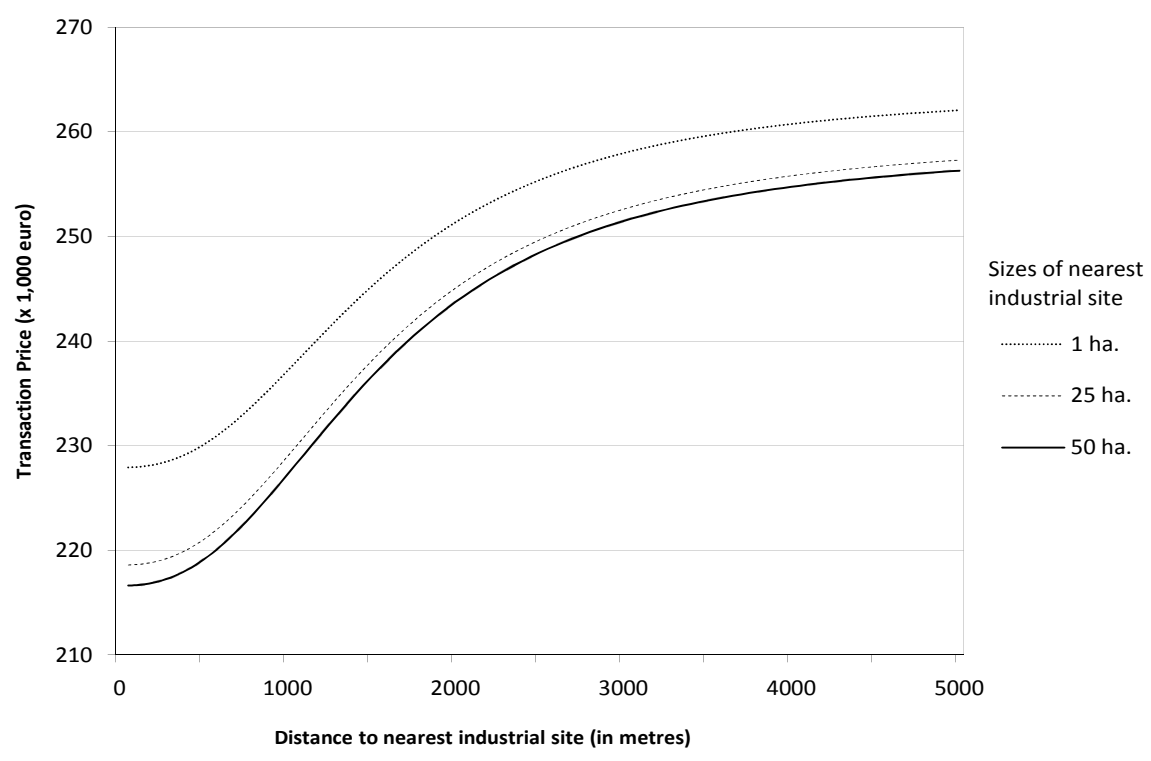


Fig. 4. Transaction price gradient functions for various different site sizes

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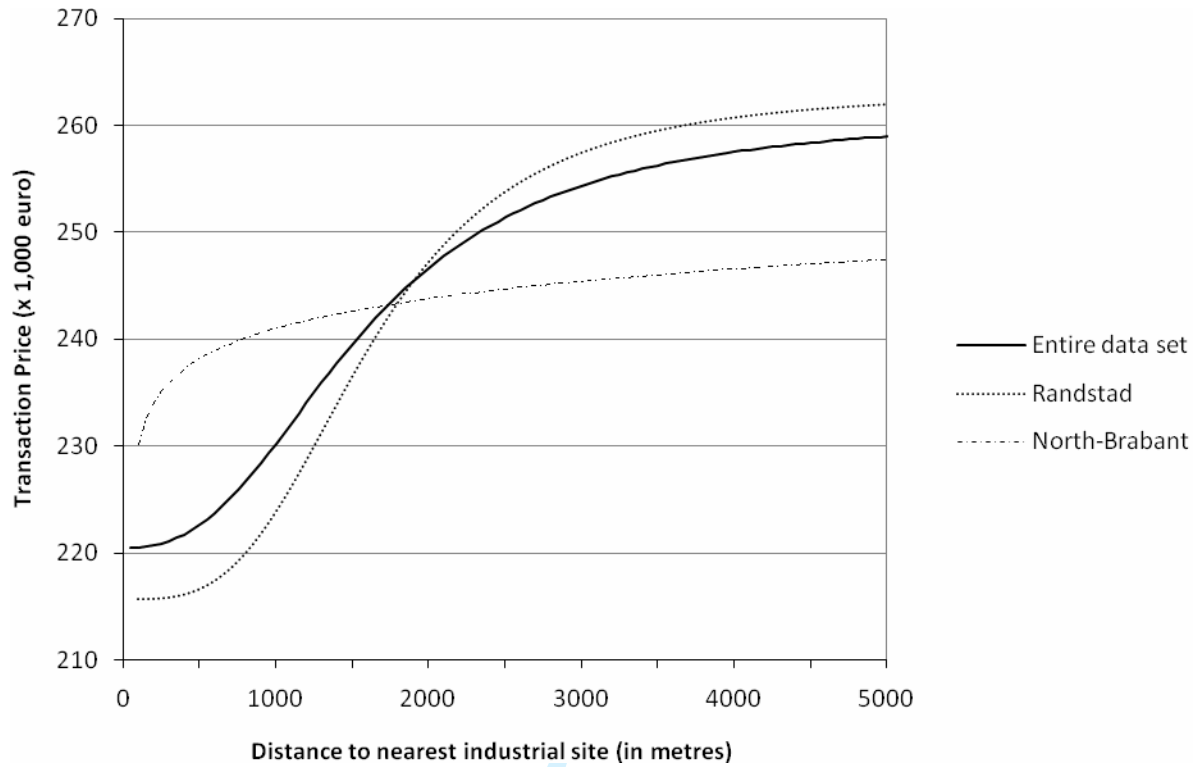


Fig. 5. Transaction price gradient functions for different regional samples