# The Internal Structure of Cities:

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# 7 The impact of mixed land use on residential property values[*]

## 7.1 Introduction

Mixed land use has become one of the backbones of contemporary US planning policies such as Smart Growth and New Urbanism. In Europe as well, the widely implemented Compact City Concept aims to increase densities and mixed land use (Rowley, 1996; Koomen et al., 2008). Many European cities pursue relatively stringent land use policies. It may therefore seem surprising that debates on compact development and mixed land-use are much less heated in Europe than in the United States (Dieleman et al., 1999; Van der Valk, 2002). This is mainly because mixed land use is nothing new in European cities. Since medieval times, there has been a great mixture of working and living in the historic city centres of many European cities (Anas et al., 1998, Brueckner et al., 1999).

Despite a wide variety of definitions, the European compact city concept generally focuses on relatively high-density, mixed neighbourhoods in terms of land use, that are well accessible by public transport (Burton, 2000). Underlying the popularity of this concept is the belief that the co-location of social functions leads to a sustainable and liveable urban environment. However, there are some critical voices that argue that this concept is mainly supply-driven, while individual's preferences do not play a role in decisions of (local) governments. It is also argued that the benefits and costs of mixed use, as well as compact development have not been well understood (Jenks et al., 1996; Dieleman et al., 1999; Burton, 2000)

In this chapter, we contribute to the literature by investigating the willingness to pay of home-owners for mixed land use. Mixed land use is considered as an important component of the compact city concept, as compactness implies proximity of households to each other, but also to different types of land use (see Rowley; 1996). More specifically, we attempt to determine the effect of mixing employment and residential land use on housing values, by means of a semiparametric hedonic house price analysis.[146] A common idea in the compact city concept is that in attractive urban areas, each neighbourhood provides a sufficiently rich variety of functions, which allows its inhabitants to realise all their daily activities without having to move to other parts of the city (Handy, 1992; Breheny, 1994). Grocery shops, basic amenities, and sufficient employment for the inhabitants of the neighbourhood should preferably be available within walking distance, which is only possible if there is a variety of jobs

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146 Mixing employment and residential use is arguably one of the most important aspects of mixed land use, but certainly does not cover it completely. Other potentially relevant aspects – like mixing various types of housing in residential areas – are ignored in the present study.

in each neighbourhood. The basic research question to be answered is then: *do home-owners value mixing of employment and residential land use?*

This study adds to the literature in three important aspects. First, most studies make strong assumptions on the functional form of the hedonic price function. Ekeland et al. (2004), among others, argue that the relationship between house prices and various attributes is complex and nonlinear, which implies that it is hard to defend any specific functional form on a priori grounds. It is therefore preferable to avoid such assumptions through the use of nonparametric or semiparametric specifications. Our estimation procedure leads to *distributions* of willingness to pay (WTP) parameters for different aspects of mixed land-use. We relate these distributions to household characteristics and different house types and price segments of the housing market to learn about households' preferences for mixed land use. Our results show that there is indeed substantial heterogeneity in the willingness to pay for diversity, as well as in the willingness to pay for different land uses. For example, households residing in apartments are willing to pay about 2.4 percentage points more for diversity than households dwelling in other house types.

Second, in the literature it is often assumed that some uses are compatible with residential land (e.g. business land), whereas others are not (e.g. industrial land). This seems plausible, but empirical work that confirms (or rejects) this suggestion appears to be scarce. Using a rather detailed classification of sectors, we are able to provide more insight in which uses are compatible with housing and which are not.

Third, measuring the effects of diversity of land use may be complicated, as the impact of mixed land use is multidimensional. We therefore include in our hedonic equation a variable that measures the *diversity* of land uses and variables that measure the *presence* of mixed land use. Based on the estimates, we define a new diversity index that is only based on land uses that are compatible with residential use. The impact of this index appears to be positive: the effect of one standard deviation increase in this adjusted diversity index leads to an increase in house price of on average 1-3 percent.

The chapter proceeds as follows. Section 7.2 introduces the Compact City Concept and discusses previous hedonic studies that investigate the effects of mixed land use. In Section 7.3 the data are described and the regional context is considered. Section 7.4 discusses our estimation techniques. In Section 7.5 we present our results. Section 7.6 concludes and draws some policy implications.

## 7.2 Hedonic price methods and mixed land use

### *A. The compact city concept*

Mixed land use is defined as a mixture of commercial, residential and industrial land within a certain area. In the ancient Greek and Roman cities, but also in the cities of the Middle Ages, living, working and shopping were all located within the city walls (Wright, 1967; Coupland, 1997). In the early 20th century this 'natural' co-location of land uses came to an end. Owing to technological progress, especially in the transport sector, and changes in cultural behaviour, land uses were often separated (Grant, 2004). Nevertheless, cities in Europe have evolved differently than American cities (Anas et al., 1998). There is a great mixture of businesses and houses, mainly because of the presence of cultural (historic) amenities. Furthermore, public transportation plays a more important role in daily travel. Urban growth patterns are more regular because of more stringent imposition of land-use controls and other types of urban planning (Batty and Longley, 1994; Anas et al., 1998).

In 1961, Jane Jacobs was the first to argue that a balanced mix of living and working in an urban block may lead to livable, safe and viable neighbourhoods (Jacobs, 1961). More than a decade later the compact city policy was introduced in Europe and enjoyed its heyday in the 1980s (Faludi and Van der Valk, 1994; Korthals Altes, 2007). In 1990, the European Commission still promoted the compact city, mixed land use and social and cultural diversity within neighbourhoods (Breheny, 1995; Rowley, 1996). More recently, more emphasis is put on the relationship between mixed use and compact development (Vreeker et al., 2004). In a report of the European Commission, it is advised to focus on compact mixed development, in order to protect open space, reduce energy consumption, improve access to services and facilities, utilise infrastructure more efficiently and facilitate agglomeration economies (Burton, 2000; Working Group on Sustainable Land Use, 2001; Vreeker et al., 2004). However, it is argued that the costs of land use policies have not been weighted against potential gains (Gomez-Ibanez, 1991). Costs that may arise because of mixed compact development may be congestion effects, a rise in property costs and conflicts between different land uses (think of visual, noise and air pollution) (Breheny, 1992).

In Europe there are very few studies that systematically test impacts of land use policies and investigate preferences of individuals and firms for specific lay-outs of the spatial environment. In this chapter we aim to gain insight in the preferences of home-owners for mixing of employment and residential land use, employing a hedonic price approach.

### *B. Hedonic Studies*

A few papers have used the hedonic method to investigate the effects of mixed land use. In two early studies, Cao and Cory (1981) and Lafferty and Frech (1978) find that residential property values increase when the amount of industrial and public land increases. Cao and Cory (181) also discover that commercial land and non-single family homes have a positive impact on residential properties. They conclude that an optimal mix of land uses must be sought, whereas monofunctional land-use or separation of the different activities must be discouraged. Burnell (1985) concentrates on the effects of industrial land use on residential property values in Cook County, Illinois. He makes a distinction between localised and non-localised externalities and finds that residents value the presence of industrial activity positively, although property values are lower in municipalities that suffer from severe pollution.[147] An increase in commercial use will also lead to an increase in the property values. Burnell (1985) concludes that not only the presence of industrial activity is important but also the type of industrial activity.

More recently, Song and Knaap (2004) analyse the effects of mixed land uses on house prices in a fully parametric setup. Their main finding is that mixing commercial activities with residential use will affect house values positively. The ratio of service jobs-to-residents has a small positive effect. The authors conclude that it is very important how the land is mixed: there must be a careful selection of the

[147] An example of a localised externality can be visual pollution, while an example of a non-localised externality may be air pollution.

activities that are to be mixed. This observation is in line with their previous study of policies related to New Urbanism in which they develop quantitative measures of urban form and perform a hedonic price analysis (Song and Knaap, 2003). Their findings suggest that some of the design features of New Urbanism (amongst others, mixed use and accessible commercial land use) capitalise in residential property values, while other features do not have a significant impact. To further address these issues, we will disaggregate employment to different industrial sectors.

So, there is some evidence that the presence of particular types of industrial land use in residential areas can lead to higher property values. However, most of the research employs rough classifications of employment (industrial, commercial or residential land) and merely investigates the effect on single-family houses. We noted above that the available literature pays scant attention to the impact of mixing employment with residential land use. It is assumed that households will like (and prefer) a mixed urban environment in terms of different land uses other than housing. In our setup, where employment is an indicator for land use, this suggests that not just the number of jobs, but also the composition of total employment in terms of industries matters for mixed land use. We will then include an index in our hedonic equation that measures the diversity of land use and condition on the number of jobs in each sector in vicinity of the house. Using semiparametric methods we are then able to show that there is substantial heterogeneity in the WTP for different aspects of mixed land use.

## 7.3 Data sets and regional context

### *A. Data sets*

Our analysis is based upon three data sets. The first data set is from the NVM (Dutch Association of Brokers) and consists of 10,152 housing transactions. It contains information on about 80 percent of all transactions in 2006 in the Rotterdam City Region. The data set includes a number of structural attributes of the house, such as size, number of rooms, and type of house. We removed a small number of observations.[148]

The second database was constructed by the Chamber of Commerce, which comprises data from all firms/establishments that were located in the Rotterdam City Region in 2006. From these 43,911 establishments we have information about the location on a six-digit postcode (PC6) area, the number of employees, and the establishment's sector including the agricultural sector, business services, education and healthcare, government, manufacturing, leisure (cafés, cinemas etc.), retail and wholesale. Because it is somewhat unclear what agricultural employment measures (does it for example measure the accessibility to open space?) we exclude it from the analysis.[149] In the literature, mixed land use is sometimes defined as mixing *compatible* uses, and therefore industrial land use is excluded (Calthorpe and Fulton, 2001). However, we aim to test which uses are compatible with residential use and do not want to exclude industrial use from the outset.

[148] We deleted all transaction prices below € 25,000 and above € 2.5 million. We also removed all observations which refer to properties smaller than $25m^2$ or $100m^3$ and larger than $500m^2$ or $2000m^3$. After these deletions, the database consists of 10,057 values.
[149] It may be shown that this does not influence our main results.

We also use a database at a PC6-level, obtained from Statistics Netherlands, that provides us information about the number of households living in this postcode in 2005, as well as the share of ethnic minorities in the postcode. Furthermore, we gather information on the distance to the nearest 1000 square meter of open space and include the distance to the city centre of Rotterdam, to control for accessibility of employment. This is potentially important as the mixed use variables may capture a commuting effect, as the current employment pattern is decentralised. In the sensitivity analysis we will show that our results are almost the same when we replace distance to centre by distance to the nearest *sub*centres. We also include the nearest highway ramp and the distance to the nearest railway station.

These datasets were integrated into a single database that contains for each house the transaction price, a number of structural attributes, a number of neighbourhood variables, such as accessibility measures, share of ethnic minorities and distance to open space, and a number of variables that relate to mixed land use

*B. How to measure mixed land use?*

To construct variables that measure mixed land use, we rely on geographical information systems and determine for each property a *buffer*. We sum employment in different sectors in property-specific buffers. So, employment measures as well as indices of mixed use are property-specific. This enables us to pay close attention to the effect of different types of employment on residential property values and to identify which sectors are compatible with mixed land use. We think that the use of a buffer is more convenient than a predefined neighbourhood because the size of each buffer for each house is the same and is not subject to arbitrarily-defined neighbourhood boundaries. We assume a buffer radius of 500 meter because we may expect that the effects of mixed land use are very local.[150] We then define a diversity index to examine the impact of a mixture of employment and housing on property values. Let $H_h$ denote the number of households in a neighbourhood of house $h$ and $E_{gh}$ the number of employees in sector $g$. The diversity index $D$ for house $h$ is defined as the inverse of the Hirschmann-Herfindahl index:[151]

(7.1) $$D_h = \frac{1}{\sum_{\forall g}\left(P_{gh}^2\right) + P_{Hh}^2},$$

where $P_{gh} = E_{gh}/\left(H_h + \sum_{\forall g}\left(E_{gh}\right)\right)$ and $P_{Hh} = H_h/\left(H_h + \sum_{\forall g}\left(E_{gh}\right)\right)$. In other words, $P_{gh}$ and $P_{Hh}$ represent respectively employment and household shares of the sum of employment and households. If activities in the buffer of the house under consideration are fully concentrated in one sector, or when only households occupy in the neighbourhood of house $h$, we find $D_h = 1$ and this index increases as activities in this neighbourhood become more diverse (see Duranton and Puga, 2000). In our data the maximum of the index is 6.28. We will include $D_h$ in our hedonic equations to examine whether

[150] A number of studies indicate that the effects of the environment on the value of a house have a localised nature. For example, Palmquist (1992) and Kiel and Zabel (2001) find that a number of environmental effects have a localised impact on residential property values. Also Rouwendal and Van der Straaten (2008) found that the effects of open space are localised (within 500m of each house). A buffer size of 500 meter is therefore a natural starting point of the analysis.

[151] In the sensitivity analysis, we will provide also the effects of other indices on housing values and show that our results are robust to the choice of diversity index.

households value the *mix* of households and different types of employment. Appendix 7.A presents the descriptive statistics of the included variables and we also present a histogram of the diversity index.

### *C. Regional context*

The Rotterdam City Region is located in the west of the Netherlands and hosts the largest port in terms of traffic in Europe (Ducruet et al., 2011). The total population of the Region was 1,175,630 in 2006, which is about 7 percent of the national population. Rotterdam is by far the largest city in the Region with 584,060 inhabitants and is the second largest city in the Netherlands. However, the city is struggling with a relatively high unemployment rate and low average income and educational levels compared to other cities in the Netherlands (Statistics Netherlands, 2007). One aim of local policies is therefore to attract high skilled workers and high income households by offering, among other things, an attractive and dynamic urban environment (Municipality of Rotterdam, 2010). The Municipality of Rotterdam is developing special areas where residential and commercial activities are co-located. An

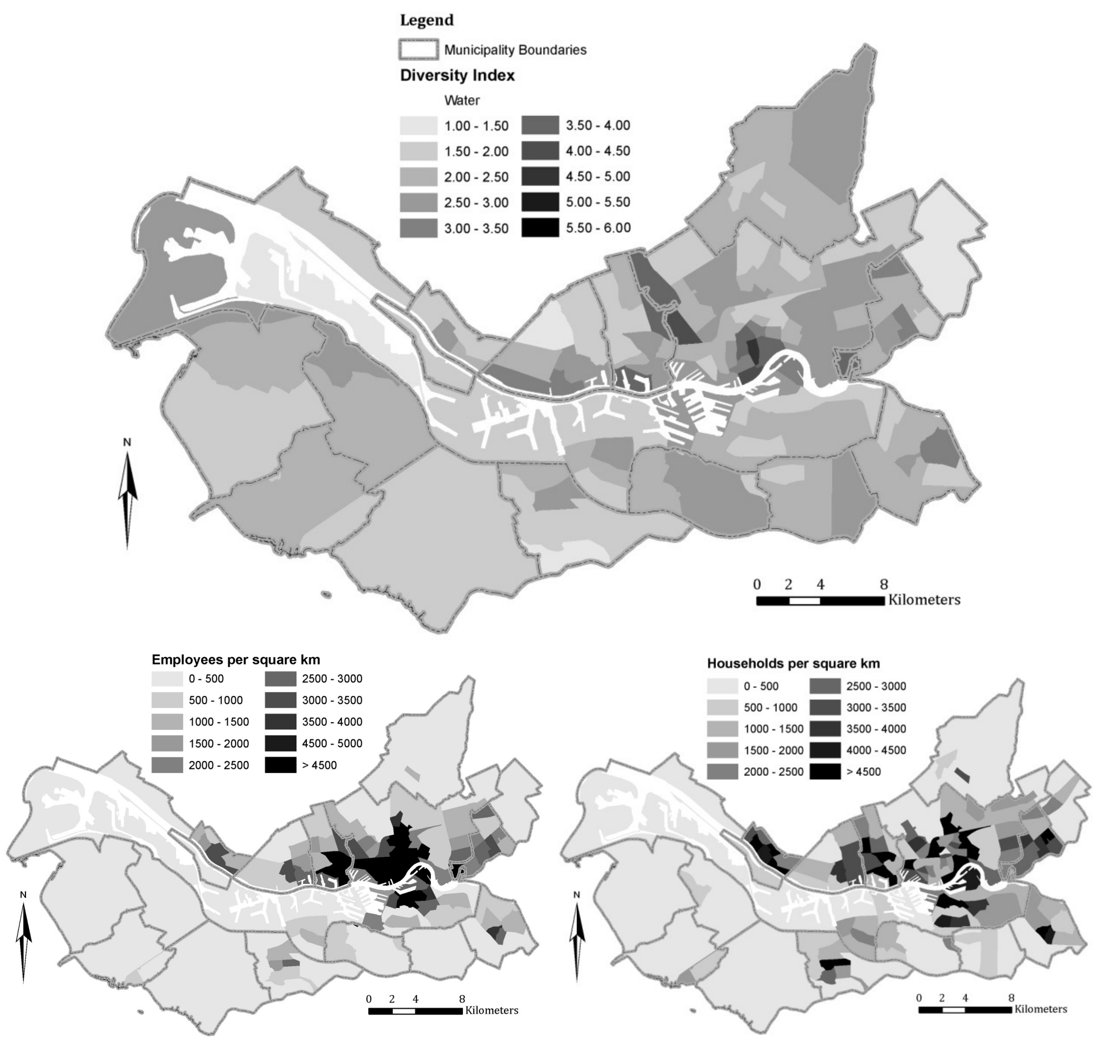


FIGURE 7.1 — DIVERSITY, EMPLOYMENT AND HOUSEHOLD DENSITY IN THE ROTTERDAM REGION

example is the redevelopment of a number of former port areas into vibrant mixed use areas. The white paper 'Stadsvisie Rotterdam 2030' (Municipality of Rotterdam, 2007) cites the Lloyd quarter and the Wilhelminapier as examples of such mixing of in one area:

*"A particular area in Delfshaven is the Lloyd quarter, a former port area, where there is a mix of living and working."*

And:

*"The Wilhelminapier [is] a location with a rich history, a skyline and an attractive mix of living, working, culture, hotels, restaurants and other urban amenities [...]. This will be the trendy, most vibrant mixed urban area of Rotterdam."*

Figure 7.1 represents a map of the City Region, which consists of 16 municipalities. We compute the average diversity index for each postcode area. Especially in the city centre of Rotterdam and Schiedam the diversity of uses is high. There are also a number of areas that are largely monofunctional. For example, some port areas (e.g. Europoort), as well as residential areas in the east of the Rotterdam City Region. We also present the employment and household density in the City Region in Figure 7.1. Employment is predominantly concentrated in the centre of Rotterdam, whereas residential use is more spread over the region.

Because there are numerous examples of actual mixed land-use as well as more monofunctional areas, the city region of Rotterdam is a suitable region to study the effects of mixed land-use. We can compare the impact of having a mixed urban environment with the effects of a more monofunctional lay out.

## 7.4 Model estimation

### *A. A parametric hedonic price function*

A linear or loglinear specification of the hedonic price function is often used because it is easy to interpret the coefficients (Freeman, 1993): in a linear specification the coefficients are equal to the (constant) marginal prices, while in a loglinear specification the coefficients denote (constant) elasticities. Following this empirical practice, we will start with a loglinear specification of the hedonic price function:

(7.2) $$\log P_h = \alpha D_h + \beta H_h + \gamma E_h + \delta X_h + \theta M_h + \epsilon_h,$$

where $\alpha$, $\beta$, $\gamma$, $\delta$ and $\theta$ are coefficients to be estimated, $E_h$ is a matrix consisting of employment in different sectors, $X_h$ are control variables, $M_h$ are municipality fixed effects to control for unobserved heterogeneity and $\epsilon_h$ is a house-specific error term. We do not transform the employment variables by taking logs, because many houses have zero employment in some sectors, but we standardize all variables related to mixed land use with unit standard deviations to facilitate interpretation.[152] The loglinear specification imposes constant elasticities for the explanatory variables in logarithm and

[152] Adding an arbitrary constant may bias the results substantially (Flowerdew and Aitkin, 1982; Burger et al., 2009).

constant semi-elasticities for the untransformed variables, which may be as restrictive as imposing constant marginal prices.[153]

As in the previous Chapter, it may be argued that our measures of mixed land use are endogenous. In a bid rent context, mixed land use will occur at locations where multiple sectors place a similar value on land (see Lucas and Rossi-Hansberg, 2002; McMillen, 2010). Then, locations that are attractive for unobserved reasons experience higher prices for both firms and households, leading to a spurious correlation between mixed land use and house prices. We also show in Section 7.4.D that by using spatial econometrics, so by including a spatial lag and spatial error, the results are remarkably similar, suggesting that unobserved endowments are not highly correlated with measures of mixed land use. Furthermore, there may be reverse causality between some sectors and house prices, as some shops and restaurants may co-locate with high income households. We leave a full investigation of this potential endogeneity problem for further research, but there is some anecdotal evidence that in the short run land use patterns are quite persistent (and therefore exogenous). Using a land use dataset from Statistics Netherlands, it may be shown that between 2003 and 2006 only 1.3 percent of the locations experience a change in land use. Moreover, Vermeulen and Rouwendal (2007) show that housing supply in the Netherlands is almost fully inelastic in the short-run and does not respond to rapid changes in the environment.

### *B. A semiparametric hedonic price function*

Nonparametric estimation methods have the potential to describe the hedonic price function and the associated implicit prices more accurately when enough data are available (Sheppard, 1999). Although these methods are not yet much applied in applied urban economics, some recent empirical studies indeed estimate nonparametric and semiparametric hedonic price functions (see Anglin and Gencay, 1996; McMillen, 1996; Bajari and Kahn, 2005; 2008; Bin, 2005; Bontemps et al., 2008, McMillen and Redfearn, 2010). To avoid the 'curse of multidimensionality', we estimate a partially linear hedonic price function:

(7.3) $$\log P_h = \Phi(D_h, H_h, E_h) + \delta X_h + \theta M_h + \epsilon_h,$$

where $\Phi(\cdot)$ is some function of mixed land use attributes. We estimate $\Phi(\cdot)$ by local linear regression techniques. Locally weighted regression is the most common nonparametric approach to analyse spatial data (McMillen and Redfearn, 2010).[154] Local methods have a lower asymptotic bias than the Nadaraya-Watson estimator and a lower asymptotic variance than the Gasser-Müller estimator, but more importantly, have been shown to generate plausible estimates of WTP coefficients (Bajari and Kahn, 2005; McMillen and Redfearn, 2010, see Chapters 2, 4, 6, 8). So, for each observation $h$ we run a locally weighted regression, where greater importance is assigned to observations with attributes that are

[153] We also have experimented with Box-Cox specifications in a previous version of this chapter. Then, the willingness to pay for all characteristics depends only on the price of the house, and the value of the particular characteristic under consideration. This rules out differences between marginal willingness to pay for mixed land use aspects among inhabitants of apartments and single family houses, which will be shown to be substantial in our empirical work using semiparametric techniques. It appears that the results of the Box-Cox specifications are similar to the results of the loglinear specification. Results are available upon request.

[154] Locally weighted regression is developed by Cleveland and Devlin (1988) and was first applied in urban economics by Meese and Wallace (1991).

similar to $h$. The weights are computed on the basis of a bisquare kernel that takes into account the geographical distance between two observations (see McMillen, 2010):

(7.4)
$$K_{h\tilde{h}} = \left(1 - \left(\frac{d_{h\tilde{h}}}{d_T}\right)^2\right)^2 I(d_{h\tilde{h}} < d_T),$$

where $K_{h\tilde{h}}$ is the kernel weight of $h$ in the local regression of $\tilde{h}$, $d_{h\tilde{h}}$ is the distance in kilometres between observation $h$ and $\tilde{h}$, and $d_T$ denotes the threshold distance. Lower values of $d_T$ lead to a lower mean-squared error, but to a higher variance of the estimator. Larger values of $d_T$ may create a larger bias when the underlying function is nonlinear (Fan and Gijbels, 1996) (Note that when $d_T \rightarrow \infty$, Specification (3) is identical to Specification (2)). After visual inspection of the results, we set $d_T$ equal to 5 kilometres.[155]

As equation (7.2) is partially linear, we employ the Robinson procedure (Robinson, 1988). First, we regress $\log P_h$, $X_h$ and $M_h$ on $D_h, H_h, E_h$ nonparametrically. Then, we regress the residuals of $\log P_h$ on the residuals of $X_h$ and $M_h$. This leads to $\sqrt{N}$-consistent estimates for $\delta$ and $\theta$. Robinson (1988) showed that the coefficients are estimated at parametric rates of convergence, despite the presence of a nonparametric part. The last step is to regress $\log P_h - \hat{\delta} X_h - \hat{\theta} M_h$ nonparametrically on $D_h, H_h, E_h$ to get an estimate for $\Phi(\cdot)$.

Because we use semiparametric regression methods, we have distributions of the marginal willingness to pay (MWTP) for mixed land use attributes. We will present the (spatial) variation in the preference for different attributes using histograms and maps. We will also examine how the semi-elasticities $\hat{\alpha}_h$ vary with house prices. As it is well known that house prices are highly correlated with income, this provides information about the relationship between the value attached to mixed neighbourhoods and income (see Gan and Hill, 2008). We also investigate how $\hat{\alpha}_h$ varies between different housing types. We may expect that households living in apartments have other preferences for mixed land use attributes than households living in detached houses. For example, households living in apartments probably attach value to diverse urban neighbourhoods and prefer to visit local shops, whereas suburbanites, living in (semi-)detached houses, have a stronger preference for low densities. This second exercise focuses on the preferences of households living in a particular type of housing and although we acknowledge that the choice of the housing type is endogenous, the information presented is potentially valuable to policy makers who aim to increase the attractiveness of a particular neighbourhood characterised by a certain price level or a certain housing type by, for instance, increasing the mixedness of land use.

## 7.5 Results

### *A. Empirical results*

In Table 7.1 we present the results. In Specification (1), we include the diversity index and the number of households and employees within 500 meters of the house. In Specification (2) we split up the

[155] This value may seem large, but as the objective is to estimate marginal effects (instead of estimating predictions), the threshold distance should be larger in order to generate plausible estimates (Pagan and Ullah, 1999; McMillen, 2004; McMillen, 2010). In the sensitivity analysis we will provide a robustness check for the choice of $d_T$.

employment in different sectors. Specification (3) and (4) are the semiparametric specifications.[156] In Specification (1), we observe that the diversity index has a small positive impact on house prices. Household density has a negative impact on house prices: one standard deviation increase in the number of households leads to a decrease in the house price of about 4.5 percent. Households do not prefer to live in high density neighbourhoods because higher densities are often associated with negative externalities, such as reduced privacy and higher crime rates (Glaeser et al., 2005a).

In contrast, but in line with Chapter 6, employment has a positive impact on house prices: a standard deviation increase in employment leads to increase in house prices of about 2 percent. Employment is likely a proxy here for all kinds of local urban amenities. We recognise that this effect is not very informative and therefore we split up employment in 7 different sectors in Specification (2). The diversity index then has a larger positive impact: one standard deviation increase in diversity leads to increase in house prices of about 2.5 percent. This suggests that households attach substantial value to a diversified neighbourhood. Employment in different sectors is significantly correlated with house prices.[157]

Specification (3) employs the semiparametric estimation procedure to verify the impact of diversity, households and employment on house prices. It is shown that the average employment effect is somewhat lower than the effect found in Specification (1), but the average effect of diversity and households are similar. In Specification (4) we again have a closer look at the effect of different sectors. We present average coefficients and their standard deviations for the variables related to mixed land use. It is striking that the *average* coefficient of the diversity index is substantially lower than the coefficient in Specification (2), suggesting that assumptions regarding the functional form of the hedonic price function are not correct. The average effects of the land uses are almost identical to the effects of Specification (2). A number of land uses have a positive impact on house prices. Sectors compatible with residential use are business services, education and healthcare, leisure and retail. For example, one standard deviation increase in the number of employees in the business services sector leads to an increase in house price of on average 5 percent. Households may prefer to live close to such employment because of lower commuting costs, shorter shopping trips and more intense local ‘buzz’ (for example, cafés and restaurants encourage active street life; Glaeser et al., 2001). Employment in the manufacturing, government and wholesale sector is negatively related to house prices. Negative externalities related to employment in these sectors may be visual, noise and air pollution (Burnell, 1985).

[156] We could not test whether the semiparametric estimation procedure better describes the relationship between attributes and house prices than the OLS-specifications. There are some tests for functional form (for example, the Zheng test; Zheng, 1996), but these tests involve matrix multiplications. Because we have a substantially large dataset, computational restrictions inhibit us from computing these tests. However, note that the $R^2$ for the semiparametric models is somewhat higher.
[157] We also may show that our results are robust to the choice of buffer size, exclusion of fixed effects, the choice of threshold distance and the formulation of the diversity index. The results of the sensitivity analysis are available upon request.

TABLE 7.1 — REGRESSION RESULTS ON THE IMPACT OF MIXED LAND USE ON PROPERTY VALUES
*(Dependent variable: the logarithm of house price)*

| | (1) | | (2) | | (3) | | (4) | |
|---|---|---|---|---|---|---|---|---|
| Diversity index | 0.006 | (0.003)** | 0.026 | (0.004)*** | 0.004 | 0.042 | 0.009 | 0.066 |
| Households | -0.044 | (0.004)*** | -0.046 | (0.004)*** | -0.046 | 0.066 | -0.055 | 0.103 |
| Employment | 0.018 | (0.004)*** | | | 0.002 | 0.181 | | |
| Business services | | | 0.017 | (0.004)*** | | | 0.014 | 0.714 |
| Education and healthcare | | | 0.003 | (0.002) | | | 0.005 | 0.670 |
| Government | | | -0.008 | (0.003)*** | | | -0.011 | 0.214 |
| Manufacturing | | | -0.024 | (0.003)*** | | | -0.022 | 0.090 |
| Leisure | | | 0.023 | (0.005)*** | | | 0.088 | 0.307 |
| Retail | | | -0.005 | (0.003) | | | 0.001 | 0.079 |
| Wholesale | | | -0.018 | (0.003)*** | | | -0.023 | 0.088 |
| Volume $m^3$ *(log)* | 0.543 | (0.031)*** | 0.540 | (0.031)*** | 0.533 | (0.018)*** | 0.516 | (0.018)*** |
| Size $m^2$ *(log)* | 0.352 | (0.031)*** | 0.348 | (0.031)*** | 0.347 | (0.019)*** | 0.347 | (0.018)*** |
| Terraced | -0.010 | (0.008) | -0.009 | (0.008) | 0.000 | (0.007) | 0.011 | (0.007) |
| Semi-detached | 0.083 | (0.009)*** | 0.082 | (0.009)*** | 0.094 | (0.008)*** | 0.102 | (0.008)*** |
| Detached | 0.404 | (0.018)*** | 0.400 | (0.018)*** | 0.399 | (0.013)*** | 0.409 | (0.013)*** |
| Rooms | -0.007 | (0.002)*** | -0.007 | (0.002)*** | -0.006 | (0.002)*** | -0.006 | (0.002)*** |
| Garage | 0.026 | (0.011)** | 0.025 | (0.011)** | 0.032 | (0.010)*** | 0.029 | (0.009)*** |
| Garden | 0.021 | (0.006)*** | 0.023 | (0.006)*** | 0.026 | (0.006)*** | 0.028 | (0.005)*** |
| No central heating | -0.100 | (0.009)*** | -0.096 | (0.008)*** | -0.092 | (0.007)*** | -0.089 | (0.007)*** |
| Listed building | 0.110 | (0.037)*** | 0.103 | (0.037)*** | 0.093 | (0.030)*** | 0.100 | (0.029)*** |
| Distance centre *(in km)* | -0.018 | (0.002)*** | -0.017 | (0.002)*** | -0.026 | (0.002)*** | -0.023 | (0.002)*** |
| Distance highway ramp *(in km)* | 0.006 | (0.003)** | 0.005 | (0.003)** | 0.007 | (0.003)** | 0.004 | (0.003) |
| Distance station *(in km)* | -0.005 | (0.002)* | -0.006 | (0.002)*** | 0.005 | (0.003)* | 0.013 | (0.004)*** |
| Distance open space *(in km)* | 0.016 | (0.008)** | 0.007 | (0.008) | 0.022 | (0.009)** | 0.005 | (0.010) |
| Share of ethnic minorities | -0.006 | (0.000)*** | -0.006 | (0.000)*** | -0.005 | (0.000)*** | -0.005 | (0.000)*** |
| Construction year (5) | Yes | | Yes | | Yes | | Yes | |
| Municipality fixed effects (16) | Yes | | Yes | | Yes | | Yes | |
| Buffer size *(in km)* | 0.5 | | 0.5 | | 0.5 | | 0.5 | |
| Threshold distance $d_T$ *(in km)* | ∞ | | ∞ | | 5 | | 5 | |
| Number of observations | 10,057 | | 10,057 | | 10,057 | | 10,057 | |
| $R^2$ | 0.8361 | | 0.8397 | | 0.8463 | | 0.8560 | |

*Notes:* The dependent variable is the logarithm of house price. For Specifications (3) and (4) we present the mean estimates and standard deviations of the variables related to mixed land use. The standard errors are between parentheses.

*** Significant at the 0.01 level
** Significant at the 0.05 level
* Significant at the 0.10 level

Based on these results, it seems plausible to restrict the diversity index to land uses that are compatible with residential use. It may then be expected that the impact of this adjusted diversity index is higher, as households are thought to dislike a diversity of incompatible uses. We then construct a new diversity index based on compatible land uses (business services, education and healthcare, leisure and retail) *and residential use*. The results are presented in Table 7.2. The diversity index now has a larger effect on house prices: one standard deviation increase in the adjusted diversity index increases house prices with 1.1–3.4 percent, dependent on the preferable specification. Different land uses have a similar impact compared to the results presented in Table 7.1. So, these results suggest

TABLE 7.2 — REGRESSION RESULTS ON THE IMPACT OF MIXED LAND USE WITH AN ADJUSTED DIVERSITY INDEX
*(Dependent variable: the logarithm of house price)*

| | (5) | | (6) | | (7) | | (8) | |
|---|---|---|---|---|---|---|---|---|
| Diversity index (adjusted) | 0.025 | (0.004)*** | 0.031 | (0.003)*** | 0.034 | 0.047 | 0.011 | 0.077 |
| Households | -0.044 | (0.003)*** | -0.047 | (0.004)*** | -0.043 | 0.063 | -0.061 | 0.103 |
| Employment | 0.003 | (0.004) | | | -0.036 | 0.160 | | |
| Business services | | | 0.012 | (0.004)*** | | | 0.006 | 0.779 |
| Education and healthcare | | | -0.002 | (0.003) | | | 0.013 | 0.634 |
| Government | | | -0.005 | (0.003) | | | -0.004 | 0.241 |
| Manufacturing | | | -0.019 | (0.003)*** | | | -0.019 | 0.070 |
| Leisure | | | 0.022 | (0.005)*** | | | 0.086 | 0.344 |
| Retail | | | -0.009 | (0.003)*** | | | 0.003 | 0.093 |
| Wholesale | | | -0.015 | (0.003)*** | | | -0.018 | 0.058 |
| Control variables (20) | Yes | | Yes | | Yes | | Yes | |
| Municipality fixed effects (16) | Yes | | Yes | | Yes | | Yes | |
| Buffer Size *(in km)* | 0.5 | | 0.5 | | 0.5 | | 0.5 | |
| Threshold distance $d_T$ *(in km)* | ∞ | | ∞ | | 5 | | 5 | |
| Number of observations | 10,057 | | 10,057 | | 10,057 | | 10,057 | |
| $R^2$ | 0.8361 | | 0.8397 | | 0.8483 | | 0.8564 | |

*Note:* See Table 7.1.

that business services, education and healthcare, leisure and retail have a positive impact. Mixing these land uses with housing may generate a diversity premium. Although average effects are interesting, the standard deviations of the coefficients of Specification (8) reveal that there is much heterogeneity in the WTP for different aspects of mixed land use. In the next subsection we will investigate this heterogeneity in more detail.

The control variables have in general plausible signs. When a house is larger in terms of lot size or volume, the price is higher. Furthermore, more privacy (detached vs. apartment), a garage, a garden and a central heating also contribute to higher house prices. An increase in distance to the city centre leads to a decrease in the house price, ceteris paribus. Residing near a railway station or highway ramp leads in general not to large statistically significant changes in house prices. One percent increase in the share of ethnic minorities will lead to a decrease in residential property values of 0.6 percent. This result is in accordance with Waddell et al. (1993), who found lower house prices when the share of Hispanics and blacks in neighbourhoods was higher. We note that the coefficients of the control variables are similar over different specifications.

### *B. Heterogeneity in WTP for mixed land use*

In this section, we investigate the heterogeneity in the preferences for different aspects of mixed land use. Figure 7.2 presents the distributions of the WTP for diversity and business services. Figure 3 presents maps of the WTP for households and retail. Other histograms and maps are available upon request.

We observe that there is in general much heterogeneity in the MWTP values. For diversity, about 95 percent of the observations have a preference that is between -10 and 10 percent of the house price. About 35 percent of the observations value diversity negatively. So, for some areas diversity is valued positively, whereas in other areas diversity is considered as not attractive. Indeed, in it may be shown that especially in the diverse city centre of Rotterdam, diversity is valued positively. For about 90 percent of the observations household density is negatively impacting housing prices. Similar to Song and Knaap (2004), this may be a concern for planning policies that aim to increase density of households. Although a dense district with high-rise apartments is not considered as attractive, for many other land uses households are willing to pay for increases in density. For example, more than 70 percent of the households are willing to pay for increases in the employment of business services, education and leisure activities. It is also shown that for incompatible uses, such as manufacturing and wholesale, still about 35 percent of the households do not value this negatively. It probably highly depends on the type of firm that is located nearby: a large oil refinery has probably a much larger negative effect than an ordinary industrial building. The effect of retail on property values is somewhat inconclusive, as about 60 percent of the households values nearby shops positively. Positive benefits of retail relate to less travel time of shopping trips and more local 'buzz', but shops also generate negative externalities (lack of parking space, noise pollution etc.). Moreover, Grant (2004) argues that the current shopping behaviour is changed because of the increased car mobility: people travel to large shopping malls which are located on unattractive industrial areas instead of shopping in local shops. Therefore, having a shop in the vicinity does yield fewer benefits.

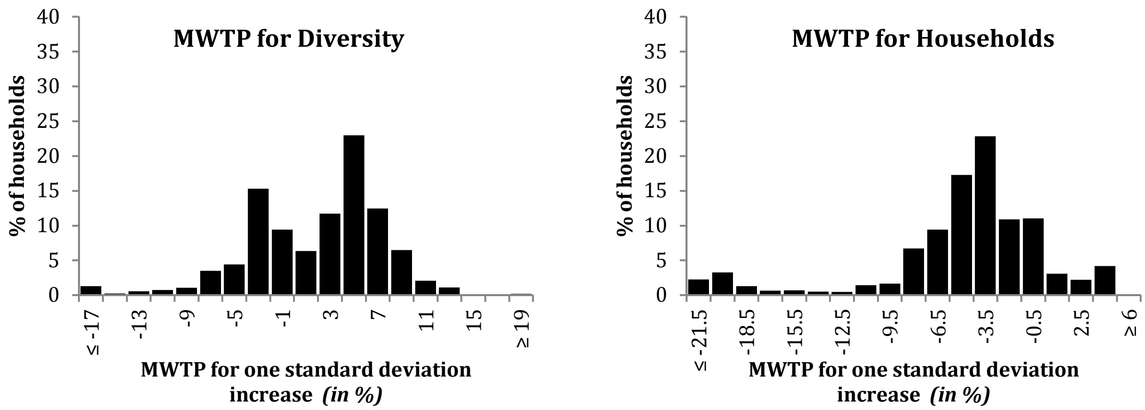


FIGURE 7.2 — HETEROGENEITY IN MWTP FOR DIVERSITY AND HOUSEHOLD DENSITY

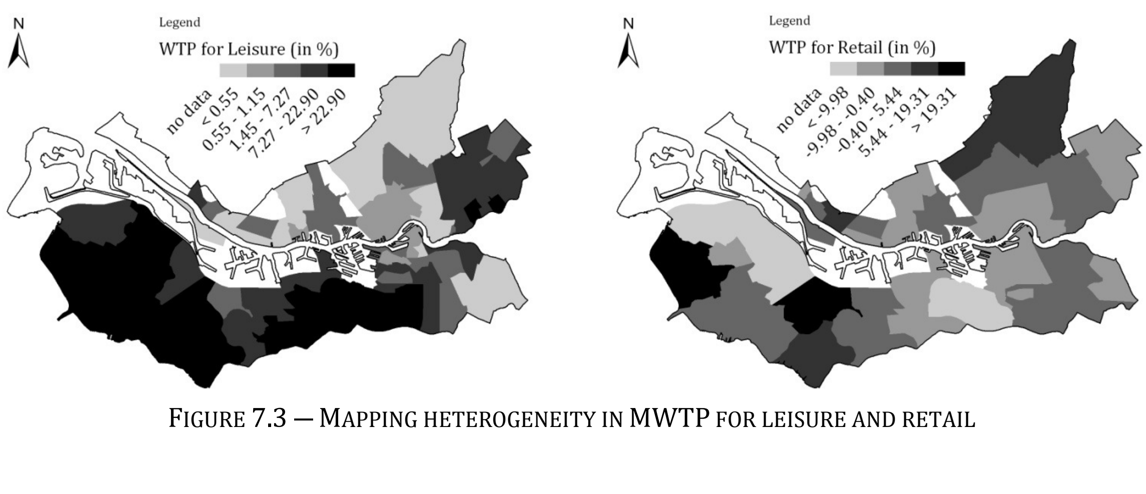


FIGURE 7.3 — MAPPING HETEROGENEITY IN MWTP FOR LEISURE AND RETAIL

We also map the coefficients at a PC4 level (so we take the average of coefficients in a PC4 area). Examples are given in Figure 7.3. We do not observe clear geographical patterns, although for leisure it is striking that the areas that are on the south bank of the river Maas have a relatively high preference for leisure activities.

*C. Heterogeneity in WTP for Mixed Land Use Related to Housing Characteristics*

Preferences for aspects of mixed land use may vary with structural housing characteristics. For example, we may expect that households living in apartments in the city centre have other preferences for mixed land use attributes than households living in detached houses located in the suburbs. Although these preferences may be related to observable household characteristics, it seems likely that at least in part they are also related to unobservable housing characteristics that contribute to the sorting of households in particular types of housing. In this subsection, we first investigate how the preferences (measured by the estimated semi-elasticities) for mixed land use vary with house price, which is interesting as high-income households tend to occupy more expensive houses. Second, we show how heterogeneity in the semi-elasticities of mixed land use is related to different house types.

We first relate the house price to the semi-elasticities of different aspects of mixed land use. Figure 7.4 provides some examples; more figures are available upon request. The dotted lines indicate a 95 percent confidence interval. For household density, we see a strong decline in the WTP: a household that occupies a house that is worth € 125,000 is willing to pay -5 percent of the house price for a standard deviation increase in the number of households, whereas this is about -8 percent for households that occupy houses that are € 350,000. For business services and manufacturing we also observe a decreasing marginal WTP in house price. For other sectors the pattern is less regular and more difficult to explain. For example, the semi-elasticities for retail is about constant for houses that are less than € 225,000. After that, it increases somewhat and then decreases (see Figure 7.4).

Second, we investigate whether semi-elasticities vary over different house types. Table 7.3 summarises the results. It is shown that diversity is only significantly different from zero for apartment-occupiers: one standard deviation increase in the diversity index leads to an increase in apartment

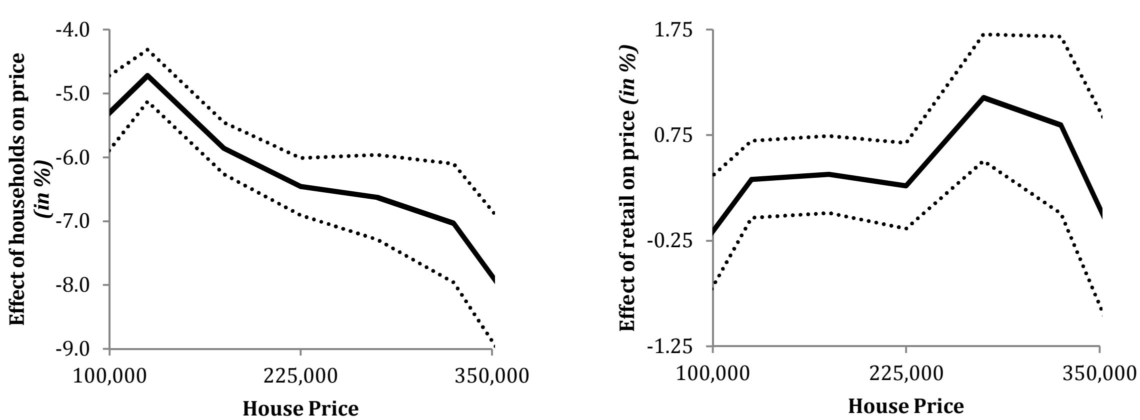


FIGURE 7.4 — MWTP FOR HOUSEHOLD DENSITY AND RETAIL FOR DIFFERENT HOUSE PRICES

TABLE 7.3 — AVERAGE SEMI-ELASTICITIES FOR DIFFERENT HOUSE TYPES

| | Apartments | Terraced | Semi-Detached | Detached |
|---|---|---|---|---|
| Diversity index | 0.024 (0.001)*** | -0.001 (0.001) | -0.003 (0.002)* | -0.002 (0.004) |
| Households | -0.052 (0.001)*** | -0.065 (0.002)*** | -0.066 (0.002)*** | -0.115 (0.005)*** |
| Business services | 0.010 (0.011) | -0.014 (0.014) | 0.026 (0.019) | 0.035 (0.040) |
| Education and healthcare | 0.007 (0.009) | 0.032 (0.011)*** | 0.001 (0.015) | -0.011 (0.033) |
| Government | -0.008 (0.003)** | 0.007 (0.004)* | -0.010 (0.006)* | -0.011 (0.013) |
| Manufacturing | -0.013 (0.001)*** | -0.018 (0.001)*** | -0.022 (0.002)*** | -0.103 (0.004)*** |
| Leisure | 0.048 (0.005)*** | 0.105 (0.006)*** | 0.136 (0.008)*** | 0.208 (0.018)*** |
| Retail | -0.001 (0.001) | 0.006 (0.002)*** | 0.010 (0.002)*** | 0.014 (0.005)*** |
| Wholesale | -0.016 (0.001)*** | -0.021 (0.001)*** | -0.024 (0.001)*** | -0.003 (0.003) |

*Notes:* We present the conditional means of the coefficients for each housing type. The standard deviations are between parentheses.

*** Significantly different from zero at the 0.01 level
** Significantly different from zero at the 0.05 level
* Significantly different from zero at the 0.10 level

prices of 2.4 percent. This suggests that households that prefer urban living (as most apartments are in dense urban areas) also prefer diverse neighbourhoods. Moreover, these households also have a less negative preference for household density, compared to households that occupy other house types. The difference between is the semi-elasticities is about 6 percentage points. Households that reside in detached houses have stronger preferences for leisure and retail: one standard deviation increase in the employment in leisure and retail activities leads to an increase in the house price of detached houses of respectively 20.8 and 1.4 percent. These results confirm that some heterogeneity is explained by housing attributes.

*D. Spatial econometrics*

House prices are often strongly correlated over space, as house buyers and sellers tend to interact spatially. Many empirical studies take into account the potential bias and loss of efficiency that can result when spatial dependence is ignored in the estimation process (Anselin and Lozano-Gracia, 2009). Spatial econometric methods have been developed that incorporate the spatial dependence in cross-sectional data into model specification by including a spatial lag or spatial error (Anselin, 1988; Anselin and Bera, 1998; Kelejian and Prucha, 1998; 2004). LeSage and Pace (2009) argue that ignoring a spatial lag may lead to a bias in all estimated coefficients. It is therefore suggested that, at a minimum, one should include a spatial lag in the regression (Carruthers and Clark, 2010). We therefore will estimate spatial econometric models as a robustness check for specifications that use ordinary least squares (see Specification (1) and (2)).[158] The specification to be estimated is then:

(7.5) $$\log P_h = \rho W_h P_{-h} + \alpha D_h + \beta H_h + \gamma E_h + \delta X_h + \theta M_h + \epsilon_h,$$

where $\rho$ is a parameter that indicates if there is a spatial lag, $P_{-h}$ are all other house prices and $W_h$ is a weight vector. The weight of house $\tilde{h}$ in the weight vector of house $h$ is again defined using a bisquare

[158] Moreover, it is too computational demanding to include a spatial lag and spatial error in the semiparametric models.

TABLE 7.4 — SPATIAL ECONOMETRIC REGRESSION RESULTS ON THE IMPACT OF MIXED LAND USE
*(Dependent variable: the logarithm of house price)*

| | (9) | (10) | (11) | (12) |
|---|---|---|---|---|
| Diversity Index | 0.009 (0.003)*** | 0.025 (0.003)*** | 0.004 (0.003) | 0.016 (0.003)*** |
| Households | -0.030 (0.003)*** | -0.030 (0.004)*** | -0.044 (0.003)*** | -0.047 (0.004)*** |
| Employment | 0.020 (0.003)*** | | 0.013 (0.003)*** | |
| Business Services | | 0.012 (0.004)*** | | 0.011 (0.004)*** |
| Education and Healthcare | | 0.003 (0.002) | | 0.001 (0.002) |
| Government | | -0.002 (0.003) | | -0.003 (0.003) |
| Manufacturing | | -0.012 (0.003)*** | | -0.013 (0.003)*** |
| Leisure | | 0.025 (0.004)*** | | 0.014 (0.004)*** |
| Retail | | -0.007 (0.003)** | | 0.000 (0.003) |
| Wholesale | | -0.020 (0.002)*** | | -0.015 (0.002)*** |
| Spatial Lag ($\rho$) | 0.437 (0.016)*** | 0.427 (0.016)*** | 0.106 (0.016)*** | 0.122 (0.016)*** |
| Spatial Error ($\lambda$) | | | 1.133 | 1.085 |
| Control Variables (20) | Yes | Yes | Yes | Yes |
| Municipality FE (16) | Yes | Yes | Yes | Yes |
| Buffer Size *(in km)* | 0.5 | 0.5 | 0.5 | 0.5 |
| Threshold Distance $d_T$ *(in km)* | 2.5 | 2.5 | 2.5 | 2.5 |
| Number of Observations | 10,057 | 10,057 | 10,057 | 10,057 |

*Note:* See Table 7.1.

weighting function: $W_{h\tilde{h}} = (1-(d_{h\tilde{h}}/d_T)^2)^2 I(d_{h\tilde{h}} < d_T)$, where $d_T$ is set to 2.5.[159] We may also include a spatial error. Then $\epsilon_h = \lambda W_h \xi_h + \upsilon_h$, so the error term consists of a residual that is correlated over space $\xi_h$ and a random term $\upsilon_h$. To re-estimate Specifications (1) and (2) in the presence of spatial dependence, we will use the three-stage procedure of Keleijan and Prucha (1998) (see also Keleijan and Prucha, 1999).[160] The results are presented in Table 7.4.

In Specifications (9) and (10), we assume that there is only a spatial lag, while in Specifications (11) and (12) we also allow for a spatially correlated residual. The results are in general very robust and very similar to the results presented in Table 7.1 although we find substantial and statistically significant positive spatial dependence. As expected, house prices are positively correlated over space for unobserved reasons. The spatial error is also substantial, suggesting correlation among the residuals.[161] It is furthermore observed that the impact of employment in the government sector is effectively zero when we allow for a spatial lag and spatial error, but the impact of diversity, business services, manufacturing, leisure and wholesale remain statistically significant. It is also shown that the coefficients have almost the same magnitude as in Specifications (1) and (2). We may therefore conclude that the variables of interest are unlikely to be strongly correlated with unobserved spatial factors.

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[159] We also experimented with other threshold values, but this does not seem to influence our results.
[160] The procedure is programmed in Gauss 8.0. Details are available upon request.
[161] As argued by Kelejian and Prucha (1998), $\lambda$ is a nuisance parameter and does not have to be between 0 and 1, because the error is estimated using a generalised method of moments estimator. This implies that the parameter cannot be interpreted as a correlation coefficient.

## 7.6 Conclusions

Contemporary European urban planning policies aim to mix land uses in compact neighbourhoods. However, the pronounced (net) benefits or costs of mixed land use are poorly understood. In this chapter we have examined whether households value mixing of employment and living, employing a semiparametric hedonic price methodology.

We first investigated the effects of a diversified environment and compute the implied MWTP for different land uses not only for residents occupying single-family homes, but we also incorporate apartment occupiers. It appears that a more diversified environment is positively correlated with house prices. A one standard deviation increase in diversity leads to an increase in house prices of 1.1–3.4 percent. The MWTP for diversity is higher when we only include land uses that are compatible with residential use in the diversity index. Households put value on diversity, but dislike high household densities. Some land uses are incompatible with residential use, such as manufacturing and wholesale. Business services, education and healthcare, leisure and retail activities are valued positively by households, although the WTP for an additional employee is in some cases very small. In general, we may conclude that a good mixture of land uses, such as businesses and leisure activities, may lead to an increase in housing values up to 6 percent, compared to a house located in a monofunctional area. It is important to note that household densities should not be too high. Second, we showed that there is substantial heterogeneity in the WTP for different aspects of mixed land-use. It appears that apartment occupiers are willing to pay more for a diversified neighbourhood, but less for additional employment in specific sectors.

Our findings also have implications for urban planning policies. It is shown that *household* density is not considered as attractive in the context of the Netherlands. Apparently, crowding effects dominate potential positive effects, especially because we control for amenities (parks, leisure activities, etc.). This is bad news for contemporary compact city policies that aim at increasing household densities in urban areas. However, the story is more nuanced, as diversity of uses and *density of employment* generally contribute to higher house prices. Our results strongly suggest that when compatible land uses and residential use are mixed, this will lead to positive effects. So, policy makers should carefully define a mix of compatible uses and should not increase the household density by too much in order to assure a price premium in mixed areas.

There is plenty of scope for further research in this topic. First, we only take into account home owners to validate the impact of mixed land use. Further research could also take the preferences of the other actors into account, and examine, for example, whether mixed land use will lead to increased profits for firms. Second, and this is important, future studies may address the potential endogeneity of land uses more thoroughly and seek valid instruments.

## Appendix 7.A Descriptives

TABLE 7.A1 — DESCRIPTIVE STATISTICS OF HOUSING TRANSACTIONS

| | Mean | Std.Dev. |
|---|---|---|
| House Price | 216,947.50 | (137284.42) |
| Diversity, $D_h$ | 2.05 | (0.88) |
| Mixed Index, $MI_h$ | 0.30 | (0.18) |
| Job-Household Ratio, $J_h$ | 0.60 | (0.81) |
| Households | 2,714.00 | (1,618.14) |
| Business Services | 431.49 | (1,102.79) |
| Education and Healthcare | 456.74 | (695.77) |
| Government | 123.71 | (369.15) |
| Manufacturing | 220.88 | (391.16) |
| Leisure | 122.10 | (288.37) |
| Retail | 252.87 | (382.86) |
| Wholesale | 46.45 | (99.42) |
| Volume ($m^3$) | 316.43 | (138.38) |
| Size ($m^2$) | 113.77 | (44.97) |
| Terraced | 0.31 | (0.46) |
| Semi-Detached | 0.17 | (0.37) |
| Detached | 0.04 | (0.19) |
| Rooms | 4.05 | (1.35) |
| Garage | 0.05 | (0.21) |
| Garden | 0.48 | (0.50) |
| No Central Heating | 0.08 | (0.27) |
| Monument | 0.00 | (0.06) |
| Construction 1961-1970 | 0.14 | (0.35) |
| Construction 1971-1980 | 0.14 | (0.34) |
| Construction 1981-1990 | 0.15 | (0.36) |
| Construction 1991-2000 | 0.17 | (0.37) |
| Construction ≥2001 | 0.07 | (0.25) |
| Distance Centre | 8.20 | (6.00) |
| Distance Highway Ramp | 2.28 | (1.64) |
| Distance Station | 2.88 | (2.89) |
| Distance to Open Space | 0.17 | (0.14) |
| Share of Ethnic Minorities | 28.91 | (17.10) |
| Number of Observations | 10,057 | |

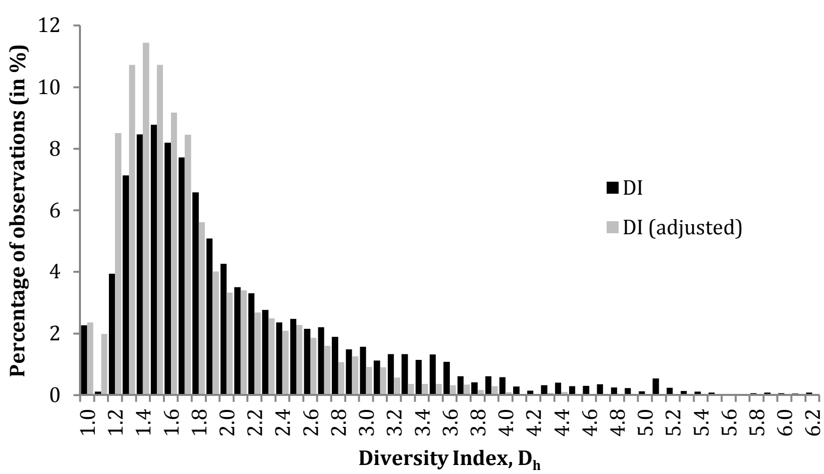


FIGURE 7.A1 — THE DISTRIBUTION OF THE (ADJUSTED) DIVERSITY INDEX