University of Groningen

Redevelopment of Industrial Heritage: Insights into External Effects on House Prices

van Duijn, Mark; Rouwendal, Jan; Boersema, Richard

Published in:
Regional Science and Urban Economics

DOI:
[10.1016/j.regsciurbeco.2016.02.001](https://doi.org/10.1016/j.regsciurbeco.2016.02.001)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2016

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

van Duijn, M., Rouwendal, J., & Boersema, R. (2016). Redevelopment of Industrial Heritage: Insights into External Effects on House Prices. *Regional Science and Urban Economics*, 57, 91-107.
<https://doi.org/10.1016/j.regsciurbeco.2016.02.001>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Redevelopment of industrial heritage: Insights into external effects on house prices

Mark van Duijn^{a,b,c,*}, Jan Rouwendal^{a,c,d}, Richard Boersema^a

^a Department of Spatial Economics, Faculty of Economics and Business Administration, VU University, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands

^b Department of Economic Geography, and Population Research Centre, Faculty of Spatial Sciences, University of Groningen, Landleven 1, 9747 AD Groningen, The Netherlands

^c Tinbergen Institute, Gustav Mahlerplein 117, 1082 MS Amsterdam, The Netherlands

^d Amsterdam School of Real Estate, Jollemanhof 5, 1019 GW Amsterdam, The Netherlands

ARTICLE INFO

Article history:

Received 9 September 2014

Received in revised form 25 January 2016

Accepted 4 February 2016

Available online 13 February 2016

JEL classification:

C21

D62

H43

R0

Keywords:

Industrial heritage

Redevelopment

Urban revitalization

External effects

Hedonic prices

ABSTRACT

Local policy makers seek ways to deal with abandoned industrial heritage in their jurisdictions. Many are demolished, but in some cases considerable investments are made to preserve the cultural aspects of industrial sites. The renewal plans are usually designed to stimulate urban renewal in the vicinity of these sites. Little seems to be known about the effectiveness of these policies. In this paper, we study whether the redevelopment of 36 industrial heritage sites in The Netherlands caused positive external effects by investigating the development of house prices in nearby residential areas. We use a difference-in-difference design by comparing quality-adjusted house prices in a predefined target and control area before the start, between the start and the completion and after the completion of the redevelopment. We also model the spatial and temporal dimensions of these external effects. We find that these dimensions matter substantially. We find that negative externalities on house prices before the start completely disappear after the start of the redevelopment of industrial heritage sites. We also find evidence for positive and local effects on house prices after the completion, but this result disappears when we remove the projects located in the largest cities.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Many manufacturing firms left the urban sites in which they located in the 19th or early 20th century. As a result, most industrial sites lost their original function and got abandoned. Policy makers search to deal with the unused land. Local policy makers can decide to 1) leave it as it is, 2) demolish the existing buildings and redevelop the land, or 3) renovate the existing buildings while simultaneously making them suitable for new functions. The last alternative is especially attractive when the existing buildings have heritage value. The idea to renovate old factories became popular in connection with Jacobs's (1961) suggestion that new ideas need old buildings and, later, Florida's (2002) creative city concept. Many policy makers now believe that renovation of an abandoned industrial site is a tool to upgrade neighborhoods by attracting higher educated residents, firms from the creative sector and tourists. There are many examples of such redeveloped industrial heritage sites throughout the world: well-known examples include the former power plant site, Erie, PA, US; Rheinauhafen, Cologne,

Germany; King's Cross, London, UK; Kings Waterfront, Liverpool, UK; Gasometers, Vienna, Austria. In The Netherlands only, we have identified 69 redevelopment projects that are finished or in progress, which involves redeveloping industrial heritage sites which have lost their original function, and many more projects are planned.¹

It seems plausible that the redevelopment of industrial heritage has a positive (external) effect on the living environment of surrounding residential areas, as is often argued by policymakers.² However, the evidence underlying this opinion is often limited to impressions and references to well-known examples that are generally considered as *success stories*. There does not appear to exist much research that underlies this opinion. Maliene et al. (2012) argue, based on descriptive statistics, that the redevelopment of these brownfield sites has the potential to promote the urban renaissance. They state that these redeveloped brownfield sites attract people, predominantly for the retail and leisure

* Corresponding author.

E-mail address: mark.van.duijn@rug.nl (M. van Duijn).

¹ An overview of these redevelopment projects can be found at <http://www.kennisbankherbestemming.nu/>. After deleting some of the projects, we end up with 36 projects which are investigated in this paper. The reasons for deleting projects can be found in Section 2.

² For example, see SBR and Aedes (2010) or CPB and PBL (2010).

facilities and the attractiveness of the location. They also warn local policy makers that each brownfield site is unique and that there is no 'one-size-fits-all' recipe for success. However, their study lacks detailed empirical research to provide evidence on these matters. More attention has been given to the redevelopment of brownfield sites in general; see e.g. Linn (2013). Linn (2013) focuses on the certification that owners of such sites are not subject to federal or state liability for contamination of these sites. Our attention is more focused on the heritage aspects and the associated potential of generating external effects.

In this paper we present an analysis of the impact of 36 renovation projects in The Netherlands concerning industrial heritage on house prices in the surrounding neighborhoods. The focus of interest will be on the measurement of the external effects and the possible existence of general properties of these effects, for instance on the spatial and temporal dimensions.

Our paper contributes to the economic literature that investigates urban revitalization policies (e.g. Ahlfeldt et al., 2013b; Brooks and Phillips, 2007; Koster and Van Ommeren, 2013; Rossi-Hansberg et al., 2010; Koster and Rouwendal, 2015). Most of this literature is focused on investments in housing and living quality of a specific target area. The present paper is different in many ways. We study the impact of investments in industrial heritage and not directly into housing. We distinguish between external effects on house prices of nearby residential areas occurring before the start of the redevelopment, between the start and the completion, and after the completion of the redevelopment of industrial heritage. We use a difference-in-difference hedonic approach to investigate whether there are indeed external effects caused by the industrial heritage and how large those effects are on house prices of nearby residential areas. We pay special attention to defining the target and control area. This study aims at providing more insights in the possible external effects of industrial heritage sites before and after their redevelopment. Measurement of the size of these external effects clearly provides important information for local policy makers who decide whether and how to redevelop used land.

This paper is also connected to a larger, more general, stream of literature that investigates the value of urban amenities (e.g. Ahlfeldt, 2011; Brueckner et al., 1999; Carlino and Coulson, 2004; Chen and Rosenthal, 2008; Cheshire and Sheppard, 1995; Ioannides, 2003). This literature argues that urban amenities have become increasingly important to the attractiveness of the urban areas and that especially higher educated households are attracted to the city center. This phenomenon is argued to be the driving force behind the economic prosperity of cities (Carlino and Saiz, 2008; Glaeser et al., 2001).

We collected data of 36 industrial heritage sites and we compare house prices in a time window that includes the redevelopment period. We make use of a rich dataset of housing transactions and structural characteristics of the sold residential properties provided by the *Dutch Association of Real Estate Agents* (NVM) that covers the period 1990 to 2011. Our general findings suggest that prior to the redevelopment negative external effects are present, but they disappear when the redevelopment starts. This also implies that there are anticipation effects. Positive external effects are present, but they disappear when we exclude the redevelopment projects located in the larger cities.

The remainder of this paper is organized as follows. [Section 2](#) provides some theoretical background on external effects and a brief description on the projects of redeveloped industrial heritage sites. [Section 3](#) introduces the methodology used in our analysis. The data and some descriptive statistics are presented in [Section 4](#). Estimation results are reported and discussed in [Section 5](#). The paper ends with a summary of the key findings and conclusions.

2. Background

This section provides some theoretical background on external effects and briefly describes the Dutch projects of industrial heritage redevelopment that are investigated in this paper.

2.1. Theoretical background

Existing buildings deteriorate over time if they are not maintained properly. Since maintenance decisions are often spatially correlated, the quality of the whole neighborhood may decrease over time. There is a large stream of literature investigating the depreciation (and renewal) of urban areas (e.g. Brueckner and Rosenthal, 2009; Coulson and Bond, 1990; Harding et al., 2007; Rosenthal, 2008; Smith, 2004). Abandoned industrial sites are often large and may well have a negative impact on the neighborhoods in which they are located and become a disamenity for the nearby residential areas. In this paper we focus on industrial sites with cultural, historic aspects that policy makers prefer to preserve. Investments made in the renewal of such industrial heritage sites, are primarily focused on preserving the heritage value. It is often the case that the real estate of industrial heritage sites are listed built monuments, which implies that, in the interest of preserving the heritage value, it is not allowed to make significant changes to the exterior of the real estate. The listed status implies that the site is eligible for subsidies to restore and maintain the building, which are usually a substantial part of the investments in industrial heritage. Restoration transforms a dilapidated building into a bright one and this may reasonably be expected to have a positive impact on the quality of the surrounding neighborhood.

Apart from the real estate itself, the redevelopment of the rest of the industrial site could be expected to generate additional external effects. For instance in The Netherlands, large parts of these sites are often transformed into public green, which used to be scarce in the 19th and early 20th century neighborhoods where most of these sites are located.

In this paper, we investigate three types of external effects on house prices. First, we investigate whether the industrial heritage site was a disamenity for the nearby residential area before the start of the redevelopment. It might be that the presence of the industrial heritage site generates negative external effects on house prices and that this negative effect changes over time and space. Second, we check for anticipation effects between the start and the completion of the redevelopment project. One could argue that households anticipate house prices to increase nearby these industrial heritage sites that will be redeveloped. Third, we investigate whether the investments made in industrial heritage sites generate positive external effects on house prices of nearby houses. It is expected that positive externalities emerge if 1) the redevelopment contains significant (positive) changes in the exterior of the industrial heritage site, like building attractive new residential houses or creating parks on the industrial terrain, or if 2) the redevelopment replaces a disamenity, like abandoned buildings and contaminated soil.³

2.2. Selection of the redeveloped industrial heritage sites

In the last decades there have been many redevelopment projects in The Netherlands. More than a quarter of these projects – 69 in total – involve industrial sites with some kind of heritage value. The redevelopment projects for industrial heritage sites are spread over the country but most can be found in the western part of The Netherlands – also known as the *Randstad* – where around 80% of the economic activity takes place. Decisions to redevelop these industrial heritage sites were taken independently from each other by local governments and real estate investors. In each of the projects, the focus was on the preservation of the historical value of the sites. Especially these projects in the larger cities in The Netherlands received both local and national media attention.

A number of redevelopment projects were not included in our analysis for several reasons. First, we dropped 26 projects because they are

³ For a more extensive overview on the different kind of external effects caused by (housing) investments, see Schwartz et al. (2006).

not finished yet. The redevelopment of industrial heritage sites takes on average three years from start to completion, but there is some variation which depends on the details of the redevelopment (e.g. the redevelopment takes longer if the soil is contaminated or there is a lot of real estate that needs to be renovated). We use 12 of these 26 projects – only the ones that did not start the redevelopment before 2009 – to do a falsification exercise that will be discussed in Section 4. Second, we dropped an additional 7 projects because these industrial sites were not located near residential areas. Hence, we do not observe enough housing transactions before, between and after the redevelopment within 1 km. This leaves us with 36 projects which were all included in the analysis. Fig. A.1 in Appendix A shows a map with the locations of these industrial sites that are used in the analysis.

3. Methodology and data

In this paper, we investigate the external effects that influence house prices in surrounding residential areas before, between the start and completion, and after the completion of the redevelopment of 36 industrial heritage sites in The Netherlands. By definition, externalities do not have observable market prices. The value attached to them must therefore be measured in an indirect way. We use house prices in the vicinity of the sites for that purpose, and therefore have to face the challenge that it is not obvious which areas may have received an external effect of the redevelopment and how to disentangle it from other influences that acted simultaneously on the housing price. We therefore pay careful attention to defining the target and control area. Nearby houses get ‘treatment’ in the sense that the prices of these houses have possibly been influenced by the external effects from the redevelopment of an industrial site. These nearby houses are then in the ‘target’ group, but it is not a priori obvious what is nearby and what is not. In this section, we present our baseline empirical framework and a description of the data.

3.1. Empirical framework of the baseline specification

We start with the standard hedonic framework of Rosen (1974). We observe transaction prices, year of transaction, location of the sold house, distance to the industrial heritage site, various housing characteristics, and some neighborhood characteristics. The most straightforward approach to identify external effects would be to regress the prices on the distance to the nearby industrial heritage site and the interaction between the year of redevelopment of the industrial heritage site and the distance, controlling for housing characteristics, such as floor area and number of rooms, and neighborhood characteristics, such as population density and share of migrants. If there are any external effects caused by the redevelopment of industrial heritage sites, one would expect a significant result on the interaction variable. However, this approach has important shortcomings. First, this model does not account for possible anticipation effects. Second, this approach leads to one coefficient that captures the external effect, which is then an average (linear) effect depending on the average distance to the redeveloped industrial heritage site. Third, it is likely that there are more forces that influence house prices and, when unobserved, they may cause omitted variable bias.

To address these problems, we use and extend the model specification that is developed by Schwartz et al. (2006). Schwartz et al. (2006) specify a model to identify external effects caused by housing investments. In our case, the investments in industrial heritage sites are investigated. The baseline specification – closely related to Schwartz et al. (2006) – is defined as:

$$\ln(P_{ijt}) = \sum_{s=1}^S \alpha_s R_{itrs} + \sum_{s=1}^S \theta_s R_{itrs} D_i + \sum_{s=1}^S \varphi_s R_{itrs} D_i^2 + \sum_{k=1}^K \beta_k X_{kit} + \gamma_t Y_t + \pi_j N_j + \varepsilon_{it}, \quad (1)$$

where P_{ijt} is the house price transactions of property i that is located in neighborhood j at transaction year t ; R_{itrs} is a vector of ring variables s , that depend on where property i is located, the year of transaction t , the treatment radius r (described in more detail below); D_i is the Euclidean or ‘crow’ distance in meters from the sold property to the industrial heritage site; X_{kit} are structural characteristics k of property i sold in year t , which are described in Section 4; Y_t a vector of dummy variables taking one for year t and zero otherwise; N_j is a neighborhood dummy variable taking one for neighborhood j and zero otherwise; ε_t is an idiosyncratic error term. α_s , θ_s , φ_s , β_k , and γ_t are parameters to be estimated. Note that we include all redevelopment projects. We also control for neighborhood and time fixed effects.⁴

We specify five different ring variables (R_{itrs}). These variables allow us to capture the external effect of redeveloping industrial heritage sites. First, we include a distance ring dummy ($s = \text{BEFORE}$) if the location of property i falls within the treatment radius r . The coefficient of the BEFORE dummy can (eventually) be interpreted as the (negative) external effect of the abandoned industrial heritage site before redevelopment. Second, we include a variable ($s = \text{TREND BEFORE}$) that calculates the time difference between the transaction and the start of the redevelopment if the property is sold before the start of the redevelopment. This variable captures the (linear) trend effects before the start of the redevelopment. Third, we include a dummy ($s = \text{BETWEEN}$) if the location of property i falls within the treatment radius r and the transaction year of the sold property is between the start and the completion of the redevelopment. The BETWEEN dummy picks up some of the anticipation effects.⁵ Fourth, we include a dummy ($s = \text{AFTER}$) if the location of property i falls within the treatment radius r and the redevelopment year of the sold property is after the completion of the redevelopment. This is the main variable of interest showing whether there are external effects after the redevelopment is complete within the treatment radius. Finally, we include a variable ($s = \text{TREND AFTER}$) that captures the time difference between the transaction and the completion of the redevelopment if the criteria of the AFTER dummy is met. This allows us to check whether the degree of the external effects changes (linearly) over time.

Each of these distance ring variables are also interacted with the distance to the industrial heritage site, D (in meters), which allows for a spatial component that measures the distance decay of the external effects. We also include the quadratic form of the distance variable to see whether the distance decay is linear, concave or convex.⁶

3.2. Target groups

The target group is defined as those sold houses that received treatment. A sold house receives treatment if the house is within a certain distance (treatment radius) to the redeveloped industrial heritage site and the transaction year is equal or larger than the redevelopment year.

Let us first discuss the distance. Since it is *ex ante* difficult to predict the extent of the external effect – if there is any – we define different areas that are targeted. We start with a treatment radius of 1 km. This assures us that there are no sold houses in the control group that receive treatment. We use the baseline specifications – and later on, robustness checks – to investigate the decay of the external effect over space. Using this strategy, we let the data and our model specifications tell us what the reach of the external effects are and their distance decay.

It is also not always easy to identify the exact redevelopment year for most of the industrial heritage sites. The redevelopment process of

⁴ This implies that we control for all neighborhood characteristics in the target and control area that remain constant over time and for any common trend in the house prices.

⁵ It is likely that the anticipation effect started before the start of the redevelopment project. However, given our data, it is difficult to account for earlier anticipation effects. In this way, we let the data decide whether there are anticipation effects when the redevelopment is in progress looking at the significance of the estimators.

⁶ We also used higher-order polynomials for the interactions with distance. These higher-order polynomials were found to be insignificant.

industrial heritage sites is often phased and different parts of the redevelopment process finish at different moments in time. For our 36 cases, we investigated the redevelopment period carefully and chose to treat the moment that the redevelopment of the real estate was finished as the year of redevelopment and account for some of the anticipation effects by using the moment that the redevelopment started as the start of the redevelopment.

This already covers part of the problem that is often present in these types of research. Namely, households should be able to anticipate to changes in their neighborhood. In a world where there is perfect information and no mobility costs, households are likely to anticipate the upcoming changes to the industrial heritage sites. What happens is that if households know the neighborhood will improve in the near future, the neighborhood will possibly become more attractive and, therefore, house prices will increase even before the redevelopment takes place. However, the housing market is more rigid and households often do not have perfect information. In addition, debate on these redevelopment projects by local governments can be complex and often take a lot of time. For example, the idea to transform the Amsterdam *Westergasfabriek* started decades ago but the redevelopment eventually started in 2000. In this paper, we cannot check for all anticipation effects due to data limitations but we do account for the anticipation effect between the start and finish of the redevelopment project. If there are some anticipation effects before the start of the redevelopment period, this will likely cause an underestimate of the measured external effects of the BEFORE variable. The anticipation effects before the start of redevelopment will then be reflected by the coefficient of the TREND BEFORE variable.

3.3. Data and descriptive statistics

We use residential property transaction data provided by the Dutch Association of Real Estate Agents (NVM). This dataset contains a large share (between 60 and 75%) of owner-occupied house transactions in The Netherlands between 1985 and 2011. We have information on the exact location of those houses, the transaction price, and a whole list of structural characteristics of the sold houses, such as floor area (in square meters), the number of rooms, maintenance status, type of house, parking, monument status, year of construction, et cetera. We start with selecting these houses that are within 2 km of the redevelopment projects and were sold between 1990 and 2011. For each of these house we calculate the distance to the nearest industrial heritage site.

Besides the location of the redevelopment industrial site, we want to control for other industrial heritage site characteristics. We include the size of the site and the number of other redeveloped industrial heritage sites within 10 km.

We also collect spatial data to control for time-variant local characteristics.⁷ We use the location of listed built monuments, provided by the RCE Netherlands Cultural Heritage Agency, to calculate the number of listed built monuments per 50 m radius for each sold house. We include this variable in our estimation to account for the special (historic) atmosphere that is provided by a bundle of listed built monuments. In addition, we use some information of the neighborhood.⁸ In The Netherlands, neighborhoods have, on average, around 1500 inhabitants. We include population density, the share of foreign migrants, average household size, and the share of young and elderly people which are provided by Statistics Netherlands. ABF Research has provided us with data on the distance to the nearest

intercity station. Table 1 shows a summary of the descriptive statistics for the variables that we include in our estimation procedure.

4. Results of the baseline specification

In this section, we report the estimation results of the baseline specification of the difference-in-difference hedonic price model. We investigate whether there are external house price effects of redeveloping industrial heritage sites on nearby houses and the magnitude of these external effects over time and space. We report the results of the baseline where the target area is defined as the area within the first 1000 m from the redeveloped industrial heritage site. The control area is defined the area between 1000 and 2000 m. We test our empirical strategy by doing a falsification exercise following Dávila and Mora (2005) and Ratcliffe and Von Hinke Kessler Scholder (2015). That is, we re-estimated our model on a number of abandoned industrial sites where no redevelopment took place. We estimated a few statistically significant coefficients, but they have the expected negative sign and the economic significance of the implied effects is close to zero. Therefore we show that our model performs well. Additional information and results can be found in Appendix B. In Section 5 we do some additional sensitivity analyses where we change the definition of the target and control areas.

4.1. Regression results of the baseline specification

Table 2 reports the key coefficients and standard errors for the baseline model for the 36 industrial heritage redevelopment projects. For the final specifications, the adjusted R^2 is close to 0.9 – as a consequence of including time and location fixed effects – which suggests that the model fit is good with respect to the hedonic price literature (see, for example, Schwartz et al., 2006).

The key variables are BEFORE, BEFORE TREND, BETWEEN, AFTER and AFTER TREND variables from Eq. (1). Column (1) and Column (2) of Table 2 reports the results of a naive hedonic price regression only including the key variables and year fixed effects in Eq. (1) and, in addition, the structural characteristics, building period dummies, and industrial site characteristics in Eq. (2). Column (3) includes neighborhood fixed effects to control for all time-invariant neighborhood characteristics. The negative external effects before the start of the redevelopment are now clearly present. The coefficients of the external effects between the start and the completion and after the completion of the redevelopment are slightly lower. Finally, in Column (4) we add time-variant neighborhood characteristics which show similar signs but lower effects. Let us discuss the results of Column (4) which is our preferred specification.

The main coefficient of the BEFORE variables in Column (4) is negative and significantly different from zero. The results indicate that prior to the start of the redevelopment, houses located next to an industrial heritage site ($TREND = 0$ and $D = 0$) sold for 2.5% ($= (\exp^{(-0.0258)} - 1) * 100$) less than houses between 1000 and 2000 m of the industrial heritage site. This suggests that these former industrial heritage sites were a disamenity for nearby houses before the start of the redevelopment, as is in line with the findings of De Groot and De Vor (2011). However, these results have a substantial lower spatial effect than De Groot and De Vor (2011) who found that the negative external effects had a range of 2 km.⁹

The spatial dimension shows some impact but only for the trend before the start of the redevelopment. The interactions between the BEFORE dummy and distance variables are not significant. This implies that just before the start of the redevelopment the whole target area experienced negative external effects. The trend effect before the

⁷ This is an important shortcoming of many papers. It is difficult to address all time-variant developments (e.g. other local development projects). Also in this paper, such projects are not registered systematically and therefore hard to collect specific information on these projects.

⁸ Neighborhoods (*buurten* in Dutch) in the Netherlands are relatively small areas which are classified by Statistics Netherlands.

⁹ The results are not perfectly comparable because we focus specifically on heritage sites across the Netherlands and De Groot and De Vor (2011) focus on all types of industrial sites in only a part of the Netherlands. In addition, we use a more comprehensive empirical strategy because we are not only interested in the negative external effects.

Table 1
Descriptive statistics (N = 208,305).

	Mean	S.D.	Min.	Max.
<i>Structural characteristics</i>				
Transaction price (in k euros)	179.934	126.946	25	1500
Floor space (in m ²)	105.132	45.695	10	1000
Rooms (#)	3.877	1.415	1	10
Housing type – Apartment (1 = yes)	0.582	0.493	0	1
Housing type – Detached house (1 = yes)	0.039	0.192	0	1
Housing type – Semi-detached house (1 = yes)	0.069	0.253	0	1
Housing type – Corner house (1 = yes)	0.080	0.271	0	1
Balcony (1 = yes)	0.392	0.488	0	1
Terrace (1 = yes)	0.080	0.272	0	1
Parking (1 = yes)	0.140	0.347	0	1
Well-maintained garden (1 = yes)	0.144	0.351	0	1
Bad inside maintenance (1 = yes)	0.152	0.359	0	1
Bad outside maintenance (1 = yes)	0.110	0.313	0	1
Central heating (1 = yes)	0.832	0.374	0	1
Listed built monument (1 = yes)	0.024	0.154	0	1
<i>Building periods</i>				
Building period <1945 (1 = yes)	0.033	0.179	0	1
Building period 1945–1960 (1 = yes)	0.523	0.499	0	1
Building period 1961–1970 (1 = yes)	0.097	0.296	0	1
Building period 1971–1980 (1 = yes)	0.104	0.305	0	1
Building period 1981–1990 (1 = yes)	0.089	0.285	0	1
Building period 1991–2000 (1 = yes)	0.074	0.262	0	1
Building period >2000 (1 = yes)	0.080	0.271	0	1
<i>Industrial heritage site characteristic</i>				
Terrain (in m ²)	107,516	309,396	200	1,200,000
Other redeveloped industrial heritage sites (# within 10 km)	1.003	1.551	0	6
<i>Neighborhood characteristics</i>				
Population density (#/km ²)	7157.600	5146.903	0	29,900
Foreign migrants (%)	12.717	13.395	0	91
Distance to nearest intercity station (m)	2953.341	5400.510	78	39,661
Monuments within 50 m (#)	0.850	3.583	0	41
Average household size (#)	2.274	0.653	0	4
Young people (%)	14.203	5.765	0	35
Elderly people (%)	13.807	8.512	0	88

Note: For the descriptive statistics, we only include sold houses that are within 2 km of our sample of redeveloped industrial heritage sites.

Table 2
Regression results of the baseline specification.

	(1)	(2)	(3)	(4)
Sample size	<2000 m	<2000 m	<2000 m	<2000 m
Target area	0–1000 m	0–1000 m	0–1000 m	0–1000 m
Control area	1000–2000 m	1000–2000 m	1000–2000 m	1000–2000 m
Before	−0.0327 (0.0233)	0.0280* (0.0159)	−0.0329*** (0.0122)	−0.0258** (0.0122)
Before * D	0.000312*** (8.45e-05)	1.82e-05 (5.74e-05)	5.36e-05 (4.17e-05)	4.09e-05 (4.16e-05)
Before * D ²	−3.24e-07*** (7.05e-08)	−7.83e-08* (4.75e-08)	−2.63e-08 (3.38e-08)	−1.86e-08 (3.37e-08)
Trend before	−0.00382 (0.00373)	−0.00858*** (0.00256)	−0.00191 (0.00193)	−0.00269 (0.00191)
Trend before * D	1.74e-07 (1.35e-05)	1.45e-05 (9.24e-06)	1.24e-05* (6.86e-06)	1.37e-05** (6.81e-06)
Trend before * D ²	5.72e-09 (1.12e-08)	−6.35e-09 (7.64e-09)	−1.00e-08* (5.63e-09)	−1.12e-08** (5.58e-09)
Between	0.146*** (0.0292)	0.0416** (0.0193)	0.0408*** (0.0139)	0.0295** (0.0139)
Between * D	−0.000588*** (0.000107)	−0.000274*** (7.04e-05)	−0.000132*** (4.95e-05)	−0.000118* (4.95e-05)
Between * D ²	4.33e-07*** (8.98e-08)	2.39e-07*** (5.86e-08)	9.89e-08** (4.06e-08)	9.50e-08** (4.06e-08)
After	0.180*** (0.0336)	0.0639*** (0.0215)	0.0479*** (0.0153)	0.0317** (0.0153)
After * D	−0.000648*** (0.000125)	−0.000246*** (7.96e-05)	−0.000137** (5.55e-05)	−9.97e-05* (5.54e-05)
After * D ²	4.41e-07*** (1.06e-07)	1.80e-07*** (6.71e-08)	8.65e-08* (4.60e-08)	6.43e-08 (4.60e-08)
Trend after	0.0187*** (0.00616)	−0.00247 (0.00326)	0.00401 (0.00256)	0.00394 (0.00256)
Trend after * D	2.93e-05 (2.41e-05)	5.72e-05*** (1.30e-05)	2.52e-05** (9.92e-06)	2.19e-05** (9.91e-06)
Trend after * D ²	−1.67e-08 (2.10e-08)	−4.20e-08*** (1.14e-08)	−2.52e-08*** (8.60e-09)	−2.28e-08*** (8.58e-09)
Year fixed effects (21)	YES	YES	YES	YES
Structural characteristics (14)	NO	YES	YES	YES
Building period dummies (6)	NO	YES	YES	YES
Industrial site characteristics (3)	NO	YES	YES	YES
Neighborhood fixed effects (643)	NO	NO	YES	YES
Neighborhood characteristics (7)	NO	NO	NO	YES
Observations	208,305	208,305	208,305	208,305
Adjusted R ²	0.369	0.749	0.897	0.898

Note: Dependent variable is ln(transaction price). The coefficients of the control variables for specification (4) can be found in Table C.1 of Appendix C. The other coefficients can be obtained from the author. Robust standard errors are reported between parentheses.

* p < 0.10.

** p < 0.05.

*** p < 0.01.

redevelopment (BEFORE TREND) is also not significant, however, the interactions between the trend and the distance variables are significant. This implies that houses further away from the industrial heritage site experienced lower negative effects from the industrial heritage site and these effects were decreasing over time until the start of the redevelopment. This could indicate that there were some anticipation effects before the start of the redevelopment.

The coefficient that captures a part of the anticipation effect of the redevelopment project, the variable BETWEEN, is significantly different from zero. This implies that the negative external effects that were present before the start of the redevelopment disappeared after the start and that additional positive external effects are observed. This can also be interpreted as part of the anticipation effects. The results show that the spatial dimension matters. We find that the positive external effect between the start and completion of the redevelopment is decreasing non-linearly over space. Estimation results imply a decrease of 1.1%-point ($= (\exp^{(-0.000118 \cdot 100 + 9.50e^{-8} \cdot 100^2)} - 1) \cdot 100$) for the first 100 m and this decrease diminishes over space until the positive effect disappears which is around 300 m.

Next we discuss the presence of external effects within the treatment radius after the redevelopment project is finished. The coefficients of the variable AFTER and TREND AFTER capture this effect on house prices. The main coefficient of AFTER is positive and significant. The TREND AFTER coefficient is positive but not significant. This implies that positive external effects arise immediately after the completion of the industrial heritage site but do not have a general trend effect. The effect is higher than the BETWEEN variable so this implies that the effect was fully not anticipated. The positive external effects decrease over space but this decrease diminishes over time.

4.2. Implications of the baseline results

The top panel of Fig. 1 shows the relative price response over space and for four different periods for the negative external effects before the start of the redevelopment. The bottom line represents the price response of sold houses within 500 m one year before the start of the redevelopment compared to the control group. The top line represents the same thing only now for four years before the start of the redevelopment. The relative price response shows that transaction prices for houses next to the site did not change in the last couple of years. For the houses slightly further away (around 500 m) from the industrial heritage site, these houses were starting to sell for less in the years before the start of the redevelopment. This implies that, at least, policy makers did not choose which industrial heritage site to redevelop only based on transaction prices of sold houses.¹⁰

The bottom panel of Fig. 1 shows the relative price response over space and for four different periods for the effects after the completion of the redevelopment using specification (4). The bottom line represents the price response of sold houses within 500 m one year after the completion of the redevelopment compared to the control group. The top line represents the same thing only now for four years after the completion of the redevelopment. The relative price response shows that the premium for houses next to the redeveloped site did not change after the redevelopment for several years. For the houses slightly further away (around 500 m) from the redeveloped industrial heritage site, these houses were starting to sell for more in the years after the start of the redevelopment. This suggests that the range of the positive external effects increased and that larger parts of the neighborhood perceived the benefits of the redevelopment in terms of higher house prices.

So, summarizing, the spatial results of Table 2 and the graph in Fig. 1 indicate that if external effects are present, these effects are rather local.

¹⁰ However, there might be other factors involved that policymakers use to choose which industrial heritage sites get redeveloped and which do not. If there is selection on what to redevelop and what not, it is likely not based on transaction prices.

This suggests that we could lower the range of our target area – the sold houses that might have experienced external effects from the industrial heritage site. We ran estimations where we set the target area at a radius of 500 m instead of 1000 m and where we did not change the control group. We found similar results.

5. Sensitivity analyses

In this section, we provide additional analyses to investigate the robustness of our results. First, we use a flexible alternative to the baseline specification to focus on the range of the external effects and show its results. Second, we perform a repeated sales analysis. Third, we focus on possible selection issues of the control group. We use standard propensity score matching to find control neighborhoods which are as similar as our target area. Fourth, we do a Chow (1960) test to see whether there are differences in coefficients for redevelopment projects of the largest cities compared to the other cities and villages in The Netherlands.

5.1. Alternative specification

In our baseline specification, we (experimentally) set the treatment radius for our target areas. One can imagine that the range of the external effects before the start, between the start and completion and after the completion of the redevelopment project can differ. In addition, the distance decay is allowed to be linear, concave or convex over the distance to the industrial heritage site. As an even more flexible alternative to the baseline specification, we extend the specification by defining the treatment radius r somewhat differently. We propose to draw 250 m rings within the treatment radius r , which allows us to estimate several treatment coefficients depending on whether the observed sold house is within a certain distance ring from the redeveloped industrial heritage site. In other words, we draw 250 m rings around the redeveloped industrial heritage site where we identify groups of houses that are sold in each distance ring given a certain treatment radius $r_{\max}$, which can be set according to the findings of the baseline specification. This allows us to simply find the reach of the external effect for each redevelopment project. In addition, it allows for a more flexible specification regarding the distance decay function. The alternative specification is then:

$$\ln(P_{ijt}) = \sum_{r=d_1-d_2}^{r_{\max}} \sum_{s=1}^S \alpha_{rs} R_{itrs} + \sum_{k=1}^K \beta_k X_{ki} + \gamma_t Y_t + \pi_j N_j + \varepsilon_{it}, \quad (2)$$

where we do not include the distance as a continuous variable but we estimate separate coefficients for different distance rings. The parameters α_{rs} allow for different house price distributions within the treatment radius and should also capture the external effect of the redeveloped industrial heritage site, but somewhat differently than in the baseline model. The number of observations allows us to use rings of 250 m. This implies that we get a coefficient, α_{rs} , for each distance ring (0 m–250 m, 250 m–500 m, et cetera).¹¹ Together these coefficients define a step function where the impact of the redeveloped site is discontinuous at multiples of 250 m. This specification offers a flexible way to relax the assumption on the homogeneity of the external effect within the treatment radius. However, we do assume that the unobserved (time-variant) forces that could influence house prices between each ring are homogenous. This assumption is more likely to hold with the use of distance rings than when one uses neighborhoods to identify the target and control areas.¹² The other parameters control

¹¹ See the technical appendix of Van Duijn et al. (2014) for a graphical overview of some of the industrial heritage sites.

¹² The omitted variable bias caused by other unobserved investments or developments is likely to be less problematic using small distance rings compared to using neighborhoods. This is evident when the unobserved investments or developments are targeted at neighborhoods. Hence, using distance rings (partially) overcomes this problem.

Fig. 1. Relative price response over space and for different trends before the start of the redevelopment (top panel) and after the completion of the redevelopment (bottom panel). Note: The calculations are based on the coefficients of specification (4) which are at least significantly different from zero on a 90% level, the years (t) before the start or after the completion, and the distance from the nearest industrial heritage site.

for observed structural characteristics, year effects, and unobserved time-invariant neighborhood characteristics.

Table 3 reports only the coefficients of the key variables and its standard errors for the alternative specification. Columns (1) and (2) of Table 3 reports the results of a specification that is closely related to Columns (3) and (4) of Table 2, respectively. Both specifications show more-or-less similar results. There seems to be negative external effects of the industrial heritage sites before the start of the redevelopment. These are around -3% for houses sold within 250 m of the industrial heritage site. The coefficients for the other distance rings are lower if they are significant at all.

The trend effects before the start of the redevelopment show that the houses around 500 m became more-and-more unattractive over time. This is more-or-less in line with the results from the baseline specification (see top panel of Fig. 1). The BETWEEN variables show only very local positive and significant results. The sign and value seem to be of the same magnitude as in Table 2, but the spatial decay of the effects is less apparent. For the AFTER variables we find some mixed results. In specification (1) we find both positive external effect and positive trend effects after the redevelopment. In specification (2) we only find positive trend effects. This is not fully in line with the results of the baseline specifications from Table 2 where we do find positive external effects but the trend effects are less apparent.

5.2. Repeat sales analysis

The baseline analysis has relied on the difference-in-difference hedonic price methods. The results might be biased if there are omitted variables. Because we focus on developments over time, the relevant omitted variable bias refers to unobserved characteristics of houses that are more frequently present in houses sold before the start, between the start and completion, or after the completion of the redevelopment projects. A robustness check to address this potential bias is to perform a repeat sales analysis. Repeat sales of the same houses through time are observed in our data. The main advantage of this method is that it accounts for fixed effects at the level of the individual house. This

implies that it controls for any time-invariant characteristics of the house and neighborhood.¹³

On the other hand, the repeated sales method may be less desirable compared to our difference-in-difference hedonic price method due to the potential selection bias associated with including only those houses which are sold more than once during the observation period in the analysis. Even apart from this, it decreases the number of observations which may yield less reliable estimates.

The repeat sales equation that we estimate is closely related to the one used by Schwartz et al. (2006). It can be easily derived from Eq. (1):

$$\Delta_{t,\tau} \ln(P_{ij}) = \sum_{s=1}^S \alpha_s T_{irs} + \sum_{s=1}^S \theta_s T_{irs} D_i + \sum_{s=1}^S \varphi_s T_{irs} D_i^2 + \sum_{k=1}^K \beta_k \Delta_{t,\tau} X_{ki} + \gamma_t Y_t - \gamma_\tau Y_\tau + \Delta_{t,\tau} \varepsilon_i, \quad (3)$$

where $\Delta_{t,\tau}$ represents the difference between transaction time t and the previous transaction time τ and T_{irs} represents the ‘new’ ring variables. The ring variables are redefined in such a way that it measures the transition from one stage of the redevelopment to the other (before-between, between after and before after). The interpretation of the estimates of the ring variables (T_{irs}) is therefore different compared to the ring variables (R_{irs}) of Eq. (1). For more detailed information and derivations, see Appendix E. Note that Eq. (3) also accounts for changes in the all of the structural characteristics that may occur between the two transaction times.

Table 4 reports the results from the repeated sales analysis using Eq. (3). Results show that there are clear anticipation effects. If a house was sold before the start of the redevelopment project very close to the industrial heritage site ($D = 0$) and if that same house was sold again between the start and completion of the site, the price of the sold house was on average 4.75% higher due to the redevelopment project. This percentage decreases in the distance to the heritage site in a non-linear fashion. These results compared to Table 2 are not

¹³ The repeat sales method does not address the possibility that changes in unobserved characteristics occur over time, perhaps in relation with the investment in the heritage site.

Table 3
Regression results of the alternative specification.

	(1)		(2)	
Sample size	<2000 m		<2000 m	
Target area	0–1000 m		0–1000 m	
Control area	1000–2000 m		1000–2000 m	
Before (0 m–250 m)	–0.0349***	(0.00829)	–0.0308***	(0.00834)
Before (250 m–500 m)	–0.0131***	(0.00474)	–0.00854*	(0.00480)
Before (500 m–750 m)	–0.0133***	(0.00393)	–0.0123***	(0.00398)
Before (750 m–1000 m)	–0.00598*	(0.00323)	–0.00360	(0.00327)
Trend before (0 m–250 m)	0.00109	(0.00126)	0.000964	(0.00125)
Trend before (250 m–500 m)	0.000342	(0.000721)	–0.000513	(0.000712)
Trend before (500 m–750 m)	0.00225***	(0.000594)	0.00213***	(0.000590)
Trend before (750 m–1000 m)	0.00126**	(0.000543)c	0.000539	(0.000541)
Between (0 m–250 m)	0.0315***	(0.00952)	0.0232**	(0.00950)
Between (250 m–500 m)	–0.00123	(0.00514)	–0.00867*	(0.00512)
Between (500 m–750 m)	–0.00160	(0.00440)	–0.00514	(0.00439)
Between (750 m–1000 m)	0.00261	(0.00370)	2.68e–05	(0.00369)
After (0 m–250 m)	0.0266**	(0.0104)	0.0163	(0.0104)
After (250 m–500 m)	0.0143**	(0.00588)	0.00799	(0.00586)
After (500 m–750 m)	–0.0109**	(0.00512)	–0.0112**	(0.00512)
After (750 m–1000 m)	–0.00211	(0.00448)	–0.00340	(0.00447)
Trend after (0 m–250 m)	0.00940***	(0.00173)	0.00902***	(0.00173)
Trend after (250 m–500 m)	0.00813***	(0.00116)	0.00717***	(0.00116)
Trend after (500 m–750 m)	0.0111***	(0.00110)	0.00986***	(0.00110)
Trend after (750 m–1000 m)	0.00588***	(0.00102)	0.00489***	(0.00102)
Year fixed effects (21)	YES		YES	
Structural characteristics (14)	YES		YES	
Building period dummies (6)	YES		YES	
Industrial site characteristics (3)	YES		YES	
Neighborhood fixed effects (643)	YES		YES	
Neighborhood characteristics (7)	NO		YES	
Observations	208,305		208,305	
Adjusted R ²	0.897		0.897	

Note: Dependent variable is $\ln(\text{transaction price})$. The coefficients of the other variables for specification (2) can be found in Table C.2 of Appendix C. The other coefficients can be obtained from the author. Robust standard errors are reported between parentheses.

* $p < 0.10$.

** $p < 0.05$.

*** $p < 0.01$.

Table 4
Regression results of the repeated sales specification.

	(1)	
Target area	0–1000 m	
Control area	1000–2000 m	
Transition: Before–Between	0.0464***	(0.0125)
Before–Between * D	–0.000116***	(4.33e–05)
Before–Between * D ²	8.42e–08**	(3.55e–08)
Transition: Between–After	0.0212	(0.0243)
Between–After * D	2.08e–05	(9.04e–05)
Between–After * D ²	–6.50e–08	(7.48e–08)
Transition Before–After	0.0121	(0.0249)
Before–After * D	–1.95e–05	(8.52e–05)
Before–After * D ²	–2.37e–08	(6.84e–08)
Trend after	0.0179*	(0.00975)
Trend after * D	–1.74e–05	(3.54e–05)
Trend after * D ²	7.54e–09	(2.87e–08)
Differenced year dummies	Yes	
Differenced structural characteristics	Yes	
Building period dummies	–	
Industrial site characteristics	–	
Neighborhood fixed effects	–	
Differenced neighborhood characteristics	Yes	
Observations	74,513	
Adjusted R ²	0.803	

Note: Dependent variable is the difference between $\ln(\text{transaction price})$ of the same house at time t and τ . The other coefficients can be obtained from the author. Robust standard errors are reported between parentheses. Building period dummies, industrial site characteristics and neighborhood fixed effects are time-invariant and therefore no coefficients can be obtained for them.

* $p < 0.10$.

** $p < 0.05$.

*** $p < 0.01$.

so different from the BETWEEN variable. We find no significant results for houses that were sold between the start and completion of the redevelopment and again after the completion of the redevelopment. We also find no effect for houses that were sold before the redevelopment and again after the completion of the redevelopment. Although the coefficients for positive external effects after the redevelopment are positive, they are not significant. This is not in line with the results from Table 2 but they are more in line with the results in Table 3. The results do suggest some positive trend effects after the redevelopment but it is weakly significant.

5.3. Matching

For the difference-in-difference methodology it is important that the ‘target’ and ‘control’ group are identical, except for the ‘treatment’ variable, to find consistent estimators for the effect of the ‘treatment’. In the literature, it is standard practice to use the outer rings as control areas (see, for example, Ahlfeldt et al. (2013a); Helmers and Overman (2012), and Schwartz et al. (2006)). This is what we do initially. We start by including sold houses within 2000 m of the redeveloped industrial heritage site. The initial target group are those houses that are within 1000 m of the redeveloped industrial heritage site and are sold after the completion of the redevelopment (AFTER). By including additional variables (BEFORE and BETWEEN, specified above), the control group is then defined as those sold houses that are between 1000 and 2000 m of the redeveloped industrial heritage site.¹⁴ This methodology

¹⁴ We also excluded some distance rings between the target and control group to minimize spillover effects between the two groups. The results show negligible changes.

Table 5

Comparison neighborhood characteristics based on propensity score matching.

	Target group (houses sold within 1 km of a redeveloped industrial heritage site)		Control group (houses in neighborhoods based on propensity score matching and not within 1.5 km of a redeveloped industrial heritage site)	
Population density (#/km ²)	7364.76	5572.75	8599.97	6210.06
Foreign migrants (%)	10.73	13.51	10.29	13.81
Distance to nearest intercity station (m)	3437.35	6762.13	2665.54	3517.74
Monuments within 50 m (#)	0.77	2.97	1.21	3.36
Average household size (#)	2.66	0.73	2.46	0.95
Young people (%)	13.59	5.80	12.91	5.74
Elderly people (%)	11.99	6.36	12.97	9.09

does imply that the outer rings, or the control area, should be identical to the target area to produce consistent estimates of the external effect. It can be argued that this is an implausible assumption because the researcher is often not able to fully capture the differences between the control and target group, although we correct for many of them.

Another argument is that there could be a problem of selection. The industrial sites that received rehabilitation could have been chosen because policymakers expected these locations to have substantial external effects. If this is true then the target area is not randomly assigned and we could, as an alternative, use a matching procedure to match similar neighborhoods to our target area and define those matched neighborhoods as control areas. Using these matching estimators to define a specific control group that is closely identical to the target group is becoming more popular in the economic literature (e.g. Ahlfeldt et al., 2013b; Koster and Van Ommeren, 2013; McMillen and McDonald, 2002; Muehlenbachs et al., 2013).¹⁵

We use the method of Rosenbaum and Rubin (1983) in a similar fashion as in Koster and Van Ommeren (2013). The idea is that neighborhoods prior to the redevelopment have similar characteristics and therefore have similar propensity scores, which are estimated by a probit (or logit) regression. We include many neighborhood characteristics, such as population density, share of foreign migrants, distance to the nearest train station, et cetera. This method enables us to match neighborhoods by minimizing the difference in propensity scores between the target and control neighborhoods. Potential control neighborhoods are located between 1.5 km and 10 km from the redeveloped industrial heritage sites. This ensures that it is impossible that the redevelopment of the industrial heritage site has had any impact on the price of the sold houses in the control area. These matched pairs are then more-or-less identical to each other, except for the treatment that the target area has had due to the redevelopment of the industrial heritage. Table 5 shows descriptive statistics of the neighborhood characteristics between the target and control group for which the control group is based on the propensity score matching procedure.¹⁶ Note that in our preferred specifications we do control for these neighborhood characteristics by adding them as explanatory variables.

Table 6 reports the results of four specifications that takes into account a treatment area of 500 m, which is based on previous estimation results, and a different control area, which is based on propensity score matching. The outline of Table 6 is comparable to Table 2. The results in the different columns show the development of the size and significance of the coefficients when we start to control for more factors. It shows how omitted variables can have an influence on the results of a difference-in-difference hedonic model.

If we focus on Column (4) and compare these results with Column (4) of Table 2, there are some differences that we want to highlight. We find somewhat stronger negative external effects before the start of the redevelopment of the industrial heritage sites. A house next to the industrial heritage site before the start of the redevelopment (TREND = 0 and D = 0) sold for around 6% less than comparable houses based on their propensity score. The spatial effect is also somewhat different as we now find that there are also positive and significant trend effects. The interactions between the trend and distance variables are also significant – just as in Table 2. See Appendix D for the price response figures which show a different picture, but the conclusion stays more-or-less the same. In recent years the negative external effect increased before the start of the redevelopment. However, for this specification the magnitude of the increase in negative external effect differs for houses close and further away from the industrial heritage site in a non-linear u-shaped form. Another noticeable difference between Column (4) of Table 6 and Table 2 is that the positive external effects disappear, but positive trend effects appear after the completion of the industrial heritage site. The trend effect after completion of the redevelopment is the same for all houses within 500 m from the redeveloped industrial heritage sites. The effect increases house prices with 1%-point per year compared to the control group that is now based on propensity score matching. This implies that positive external effects do not immediately arise after the redevelopment but that it takes some time.

5.4. Are our results driven by the large cities?

Another way to look at the selection problem is that it is likely that the large redevelopment projects in the larger cities have higher external effects (e.g. these projects get more national (media) attention or policy makers are better able to identify and predict 'successful' redevelopment projects). This could drive up the coefficients that we find in our previous specification. To test this we split the dataset into two. In the first dataset we only keep the redevelopment projects in the "G4" cities in The Netherlands and in the second dataset the remaining projects.¹⁷ The G4 cities in The Netherlands include Amsterdam, Rotterdam, Den Hague and Utrecht. They form the heart of the Randstad area, where most of the economic activity in The Netherlands takes place. The specification that we use for the two separate regressions is similar to the specification (4) of Table 2. These regressions form a basis for a Chow (1960) test. Its null hypothesis is that the intercepts and slopes are identical between the G4 cities and the other cities and villages.

Table 7 reports the results for our preferred specification that for Column (1) only includes the G4 cities and for Column (2) excludes the G4 cities. The coefficients of our key variables show some differences compared to the pooled model (specification 4 of Table 2). For Column (1) the effects are significant but larger. For Column (2) the significance disappears almost completely, except for the TREND BEFORE variables. The Chow F-statistic (14.56) is also significantly different from zero at the 99% level. This implies that industrial heritage sites before and

¹⁵ For more details on matching techniques, see Abadie and Imbens (2002, 2006, 2011) and Abott and Klaiber (2013).

¹⁶ We used the *psmatch2* command in STATA on the neighborhood data to find control areas which are as similar as possible to the target areas. The output gives each neighborhood a 'propensity score'. A neighborhood that did not receive treatment and which has the closest score to the score of a treatment neighborhood will be chosen as one of the control groups. This type of matching is done for each of the treatment neighborhoods.

¹⁷ The big four cities are located in the Randstad and include Amsterdam, Den Hague, Rotterdam and Utrecht.

Table 6
Regression results of the matching specification.

	(1)		(2)		(3)		(4)	
Target area	0–500 m		0–500 m		0–500 m		0–500 m	
Control area	Prop. score		Prop. score		Prop. score		Prop. score	
Before	–0.000146	(0.0429)	–0.0246	(0.0314)	–0.0682**	(0.0322)	–0.0607*	(0.0316)
Before * D	–0.000474	(0.000298)	–0.000272	(0.000218)	0.000106	(0.000167)	0.000164	(0.000168)
Before * D ²	9.59e-07*	(4.93e-07)	4.44e-07	(3.60e-07)	–1.02e-07	(2.73e-07)	–2.19e-07	(2.73e-07)
Trend before	–0.0136*	(0.00723)	–0.0136***	(0.00503)	0.0121***	(0.00416)	0.0140***	(0.00413)
Trend before * D	8.46e-05*	(5.03e-05)	4.74e-05	(3.47e-05)	–4.31e-05	(2.85e-05)	–6.79e-05**	(2.83e-05)
Trend before * D ²	–1.55e-07*	(8.25e-08)	–6.67e-08	(5.69e-08)	7.41e-08	(4.62e-08)	1.15e-07**	(4.58e-08)
Between	–0.0138	(0.0529)	0.0796**	(0.0365)	0.0620**	(0.0276)	0.0536*	(0.0276)
Between * D	0.000843**	(0.000377)	–0.000393	(0.000262)	–0.000352*	(0.000193)	–0.000377*	(0.000193)
Between * D ²	–2.04e-06***	(6.32e-07)	4.18e-07	(4.39e-07)	4.05e-07	(3.17e-07)	4.70e-07	(3.18e-07)
After	0.0659	(0.0618)	0.0354	(0.0407)	0.0277	(0.0303)	0.0107	(0.0304)
After * D	0.000168	(0.000443)	–7.71e-05	(0.000293)	–8.71e-05	(0.000214)	–8.88e-05	(0.000214)
After * D ²	–7.62e-07	(7.47e-07)	–1.16e-08	(4.95e-07)	8.04e-08	(3.55e-07)	1.28e-07	(3.54e-07)
Trend after	0.0352***	(0.0110)	–0.00573	(0.00607)	0.00873*	(0.00471)	0.00972**	(0.00469)
Trend after * D	–9.22e-05	(8.28e-05)	9.04e-05**	(4.59e-05)	5.77e-06	(3.56e-05)	–3.99e-06	(3.54e-05)
Trend after * D ²	1.68e-07	(1.46e-07)	–1.29e-07	(8.15e-08)	–7.56e-09	(6.27e-08)	3.06e-09	(6.24e-08)
Year fixed effects (21)	Yes		Yes		Yes		Yes	
Structural characteristics (17)	No		Yes		Yes		Yes	
Building period dummies (6)	No		Yes		Yes		Yes	
Industrial site characteristics (3)	No		Yes		Yes		Yes	
Neighborhood fixed effects (397)	No		No		Yes		Yes	
Neighborhood characteristics (7)	No		No		No		Yes	
Observations	40,696		40,696		40,696		40,696	
Adjusted R ²	0.361		0.767		0.898		0.899	

Note: Dependent variable is $\ln(\text{transaction price})$. The coefficients of the control variables for specification (4) can be found in Table C.3 of Appendix C. The other coefficients can be obtained from the author. Robust standard errors are reported between parentheses.

* $p < 0.10$.

** $p < 0.05$.

*** $p < 0.01$.

after the redevelopment have (almost) no external effects on house prices in the (smaller) cities and villages in The Netherlands. This suggests that significant external effects are only observed in

redevelopment projects in larger cities and that our earlier results were driven by the redevelopment of industrial heritage sites there. This is in line with results reported in the working paper version of

Table 7
Regression results after splitting dataset between G4 cities and the rest.

	(1)		(2)	
	G4 only		Excluding G4	
Target area	0–1000 m		0–1000 m	
Control area	1000–2000 m		1000–2000 m	
Before	–0.0906***	(0.0285)	0.000629	(0.0135)
Before * D	0.000247**	(9.59e-05)	–1.10e-05	(4.57e-05)
Before * D ²	–1.77e-07**	(7.54e-08)	1.56e-08	(3.73e-08)
Trend before	–0.00508	(0.00574)	–0.00419*	(0.00203)
Trend before * D	4.31e-06	(1.91e-05)	1.66e-05**	(7.29e-06)
Trend before * D ²	4.61e-09	(1.49e-08)	–1.44e-08**	(6.02e-09)
Between	0.0864***	(0.0315)	0.0121	(0.0153)
Between * D	–0.000251**	(0.000110)	–7.78e-05	(5.48e-05)
Between * D ²	1.92e-07**	(8.77e-08)	6.24e-08	(4.52e-08)
After	0.0957***	(0.0315)	0.0102	(0.0180)
After * D	–0.000320***	(0.000111)	–1.65e-05	(6.54e-05)
After * D ²	2.42e-07***	(8.91e-08)	–4.75e-09	(5.47e-08)
Trend after	0.000991	(0.00354)	0.00403	(0.00368)
Trend after * D	2.02e-05	(1.39e-05)	1.61e-05	(1.40e-05)
Trend after * D ²	–2.01e-08*	(1.21e-08)	–1.83e-08	(1.20e-08)
Year fixed effects	Yes		Yes	
Structural characteristics	Yes		Yes	
Building period dummies	Yes		Yes	
Industrial site characteristics	Yes		Yes	
Neighborhood fixed effects	Yes		Yes	
Neighborhood characteristics	Yes		Yes	
Observations	72,760		135,545	
Adjusted R ²	0.916		0.892	

Note: Dependent variable is $\ln(\text{transaction price})$. The coefficients of the control variables can be obtained from the author. Robust standard errors are reported between parentheses. The resulting Chow test produced the statistic $F(709,206,887) = 14.56^{***}$.

* $p < 0.10$.

** $p < 0.05$.

*** $p < 0.01$.

Table 8

Redevelopment costs and external benefits on house prices.

	Owner-occupied houses only	Owner-occupied + rental houses
Total external benefits on house prices (in 2013 mln euros)	46–184	129–484
Total redevelopment costs (in 2013 mln euros)	453	453
Percentage covered	10%–41%	28%–107%

Note: All values are in 2013 prices.

this article, Van Duijn et al. (2014), where we estimate separate difference-in-difference hedonic regressions for five industrial heritage sites and only found large positive and significant external effects for the Amsterdam *Westergasfabriek* and not for the other four redevelopment projects that were not located in one of the largest cities.

6. Implications for cost–benefit analysis

In the previous two sections, we have reported many results which leads to a better understanding of the external effects of redeveloping industrial heritage sites. To make the quantitative implications for the impact of redevelopment policy even more explicit, we propose – given that we have to make some additional assumptions – to conduct a rough cost–benefit analysis to compare the monetary costs of redevelopment and the external benefits for owner-occupiers.¹⁸ These external benefits are usually not reported in the budget of redevelopment projects. Unfortunately, it is difficult to obtain the redevelopment costs of each redevelopment project in The Netherlands. We managed to obtain the total redevelopment costs (investments and subsidies) from 25 out of the 36 projects. The following calculations are based on the 25 projects which are reported in Appendix F.

First, we calculate the redevelopment costs and estimate the external benefits on house prices in 2013 prices by deflating the prices with the consumer price index, collected from Statistics Netherlands. Second, we ignore ‘possible’ benefits on commercial properties so the estimated external benefits are best interpreted as lower bound estimates. Third, we count the number of owner-occupied and rental houses within each concentric ring of 100 m for the treatment area using register data on addresses and buildings (BAG). Furthermore, we assume that our results are representative for the whole owner-occupied housing stock within the treatment area.

Table 8 reports an overview of the total redevelopment costs and the total external benefits based on house prices. For the total external benefits we show a lower and upper-bound based on the preferred specification 4 in Tables 4 and 7. The external benefits reported in the first column ignore the possible benefits for rental properties within the treatment area. The reason is that a large share of the rental properties in The Netherlands – and especially in inner cities – is rent-controlled. However, if these rental houses would be sold in the future, the external benefits of these houses should not be ignored. If we assume that the effect on owner-occupied houses is identical to the effect on rental houses the external benefits increase even more substantially, as we show in the second column. The results show that the total external benefits on house prices is between € 46 million and € 184 million for 25 redevelopment projects if we only count the owner-occupied houses. We compare this to the total redevelopment costs of these 25 projects which is € 453 million. It appears that the external benefits cover between 10 and 41% of the total redevelopment costs. The total external benefits increase to € 129 million and € 484 million if not only owner-

occupied houses but also rental houses are counted, which cover between 28 and 107% of the total redevelopment costs. In general, this suggests that the external benefits of renovating industrial heritage sites – close to residential areas – are important to consider in spatial policy as they cover a substantial part of the redevelopment costs.

7. Conclusions

In this paper, we investigate the presence of external effects of the redevelopment of the industrial heritage sites on house prices, making a distinction between years before the start, between the start and completion, and after the completion of the redevelopment projects. We used 36 finished projects which were former industrial heritage sites with a cultural-historic background that lost their original function. These projects are spread over The Netherlands. Local governments independently decided that the cultural-historic aspects of these sites should be preserved by redevelopment.

We use a difference-in-difference hedonic price methodology that compares quality-adjusted house prices of sold houses within a certain treatment radius before the start, between the start and completion, and after the completion of the redevelopment project and compared them to a predefined control area. We control for many housing, industrial heritage site and neighborhood characteristics and pay special attention to defining the treatment and control area. In our baseline specification the treatment area is defined as those sold houses within 1000 m of the redeveloped industrial heritage site. The control area is first defined as the most outer ring (sold houses between 1000 m and 2000 m of redeveloped industrial heritage sites) but we also use a matching estimator to define a control area that is as similar as possible to the treatment area given many local characteristics. Our methodology tries to minimize the omitted variable bias – often caused by unobserved investment or developments in the vicinity of the industrial heritage sites – by using different specifications and by controlling for neighborhood and time fixed effects. The development of the coefficients over the different specifications shows possible overestimation of earlier research on external effects. Our conclusions are as follows: 1) Negative external effects before the start of the redevelopment of industrial heritage sites are relatively small and local compared to other (similar) literature. De Groot and De Vor (2011) find larger effects both in magnitude as in spatial effects. However, they investigate all types of industrial sites in only a part of The Netherlands and the empirical methodology is less extensive. 2) If negative external effects are present, they disappear at or just after the start of the redevelopment which suggests anticipation effects in the housing market. 3) Positive external effects on house prices are present after the completion of the redevelopment of industrial heritage sites in the larger cities in The Netherlands. However, our results are not conclusive on when these positive external effects arise. In some specifications, we find already positive external effects before the completion of the industrial site. In other specifications, we find positive trend effects that emerge gradually over time after the redevelopment of industrial heritage.

This paper has clear policy relevance. First, it has been argued that redevelopment of industrial and other heritage has important positive effects on the surrounding neighborhoods. See, for instance, Rypkema (1994) and Listokin et al. (1998). Our results only provide

¹⁸ The estimated benefits are based on the regression results in Table 7. Therefore, we assume that the estimated price effects are constant for all owner-occupied houses, across the redevelopment projects within the G4 cities, across the projects within the other cities/villages, and across the study period 1990–2011.

partial support for such claims. In summary, they strongly confirm the effectiveness of redevelopment policies in removing negative external effects of abandoned industrial heritage sites. However, they do not confirm the emergence of positive external effects after their completion outside the four largest cities. This suggests that an urban environment is an important driver of the emergence of positive external effects after redevelopment. Second, the external benefits cover a substantial part of the redevelopment costs. This suggests that external benefits of redeveloping industrial sites – or maybe even redevelopment in general – on residential areas should be considered in spatial policy.

Acknowledgments

The authors gratefully acknowledge Platform 31, the University of Groningen, and VU University for their financial support. We thank NVM, ABF Research and Statistics Netherlands for providing us with excellent data. We thank the Editor Giovanni Peri, two anonymous referees, Henri Overman, Marc Francke and the participants in the Urban Future Lectures, ERES and AREUEA conferences for constructive comments on previous drafts. We also thank Floris Lazrak and Michiel Daams for their involvement in different stages of the project that resulted in this paper.

Appendix A. The location of industrial heritage sites used in our analysis

Fig. A.1. Industrial heritage sites that are included in our analysis.

Appendix B. Falsification exercise

We consider a falsification exercise to test the credibility of our proposed empirical strategy. The idea is that we want to investigate our empirical strategy if we only use industrial heritage sites which did *not* undergo redevelopment. We follow a similar method used by [Dávila and Mora \(2005\)](#) and [Ratcliffe and Von Hinke Kessler Scholder \(2015\)](#). In our industrial heritage data, we identify 26 redevelopment projects which are not completed yet. Because we find anticipation effects between the start and the completion of the redevelopment projects we have to drop those projects which already started with the redevelopment. This leaves us with 12 redevelopment projects (see [Fig. A.1](#) in [Appendix A](#) for the location of these projects).

One important aspect of our empirical strategy is that we know the start and completion of the redevelopment projects. Because our empirical strategy heavily relies on this information, we have to impose these ‘pseudo’-years for the redevelopment projects in the falsification exercise. We

randomly assign the start of the redevelopment which should be within the time window for which we have transaction data (pseudo-start year). The average time to complete the redevelopment is around three years. Therefore, we assign the pseudo-year of completion three years after the start of the redevelopment. These pseudo-years are essential to identify our key variables. We create multiple sets of pseudo-years to make sure we find average effects. We expect our key coefficients to be negative because the redevelopment did not actually took place and thus negative external effects are likely to be found. These negative external effects is something we observe in almost every specification (see the BEFORE coefficients).

Table B.1 reports the results of the average effects based on ten regressions where we separately drew random start years. Most of the key coefficients are negative – as we expected – but they are not significant. However, these results gives us faith that in this paper we apply a solid empirical strategy.

Table B.1

Regression results based on falsification exercise with pseudo years.

	(1)	
Sample size	<2000 m	
Target area	0–000 m	
Control area	1000–2000 m	
Year of start	Randomly drawn	
Year of completion	= Year of start + 3	
Before	0.0012	(0.03382)
Before * D	– 2.00E-05	(1.17E-04)
Before * D ²	1.12E-08	(9.56E-08)
Trend before	– 0.0108	(0.00687)
Trend before * D	– 2.20E-06	(2.36E-05)
Trend before * D ²	1.08E-08	(1.89E-08)
Between	– 0.0329	(0.03574)
Between * D	1.02E-04	(1.29E-04)
Between * D ²	– 6.43E-08	(1.07E-07)
After	– 0.0467	(0.03529)
After * D	2.30E-04**	(1.27E-04)
After * D ²	– 1.89E-07**	(1.05E-07)
Trend after	– 0.0069*	(0.00328)
Trend after * D	1.68E-05	(1.23E-05)
Trend after * D ²	– 8.70E-09	(1.05E-08)
Year fixed effects	Yes	
Structural characteristics	Yes	
Building period dummies	Yes	
Industrial site characteristics	Yes	
Neighborhood fixed effects	Yes	
Neighborhood characteristics	Yes	
Observations	60,603	
Adjusted R ²	0.899	

Note: The values are based on the average of ten regressions. In each of the regressions the pseudo years were randomly drawn again. In this way we make sure we did not report an outlier based on one draw. Dependent variable is $\ln(\text{transaction price})$. The other coefficients can be obtained from the author. Robust standard errors are reported between parentheses.

* $p < 0.10$.

** $p < 0.05$.

*** $p < 0.01$.

Appendix C. Regression results from the omitted variables in the paper

Table C.1

Table 2 continued: Results from the other variables (specification 4 only).

$\ln(\text{floorspace in m}^2)$	0.571***	(0.00518)	Transaction year 1990 (ref: 2011)	– 1.274***	(0.00580)
Rooms (#)	0.0414***	(0.000996)	Transaction year 1991	– 1.224***	(0.00532)
House (ref: apartment)	– 0.0674***	(0.00175)	Transaction year 1992	– 1.132***	(0.00527)
Detached house	0.255***	(0.00349)	Transaction year 1993	– 1.024***	(0.00502)
Semi-detached house	0.0883***	(0.00227)	Transaction year 1994	– 0.946***	(0.00464)
Corner house	0.0158***	(0.00165)	Transaction year 1995	– 0.870***	(0.00446)
Balcony	0.00452***	(0.00107)	Transaction year 1996	– 0.751***	(0.00457)
Terrace	0.0488***	(0.00176)	Transaction year 1997	– 0.648***	(0.00433)
Private parking	0.135***	(0.00178)	Transaction year 1998	– 0.546***	(0.00422)
Well maintained garden	0.0775***	(0.00133)	Transaction year 1999	– 0.394***	(0.00408)
Bad maintenance inside	– 0.0936***	(0.00155)	Transaction year 2000	– 0.311***	(0.00334)
Bad maintenance outside	– 0.0722***	(0.00184)	Transaction year 2001	– 0.218***	(0.00317)
Central heating	0.0955***	(0.00142)	Transaction year 2002	– 0.156***	(0.00308)
Listed built monument status	0.0975***	(0.00368)	Transaction year 2003	– 0.136***	(0.00295)
Size of the industrial site (in m ²)	7.57e-09	(8.89e-09)	Transaction year 2004	– 0.101***	(0.00287)
Other redevelopment projects within 10 km (#)	– 0.0133***	(0.00135)	Transaction year 2005	– 0.0606***	(0.00279)
Other redevelopment projects within 10 km radius (#2)	0.00494***	(0.000228)	Transaction year 2006	– 0.0191***	(0.00267)
Foreign migrants (%)	– 0.00183***	(0.000166)	Transaction year 2007	0.0288***	(0.00259)
$\ln(\text{population density})$	0.0228***	(0.00138)	Transaction year 2008	0.0556***	(0.00261)

(continued on next page)

Table C.1 (continued)

ln(distance to train station)	−0.00530**	(0.00251)	Transaction year 2009	0.00151	(0.00258)
Listed built monuments in a 50 m radius (#)	0.000232	(0.000235)	Transaction year 2010	−0.000835	(0.00262)
Average household size (#)	−0.0574***	(0.00236)			
Young people (%)	0.00300***	(0.000314)	Constant	.521***	(0.0296)
Elderly people (%)	−0.00296***	(0.000204)			
Built in period <1945 (ref: built in period after 2000)	−0.210***	(0.00304)	Observations	208,305	
Building period 1945–1960	−0.252***	(0.00337)	Adjusted R ²	0.898	
Building period 1961–1970	−0.260***	(0.00352)			
Building period 1971–1980	−0.219***	(0.00344)			
Building period 1981–1990	−0.167***	(0.00344)			
Building period 1991–2000	−0.0661***	(0.00328)			

Note: Results from the other cases can be obtained from the author. Robust standard errors are reported between parentheses.

* p < 0.10.

** p < 0.05.

*** p < 0.01.

Table C.2

Table 3 continued: Results from the other variables (specification 2 only).

ln(floorspace in m ²)	0.571***	(0.00518)	Transaction year 1990 (ref: 2011)	−1.274***	(0.00581)
Rooms (#)	0.0414**	(0.000996)	Transaction year 1991	−1.224***	(0.00532)
House (ref: apartment)	−0.0675***	(0.00175)	Transaction year 1992	−1.132***	(0.00527)
Detached house	0.255***	(0.00349)	Transaction year 1993	−1.024***	(0.00503)
Semi-detached house	0.0882***	(0.00227)	Transaction year 1994	−0.946***	(0.00464)
Corner house	0.0158***	(0.00165)	Transaction year 1995	−0.869***	(0.00446)
Balcony	0.00452***	(0.00107)	Transaction year 1996	0.751***	(0.00457)
Terrace	0.0487***	(0.00176)	Transaction year 1997	−0.648***	(0.00433)
Private parking	0.135***	(0.00178)	Transaction year 1998	−0.546***	(0.00422)
Well maintained garden	0.0775***	(0.00133)	Transaction year 1999	−0.394***	(0.00408)
Bad maintenance inside	−0.0936***	(0.00155)	Transaction year 2000	−0.311***	(0.00334)
Bad maintenance outside	−0.0722***	(0.00184)	Transaction year 2001	−0.218***	(0.00317)
Central heating	0.0955***	(0.00142)	Transaction year 2002	−0.157***	(0.00308)
Listed built monument status	0.0974***	(0.00368)	Transaction year 2003	−0.136***	(0.00295)
Size of the industrial site (in m ²)	7.54e-09	(8.89e-09)	Transaction year 2004	−0.101***	(0.00287)
Other redevelopment projects within 10 km (#)	−0.0133***	(0.00135)	Transaction year 2005	−0.0608***	(0.00279)
Other redevelopment projects within 10 km radius (#2)	0.00494***	(0.000228)	Transaction year 2006	−0.0192***	(0.00267)
Foreign migrants (%)	−0.00182***	(0.000167)	Transaction year 2007	0.0287***	(0.00259)
ln(population density)	0.0227***	(0.00139)	Transaction year 2008	0.0554***	(0.00261)
ln(distance to train station)	−0.00537**	(0.00250)	Transaction year 2009	0.00143	(0.00258)
Listed built monuments in a 50 m radius (#)	0.000223	(0.000235)	Transaction year 2010	−0.000815	(0.00262)
Average household size (#)	−0.0577***	(0.00237)			
Young people (%)	0.00301***	(0.000314)	Constant	9.523***	(0.0295)
Elderly people (%)	−0.00297***	(0.000204)			
Built in period <1945 (ref: built in period after 2000)	−0.210***	(0.00304)	Observations	208,305	
Building period 1945–1960	−0.252***	(0.00337)	Adjusted R ²	0.898	
Building period 1961–1970	−0.260***	(0.00352)			
Building period 1971–1980	−0.219***	(0.00344)			
Building period 1981–1990	−0.167***	(0.00344)			
Building period 1991–2000	−0.0661***	(0.00328)			

Note: Results from the other cases can be obtained from the author. Robust standard errors are reported between parentheses.

* p < 0.10.

** p < 0.05.

*** p < 0.01.

Table C.3

Table 6 continued: Results from the other variables (specification 4 only).

ln(floorspace in m ²)	0.652***	(0.00966)	Transaction year 1990 (ref: 2011)	−1.337***	(0.0162)
Rooms (#)	0.0340***	(0.00211)	Transaction year 1991	−1.280***	(0.0137)
House (ref: apartment)	−0.0226***	(0.00427)	Transaction year 1992	−1.184***	(0.0137)
Detached house	0.185***	(0.00802)	Transaction year 1993	−1.098***	(0.0132)
Semi-detached house	0.0699***	(0.00550)	Transaction year 1994	−1.020***	(0.0124)
Corner house	0.000655	(0.00460)	Transaction year 1995	−0.955***	(0.0114)
Balcony	0.00853***	(0.00241)	Transaction year 1996	−0.829***	(0.0114)
Terrace	0.0532***	(0.00364)	Transaction year 1997	−0.717***	(0.0114)
Private parking	0.119***	(0.00421)	Transaction year 1998	−0.590***	(0.0105)
Well maintained garden	0.0896***	(0.00337)	Transaction year 1999	−0.392***	(0.0104)
Bad maintenance inside	−0.109***	(0.00377)	Transaction year 2000	−0.328***	(0.00823)
Bad maintenance outside	−0.0826***	(0.00436)	Transaction year 2001	−0.234***	(0.00770)
Central heating	0.0962***	(0.00319)	Transaction year 2002	−0.171***	(0.00728)
Listed built monument status	0.0774***	(0.00624)	Transaction year 2003	−0.162***	(0.00690)
Size of the industrial site (in m ²)	1.73e-08	(1.47e-08)	Transaction year 2004	−0.117***	(0.00669)
Other redevelopment projects within 10 km radius (#)	−0.0109***	(0.00281)	Transaction year 2005	−0.0782***	(0.00642)
Other redevelopment projects within 10 km ² (#2)	0.00307***	(0.000431)	Transaction year 2006	−0.0248***	(0.00601)
Foreign migrants (%)	−0.00360***	(0.000417)	Transaction year 2007	0.0404***	(0.00578)
ln(population density)	0.00581	(0.00390)	Transaction year 2008	0.0671***	(0.00590)

Table C.3 (continued)

ln(distance to trainstation)	−0.000424	(0.00550)	Transaction year 2009	0.00392	(0.00575)
Listed built monuments in a 50 m radius (#)	−0.000452	(0.000363)	Transaction year 2010	0.0130**	(0.00587)
Average household size (#)	−0.0743***	(0.00562)			
Young people (%)	0.00802***	(0.000926)	Constant	9.335***	(0.0635)
Elderly people (%)	0.000108	(0.000519)			
Built in period <1945 (ref: built in period after 2000)	−0.190***	(0.00590)	Observations	40,696	
Building period 1945–1960	−0.217***	(0.00703)	Adjusted R2	0.899	
Building period 1961–1970	−0.233***	(0.00824)			
Building period 1971–1980	−0.212***	(0.00689)			
Building period 1981–1990	−0.157***	(0.00676)			
Building period 1991–2000	−0.0669***	(0.00660)			

Note: Results from the other cases can be obtained from the author. Robust standard errors are reported between parentheses.

* $p < 0.10$.

** $p < 0.05$.

*** $p < 0.01$.

Appendix D. Additional price response figures (based on Table 6)

Fig. D.1. Relative price response over space and for different trends before the start of the redevelopment (top panel) and after the completion of the redevelopment (bottom panel) using the matching specification. Note: The calculations are based on the coefficients of specification (4) which are at least significantly different from zero on a 90% level, the years (t) before the start or after the completion, and the distance from the nearest industrial heritage site.

Appendix E. Additional information repeat sales analysis

The repeat sales specification is derived using the baseline specification which is closely related to Schwartz et al. (2006). We substantially differ from Schwartz et al. (2006) in two ways. First, the structural characteristics of houses can change over time. We allow for these changes over time. It is not uncommon in The Netherlands that owner-occupiers increase the quality of their house by investing in a dormer or other extension projects. Second, we have included more stages of the redevelopment process which are reflected in the ring variables (R_{itrs}) namely the BEFORE, BETWEEN and AFTER variables. If we use repeat sales analysis we are able to compare the transitions of these different stages. This implies that we estimate a 'before-between' transition effect if we observe that houses are sold before the start and again between the start and the completion of the redevelopment. We can do the same for the transitions 'between-after' and 'before-after'. We show this in a more formal notation below.

We start with the natural logarithm of for house price transactions of house i in neighborhood j at time t which is identical to Eq. (1):

$$\ln(P_{ijt}) = \sum_{s=1}^S \alpha_s R_{itrs} + \sum_{s=1}^S \theta_s R_{itrs} D_i + \sum_{s=1}^S \varphi_s R_{itrs} D_i^2 + \sum_{k=1}^K \beta_k X_{kit} + \gamma_t Y_t + \pi_j N_j + \varepsilon_{it}, \quad (E1)$$

If the same house is sold more than once, we observe the same house multiple times with different transaction times. To arrive at the repeat sales specification, we first transform Eq. (E1) into the following equation:

$$\ln(P_{ij\tau}) = \sum_{s=1}^S \alpha_s R_{itrs} + \sum_{s=1}^S \theta_s R_{itrs} D_i + \sum_{s=1}^S \varphi_s R_{itrs} D_i^2 + \sum_{k=1}^K \beta_k X_{kit} + \gamma_\tau Y_\tau + \pi_j N_j + \varepsilon_{it}, \quad (E2)$$

where τ is the previous transaction where $\tau < t$. Subtracting Eq. (E1) from Eq. (E2) gives the change in the natural logarithm for house price transactions:

$$\Delta_{t,\tau} \ln(P_{ij}) = \sum_{s=1}^S \alpha_s \Delta_{t,\tau} R_{irs} + \sum_{s=1}^S \theta_s \Delta_{t,\tau} R_{irs} D_i + \sum_{s=1}^S \varphi_s \Delta_{t,\tau} R_{irs} D_i^2 + \sum_{k=1}^K \beta_k \Delta_{t,\tau} X_{ki} + \gamma_t Y_t - \gamma_\tau Y_\tau + \Delta_{t,\tau} \varepsilon_i, \quad (\text{E3})$$

where $\Delta_{t,\tau}$ represents the difference between transaction time t and the previous transaction time τ . Note that the characteristics which are time-invariant are eliminated from the equation.

Special attention needs to be paid to the ring variables (R_{irs}). In Section 3.1 we specify five different ring variables which are denoted by s , BEFORE, BEFORE TREND, BETWEEN, AFTER, and AFTER TREND. Let us first focus on the three different stages and ignore the trend variables. These three dummy variables are connected with each other. If the same house within 1000 m of the industrial heritage site is sold before, between the start and the completion and after the completion of the project, the following is observed:

1. House A is within 1000 m of the industrial heritage site and is sold before the start of the redevelopment:
BEFORE = 1, BETWEEN = 0, AFTER = 0.
2. House A is sold again a number of years later just after the start, but before the completion of the redevelopment:
BEFORE = 1, BETWEEN = 1, AFTER = 0.
3. House A is sold again for the third time after the completion of the redevelopment¹⁹:
BEFORE = 1, BETWEEN = 0, AFTER = 1.

This implies that if look at the changes – as is reflected by $\Delta_{t,\tau} R_{irs}$ in Eq. (E3) – we observe the following:

Transition 2-1: $\Delta_{2,1} \text{BEFORE} = 0, \Delta_{2,1} \text{BETWEEN} = 1, \Delta_{2,1} \text{AFTER} = 0.$

Transition 3-2: $\Delta_{3,2} \text{BEFORE} = 0, \Delta_{3,2} \text{BETWEEN} = -1, \Delta_{3,2} \text{AFTER} = 1.$

As one might suspect already, taking the difference from transaction 2-1 is not problematic, however taking the difference from transaction 3-2 is when we want to estimate the repeat sales specification. This means that the external effects after the redevelopment project are both picked up by the coefficients for the BETWEEN and AFTER variable. We propose to solve this issue to define ring variables in such a way that they are based on the transition between different stages of the redevelopment process:

Transition 2-1: BEFORE–BETWEEN = 1, BETWEEN–AFTER = 0, BEFORE–AFTER = 0.

Transition 3-2: BEFORE–BETWEEN = 0, BETWEEN–AFTER = 1, BEFORE–AFTER = 0.

The equation that we propose and estimate in this paper is then as follows:

$$\Delta_{t,\tau} \ln(P_{ij}) = \sum_{s=1}^S \alpha_s T_{irs} + \sum_{s=1}^S \theta_s T_{irs} D_i + \sum_{s=1}^S \varphi_s T_{irs} D_i^2 + \sum_{k=1}^K \beta_k \Delta_{t,\tau} X_{ki} + \gamma_t Y_t - \gamma_\tau Y_\tau + \Delta_{t,\tau} \varepsilon_i, \quad (\text{E4})$$

where T_{irs} are the transition ring variables.

In addition to solving the issue, we can now also separate the external effects after the redevelopment into two: 1) an effect between houses sold before the start and after the completion and 2) an effect between houses sold between the start and after the completion and after the completion of the redevelopment. These transition dummy variables can be interacted with the trend and distance variables in a similar fashion as is described in Section 3.1.

Appendix F. Additional information counterfactual analysis

Table F.1

25 redevelopment projects which included total redevelopment costs.

Project	Location	Start of redevelopment	End of redevelopment	Total redevelopment costs (in €)
Damastfabriek, Ootmarsum	Ootmarsum	2007	2008	2,230,000
De Witte Dame, Eindhoven	Eindhoven	1994	1998	120,000
DRU-cultuurfabriek te Ulft	Ulft	2006	2009	15,000,000
Gasfabriek Meppel	Meppel	2006	2009	5,700,000
Graansilo's, Amsterdam	Amsterdam	1997	2000	17,700,000
Groot HandelsGebouw	Rotterdam	2002	2005	63,530,000
Leerlooierij Driesen, Dongen	Dongen	2004	2005	1,390,558
Nieuwe Energie, Leiden	Leiden	2007	2008	9,700,000
NJ Menko, Enschede	Enschede	2006	2008	8,300,000
Silo Weijers, Deventer	Deventer	2001	2005	2,700,000
Station Klarendal, Arnhem	Arnhem	2005	2008	2,500,000
TETEM portiersloge annex trafogebouw, Enschede	Enschede	2009	2009	380,000
Villa Augustus, Dordrecht	Dordrecht	2005	2007	6,000,000

¹⁹ Note that BEFORE is always 1 for house A because house A is sold in the treatment area. The reference where BEFORE = 0 is the control area. Because we include the BETWEEN and AFTER dummies, this implies that the BEFORE dummy can be interpreted as the external effect of the industrial site before the start of the redevelopment.

Table F.1 (continued)

Project	Location	Start of redevelopment	End of redevelopment	Total redevelopment costs (in €)
Westergasfabriek, Amsterdam	Amsterdam	2000	2003	66,500,000
Wooncomplex Tricot, Winterswijk	Winterswijk	2003	2006	21,000,000
Zaanse Chocoladefabriek (voorm. Verkadefabriek)	Zaandam	2004	2009	10,000,000
CaballeroFabriek, Den Haag	Den Haag	2003	2006	10,000,000
Dobbelmanterrein, Nijmegen	Nijmegen	2003	2008	35,000,000
IJzergieterij Stork in Hengelo	Hengelo	2000	2008	69,000,000
Leerlooierij Heerenveen	Heerenveen	2006	2007	548,000
Lichttoren Eindhoven	Eindhoven	2005	2009	1,600,000
Locomotiefremise Bad Nieuweschemans	Bad Nieuweschemans	2004	2004	1,285,000
Paardentramremise Amsterdam	Amsterdam	2003	2004	7,192,000
Pakhuis de Zwijger, Amsterdam	Amsterdam	2005	2006	7,500,000
Watertoren Soest	Soest	2002	2004	631,000

References

- Abadie, A., Imbens, G., 2002. Simple and bias-corrected matching estimators for average treatment effects. NBER Working Paper 283.
- Abadie, A., Imbens, G., 2006. Large sample properties of matching estimators for average treatment effects. *Econometrica* 74 (1), 235–267.
- Abadie, A., Imbens, G., 2011. Bias-corrected matching estimators for average treatment effects. *J. Bus. Econ. Stat.* 29 (1), 1–11.
- Abott, J.K., Klaiber, H.A., 2013. The value of water as an urban club good: a matching approach to community-provided lakes. *J. Environ. Econ. Manag.* 65 (2), 208–224.
- Ahlfeldt, G.M., 2011. Blessing or curse? appreciation, amenities and resistance to urban renewal. *Reg. Sci. Urban Econ.* 41 (1), 32–45.
- Ahlfeldt, G.M., Möller, K., Waights, S., Wendland, N., 2013a. Game of zones: the economics of conservation areas. Working Paper.
- Ahlfeldt, G.M., Maennig, W., Richter, F.J., 2013b. Urban renewal after the Berlin Wall. Working Paper.
- Brooks, L., Phillips, J., 2007. Inside the gift horse's mouth: city spending, political institutions and the community development block grant program. McGill University Working Papers.
- Brueckner, J.K., Rosenthal, S.S., 2009. Gentrification and neighborhood housing cycles: will America's future downtowns be rich? *Rev. Econ. Stat.* 91 (4), 725–743.
- Brueckner, J.K., Thisse, J.F., Zenou, Y., 1999. Why is central Paris rich and downtown Detroit poor? An amenity-based theory. *Eur. Econ. Rev.* 43 (1), 91–107.
- Carlino, G.A., Coulson, N.E., 2004. Compensating differentials and the social benefits of the NFL. *J. Urban Econ.* 56 (1), 25–50.
- Carlino, G.A., Saiz, A., 2008. City beautiful. IZA Discussion Paper No. 3778.
- Chen, Y., Rosenthal, S.S., 2008. Local amenities and life-cycle migration: do people move for jobs or fun? *J. Urban Econ.* 64 (3), 519–537.
- Cheshire, P., Sheppard, S., 1995. On the price of land and the value of amenities. *Economica* 62 (246), 247–267.
- Chow, G.C., 1960. Tests of equality between subsets of coefficients in two linear regressions. *Econometrica* 28 (3), 591–605.
- Coulson, N.E., Bond, E.W., 1990. A hedonic approach to residential succession. *Rev. Econ. Stat.* 72 (3), 433–444.
- CPB & PBL, 2010. Evaluatie Beoordelingen Nota Ruimteprojecten. Centraal Planbureau en Planbureau voor de Leefomgeving, Den Haag.
- Dávila, A., Mora, M., 2005. Changes in the earnings of Arab men in the US between 2000 and 2002. *J. Popul. Econ.* 18 (4), 587–601.
- De Groot, H.L.F., De Vor, F., 2011. The impact of industrial sites on residential property values: a hedonic pricing analysis from The Netherlands. *Reg. Stud.* 45 (5), 609–623.
- Florida, R., 2002. *The Rise of the Creative Class*. Basic Books, New York.
- Glaeser, E.L., Kolko, J., Saiz, A., 2001. Consumer city. *J. Econ. Geogr.* 1 (1), 27–50.
- Harding, J.P., Rosenthal, S.S., Sirmans, C.F., 2007. Depreciation of housing capital, maintenance, and house price inflation: estimates from a repeat sales model. *J. Urban Econ.* 61 (2), 193–217.
- Helmers, C., Overman, H., 2012. My precious! The location and diffusion of scientific research: evidence from the synchrotron diamond light source. Working Paper.
- Ioannides, Y.M., 2003. Interactive property valuations. *J. Urban Econ.* 53 (1), 145–170.
- Jacobs, J., 1961. *The Death and Life of Great American Cities*. Random House, New York.
- Koster, H.R.A., Rouwendal, J., 2015. Historic amenities and housing externalities: evidence from The Netherlands. Tinbergen Institute Discussion Paper, TI 2015-023/VIII.
- Koster, H.R.A., Van Ommeren, J.N., 2013. Spatial externalities and place-based policies: evidence from The Netherlands. Working Paper.
- Linn, J., 2013. The effect of voluntary Brownfields programs on nearby property values: evidence from Illinois. *J. Urban Econ.* 78 (1), 1–8.
- Listokin, F., Listokin, B., Lahr, M.L., 1998. The contributions of historic preservation to housing and economic development. *Hous. Policy Debate* 9, 431–478.
- Maliene, V., Wignall, L., Malys, N., 2012. Brownfield regeneration: waterfront site developments in Liverpool and Cologne. *J. Environ. Eng. Landsc. Manag.* 20 (1), 5–16.
- McMillen, D.P., McDonald, J.F., 2002. Land values in a newly zoned city. *Rev. Econ. Stat.* 84 (1), 62–72.
- Muehlenbachs, L., Spiller, E., Timmins, C., 2013. The housing market impacts of shale gas development. NBER Working Paper No. 19796.
- Ratcliffe, A., Von Hinkel Kessler Scholder, S., 2015. The London bombings and racial prejudice: evidence from the housing and labor market. *Econ. Inq.* 53 (1), 276–293.
- Rosen, S., 1974. Hedonic prices and implicit markets: product differentiation in pure competition. *J. Polit. Econ.* 82 (1), 34–55.
- Rosenbaum, P.R., Rubin, D.B., 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika* 70 (1), 41–55.
- Rosenthal, S.S., 2008. Old homes, externalities, and poor neighborhoods. A model of urban decline and renewal. *J. Urban Econ.* 63 (3), 816–840.
- Rossi-Hansberg, E., Sarte, P.D., Owens III, R., 2010. Housing externalities. *J. Polit. Econ.* 118 (3), 485–535.
- Rypkema, D.D., 1994. *The Economics of Historic Preservation: A Community leader's Guide*. National Trust for Historic Preservation, Washington D.C.
- SBR & Aedes, 2010. Juweeltjes Van Herbestemming, 17 Parels in de Stad. Stichting Bouw Research, Rotterdam, en Aedes, Den Haag.
- Schwartz, A.E., Ellen, I.G., Voicu, I., Schill, M.H., 2006. The effects of place-based subsidized housing. *Reg. Sci. Urban Econ.* 36 (6), 679–707.
- Smith, B.C., 2004. Economic depreciation of residential real estate: microlevel space and time analysis. *Real Estate Econ.* 32 (1), 161–180.
- Van Duijn, M., Rouwendal, J., Boersema, R., 2014. Transformations of industrial heritage: insights into external effects on house prices. Tinbergen Institute Discussion Paper, TI 2014-122/VIII.