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Inhoudsopgave

Abstract

The durability of real estate is closely related to physical deterioration and functional obsolescence. Aging effects appear to be particularly relevant for industrial real estate, while structures are often designed for specific production processes, and office buildings where outward appearance, which is often related to characteristics that are specific for a building's construction period, is related to the reputation of the user. These phenomena contribute to the dynamics of property prices and therefore to the returns on investment in real estate. In this paper, we examine the depreciation of commercial real estate values, for properties of different market segments and construction periods. We do so by estimating hedonic models, using rich information on transactions of commercial real estate in the Netherlands. We find that aging effects are heterogeneous over segments and construction periods, and that pre-WWII offices and industrial properties can experience increase of value with age, or “vintage” effects.

1 Introduction

Depreciation of real estate is an important factor when investigating property price and urban dynamics. It is a common perception that the value of real estate decreases with time due to physical deterioration or loss of functionality. Although the impact of aging on property prices is often modelled as a uniform process, it seems likely that it can vary between properties depending on their use, location, period of construction and architectural quality, as well as many other characteristics. Addressing the effect of age on price development may be conjectured to be particularly important when commercial real estate is investigated, as the buildings concerned are often custom-made for particular uses (i.e. functions, production techniques) and users and therefore often become outdated in the course of time. This makes the suitability of these buildings for potential users, and hence their value, vulnerable to changes in demand and technology. It is often costly to switch to a different use (and user) once the original one becomes outdated or obsolete. Naturally, such specialized buildings should be expected to be more exposed to depreciation.

It seems probable that this vulnerability is related to the commercial segment involved, depending on the extent to which the type of space can be considered a commodity. Factories are often designed for specific production processes and after becoming obsolete cause 'brownfields' that are a significant burden for central urban areas in many cities all over the world. On the other hand, shops may be expected to be more robust to the changes referred to above than industrial buildings, because their design is uniform, at least in a relative sense. Shops are also consumer-oriented, and therefore their appearance and style are more important, which may suggest that vintage buildings offer added value for retail properties. Offices may take an intermediate position.

The picture becomes still richer once it is realized that aging does not necessarily have a negative impact on property values. There are clear indications that vintage effects exist, especially in (the centers of) large cities: some older buildings are attractive *because* they are old and have specific characteristics missing in other properties and which cannot be reproduced through new construction. For instance, being located in a 19th century mansion constructed in a particular architectural style may contribute as much (or more) to a lawyer firm's image as operating from a fashionable modern-style building. In particular, it seems possible that particular types of commercial property depreciate substantially less than others, or may even appreciate over time.

Understanding these effects improves our insight into the dynamics of commercial property values. In addition, information on age effects can be used for more efficient allocation of funds, as well as for improving the accuracy of estimated price indexes. The importance of identifying the heterogeneity in property value depreciation, and possible appreciation over time, is important in the context of urban dynamics. Indeed, trends in the values of commercial real estate appear to be closely related to the revival, or decline, of urban areas (Glaeser, 2011). The close connection between location effects and depreciation points to the importance of distinguishing between the impact of a property's location and its inherent structural characteristics on the development of its value over time. We address this by controlling for fixed-effects on a small geographic scale, which allows for concise comparison between the depreciation effects of commercial properties of different segments and construction periods.

To identify vintage effects which relate to architectural style and surroundings we extend our fixed effects analysis, and exploit architectural style data and urban regulation zones data from Amsterdam. Different architectural zones represent structure quality and style, as well as urban planning characteristics of the surrounding area, thus allow us to identify the presence of vintage effect. Regulation zones define the strictness in which an outdated structure can be modified into contemporary use. Hence, it reflects the level of preservation of a structure and the likelihood that it will become obsolete. This enables us to directly identify aging effects of properties subject to different regulatory regimes, all else equal.

Our findings confirm that the effect of aging on commercial properties is not uniform over commercial uses, structure construction periods, architectural style and regulatory status. We find that while the effect is generally negative, positive aging effects (or, vintage effect) exist for certain uses, construction periods and architectural styles. This phenomenon is particularly apparent among pre-WWII industrial and office properties, but is also observed among new industrial properties.

2 Literature on depreciation of real estate

The depreciation in the value of capital has been studied extensively since the fundamental work of Hotelling (1925). Following Hotelling, depreciation is commonly modelled as a continuous function of building age, for instance in the seminal paper by Hulten & Wykoff (1981) who found an approximately geometric pattern of depreciation. Research to the depreciation effects of real estate properties, focused particularly on the effect for residential properties (references include Clapp & Giaccotto, 1998; Fisher, Smith, Stern, & Webb, 2005; Harding, Rosenthal, & Sirmans, 2007; Palmquist, 1979; Rosenthal, 2008; Shilling, Sirmans, & Dombrow, 1991; Smith, 2004; Wilhelmsson, 2008). In a recent study, Bokhari & Geltner (2016) study the impact of age on the values of commerical properties in U.S. cities, emphasizing the slowing down of the depreciation rate in the course of time.

Aging is inevitably associated with physical deterioration of a building and this is probably the main argument for modelling it as a continuous function of building age. However, from the perspective of economic analysis, this is a somewhat mechanical way of dealing with the impact of time and can be unsatisfactory for several reasons. First of all, the consequences of wear and tear can be counteracted, at least to some extent, by investing in the maintenance of a building. The decision to do so may well depend on current local circumstances that affect the expected future returns and may contribute to the finding that properties in areas with high demand generally experience slower depreciation in value (Bokhari & Geltner, 2016; Dunse, Jones, Brown, & Fraser, 2005). Second, buildings suffer not just from deterioration in functional quality, but may also become obsolescent for other reasons (see e.g. Abramson, 2016). This seems especially relevant for buildings that have been constructed to facilitate activities or production processes that have become outdated. In the context of residential real estate, Francke and van de Minne (2016) mention the example of a kitchen without enough space to add modern-day appliances. In commercial real estate this phenomenon is particularly relevant for factory buildings that were constructed to facilitate a specific production process. When this becomes outdated due to technical progress or changing economic conditions, such buildings may become virtually useless and in the past were often simply abandoned by their users, although they were often located close to city centers. Retail and office buildings may be expected to be less vulnerable to functional obsolescence, although modern digital equipment, the demand for flexible work space and green labels, all require design that is easiest to be addressed in the construction phase. Related to this is that the building in which a firm is located contributes – positively or negatively – to its image. A fashionable office building on a central site may help to attract or keep customers, while a much cheaper modest suburban building may do the opposite. , There also appear to exist vintage effects associated with the presence of specific characteristics of buildings that make them more attractive. For instance, a lawyer firm may appreciate the distinct aristocratic atmosphere of a mansion, despite the higher maintenance costs and the lack of modern facilities. Last, but certainly not least, the value of a building is not only determined by its structure but also by the land on which it is located. Depending on the state and development of the local economy, land prices may have an important impact on property prices as was shown for housing by Davis and Heathcote (2005, 2007). Francke and van de Minne (2016) show for Dutch residential real estate that physical deterioration is a main component in value decline with age, but that strong preferences for characteristics associated with pre-World War II construction, can offset these negative effects and result in positive net “vintage” effect.

These observations suggest that the effect of aging is the product of a potentially complicated interaction between the characteristics of the structure, originating from its construction, investments in maintenance and refurbishment and the development of the local economy. Moreover, depreciation of commercial real estate should be expected to be heterogeneous and differ per market segment and use (Bokhari & Geltner, 2016; Crosby, Devaney, & Law, 2012).

Identification of depreciation of real estate values in past studies is commonly estimated using hedonic models, in which property age is included as an explanatory variable. However, since depreciation is often correlated with unobservable property characteristics, insufficient control for such characteristics is a potential source of bias. The proper identification and control for depreciation of property values was also a primary concern of many empirical studies which focused on estimating property price indexes, including indexes for commercial real estate properties (Diewert & Shimizu, 2014; Francke, n.d.).

In this research we follow a hedonic approach to identify the depreciation effects of commercial real estate, for different groups of property commercial usage and year of construction and compare the effect for property characteristics and location-specific trends. A prominent source of bias in estimating aging effects is the location factor. Commercial use and architectural quality are often correlated with location within an urban area, and central locations are more attractive than non-central locations. To address this, we include a fixed-effects (FE) analysis at the 4-digit postal code area (PC4).[1] Controlling for fixed-effects in a relatively small geographical area is a powerful tool as it allows us to compare aging effects of different commercial properties within the same area, and to capture much of the aging effect which is attributed to location characteristics.

Similar to previous studies, we find that aging of properties is not uniform over commercial market segments and construction periods. However, contrary to past findings, we find appreciation (or “vintage”) effects for pre-WWII properties, for industrial and office uses.

1 We use 2017 postal code areas for the fixed-effects analysis. During that time there were approximately 4,000 four-digit postal code areas in the Netherlands.

3 Data

We use data on transactions of commercial property in the period January 1990-December 2017 referring to the whole Netherlands. The data we use were made available by NVM Business[2], Strabo[3] and StiVAD (*Stichting Vastgoeddata*).[4] Table 1 presents descriptive data for the main variables used in our analysis.

Together, these datasets include 63,901 transactions, about 77% of them reported by NVM Business. The data cover a large part of the Dutch commercial property market. All the NVM data refer to properties bought by agents who want to use them themselves (owner-occupiers). Strabo makes a distinction between transactions referring to owner-users (16.7% of our total number of observations) and investors (83.2%). StiVAD data includes 138 transactions, which consist of less than 0.25% of the transactions in the data, all of them investment properties.

Table 1 – Data descriptives

	Statistic	N	Mean	St. Dev.	Min	Max
All	Transaction price	63,901	551,008	929,619	43,109	24,468,473
	Floor area	63,901	754.308	1,179.45	23	14,500
	Investment property	63,901	0.167	0.373	0	1
	Official monument	63,901	0.038	0.191	0	1
	Protected city center	63,901	0.143	0.35	0	1
	Year of construction	63,901	1957.464	52.641	1200	2017
	Age	63,901	47.156	51.408	0	816
	Age-square	63,901	4,866.49	18,011.20	0	665,856
Industrial	Transaction price	30,328	502,712	668,434	43,109	10,000,000
	Floor area	30,328	1018.318	1,381.28	23	14,500
	Investment property	30,328	0.125	0.331	0	1
	Official monument	30,328	0.006	0.078	0	1
	Protected city center	30,328	0.032	0.177	0	1
	Year of construction	30,328	1978.626	32.495	1200	2017
	Age	30,328	27.111	31.249	0	816
	Age-square	30,328	1,711.48	8,608.14	0	665,856
Offices	Transaction price	16,974	830,299	1,394,769	43,109	24,468,473
	Floor area	16,974	767.309	1,131.02	24	14,000
	Investment property	16,974	0.206	0.404	0	1
	Official monument	16,974	0.077	0.267	0	1
	Protected city center	16,974	0.224	0.417	0	1
	Year of construction	16,974	1948.5	55.95	1330	2016
	Age	16,974	56.166	54.945	0	677
	Age-square	16,974	6,173.39	18,736.78	0	458,329

2 NVM Business is an association of brokers active in commercial real estate. Almost all small commercial real estate agents, as well as a few larger ones (e.g. Colliers) are members of NVM Business.

3 Strabo is a firm that collects information on real estate transactions from secondary sources., notably Vastgoedmarkt and PropertyNL. It concentrates on the activities of large real estate agencies (like C&W, CBRE and Jones Lang Lasalle).

4 StiVAD is a Dutch non-profit information platform, which collects and manages data on local real-*estate.*

Retail	Transaction price	16,599	353,648	631,128	43,109	18,939,000
	Floor area	16,599	258.643	433.67	23	13,500
	Investment property	16,599	0.205	0.404	0	1
	Official monument	16,599	0.056	0.229	0	1
	Protected city center	16,599	0.262	0.44	0	1
	Year of construction	16,599	1927.967	61.378	1250	2016
	Age	16,599	74.567	61.11	0	743
	Age-square	16,599	9,294.56	26,738.99	0	552,049

The raw data has incomplete information about the year of construction of the property, which is of central interest for the purposes of the present paper. We have therefore enriched that data with information about the year of construction from BAG[5] using ArcGIS.[6]

One may expect that depreciation patterns of structures are affected by their historical importance. In the Netherlands, preservation of historical building has a central role in planning and zoning system. The Dutch cultural heritage authority (RCE), defined 63,482 buildings as official listed historical buildings ("*Rijksmonumenten*"). Buildings with listed status are protected by the government, which also allocates resources to subsidize their maintenance and restoration. This form of protection reduces the cost of maintenance for older buildings but also limits the possibilities to renovate and convert them to more modern uses. Our data includes 2,410 transactions of 2,140 properties which are defined as official listed buildings. The RCE additionally defines 460 areas as "protected city centers" ("*Beschermde stads-en-dorpsgezicht*"). Protected city centers are areas within a city or a village which contain a large concentration of properties of cultural heritage or historical value and are defined so to protect their unique characteristic. Protected city areas may be perceived to be more attractive or central, compared to not-protected locations. Therefore, such areas form a locational characteristic which may not captured by our fixed-effects (as their boundaries do not necessarily conform) and are thus added as an additional location control for this analysis. Spatial information regarding protected city center is available from RCE. We divide the transaction in our data to groups based on properties' year of construction. We define eight groups of construction year intervals, which correspond with periods in the Dutch planning system (see table 1).

The control variables which were presented above may still not capture various unobserved regional factors, that may also affect depreciation. For this purpose, we include an additional fixed-effects analysis at the four-digit postal code areas (PC4) level. This strategy substantially reduces the bias which results from location factors and improves the identification of the effect of property aging. The analysis includes 2,951 fixed-effects groups, of which 65% (1,929 groups) include 5 properties or more, 57% (1,372 groups) include at least 10 properties, and 14% (363 groups) include more than 50 properties (see table 2). 431 groups include only one property and therefore are not included in the FE analysis.

5 BAG=Basis Administratie Gebouwen, a basic administration system for buildings.

6 Spatial coordinates were obtained following Dekkers and Van der Beek (2016).

Table 2 – Fixed effects groups

Number of transactions in a group	Number of groups	%	Cumulative %
100<	107	4.2%	4.2%
50 to 100	256	10.2%	14.4%
20 to 49	562	22.3%	36.7%
10 to 19	532	21.1%	57.8%
9	63	2.5%	60.3%
8	72	2.9%	63.2%
7	106	4.2%	67.4%
6	98	3.9%	71.3%
5	133	5.3%	76.5%
4	149	5.9%	82.5%
3	179	7.1%	89.6%
2	263	10.4%	100.0%
1	431		
Total	2,951		

The distribution of year of construction per market segment is presented graphically in Figure 1. For retail transactions there are clear peaks associated with buildings constructed around 1900 and smaller ones associated with the 1920s and 1950s. For offices there is also a peak around 1900, but it is followed by a decrease that lasted until WWII. Then there is a prolonged increase until approximately 1990, and a steep decrease in more recent years. Transactions in industrial properties constructed before 1940 resemble those for retail, with clear peaks around 1900 and in the 1920s. After 1945 there is a very steep increase that is only temporarily interrupted for buildings constructed at the end of the 1980s and then continues until approximately 2000.

Figure 1 – Density distribution of the transactions over year of construction

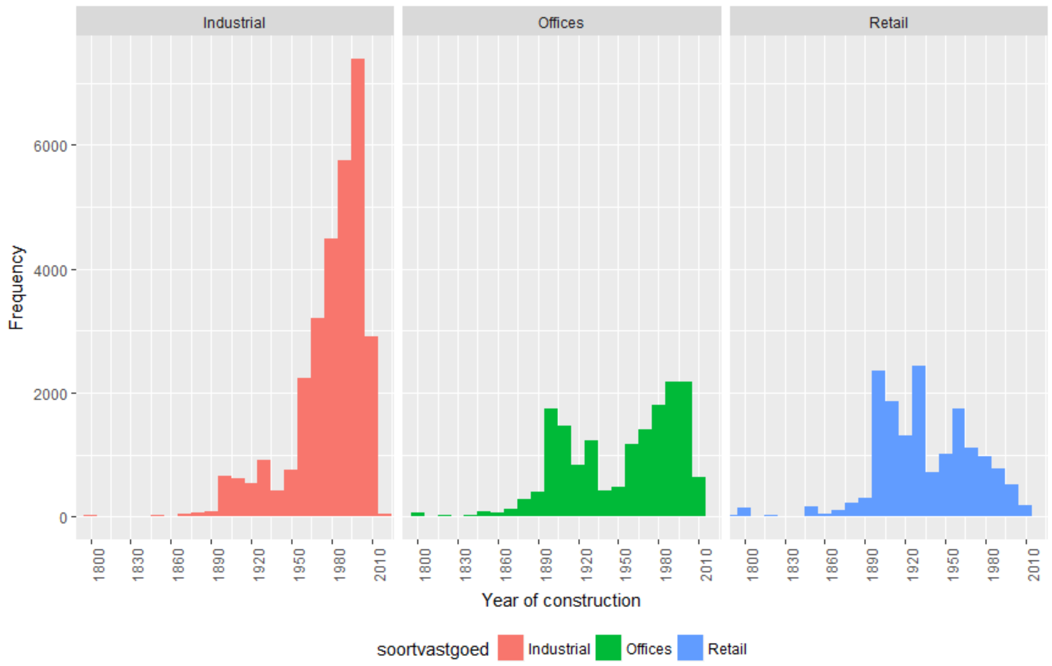


Figure 1 describes the distribution of construction year of the transactions in the data. As it is based on transaction data, the figure may not accurately reflect the age distribution of the stock of the three types of real estate. It may be that buildings in city centers, where demand is usually relatively strong, change hands more often than those in small towns or suburbs. Since these centers have often been occupied for a long time, this may have contributed to large number of retail transactions in which pre-war buildings were involved.

Examining the location distribution of properties of different age and commercial market segment, we find that indeed older buildings of all segments are more likely to be located within a protected city center (here used as an additional indication for central location, see table 1). In our data, approximately 9,130 transactions (or 14.3%) are of properties located within protected areas. As expected, transactions of pre-WWII properties occur more often in protected city centers. However, a relatively large share of transactions of new retail properties (built after) are located within protected city centers. About 17% of retail transactions of properties built between 1982 and 1990 are in protected city centers, compared with 7.4% offices and 0.5% of industrial properties from that period (see table 3).

Examination of mean transaction prices (Figure 2) shows that mean prices generally increase with year of transaction, for each commercial market segment, but also that variation is quite high within each group.

Figure 2 - Mean transaction price per construction year period

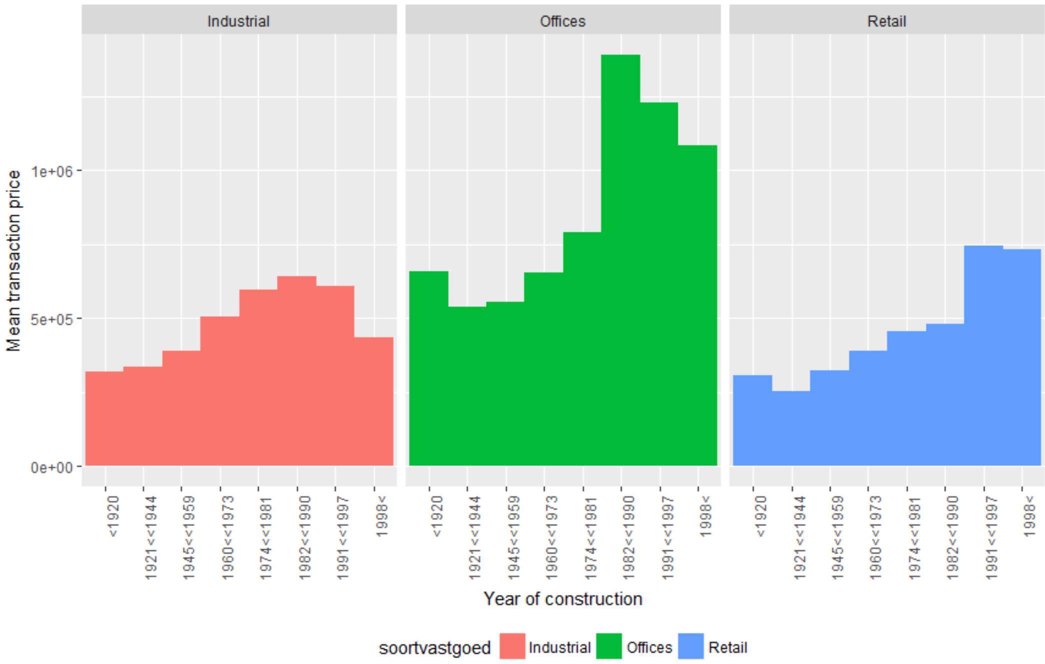


Table 3 - Descriptive statistics per market segment and year of construction groups

Market segment	Year of constructio n	N	Mean number of transactions per unique property	Share of transactions in protected city center	Mean Price	sd. Price
Industrial	<1920	1,935	1.030	33.70%	316,959	472,638
	1921<<1944	1,418	1.058	9.17%	336,631	432,930
	1945<<1959	1,238	1.076	4.77%	389,672	518,570
	1960<<1973	4,395	1.116	1.16%	503,710	588,864
	1974<<1981	4,268	1.166	0.61%	594,811	642,020
	1982<<1990	3,478	1.175	0.49%	639,242	736,568
	1991<<1997	4,514	1.156	0.51%	607,363	736,876
	1998<	9,082	1.119	0.28%	435,566	710,756
Offices	<1920	5,117	1.149	55.36%	656,726	806,603
	1921<<1944	1,824	1.139	19.85%	539,016	838,727
	1945<<1959	893	1.111	12.21%	555,050	1,050,550
	1960<<1973	2,037	1.101	7.31%	652,860	1,217,758
	1974<<1981	1,604	1.131	6.48%	790,527	1,284,264
	1982<<1990	1,574	1.154	7.43%	1,389,224	2,044,256
	1991<<1997	1,467	1.125	4.36%	1,230,654	1,792,722
	1998<	2,458	1.083	2.64%	1,083,940	1,929,481
Retail	<1920	6,532	1.075	49.02%	307,279	370,251
	1921<<1944	3,454	1.091	14.33%	254,827	298,063
	1945<<1959	1,643	1.085	10.89%	322,399	480,429
	1960<<1973	2,304	1.100	6.12%	390,036	929,442
	1974<<1981	892	1.090	10.54%	456,766	733,847
	1982<<1990	645	1.113	17.36%	485,157	817,423
	1991<<1997	545	1.116	12.66%	743,123	1,356,037
	1998<	584	1.068	8.90%	734,873	1,235,359

4 Methodology

To analyze the depreciation effect in commercial real estate we estimate a hedonic model in which the transaction price is explained by property and location characteristics.

We follow the approach of Francke and van de Minne (2016), and examine depreciation of real estate values by attempting to identify the components of property depreciation mentioned above. We include the *period* of construction in the analysis to estimate the effect of property obsolescence and to capture vintage effects, which may result from preferences towards building or architectural characteristics of each time period.[7] In addition, we introduce the *age* of the property in order to observe physical deterioration. The age of the property is closely related to the period of construction, but both variables are included to capture different effects. While the period of construction is used to capture premiums associated with a period-specific architectural style and quality, construction material and quality and other structure related characteristics, the age of the building is included to directly reflect value dynamics over time.

Dummy for official monument status is also included. Properties with listed status are often historic, but their maintenance is largely assured by the government, and therefore they are less likely to suffer from physical deterioration compared with other properties which were constructed in similar time periods.

Since the year of construction is not independent from the property location, we include additional NUTS3 regional and year variables to capture local prices trends. Our base regression model is specified as follows:

$$Ln\left(p_{i,t}\right) = \sum_k \beta_k X_{i,k} + \sum_t \delta_t D_{i,t} + \sum_\tau (\gamma_{\tau,0} + \gamma_{\tau,s} S_{i,t}) C_{i,\tau} + M_i + M_i S_{i,t} + \epsilon_{i,t} \qquad (1)$$

where: $p_{i,t}$ is the transaction price of property i in time t, $X_{i,k}$ is the value of the k-th characteristic of the property sold in transaction i. The property characteristics included in this analysis are floor area of the property, accessibility level, location within protected city center, and dummy for investment property. $D_{i,t}$ are a vector of $t = 1 \dots T$ dummy variables indicating that the transaction of property i took place in year t. $C_{i,\tau}$ are a vector of construction year groups. $S_{i,t}$ indicates the age of property in transaction i in time t. $S_{i,t}$ is specified both in logarithm form ($S_{i,t} = ln(S_{i,t})$), and in linear and square term ($S_{i,t} = S_{i,t} + \gamma_{\tau,s2} S_{i,t}^2$). The purpose of the latter is to test whether the effect of age presents a non-linear pattern (hence, the effect does not remain constant over time).[8] The interaction terms $S_{i,t}C_{i,\tau}$ represent the age effect for each group of properties constructed in a certain time period. Since ages are always higher for older properties, comparing coefficients of age effects in logarithm for different construction year groups might not be suitable. This is because at the time of observation (1990-2017), newer properties have systematically lower age values compared with older properties, and therefore a comparison between age effect cannot be clearly interpreted. For this reason, we consider the linear and square term specification as our main model. M_i is a dummy variable indicating listed status of a structure. We include an additional interaction between listed buildings and

7 Francke and van de Minne (2016) assume that functional obsolescence is time invariant. This assumption holds for residential properties but may be arguable for commercial real estate, i.e. vintage industrial locations can often be converted to leisure uses.

8 The quadratic effect is interpreted as the rate of change to the first-degree effect with time. Age and age-squared with the same sign imply that the effect strengthens with time. Opposite signs imply that the effect weakens with time, and can be reversed after a number of years.

age to observe whether properties with listed status experience different depreciation patterns. $\epsilon_{i,t}$ is the residual.

To address bias concern from unobserved location characteristics, we estimate the above model using fixed-effects for 4-digit postal codes areas.

To test our fixed-effects strategy we also estimate a simple OLS version of model (1), in which we compare our results when location fixed-effects are not considered:

$$Ln(p_{i,t}) = \sum_k \beta_k X_{i,k} + \sum_t \delta_t D_{i,t} + \sum_\tau (\gamma_{\tau,0} + \gamma_{\tau,s} S_{i,t}) C_{i,\tau} + M_i + M_i S_{i,t} + \sum_h (\alpha_{h,0} + \alpha_{h,v} v_{i,t}) R_{i,h} + \epsilon_{i,t} \quad (2)$$

In this model (2) we include several additional location control variables[9]: $R_{i,h}$ are a vector of $h = 1 \ldots H$ regional dummy variables which indicate a regional affiliation (the 40 NUTS3 regions of the Netherlands, in our case). $v_{i,t}$ is a continuous time variable which indicates the number of periods since t_0 (1990, in our case). The interaction between $R_{i,h} v_i$ therefore serves as a measure for regional time trends.

9 The fixed-effects model controls for observed and unobserved location characteristics. Adding observed location characteristics to the OLS model allows better comparison between both models' results, and underlines the bias posed by unobserved characteristics, and hence the importance of including fixed-effects.

5 Results

5.1 Main results

Table 3 presents the main results of model (1). Columns 1 and 2 describe the FE results, under polynomial and logarithmic specifications of the age effect interactions. Columns 3 and 4 describe the OLS results. Without making a distinction between commercial segments, the aging effect of properties built before 1920 becomes larger and statistically significant. With an additional year, the price of a pre-1920 property is expected to increase by 0.1% (column 1). Positive but weakly significant effect is also found for properties built immediately after the war, during 1945-1959. The aging effect is positive but statistically insignificant for properties built between 1920-1944 and after 1998, and negative and significant for post-war properties (built between 1960-1997).

Age-square coefficients are positive and significant for properties built between 1960-1990, and negative and significant for properties built before 1920 and between 1945-1959. This indicates that aging effect, either positive or negative, generally weakens with time. Since older properties have "higher age" values, square term coefficients can form a substantial factor in the overall estimated aging effect, as will be discussed later. In addition, we consider a logarithmic specification of property age, which results in an age-price elasticity of 0.103 (column 2) for properties built before 1920, 0.020 for properties built after 1998, and approximately -0.05 to -0.2 for properties built between 1945-1997.

Using the fixed-effects result (Table 3, column 1), we construct a graphical comparison of the aging effect of equal-quality properties built in different time periods by their age at time of transaction (see Figure 3 and table 4). Since properties which were constructed in different periods have different ages at the moment of observation (on transaction time), we use properties' corresponding age ranges at the time of observation (1990-2017) to measure how their expected values diverge with time. To calculate the overall effect, we also add the construction period time-invariant group effect (namely, the coefficient of the corresponding construction period dummy). Due to the square-term age coefficients, the effect of aging is not constant over time. Moreover, since older properties have systematically higher age values compared with newer properties, resulting overall aging effects may differ from the results implied from the estimated coefficients in Table 3.

Table 2 - Hedonic model results

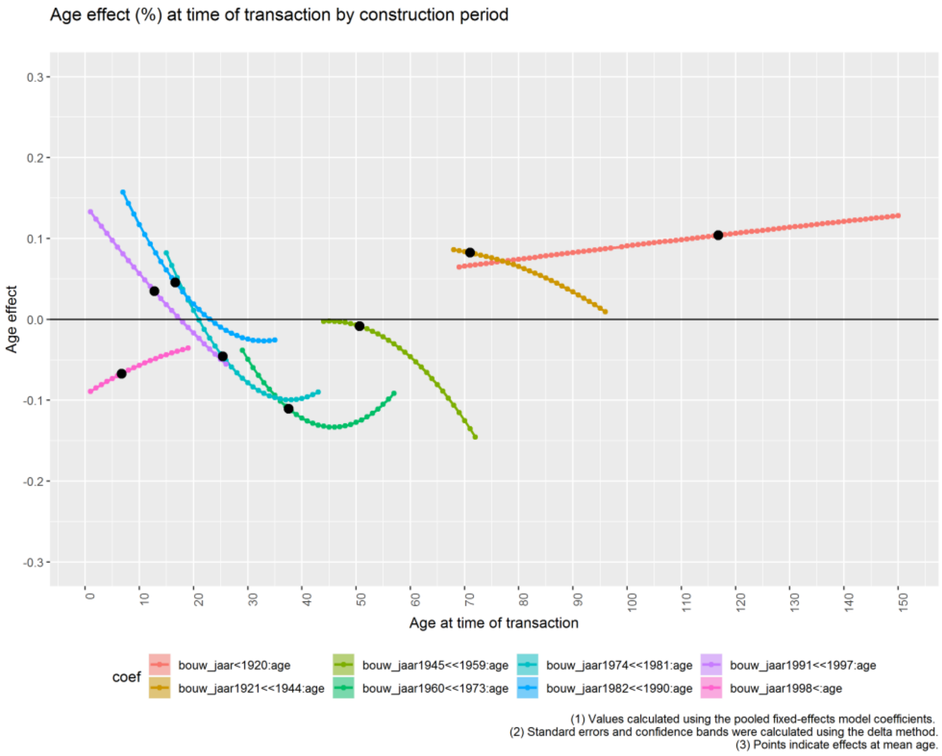
	FE	FE	OLS	OLS
	(1)	(2)	(3)	(4)
Official Monument	0.20157*** (0.02369)	0.49302*** (0.06504)	0.24434*** (0.02131)	0.64542*** (0.06713)
Protected city center	0.17642*** (0.02388)	0.17495*** (0.02381)	0.22197*** (0.00760)	0.21965*** (0.00761)
Floor area (ln)	0.60857*** (0.00508)	0.60869*** (0.00509)	0.60017*** (0.00233)	0.60045*** (0.00233)
Investment property	0.29235*** (0.00950)	0.29208*** (0.00951)	0.37679*** (0.00679)	0.37625*** (0.00679)
Const year <1920:Age	0.00101*** (0.00032)		0.00052* (0.00027)	
Const year 1921<1944:Age	0.00770 (0.01072)		0.01320 (0.00979)	
Const year 1945<1959:Age	0.01778* (0.00999)		0.01863** (0.00935)	
Const year 1960<1973:Age	-0.03075*** (0.00518)		-0.03009*** (0.00506)	
Const year 1974<1981:Age	-0.02647*** (0.00586)		-0.02579*** (0.00557)	
Const year 1982<1990:Age	-0.01805*** (0.00503)		-0.01384*** (0.00428)	
Const year 1991<1997:Age	-0.00912** (0.00400)		-0.00769* (0.00403)	
Const year 1998<:Age	0.00432 (0.00384)		0.00106 (0.00336)	
Const year <1920:Age2	-0.000001* (0.000001)		-0.000001 (0.0000005)	
Const year 1921<1944:Age2	-0.00006 (0.00007)		-0.00010 (0.00007)	
Const year 1945<1959:Age2	-0.00020** (0.00010)		-0.00020** (0.00009)	
Const year 1960<1973:Age2	0.00034*** (0.00007)		0.00034*** (0.00007)	
Const year 1974<1981:Age2	0.00035*** (0.00011)		0.00036*** (0.00011)	
Const year 1982<1990:Age2	0.00027** (0.00014)		0.00021* (0.00012)	
Const year 1991<1997:Age2	0.00006 (0.00014)		0.00002 (0.00015)	
Const year 1998<:Age2	-0.00007 (0.00021)		0.00018 (0.00020)	
Const year <1920:Age (log.)		0.10304*** (0.01787)		0.06254*** (0.01635)
Const year 1921<1944:Age (log.)		-0.07518 (0.06030)		-0.01549 (0.05533)
Const year 1945<1959:Age (log.)		-0.11187** (0.05522)		-0.08120 (0.05002)
Const year 1960<1973:Age (log.)		-0.18918*** (0.02950)		-0.14686*** (0.02659)
Const year 1974<1981:Age (log.)		-0.19769*** (0.02481)		-0.17737*** (0.02158)
Const year 1982<1990:Age (log.)		-0.10386*** (0.01838)		-0.08252*** (0.01393)
Const year 1991<1997:Age (log.)		-0.05554*** (0.00976)		-0.05285*** (0.00938)
Const year 1998<:Age (log.)		0.01958*** (0.00707)		0.01955*** (0.00572)
Monument:Age	-0.00045*** (0.00015)	-0.07559*** (0.01424)	-0.00053*** (0.00014)	-0.10159*** (0.01432)
Fixed-effects	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes
Year of construction dummies	Yes	Yes	Yes	Yes
Corop dummies	No	No	Yes	Yes
Constant	8.34***(0.04015)	7.962***(0.08737)	8.25613*** (0.06843)	8.01962*** (0.09839)
Observations	63,901	63,901	63,901	63,901
Adjusted R2	0.6714	0.67128	0.6988	0.6987
FE Groups	2,951	2,951		

Notes: (1) Robust standard errors in parentheses. (2) *p<0.1; **p<0.05; ***p<0.01

Table 4 – Estimated age effect by construction period, for properties with mean age

Construction period	Mean age of property	Age effect (%) for property with mean age
<1920	116.82	0.104
1921<<1944	71.01	0.082
1945<<1959	50.62	-0.008
1960<<1973	37.55	-0.110
1974<<1981	25.40	-0.046
1982<<1990	16.65	0.046
1991<<1997	12.79	0.035
1998<	6.74	-0.067

Figure 3 – Age price development by construction year



The overall effect of aging for a property with the average age (on the time of transaction) in each construction period group (see Table 4) is a convenient representation of the above findings. Properties built before 1920 (average age of 117 years on the time of transaction) have a positive age effect of approximately 0.104%. The effect of properties built between 1921-1944 (average age of 71 years) also have a positive but small effect of 0.08%. The effects of properties built between 1945-1981 is negative. Properties built between 1982-1997 (average ages of 16.6 and 12.8 years) show positive aging effect for properties with the mean age.

Examining the overall aging effect trends per year (Figure 3) we first observe that properties built before 1944 continue to display an overall positive aging effect. properties built between 1945-1973 and were approximately 40-70 years old during our observation period, were losing up to 0.15% in value each year, all else equal.[10] Due to square-terms coefficient signs, the effect of aging is slowly decreasing with time for properties built before 1959 and after 1998, but increasing for properties built between 1960-1997.[11] Despite negative estimated age coefficients, the overall effects of aging among properties built between 1982-1997 are largely positive (for smaller age values).

Aging effect for listed buildings is negative and statistically significant, but very small at -0.04%. The negative but very small effect suggests that listed properties depreciate slightly more than non-listed properties, all else equal. This is surprising since listed status often entails subsidies and national or municipal support in maintenance costs. Nevertheless, listed status also implies strict protection of current use and restricts renovations or structural changes, which may result in higher sensitivity to (functional) obsolescence effects, and hence also stronger depreciation in value.

5.2 OLS

When we do not consider area fixed-effects, the OLS results under both age specifications show a positive aging effects among properties which were built before 1920, and a positive effect among new properties built after 1998. Under polynomial age specification (column 3) the aging effect is statistically significant of properties built between 1945-1959. Properties built between 1945-1997 have negative age effects, the strongest effect is for properties built between 1960-1973. However, Comparable with the FE results, this effect weakens with time, as indicated by positive and significant square-term coefficients. Aging effects of listed buildings remain small and significant when fixed-effects are excluded. The OLS results are largely in line with the FE results.

5.3 Positive aging effect

The positive aging effect of certain properties is a noteworthy result, particularly when considering that location factors are controlled for using the fixed-effects estimation. A possible explanation for this finding among old properties could be the lack of control for demolished properties (Hulten & Wykoff, 1981). In this respect, older properties in which quality has deteriorated with age may have already been demolished before 1990 and hence is not observed.

The positive aging effect of relatively new buildings (constructed after 1998) is also an interesting result. One would expect that recent buildings would not show any aging effect (i.e. the coefficient would be insignificant) or maybe a small negative effect. An increase in the price with an increase of age of relatively new buildings may indicate (continuing) short supply of such

[10] -0.08% and -0.11% for properties with average age, for properties built in 1945-1959 and 1960-1973, respectively.

[11] Age-square coefficients determine the rate in which the estimated first-degree effect changes with time. For example, a positive (negative) age-square effect implies that the effect of aging increase (decreases) with every additional year.

buildings, or more specifically of buildings that meet the modern standards and preferences of real estate users.

5.4 Commercial segment subsamples

Table 5 presents the main estimation results of model (1), in which we estimate our fixed-effects model for subsamples of different commercial segments – Industrial, offices and retail properties.

When we allow for age effect to vary for different commercial property types, we find a positive and significant aging effect for historical industrial properties, of approximately 0.21% increase in price with every additional year for properties built before 1920. Aging effect of offices built between 1921-1944 is also positive (and larger), but weakly significant, at 3.2% price increase per year. Aging effect for pre-WWII retail properties is positive and weakly significant, but very small at 0.006%.

Although most of the older industrial properties are probably considered obsolete for modern industrial activity, it is possible that their positive aging effect reflects expectations of future restoration and conversion to industrial heritage site (Van Duijn, Rouwendal, & Boersema, 2016), whereas pre-WWII offices are not obsolete, and may maintain value due to architectural quality and “vintage” effect.

New industrial buildings built after 1998, are also experiencing a positive aging effect of approximately 0.85% per year. Properties constructed after WWII from all segments generally experience negative aging effect of approximately 1%-4% decrease per year. The decrease in value is strongest for industrial properties built between 1960-1981, offices built between 1960-1990, and retail built between 1960-1973. Retail properties built between 1945-1959 experience a positive aging effect of 2.6%, but weakly statistically significant.

Table 5 – Hedonic model results – per market segment

	Industrial	Offices	Retail
	(1)	(2)	(3)
Official Monument	0.13959* (0.07669)	0.18762*** (0.02764)	0.11863*** (0.03276)
Protected city center	0.15823*** (0.03644)	0.08853*** (0.02433)	0.12007*** (0.03504)
Floor area (ln)	0.65475*** (0.00647)	0.73505*** (0.00722)	0.51901*** (0.00826)
Investment property	0.09158*** (0.00943)	0.19375*** (0.01141)	0.36941*** (0.01555)
Const year <1920:Age	0.00213** (0.00083)	0.00065 (0.00043)	0.00066* (0.00038)
Const year 1921<1944:Age	0.01678 (0.02488)	0.03268* (0.01952)	0.00551 (0.01230)
Const year 1945<1959:Age	-0.01204 (0.01645)	-0.00915 (0.01920)	0.02580* (0.01426)
Const year 1960<1973:Age	-0.03603*** (0.00707)	-0.03999*** (0.00953)	-0.02936*** (0.01064)
Const year 1974<1981:Age	-0.03942*** (0.00684)	-0.04047*** (0.01262)	0.01828 (0.01341)
Const year 1982<1990:Age	-0.02056*** (0.00651)	-0.04081*** (0.00765)	-0.02608** (0.01109)
Const year 1991<1997:Age	-0.01016** (0.00467)	-0.02693*** (0.00883)	0.00594 (0.01156)
Const year 1998<:Age	0.00856** (0.00417)	-0.00876 (0.00813)	0.02109 (0.01773)
Const year <1920:Age2	-0.000003** (0.000001)	-0.000001 (0.000001)	-0.0000004 (0.000001)
Const year 1921<1944:Age2	-0.00010 (0.00017)	-0.00024* (0.00013)	-0.00004 (0.00009)
Const year 1945<1959:Age2	0.00012 (0.00016)	0.00004 (0.00018)	-0.00029** (0.00014)
Const year 1960<1973:Age2	0.00037*** (0.00009)	0.00040*** (0.00012)	0.00034** (0.00013)
Const year 1974<1981:Age2	0.00056*** (0.00013)	0.00042* (0.00024)	-0.00038 (0.00026)
Const year 1982<1990:Age2	0.00034** (0.00017)	0.00043** (0.00021)	0.00084** (0.00034)
Const year 1991<1997:Age2	0.00012 (0.00017)	0.00005 (0.00032)	0.00001 (0.00048)
Const year 1998<:Age2	-0.00017 (0.00023)	-0.00046 (0.00045)	-0.00129 (0.00112)
Monument:Age	-0.00023 (0.00054)	-0.00026 (0.00020)	-0.00030* (0.00016)
Time dummies	Yes	Yes	Yes
Year of construction dummies	Yes	Yes	Yes
Constant	7.573***(0.08441)	7.779***(0.05757)	8.989***(0.05475)
Observations	30,327	16,974	16,598
Adjusted R2	0.69114	0.72848	0.57236
FE Groups	2,497	2,221	1,913

Notes: (1) Robust standard errors in parentheses. (2) *p<0.1; **p<0.05; ***p<0.01

6 Architectural quality and protected status in Amsterdam

It is evident from the results of our main model that construction year is an important determinant of property's aging patterns. Construction year of a structure reflects quality of construction and architectural style and is therefore also related to physical maintenance costs and probability of obsolescence. Observing such factors directly, instead of indirectly through structure construction periods, allows for a better understanding of the mechanism behind the effects that property aging patterns have on their value. These issues can be more carefully explored by using data on architectural quality areas and urban regulation zones from the municipality of Amsterdam,[12] and to measure the effect of aging for each of these groups.

The municipality of Amsterdam defines thirteen architectural quality zones, based on urban expansion periods of the city's boundaries. Nevertheless, due to construction and renovations along the years, each of the areas still includes properties built during various construction periods (see Table A1).[13] In this sense, architectural quality areas may not be regarded as homogeneous in terms of architecture, but they still represent the most prevalent building styles, as well as area-specific contemporary urban planning practices. Following this, we estimate our main fixed-effects model in (1), in which we interact age with architectural quality dummies, instead of construction year dummies. The effect of aging is interpreted here as style effect, associated with an architectural style or urban planning practice.

In addition, we include control and age interactions with urban regulation zones. Amsterdam defines regulation zones which are subject to five different regimes – "protected", "special", "ordinary", "plain" and "free",[14] where "protected" regime stipulates strict preservation of structures and urban landscape, and "free" offers minimum restrictions and allows for relatively free land development. Including regulation zones and age interactions in the estimation allows to identify aging effects which are associated with both obsolescence and vintage effects. Nevertheless, interpretation of these age effects may be complicated by conflicting effects. For instance, protected areas are likely to maintain cultural, architectural and historical value, but similar to listed buildings, they may also maintain their old, and often obsolete, land uses. On the other hand, properties within areas "free" of restrictions are less likely to be exposed to positive vintage effects, but more likely to have efficiently allocated and less obsolete uses. It may also be that poorly maintained or obsolete properties within "free" areas were demolished and did not survive long enough to suffer from sever value depreciation, whereas such properties in regulated areas are restricted to remain in place. In this case, the aging effect in such areas will be overestimated.

For the analysis we use a subsample of transactions within the Amsterdam municipal area, which includes 3,078 observations. The results are reported in Tables A2, A3 and A4.

Table A2 describes the results of the main model (age and construction period interactions), estimated for the subsample of Amsterdam transactions, and its purpose of this estimation is to serve as a benchmark for the following models. The results show a positive and significant age

12 Data is available online at: https://maps.amsterdam.nl/welstand/ [Accessed: June 7th 2018].

13 For instance, 41% of (commercial) properties located in the "residential regions built after 1985" area were built before 1985.

14 *"Beschermd", "Bijzonder", "Gewoon", "Eenvoudig" and "Vrij"* in Dutch.

effect for properties built before 1920, of approximately 0.27% per year. Unlike the results for the full sample (Table 2), there is no negative and significant effect for properties built in other time periods. This suggests that property value appreciation is relatively higher within the municipality of Amsterdam compared with the national estimates.

Table A3 describes the results of the model which include architectural areas interactions with age, replacing construction period – age interactions. The results show that several areas experience positive and significant aging effect of approximately 0.1-0.4% per year. Among these areas are pre-WWII urban expansion neighborhoods, excluding the historic inner city,[15] and some of the newest areas.[16] Property transactions within the inner city of Amsterdam, where most historical urban landscape is located, show no statistically significant aging effect. Negative and significant effect exists only for one region (Residential yards and meanders)[17]. This is consistent with the results in Table 2, which show generally positive aging effect among property transactions in Amsterdam. Considering the control for locational fixed-effects, these results provides evidence that architectural and urban style matter for depreciation patterns of commercial real estate.

The results in Table A4 focus on the specific aging effect of regulation zones within Amsterdam. We find positive aging effect of 0.2% and 0.4% for properties located within areas with “special” and “plain” regulation status, respectively. The effect of “Ordinary”, the regulation level between “Special” and “Plain”, is just above the 10% statistical significance level. “Special” status stipulates that development is allowed, but under structure quality requirements, and given that the development contributes to the quality of the surrounding urban environment. “Plain” status stipulates limited provision, which focuses mainly on prevention of decline in urban quality due to new development. Positive aging effect for these different regimes can be interpreted as appreciation due to urban and structural quality (where change is still permitted in case of obsolescence) all else equal. Statistically insignificant results for areas in which regulation is most strict (high architectural quality but strict permission for uses) and least strict (low architectural quality but free permission for uses) may support this argument. This is also consistent with the finding from Table A3, that no positive or significant vintage effect was found for the historical inner city of Amsterdam.

The above estimates vary when examined for commercial segments subsamples. While the number of observations is substantially lower, we can still identify statistically significant effects for property depreciation in certain architectural quality areas and regulation areas (see Tables B1 and B2). Notably, Retail properties show positive and significant aging effects of approximately 0.25%-0.4% in areas with relatively stricter regulation. Retail properties also show higher appreciation for locations with architectural and historical value, with 1.6% value increase for properties within the 1920-1940 belt, and 0.5% for properties located in the 19th century ring. In contrast, offices and industrial properties show a negative and significant effect of approximately -0.5% to -0.75% per year in restricted areas. Offices also present depreciation in areas with older architectural style and quality (the inner city and the 19th century ring), as well as in areas designated for office terrain. We find no significant aging effect for industrial property transactions based on architectural quality area groups.

15 “De 19de-eeuwse Ring”,” Gordel `20-`40”.

16 “AUP en Post-AUP” , “Groen en Water”, ” Woongebieden > 1985”.

17 “Woonerven en meanders”.

Utilizing the richer architectural and urban regulation zones data from Amsterdam reveals that heterogeneity in commercial property aging effect is strongly linked to architectural and urban style, as well as the possibility of redevelopment and renovation. These findings are emphasized given that we control for building construction period and other characteristics. While building construction period may capture unobserved vintage, quality or operational use effects on value depreciation, these factors still vary among properties within the same construction period groups, and cause variance in depreciation effects.

7 Sensitivity Analysis

7.1 Rural and urban divide

Depreciation or appreciation of property value with time is also likely to be related to urban or rural location context. For instance, it may be that commercial properties in urban areas are less sensitive to obsolescence or physical deterioration effects. This is because higher land values in such areas are more likely to incentivize re-use or renovations, and to stimulate the efficient use of a relatively more central location. To test whether properties experience different depreciation patterns depending on their urban or rural location, we extend our fixed-effects analysis to subsamples based on rural and urban divide.

We define urban areas as municipalities which are located within the Randstad areas, a large urban area in the west of The Netherlands which contains also the four largest cities in the country (Amsterdam, Rotterdam, The Hague and Utrecht).[18] About 42% (26,960) of the observations in our sample are located within an urban area (see Table C1). As in the previous analysis, location fixed-effects are present at the four-digit postal code level.

Examining the results for rural and urban areas (Table C2) it appears that the positive age effect among properties constructed before 1920 remains, but with lower statistical significance compared with the pooled results (Table 2). This effect appears stronger among rural properties, which are expected to increase 0.1% annually, compared with 0.07% among urban properties. Positive and significant age effects of 2.7% and 1.4% also exists for rural properties built between 1945-1959 and after 1998, respectively. Comparable with the pooled results, the results also show a generally negative age effect for properties built between 1960-1997, for both rural and urban areas. Aging effect for listed buildings remains statistically significant but small for both rural and urban areas.

Aging effect on transaction prices exhibit similar patterns for urban and rural areas, but it appears that estimated positive aging effects are somewhat stronger for rural areas. Nevertheless, a standard Hausman test (Hausman, 1978) to compare the effects between the two models shows that there are no statistically significant systematic differences between the positive aging effects for rural and urban areas.

18 We have also tested an additional definition for urban locations – location within the four largest cities (exclusively). Analysis results remain robust in terms of coefficient values, magnitude and statistical significance.

8 Discussion and conclusion

The depreciation of real estate properties can be reflected both in obsolescence and loss of functionality, and in physical deterioration and loss of quality (Baum, 1993). Understanding whether an aging effect of a property follows primarily from physical deterioration of quality or obsolescence is central for deciding where funds should properly be allocated to increase its value. Depreciation or appreciation effects are also particularly important for understanding the drivers behind revival or decline of urban areas.

In this paper we apply a fixed-effects analysis to demonstrate that aging effect can vary greatly over different commercial uses and construction period. Our results show that while aging effect is often negative, a small but positive and significant aging effects, or vintage effect, exists for certain types of real estate, notably among pre-1920 industrial properties. This positive effect is also evident to a smaller extent among offices built before WWII. We find that properties constructed between 1960 and 1990 generally experience mostly negative depreciation effects, particularly offices. We also find that architectural style and quality, as well as zoning and development restriction regimes, also affect depreciation patterns, possibly by defining requirements for physical preservation while permitting or restricting structure usage.

There may be several possible interpretations for the positive aging effects. First, the supply of old structures is limited, and building with similar contemporary architectural style and quality, which often have aesthetic value (Ahlfeldt & Holman, 2017), are not produced anymore due to increase in costs of labor and changes in construction technologies (as well as current tastes). Therefore, increase in demand for historical properties, or for architectural style and quality, translates directly to increase in value with property age. In the Netherlands specifically, historical industrial buildings (built before 1920s) are rare due to a relatively small and late industrial revolution, as compared to neighboring countries.

Second, it may be that older properties are better situated within a city or sub-region. Although we control for regional effects accessibility and location within protected city center, and test for difference in estimated results between rural and urban areas, it may still be that older properties are in key micro-areas where the value of land is appreciating. This may affect the value of the property, regardless of the physical condition of the structure.

Third, property obsolescence may be less relevant for very old properties. Approximately 20% of our data is of transactions of properties built before 1920, many of which were built in the 19th century or before. Obsolescence of these properties is likely to have resulted in changes of their initial purpose already many years ago. Therefore, we expect that the depreciation of these properties would be less sensitive to obsolescence effect, compared with “newer” properties.

An additional explanation for the positive vintage effects is that despite controlling for location effects and protected status of properties, our results may still suffer from estimator bias as was noted by Hulten and Wykoff (1981) and Bokhari and Geltner (2016). It is possible that the supply of old properties suffers from a selection bias, as only properties of high quality and maintenance levels survived to this day, while poorer quality properties were demolished or converted to other uses. The latter example is common for vintage industrial sites in the Netherlands (Van Duijn et al., 2016). The anticipation for conversion to other uses or for preservation may in fact be one of the reasons for the positive aging effect for pre-war industrial properties.

9 References

Abramson, D. M. (2016). *Obsolescence : an architectural history*. University of Chicago Press.

Ahlfeldt, G. M., & Holman, N. (2017). Distinctively Different: A New Approach to Valuing Architectural Amenities. *Economic Journal*, 1–33.

Baum, A. E. (1993). Quality, depreciation and property performance. *The Journal of Real Estate Research*.

Bokhari, S., & Geltner, D. (2016). Characteristics of Depreciation in Commercial and Multifamily Property: An Investment Perspective. *Real Estate Economics*, 1–38.

Clapp, J. M., & Giaccotto, C. (1998). Residential hedonic models: A rational expectations approach to age effects. *Journal of Urban Economics*, *44*, 415–437.

Crosby, N., Devaney, S., & Law, V. (2012). Rental depreciation and capital expenditure in the UK commercial real estate market, 1993–2009. *Journal of Property Research*, *29*(3), 227–246.

Davis, M. A., & Heathcote, J. (2005). Housing and the business cycle. *International Economic Review*. Wiley/Blackwell (10.1111).

Davis, M. A., & Heathcote, J. (2007). The price and quantity of residential land in the United States. *Journal of Monetary Economics*, *54*(8), 2595–2620.

Dekkers, J. E. C., & Van der Beek, M. (2016). *Manual BAG processing. Making Snapshots from and Geocoding against the Dutch Basic Administration of Addresses and Buildings using Geo Data and Model Server (GeoDMS) version 7.026 or higher*. Amsterdam.

Diewert, W. E., & Shimizu, C. (2014). Alternative approaches to commercial property price indexes for Tokyo. *Review of Income and Wealth*, *14*(8).

Dunse, N., Jones, C., Brown, J., & Fraser, W. D. (2005). The spatial pattern of industrial rents and the role of distance. *Journal of Property Investment & Finance*, *23*(4), 329–341.

Fisher, J. D., Smith, B. C., Stern, J. J., & Webb, R. B. (2005). Analysis of Economic Depreciation for Multi-Family Property. *Journal of Real Estate Research*, *27*(4), 355–370.

Francke, M. K. (n.d.). *Handbook on commercial property price indicators*. Eurostat.

Francke, M. K., & Van de Minne, A. M. (2016). Land, Structure and Depreciation. *Real Estate Economics*, (1995), 1–37.

Glaeser, E. (2011). *Triumph of the City: how our invention makes us richer,smarter, greener, healthier and happier*.

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. *Journal of Urban Economics*, *61*, 193–217.

Hausman, J. A. (1978). Specification Tests in Econometrics. *Econometrica*, *46*(6), 1251.

Hotelling, H. (1925). A General Mathematical Theory of Depreciation. *Journal of the American Statistical Association*, *20*(151), 340–353.

Hulten, C. R., & Wykoff, F. C. (1981). The estimation of economic depreciation using vintage asset prices. An application of the Box-Cox power transformation. *Journal of Econometrics*, *15*(3), 367–396.

Palmquist, R. B. (1979). Hedonic price and depreciation indexes for residential housing: A comment. *Journal of Urban Economics*, *6*(2), 267–271.

Rosenthal, S. S. (2008). Old homes, externalities, and poor neighborhoods. A model of urban decline and renewal. *Journal of Urban Economics*, *63*(3), 816–840.

Shilling, J. D., Sirmans, C. F., & Dombrow, J. F. (1991). Measuring depreciation in single-family rental and owner-occupied housing. *Journal of Housing Economics*, *1*(4), 368–383.

Smith, B. C. (2004). Economic Depreciation of Residential Real Estate: Microlevel Space and Time Analysis. *Real Estate Economics*, *32*(1), 161–180.

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.

Wilhelmsson, M. (2008). House price depreciation rates and level of maintenance. *Journal of Housing Economics*, *17*(1), 88–101.

10 Appendix

A. Exploration of age effects for protected status and architectural quality (Amsterdam only)

Table A1 – Number of properties per construction period and architectural areas and regulation zones in Amsterdam

Construction period	<1920	1921<< 1944	1945<< 1959	1960<< 1973	1974<< 1981	1982<< 1990	1991<< 1997	1998<	Total
Urban expansion and post-expansion	24	20	7	25	24	18	25	46	189
Inner city	204	79	46	115	134	111	123	198	1010
The 19th century ring	71	42	24	84	65	58	60	116	520
Ij lands	17	3	1	2	3	11	5	12	54
1920-1940 belt	30	8	6	11	20	15	20	46	156
Green and water areas	19	16	7	26	12	16	24	30	150
Historical cores and additions	11	1	3	6	1	11	5	9	47
Offices and indusrty terrain	102	51	31	91	88	98	105	169	735
Northern outskirts	0	2	0	0	0	0	0	0	2
Transformation areas	3	0	1	3	7	4	5	11	34
Garden villages	6	4	3	14	4	4	11	10	56
Residential yards and meanders	1	0	1	0	2	0	0	0	4
Residential areas > 1985	12	4	3	22	7	7	17	49	121
Construction period	<1920	1921<< 1944	1945<< 1959	1960<< 1973	1974<< 1981	1982<< 1990	1991<< 1997	1998<	Total
Protected (Beschermd)	215	83	49	128	139	114	133	203	1064
Special (Bijzonder)	152	75	39	133	110	112	119	251	991
Ordinary (Gewoon)	103	52	34	95	87	74	100	163	708
Plain (Eenvoudig)	23	16	6	32	25	36	43	60	241
not protected (Vrij)	7	4	5	11	6	17	5	19	74

Table A2 - Main model results in Amsterdam subsample , including protected status and architectural quality

	(1)
	FE
Official Monument	0.20702 (0.12797)
Protected city center	-0.04308 (0.05632)
Floor area (ln)	0.62640*** (0.01663)
Investment property	0.29656*** (0.04087)
protected status: Special (*Bijzonder*)	0.15420* (0.08331)
protected status: Plain (*Eenvoudig*)	0.11141 (0.09084)
protected status: Ordinary (*Gewoon*)	0.10137 (0.08996)
protected status: not protected (*Vrij*)	0.12978 (0.12203)

Monument:Age	-0.00062 (0.00063)
Const year <1920:Age	0.00267*** (0.00093)
Const year 1921<1944:Age	0.05495 (0.06619)
Const year 1945<1959:Age	0.00461 (0.04602)
Const year 1960<1973:Age	-0.04225 (0.03501)
Const year 1974<1981:Age	-0.01240 (0.02915)
Const year 1982<1990:Age	-0.01270 (0.01859)
Const year 1991<1997:Age	0.01453 (0.01938)
Const year 1998<:Age	0.00664 (0.01273)
Const year <1920:Age2	-0.000004*** (0.000001)
Const year 1921<1944:Age2	-0.00037 (0.00046)
Const year 1945<1959:Age2	-0.00015 (0.00043)
Const year 1960<1973:Age2	0.00044 (0.00047)
Const year 1974<1981:Age2	0.00006 (0.00056)
Const year 1982<1990:Age2	0.00013 (0.00053)
Const year 1991<1997:Age2	-0.00070 (0.00069)
Const year 1998<:Age2	-0.00013 (0.00086)
Architectural quality area dummies	Yes
Time dummies	Yes
Year of construction dummies	Yes
Constant	***(7.992)
Observations	3,078
Adjusted R2	0.60159
FE Groups	688

Notes: (1) Protected status reference group is Protected (*Beschermd*). (2) Robust standard errors in parentheses. (3) *p<0.1; **p<0.05; ***p<0.01.

Table A3 - Main model results in Amsterdam subsample , including protected status and architectural quality (Age-architectural quality interactions)

	(1)
	FE
Official Monument	0.14963 (0.13727)
Protected city center	-0.03312 (0.06050)
Floor area (ln)	0.62875*** (0.01671)
Investment property	0.29543*** (0.03936)
protected status: Special (Bijzonder)	0.14770* (0.08312)
protected status: Ordinary (Gewoon)	0.09067 (0.09094)
protected status: Plain (Eenvoudig)	0.10640 (0.08987)
protected status: not protected (Vrij)	0.13298 (0.12253)

Monument:Age	-0.00002 (0.00069)
Urban expansion and post-expansion:age	0.00426** (0.00195)
Inner city:age	0.00108 (0.00117)
The 19th century ring:age	0.00284* (0.00147)
Ij lands:age	0.00177 (0.00240)
1920-1940 belt:age	0.00436** (0.00204)
Green and water areas:age	0.00418** (0.00202)
Historical cores and additions:age	0.00069 (0.00251)
Offices and indusrty terrein:age	0.00162 (0.00126)
Transformation areas:age	0.00119 (0.00278)
Garden villages:age	-0.00064 (0.00583)
Residential yards and meanders:age	-0.01914* (0.01125)
Residential areas > 1985:age	0.01348*** (0.00396)
Urban expansion and post-expansion:age2	-0.00001* (0.000004)
Inner city:age2	-0.000002 (0.000002)
The 19th century ring:age2	-0.00001* (0.000004)
Ij lands:age2	-0.00001 (0.00001)
1920-1940 belt:age2	-0.00001* (0.000004)
Green and water areas:age2	-0.00001** (0.000003)
Historical cores and additions:age2	-0.00001 (0.00001)
Offices and indusrty terrein:age2	-0.000002 (0.000002)
Transformation areas:age2	-0.000002 (0.00001)
Garden villages:age2	0.00001 (0.00004)
Residential yards and meanders:age2	0.00016 (0.00012)
Residential areas > 1985:age2	-0.00009*** (0.00003)
Architectural quality area dummies	Yes
Time dummies	Yes
Year of construction dummies	Yes
Constant	***(8.044)
Observations	3,078
Adjusted R2	0.59919
FE Groups	688

Notes: (1) Protected status reference group is Protected (*Beschermd*). (2) Robust standard errors in parentheses. (3) *p<0.1; **p<0.05; ***p<0.01.

Table A4 - Main model results in Amsterdam subsample , including protected status and architectural quality (Age-protected status interactions)

	(1)
	FE
Official Monument	0.15923 (0.13665)
Protected city center	-0.03624 (0.05863)
Floor area (ln)	0.62850*** (0.01658)
Investment property	0.29619*** (0.04003)
protected status: Special (Bijzonder)	0.08661 (0.09086)
protected status: Ordinary (Gewoon)	0.06128 (0.09966)
protected status: Plain (Eenvoudig)	0.03592 (0.09826)
protected status: not protected (Vrij)	0.22135 (0.14592)
Monument:Age	-0.00015 (0.00066)
protected status: Protected (Beschermed):age	0.00084 (0.00107)
protected status: Special (Bijzonder):age	0.00261** (0.00116)
protected status: Ordinary (Gewoon):age	0.00163 (0.00113)
protected status: Plain (Eenvoudig):age	0.00403* (0.00242)
protected status: not protected (Vrij):age	-0.00404 (0.00488)
protected status: Protected (Beschermed):age2	-0.000002 (0.000002)
protected status: Special (Bijzonder):age2	-0.00001** (0.000002)
protected status: Ordinary (Gewoon):age2	-0.000002 (0.000002)
protected status: Plain (Eenvoudig):age2	-0.00001** (0.00001)
protected status: not protected (Vrij):age2	0.00002 (0.00001)
Architectural quality area dummies	Yes
Time dummies	Yes
Year of construction dummies	Yes
Constant	***(8.189)
Observations	3,078
Adjusted R2	0.60030
FE Groups	688

Notes: (1) Protected status reference group is Protected (*Beschermd*). (2) Robust standard errors in parentheses. (3) *p<0.1; **p<0.05; ***p<0.01.

B. Exploration of age effects for protected status and architectural quality, per commercial segment (Amsterdam only)

Figure B1 – Architectural zones and urban regulation zones in the municipality of Amsterdam

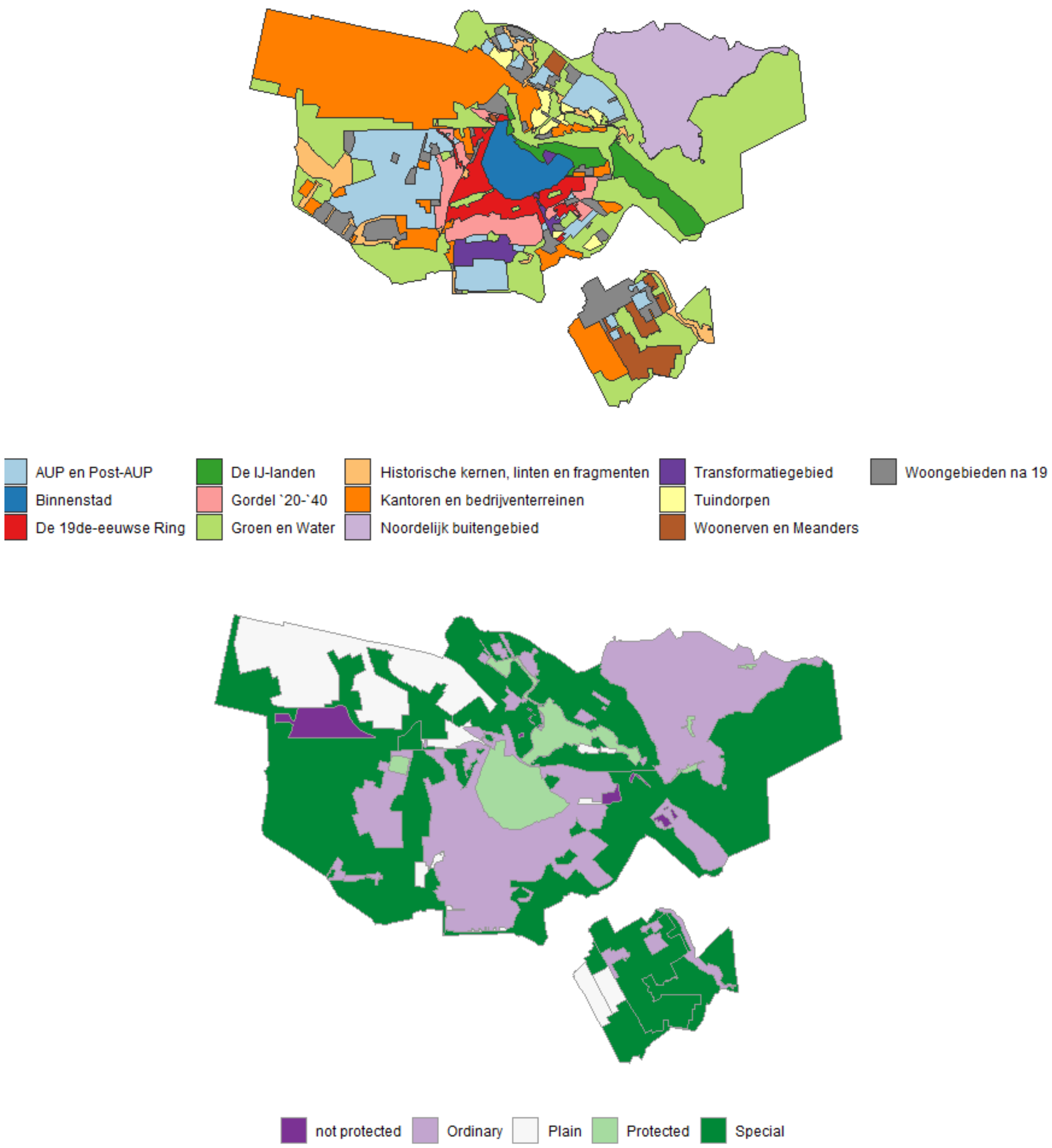


Table B1 - Main model results in Amsterdam subsample per commercial segment,, including protected status and architectural quality (Age-architectural quality interactions)

	Industrial	Offices	Retail
	(1)	(2)	(3)
Urban expansion and post-expansion:age	-0.00207 (0.00782)	-0.00699 (0.00643)	0.00483 (0.00485)
Inner city:age	-0.00564 (0.00460)	-0.00996*** (0.00374)	0.00201 (0.00143)
The 19th century ring:age	-0.00868 (0.00754)	-0.01318*** (0.00431)	0.00502** (0.00253)
Ij lands:age	-0.00723 (0.00855)	-0.00458 (0.00784)	-0.00210 (0.00367)
1920-1940 belt:age	-0.00082 (0.00481)	-0.00579 (0.01496)	0.01602*** (0.00371)
Green and water areas:age	-0.00175 (0.01001)	-0.00662 (0.00464)	-0.01158 (0.01345)
Historical cores and additions:age	0.00368 (0.01752)	-0.00977 (0.02628)	0.00604* (0.00363)
Offices and indusrty terrain:age	-0.00680 (0.00425)	-0.00804** (0.00360)	0.00185 (0.00131)
Transformation areas:age	-0.00577 (0.00468)	-0.00550 (0.04281)	0.04164*** (0.01101)
Garden villages:age	0.02901 (0.02248)	-0.00381 (0.01002)	-0.01726 (0.03237)
Residential areas > 1985:age	0.00369 (0.00620)	-0.00312 (0.00860)	0.02485 (0.02791)
Urban expansion and post-expansion:age2	-0.00002 (0.00009)	-0.0000003 (0.00004)	-0.00001 (0.00001)
Inner city:age2	0.00001 (0.00001)	0.00001** (0.00001)	-0.000003 (0.000002)
The 19th century ring:age2	0.00005 (0.00008)	0.00002** (0.00001)	-0.00001* (0.00001)
Ij lands:age2	0.00005 (0.00007)	0.000002 (0.00003)	0.00001 (0.00001)
1920-1940 belt:age2	-0.000002 (0.00001)	0.00001 (0.00012)	-0.00002*** (0.00001)
Green and water areas:age2	-0.000004 (0.00006)	0.00001 (0.00001)	0.00013 (0.00012)
Historical cores and additions:age2	0.00002 (0.00022)	0.00006 (0.00022)	-0.00001* (0.00001)
Offices and indusrty terrain:age2	0.00001 (0.00001)	0.00001** (0.000005)	-0.000003 (0.000002)
Transformation areas:age2	0.00001 (0.00002)	0.00002 (0.00038)	
Garden villages:age2	-0.00059 (0.00056)	0.000002 (0.00005)	-0.00035*** (0.00010)
Residential yards and meanders:age2			0.00015 (0.00034)
Residential areas > 1985:age2	-0.00007** (0.00003)	-0.00001 (0.00005)	-0.00024 (0.00023)
Control variables and group dummies	Yes	Yes	Yes
Constant	7.907***(0.2537)	9.138***(0.5721)	8.649***(0.4097)
Observations	1,695	735	648
Adjusted R2	0.65063	0.54781	0.33585
FE Groups	417	294	254

Notes: (1) Control variables included in the estimation are identical to those used in Tables A2, A3, A4. (2) Protected status reference group is Protected (*Beschermd*).

Table B2 - Main model results in Amsterdam subsample per commercial segment, including protected status and architectural quality (Age-protected status interactions)

	Industrial	Offices	Retail
	(1)	(2)	(3)
protected status: Protected (Beschermed):age	-0.00759* (0.00460)	-0.00716** (0.00299)	0.00259* (0.00149)
protected status: Special (Bijzonder):age	-0.00628 (0.00427)	-0.00692*** (0.00260)	0.00466*** (0.00129)
protected status: Ordinary (Gewoon):age	-0.00734* (0.00407)	-0.00543** (0.00250)	0.00234** (0.00111)
protected status: Plain (Eenvoudig):age	-0.00045 (0.00772)	-0.01070 (0.00940)	0.00302 (0.00423)
protected status: not protected (Vrij):age	-0.01453 (0.01652)	-0.01579 (0.01994)	-0.00982 (0.01229)
protected status: Protected (Beschermed):age2	0.00001* (0.00001)	0.00001** (0.000004)	-0.000004 (0.000002)
protected status: Special (Bijzonder):age2	0.00001 (0.00001)	0.00001** (0.000004)	-0.00001*** (0.000002)
protected status: Ordinary (Gewoon):age2	0.00001* (0.00001)	0.00001** (0.000003)	-0.000004** (0.000002)
protected status: Plain (Eenvoudig):age2	-0.00008 (0.00007)	0.00007 (0.00008)	-0.00001 (0.00001)
protected status: not protected (Vrij):age2	-0.00001 (0.00034)	0.00011 (0.00022)	0.00003 (0.00003)
Control variables and group dummies	Yes	Yes	Yes
Constant	8.114***(0.2677)	8.939***(0.3943)	8.682***(0.3394)
Observations	1,695	735	648
Adjusted R2	0.65268	0.55084	0.34059
FE Groups	417	294	254

Notes: (1) Control variables included in the estimation are identical to those used in Tables A2, A3, A4. (2) Protected status reference group is Protected (*Beschermd*). (3) Robust standard errors in parentheses. (3) *p<0.1; **p<0.05; ***p<0.01.

C. Main model result per urban rural settings.

Table C1 - Shares of property transactions by construction period and urban-rural location

	Rural		Urban	
Construction period	N	Freq.	N	Freq.
<1920	6,778	49.9%	6,806	50.1%
1921<<1944	3,395	50.7%	3,301	49.3%
1945<<1959	2,394	63.4%	1,380	36.6%
1960<<1973	5,381	61.6%	3,355	38.4%
1974<<1981	4,484	66.3%	2,280	33.7%
1982<<1990	3,534	62.0%	2,163	38.0%
1991<<1997	4,092	62.7%	2,434	37.3%
1998<	6,883	56.8%	5,241	43.2%
Total	36,941		26,960	

Table C2 - Hedonic model results - per rural and urban location

	Rural	Urban
	FE	FE
	(1)	(2)
Official Monument	0.20308*** (0.02746)	0.21251*** (0.03414)
Protected city center	0.15613*** (0.02975)	0.20264*** (0.03535)
Floor area (ln)	0.55652*** (0.00658)	0.67640*** (0.00687)
Investment property	0.29224*** (0.01238)	0.27853*** (0.01452)
Const year <1920:Age	0.00113** (0.00045)	0.00073 (0.00045)
Const year 1921<1944:Age	0.02172 (0.01363)	-0.00885 (0.01650)
Const year 1945<1959:Age	0.02751** (0.01289)	-0.00359 (0.01512)
Const year 1960<1973:Age	-0.03241*** (0.00684)	-0.02901*** (0.00799)
Const year 1974<1981:Age	-0.02926*** (0.00782)	-0.02593*** (0.00917)
Const year 1982<1990:Age	-0.02073*** (0.00560)	-0.01530 (0.00967)
Const year 1991<1997:Age	-0.00477 (0.00512)	-0.01625*** (0.00628)
Const year 1998<:Age	0.01453*** (0.00559)	-0.00897* (0.00491)
Const year <1920:Age2	-0.000001 (0.000001)	-0.000001 (0.000001)
Const year 1921<1944:Age2	-0.00014 (0.00009)	0.00003 (0.00011)
Const year 1945<1959:Age2	-0.00030** (0.00012)	0.00002 (0.00014)
Const year 1960<1973:Age2	0.00038*** (0.00009)	0.00029*** (0.00010)
Const year 1974<1981:Age2	0.00047*** (0.00015)	0.00023 (0.00018)
Const year 1982<1990:Age2	0.00042*** (0.00015)	0.00010 (0.00026)
Const year 1991<1997:Age2	0.000002 (0.00019)	0.00018 (0.00022)
Const year 1998<:Age2	-0.00039 (0.00031)	0.00035 (0.00028)
Monument:Age	-0.00062*** (0.00017)	-0.00040* (0.00021)
Time dummies	Yes	Yes
Year of construction dummies	Yes	Yes
Constant	8.556***(0.05296)	8.067***(0.05478)
Observations	36,941	26,960
Adjusted R2	0.63035	0.72886
FE Groups	2,024	937

Notes: (1) Robust standard errors in parentheses. (2) *p<0.1; **p<0.05; ***p<0.01

Neem voor vragen of opmerkingen contact met ons op of bezoek onze website.

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