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Honours Thesis

Hedonic Pricing and the User Cost of Housing in the Netherlands

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0.1 Declaration

I hereby declare that this submission is my own work and that, to the best of my knowledge, it contains no material which has been written by another person or persons, except where due acknowledgement has been made. This thesis has not been submitted for the award of any degree or diploma at the University of New South Wales, or at any other institute of higher education.

Aaryn Lally
28th October, 2016

0.2 Acknowledgements

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I would also like to thank Dr. Iqbal Syed for always being open to have a chat about my research, and providing useful feedback I could incorporate into my research. A special thanks also to Professor Jan de Haan for providing access to the Assen data set and his feedback on the direction of my research findings.

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Contents

0.3 Abstract

This thesis provides insight into the contribution of land and structure to property prices, and investigates housing affordability and market disequilibrium in The Netherland's residential property sector. Hedonic regression methods are used to perform an additive decomposition of property prices into land and structure components for detached housing in Assen. This analysis indicates structure size, land plot size, structure age, parking quality and house maintenance quality are significant factors in determining the land and structure values of a house. Poterba's (1984) user cost of capital framework is used to find evidence of disequilibrium in the housing market, where home ownership has been affordable relative to renting in Assen over time.

Chapter 1
Introduction

Real estate ownership is an important component of household wealth, and housing-related expenses make up a significant proportion of overall household consumption. Housing wealth has been observed to have a more significant impact on household consumption than stock price movements (Case et al, 2005). Capital accumulation through homeownership has continued to increase, and property taxation makes up a significant proportion of government funding sources. As a result, strong property market growth in countries such as the U.S. and Australia combined with stable prevailing economic conditions have been a driving factor in sustaining high levels of economic growth.

Following the Global Financial Crisis (GFC), uncertainty has increased in regards to the market and government understanding how house prices and supply-demand mechanisms are evolving. It is crucial for the government, households and investors to enhance their understanding of house price movements to achieve financial and economic growth and stability. The Reserve Bank of Australia (RBA) has identified understanding conditions and prospects in the housing sector as a key policy issue, with a focus on housing affordability, the supply and demand for housing, and the broader macroeconomic context. This will provide central banks insight into how real estate impacts economic growth, monetary policy and inflation measurement, thereby improving economic management and welfare. Additionally, accurate pricing of real estate and assessment of real estate sector risks is critical for national statistical agencies such as the Australian Bureau of Statistics (ABS) to keep accurate national accounts on capital and land stocks over time, and to measure the Consumer Price Index (CPI). Furthermore, local governments can use the land and structure decomposition to gain a more accurate measure of property tax rates on land and structure components.

Typically, national statistical agencies such as the Australian Bureau of Statistics measure house prices on a periodic basis to track house price changes. This involves tracking the median sales price for a given region over time and using these prices to create a house price index. This is based on a matched models methodology, where the details and prices of a representative selection of houses are collected in a base reference period and their matched prices collected in successive periods. Measuring house prices in this manner is limited in its ability to capture house quality adjustments over time and space, and therefore the constructed price indexes will provide misleading results because the mix of houses sold changes rapidly over time. This creates matched models sample selection bias, where the sample is unrepresentative of the residential property sector. This limitation can be overcome by decomposing property prices into it's land and structure components separately. This recognises taxation and depreciation differences between the land and structure components of a property, and controls for quality changes when measuring price changes (Francke and Vos, 2004). The decomposition will indicate what fundamental housing characteristics are driving house price movements and whether market values for houses reflect the true intrinsic value of real estate over time.

A striking case to analyse is The Netherland's residential real estate sector. The Dutch housing boom has been a key factor in enabling The Netherlands to maintain a stable level of economic growth of 2.19% per annum on average from 1995 to 2015 (CBS Statline, 2016). Following the Global Financial Crisis, the valuation and quality of Dutch real estate has come under increased scrutiny from government regulators, households, and the financial sector following recent economic, legislative, and political changes in the Euro zone. Gaining an understanding of the evolution of housing supply-demand mechanisms and house prices is important to understand the level of risk for investors, households and the government in the residential real estate sector. Understanding the key risk factors in the housing sector will allow the market and government to understand the potential contagion effects and systematic risk that The Netherland's real estate sector poses for the Euro zone and the global economy.

The Netherland's government has pursued a range of highly interventionist government policies (both direct and indirect intervention) in the residential property sector in an attempt to improve home ownership affordability. These policies include government subsidies, spatial planning laws, zoning regulations, financial guarantees on mortgages taken out by low-income households, stricter regulation of housing associations, stricter rent controls, development of financial instruments with higher loan-to-value ratios, and higher interest deductibility of mortgages. There remains debate over how these policies have distorted The Netherland's residential housing sector, and what contribution these policies have to structural problems in the Dutch economy. With this backdrop in mind, I analyse house prices and the user cost of housing in Assen.

To analyse house prices, I create a house price index using a highly detailed data set for Assen detached housing. To analyse user cost of housing, I apply Poterba's (1984) user cost of capital framework to identify market disequilibrium by comparing the theoretical user cost with actual user cost of housing. This will identify the affordability of home ownership relative to renting over time.

The house prices are decomposed into it's land and structure components separately through a hedonic methodology. Land and structure are treated as price-determining characteristics through a cost of production approach, where the hedonic price function is determined by market supply and demand forces. The hedonic price function generates partial derivatives for all periods t = 1, ..., T, which are marginal prices (also known as shadow prices). These shadow prices are used to perform the following additive decomposition in Equation 1.1;

$$V = p_L L + p_S S \tag{1.1}$$

In this framework the property's value, V, is equivalent to the property's selling price. The property's value equals the addition of land value and structure value. Land value equals the land plot size, L, multiplied by the price of a unit of land, p_L. Structure value equals the structure floor space area, S, multiplied by the price of a unit of structure floor space, p_S. The hedonic methodology used in this thesis will build on this basic empirical relationship.

The thesis is structured as follows. Chapter 2 provides a brief introduction to The Netherland's residential property market. Chapter 3 will introduce theory behind additive decomposition of house prices and the motivation behind the builder's model used in this thesis. Poterba's user cost framework, and empirical results in the literature for user cost analysis and house price index construction will also be introduced.

Chapter 4 examines key features of the Assen data set and provides a summary of the land and structure variables after data-cleaning. Chapter 5 introduces the basic hedonic framework for new and existing houses. In Chapter 6, I use linear splining of house prices based on land plot size in an attempt to improve model performance.

Chapter 7 introduces exogenous construction cost data in an attempt to address multicollinearity in the model. Chapter 8 examines the price-determining power of other land and structure characteristics in the data set. The final, preferred model is also presented in Chapter 8. Chapter 9 examines the affordability of home ownership in Assen over time and market disequilibrium using Poterba's user cost framework.

Chapter 10 considers implications of the thesis' findings, and further research directions. Chapter 11 provides a summary of the thesis' main findings.

Chapter 2
The Netherland's Residential Property Market

The Netherlands is a decentralised unitary state consisting of twelve provinces and 418 municipalities. One of these provinces is called Drenthe, located in the north-east of the Netherlands (as shown in the red box in Figure 2.1). The capital city of Drenthe is the municipality called Assen, which is the focus of the empirical investigation in this thesis.

Assen is a small provincial capital city located approximately 133 kilometres from the Dutch capital city Amsterdam. Assen lies in a flat, featureless plain approximately ten metres above sea level. Drenthe is considered a remote and low populated province, and it's topography is common of cities in The Netherland's urban fringe. The Netherland's has a very unique topography, where 26% of all land lies below sea level. The high prevalence of low-lying land has encouraged the Dutch government to enforce a spatial policy that has created dykes, weirs and polders to ensure accessible and affordable land for housing development.

Another interesting feature of The Netherlands is their population demographics. The Netherland's has the highest density out of all Euro zone countries with 488 people per square kilometre. Statistics Netherlands census data indicates that Assen's population has grown approximately 0.86% per annum on average from 59,005 in 2001, to 67,061 in 2016 (CBS Statline, 2014). This indicates that Assen does not have the same population density-pressures relative to the Netherland's average. The Netherland's has a total population of 16 million people, with 40% of the population living in the Randstand region (which refers to Amsterdam, Utrecht, the Hague and Rotterdam). This thesis' results are unlikely to hold accurately in the Randstand region due to the effect of population-density on local property markets.

Before analysing some preliminary house price results, the last key feature to note about The Netherlands is the structure and nature of government policy decisions and enforcement. The Netherland's national government uses a key planning and strategic decision framework to manage a variety of complex policy challenges in spatial planning, land use, housing allowances, social housing, infrastructure development, and the provision of public services. The strategic framework is high

Figure 2.1: Assen's Location in The Netherlands
Source: SplendidGlobal: Let's Start from Netherland's Entry Mode, `https://splendidglobal.wordpress.com/2013/03/25/lets-start-from-netherlands-entry-mode/`, March 2015.

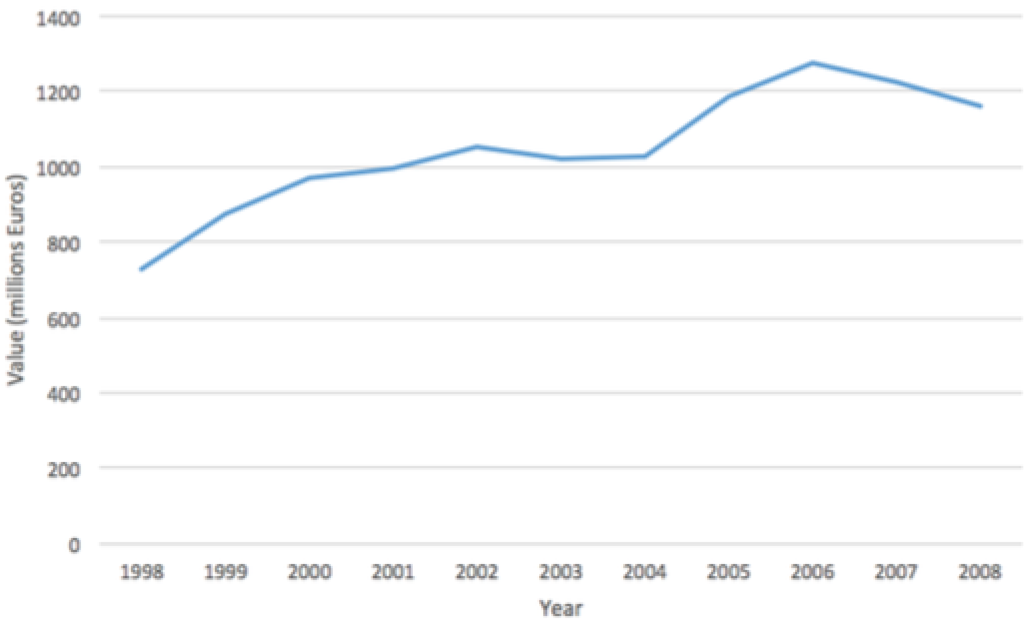

Figure 2.2: Drenthe Total Value of House Purchases
Source: CBS Statline, 'House Price Index by region; existing own homes; 2010 = 100,' October 2016.

level and empowers provincial and municipal governments to manage their local residential property sector.

I present here a quick overview of the real estate sector's performance in Drenthe between 1998 and 2008. The total value of house purchases in Drenthe grew 60% from 1998 to 2008 (from 740 to 1185 million Euros), equal to 5.46% per annum (Figure 2.2). Over the same time period, the house price index grew 110% from 1998 to 2008 (from 1 to 2.1), or 10% per annum (Figure 2.3). This indicates very strong and consistent growth in both the prices and value of housing transactions in Drenthe's residential housing sector from 1998 to 2008.

The Netherland's residential property sector has seen heavy use of interventionist policies to achieve the government's policy objectives. During the early twentieth century, The Netherland's national government focused on providing a greater quantity of affordable housing, and also focused on how to improve accessibility to this housing for a greater proportion of the population. To meet these objectives, the Housing Act was introduced in 1901. The introduction of this legislature greatly improved median housing conditions in The Netherlands. During this time, the government enforced zoning areas (allocated by provincial government authorities), developed new subsidy instruments to provide greater mortgage relief to low-income household owners, and enforced legislation that required municipal governments to

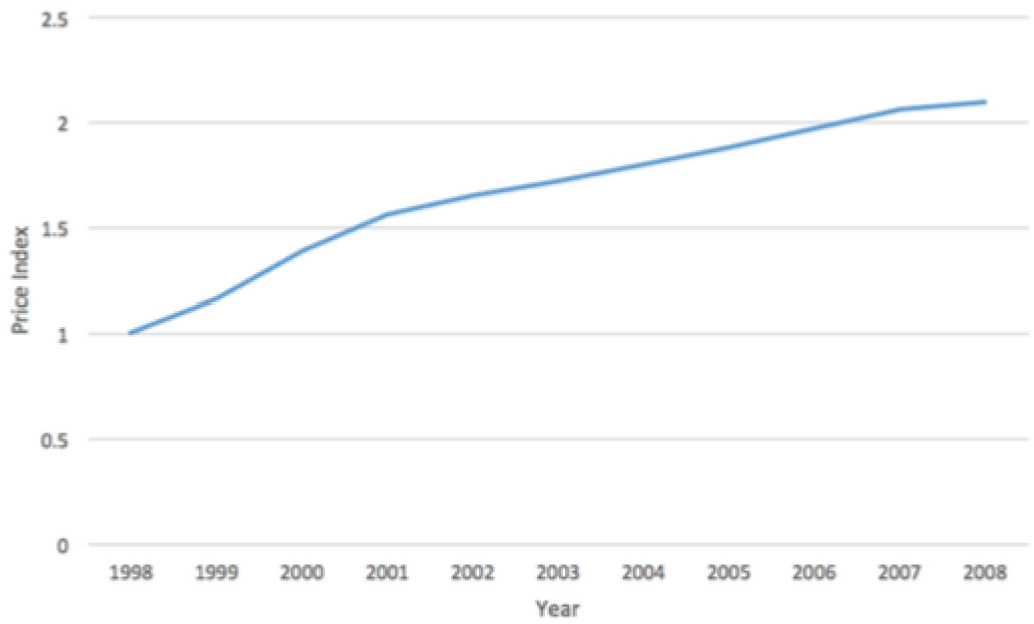

Figure 2.3: Drenthe House Price Index
Source: CBS Statline, 'House Price Index by region; existing own homes; 2010 = 100,' October 2016.

provide basic amenities and services for all residential households.

During World War 2, The Netherland's experienced another huge housing shortage. This required further intervention by the Netherland's national government to provide additional policy instruments to complement the Housing Act. The Netherland's government introduced new subsidies for companies that provided social housing, and set the level of residential gross house rents well below the market equilibrium level. These policies were hugely effective in enabling a greater proportion of low income households to enter and remain in the residential property market as home owners. The policy has had a lasting impact on The Netherland's housing market, where The Netherlands has the largest social housing proportion in the Euro zone at 33% of all dwellings (Vandevyvere and Zenthofer, 2012).

Since the early 1980s, The Netherland's government has shifted its policy focus towards improving the median quality of houses. This policy shift has coincided with an increase in home ownership in The Netherlands from 42% of total dwellings in 1980 to 60% of total dwellings in 2012. To achieve this new policy objective, a range of government policy and financial market changes have taken place. These include favourable tax policy for home owners, lower inflation levels, lower real interest rates, better mortgage-financing instruments, and low supply elasticity for new dwellings. This policy shift has made the housing sector more market-oriented by decentralising housing policy to municipalities, gradually removing subsidies for social rental housing, better targeting of housing allowances towards low income households, and making mortgage payments fully deductible for home owners (Priemus and Dieleman, 1997).

Although these policy changes have allowed strong sustainable growth in the residential property sector, this has come at a potential cost to financial stability. The combination of these changes have relaxed borrowing conditions for home-owners. In particular, the ability of home-owners to fully deduct interest payments on mortgage loans from their taxable income up to 30 years, and the opportunity to invest in newly-introduced investment mortgages (which take advantage of unlimited mortgage interest payment deductions) have significantly benefitted high-income earners and incentivised households to borrow more money to acquire property. Furthermore, credit limitations on banks have been relaxed. Banks can now take the primary and non-primary income of a household into acccount when determining the maximum mortgage amounts that can be lent. These policies have significantly increased the gross debt level in The Netherlands, with this increase strongly driven by a rise in gross mortgage debt. Currently, The Netherland's has the highest gross household debt level as a percentage of GDP in Europe at 111.4%. This worrying household debt level trend has been persistent in The Netherland's financial sector since the Second World War.

A major component of the government's housing market policy is the National Mortgage Guarantee System (NMG). As of 2012, the NMG guaranteed $141 billion Euros worth of mortgage loans (which represents 24% of The Netherland's total GDP). The NMG subsidises and stimulates higher home ownership and protects banks from credit risk (Vandevyvere and Zenthofer, 2012).

To provide a snapshot, the Dutch economy experienced consistently high economic growth leading up to the late twentieth century, with the Dutch housing boom a key factor in this trend. Following the recent Global Financial Crisis (GFC), uncertainty has increased in The Netherland's residential housing sector. This has created a decline in transaction volumes and house prices, reflecting increased risk for consumers and investors of Dutch real estate. Empirically, the mean Dutch house price fell below the long-run-average for the first time in two decades following the GFC, decreasing at an average of 3% per annum since 2008. It is likely house prices in Drenthe also fell following the GFC but this time period is not reported in this thesis' analysis. Potential reasons for the observed house price decline following the GFC are a fall in average household disposable income, tighter lending standards imposed on banks, lower employment growth, and decreased market confidence in the real estate sector. There are currently significant questions being raised about the affordability of home ownership and renting in the residential housing market, and how to make government policy more effective.

It is worth noting The Netherland's social housing sector as it is a unique feature of The Netherland's residential property sector. The Netherland's has the third largest stock of social housing in Europe, after France and the United Kingdom. As of 2005, 2.4 million out of 6.8 million (approximately one third of all dwellings) in The Netherlands were social rented dwellings and this number has remained relatively constant up to the present day. Social housing is more prevalent in urban areas. In particular, 55% of all dwellings in Rotterdam and Amsterdam are social rented properties.

The proportion of social housing is also reasonably high in remote, less populated areas like Drenthe which has a social rented housing proportion of 25% of all dwellings. The majority of this social housing stock was built between 1945 to 1990, where The Netherland's government was effectively able to incentivise increased social housing supply in the aftermath of World War 2. Housing associations supplying social housing were exempted from paying corporate tax, received subsidised prices for council land, and had their loans guaranteed under the Guarantee Fund for Social Housing. In response to house price increases over the last twenty years, the government has abolished these supply-side subsidies and shifted it's policy focus to improving housing affordability for first-home buyers.

With this backdrop in this mind, this thesis investigates the following questions. First, how has the value of Dutch residential real estate changed over time, accounting for land and structure components separately. This will build on analysis conducted by Diewert et al (2015) on Assen house sales price data. This thesis focuses on levels value analysis of the contribution of land value as a percentage of house value (also called land leverage) over time. The second question addressed by this thesis is how the affordability of residential property ownership relative to renting has evolved over time, and whether any patterns exist in observed market disequilibrium.

The Netherland's seems a good choice to analyse due to the unique nature of it's housing market structure and the high prevalence of government intervention in the sector. This thesis' analysis adds to numerous literature studies on user cost of housing, including in the US (Himmelberg, Mayer and Sinai, 2005; Baker, 2002; McCarthy and Peach, 2004), Australia (Hatzvi and Otto, 2008), the UK (Weeken, 2004), Ireland (Browne, Conefrey and Kennedy, 2013), and Finland (Kivisto, 2012). To the best of my knowledge, this thesis is the first empirical investigation of housing user cost in The Netherlands.

Chapter 3
Literature

3.1 Hedonic Price Methods

Hedonic regression is a revealed preference method used to estimate the contributory value of each explanatory characteristic to an item's price. The contributory values of each variable is determined by regressing the item's price on the vector of characteristics. These methods have many applications in the literature with particular use in industries experiencing rapid technological change (Diewert, Heravi and Silver, 2007).

Applied to a housing context, the hedonic model treats real estate as a bundle of goods sold on the market. The expected transaction price for a house is the summation of the value of the houses' characteristics (where the characteristics are divided into physical and locational factors);

$$\text{House sales price} = \text{f(Physical and Locational factors)}.$$

Physical factors measure dwelling quality and include land plot size, structure floor space, the number of bathrooms, the number of bedrooms, and parking space available. Locational factors measure the quality of the building site and include distance to the nearest train station, the provision of shops and workplaces, neighbourhood characteristics, distance to the capital city, distance to basic amenities and services such as shopping centres, and environmental quality (such as noise pollution).

There are limitations on the extent and accuracy to which these factors can be measured and quantified since there is no market for these characteristics. Each characteristic can not be sold separately, and therefore the price of each characteristic is not independently observable. Traditional discount cash flow models are inapplicable as a result. This thesis uses an additive decomposition framework to overcome these data limitations.

There are three methodologies that can be used to perform an additive decomposition of house prices into it's land and structure values separately. These are the construction cost method, hedonic regression methods, and the vacant land method.

The vacant land method determines the price of a unit of land associated with a sold property, p_L, from the sales of vacant land plots comparable in size and location. Using the estimated price p_L and the house price model $V = p_L L + p_S S$, the price of a unit of housing structure, p_S, can be determined. Available land sales are not likely to be comparable with the date at which they were sold, and there tends to be a relatively sparse volume of vacant land sales in urban centres (Clapp, 1980). This results in significant accuracy issues with this approach.

The construction cost method uses construction cost per unit of structure area (measured by National Statistical agencies) as an estimate of the price of a unit of housing structure, p_S. Using this price and the house price model $V = p_L L + p_S S$, the price of a unit of land, p_L, can be determined (Glaeser and Gyourko, 2003; Davis and Palumbo, 2008). There are significant accuracy measures in estimating unit structure price in this manner, depending on the approach used by a given statistical agency.

To avoid these accuracy issues, I use a hedonic regression which treats land and structure as separate characteristics to create a quality-adjusted price index (Diewert et al, 2015). The hedonic model is estimated using an additive decomposition framework. The hedonic function generates marginal prices for land and structure (also called shadow prices) for a given time period as partial derivatives. The partial derivatives are used to decompose the house price into it's separate land and structure components and can be interpreted as the marginal cost of producing the different characteristics.

This paper only considers physical factors to quality adjust land and structure due to data limitations with the Assen detached housing dataset. There may be an omitted variable problem caused by a lack of location data. This can be removed by explicitly accounting for spatial dependence. Hill et al (2008) suggest incorporating geospatial data with splines to perform parametric and non-parametric analysis to allow for spatial dependence. Given suitable data, such an approach would be a useful extension to this paper's findings.

The hedonic regression methodology has distinct advantages and disadvantages over other methods. Advantages of using hedonic regression methods to construct property price indexes (RPPIs) are;

1. Hedonic methods can create separate indexes for land and buildings, which are very difficult to compile otherwise,
2. Hedonic methods can adjust for sample mix changes and quality changes of individual properties,
3. Hedonic methods are flexible in constructing price indexes for different types of property that vary by dwelling-type or location,
4. The matched model approach often used in the literature to value houses is equivalent to the hedonic imputation method, allowing easy comparison of hedonic prices with existing literature.

Some of the major disadvantages of using hedonic regression methods to construct RPPIs are;

1. Hedonic methods are data intensive, and require detailed property characteristics data for all house sales. Non-homogenous data with respect to location and house type is ideal for reliable estimation where the sample can be broken into subgroups that have similar characteristics,
2. There is a high risk of multicollinearity between the land and structure components which will result in unreliable price estimates,
3. It can be difficult to sufficiently control for location if property prices differ significantly by region. A common method used to solve this problem is to stratify hedonic regressions,
4. Hedonic methods require a variety of decisions on functional form, model transformations, and error term specification. This can make replicating and validating results difficult with wide variation in price estimates.
5. Measuring quality change of land and structure is difficult. To make this easier, I assume quality is closely related to the period in which the dwellings are constructed (since regulation and construction costs change between time periods),
6. The structure values calculated will need to be adjusted to be compared with capital measurement under the perpetual inventory method.

This paper uses a cost-oriented hedonic model called the builder's model (Diewert et al, 2015). For a given time period t, location and type of land, the hedonic regression model in it's most simplistic form is Equation 3.1;

$$V = \beta S + \alpha L + \epsilon \tag{3.1}$$

The builder's model (both it's linear and non-linear specifications) are estimated using maximum likelihood estimation on the Assen data. There are two functional forms commonly used in the literature to create hedonic house price models. The first approach is the fully linear model (Equation 3.2);

$$V_n^t = \alpha^t L_n^t + \beta^t S_n^t + \epsilon_n^t \tag{3.2}$$

$$\forall t = 1, ..., T;$$
$$\forall n = 1, ..., N(t),$$

The second approach is the semi-log model (Equation 3.3);

$$lnV_n^t = \alpha^t L_n^t + \beta^t S_n^t + \epsilon_n^t \tag{3.3}$$

$$\forall t = 1, ..., T;$$
$$\forall n = 1, ..., N(t),$$

The log-linear model is not valid in an additive decomposition framework, since house value is simply the addition of land value and structure value. Thus, I use the linear model for my analysis. In situations where the additive decomposition framework is not considered, the semi-log specification is advantageous as it can help reduce heteroskedasticity and allow for constant variance of errors (Diewert, 2003).

For the builder's model, each property has a sales price, V_n^t, structure floor space area, S_n^t, building cost per square metre, β, land plot area, L_n^t, land cost per square meter, α, and an error term ϵ_n^t for a given period t, and for n = 1, ..., N(t). The property price is equivalent to the property's market value.

I make the stochastic assumption that all houses in the sample are of the same general type. I assume the error terms ϵ_n^t are independently and normally distributed with a mean of zero and constant variance. This is an additive error specification, and is preferred over the assumption of multiplicative errors in the additive decomposition framework (Diewert et al, 2015). A potential implication of assuming an additive error specification is that heteroskedastic errors may arise if expensive properties tend to have relatively large absolute errors relative to cheaper properties (Koev and Santos Silva, 2008).

In terms of running the hedonic regression, there are two techniques that can be used to quality-adjusted prices; the hedonic imputation method and the hedonic time dummy method. Both methods use hedonic regressions to remove the effects of quality changes on house prices, and can be used in a weighted or unweighted regression. However, each method yields a different result due to a difference in the averaging principle used (Pakes, 2003). The hedonic time dummy method constrains the hedonic regression parameters to be constant over time, whilst the hedonic imputation index allows the hedonic regression parameters to vary over time. This makes the hedonic imputation method more flexible in allowing for quality adjustment changes in each period, and is the preferred method for this paper.

The hedonic time dummy method provides a useful measure of house price inflation but does not specify the portion of land and structure value captured by this inflation term. This makes it very hard to create an accurate land and structure decomposition of house prices using the hedonic time dummy method.

Multicollinearity is a common problem in hedonic regression methods due to high correlation between some of the included explanatory variables. There is likely to be high collinearity between housing characteristics due to the fixed proportions of these variables in housing construction (for example, between the number of rooms and structure floor space area). Atkinson and Crocker (1987) use Bayesian techniques to treat this collinearity and note an important bias-variance tradeoff. The collinearity results in high standard errors for the regression coefficients, causing the coefficients to become unstable and increasing mis-measurement bias. The presence of collinearity raises concerns about specification issues and makes it hard to predict how different variables affect house prices.

Another common problem in a housing context is omitted variable bias. As noted by Case et al (1991), it is hard to accurately measure all housing characteristics that affect house quality and house prices over time. This problem makes it difficult to predict the magnitude and sign of the bias caused by the omitted variables, resulting in bias in the constructed hedonic indexes.

3.2 Stratified Hedonic Indices

Stratification can be used to adjust for changes in the quality mix of houses sold over time. My paper heavily draws on these stratification strategies as it seems sensible that house value may have a non-linear relationship with land plot size. Stratification techniques were popularised in the analysis of profit rates in the aerospace industry by Poirier and Garber (1974) who used spline functions to analyse and compare three distinct time periods. Another example is by Diewert and Wales (1992), who use adaptive splining to choose a suitable breakpoint specification that allows for non-linear responses with respect to time in a normalised quadratic profit function. The number of break points is first set to two, and a grid search is conducted on all possible combinations of potential break points (where the model with the largest log likelihood value is selected).

Stratifying the sample creates a piecewise linear function. The function is made up of a number of linear splines that adjust for changes in the quality mix of properties sold. An important consideration is choosing a suitable number and position of splines (Friedman and Silverman, 1989). I use median and percentile measures to optimise the breakpoint specification.

Using stratification to adjust for quality changes in houses seems sensible, since it is unlikely a single hedonic model can accurately measure housing dynamics in all house market segments. Furthermore, stratification helps to reduce sample selection bias in stock-based RPPIs to produce a more accurate comparison of price trends between different types of houses and regions.

The alternatives to spline modelling are to use dummy variables or polynomials. The dummy variable approach fits dummies to blocks of observations to avoid over-fitting issues. This method provides poor estimation if the model is continuous with respect to land plot sizes.

The use of polynomials is also undesirable due to constraint considerations with global fit of the model. De Boor (1979) finds that spline functions are continuously differentiable to the order of n - 1, whereas polynomials are only continuously differentiable to the order of n. This makes spline functions more flexible as they can respond to locally sharp areas of the function without affecting the model's global fit.

In regards to spline functional form, it is appropriate to use linear splines over higher order functions since there is no a priori reason to model land plot size in a continuously differentiable manner (Fox, 2012).

In this paper, I stratify house prices by land plot size. This uses a linear land plot trend to capture potential discontinuities and instantaneous jumps in the house price function at the spline break points. This will assign a different land price to properties based on the land plot size. The regression creates a set of variables used to construct a piecewise linear model. The linear spline function is initially flat and drops at the breakpoint (capturing a threshold effect) before becoming flat again. The threshold effect is captured by the two breakpoints which specify the start and end points of the land pot size slope change.

I assume the regression model is linear between any two corresponding break points and that the regression is connected at these break points. I also assume that the quality mix of housing within each constructed spline is the same. The effectiveness of splining depends on how significantly land prices change as land plot size increases, and on the amount of unit value bias inherent in the spline model (since each property sale is a unique good).

3.3 User Cost of Housing

Analysing user cost of housing measures deviations in the market value of houses from their theoretical equilibrium values over time. Tracking market disequilibrium changes over time measures the affordability of home ownership relative to renting, and whether there is evidence of a potential housing market bubble. Conventional metrics such as price-rent and expenditure-income ratios capture the annual rent paid for housing consumption and are typically used to measure housing affordability (Haffner and Boumeester, 2010). These approaches are directly linked to a household's relative income and are restricted in analysing how the proportion of household income spent on housing changes over time (Hulchanski, 1995). The user cost of housing approach to measuring market disequlibrium and housing bubbles has become increasingly popular in the real estate literature, such as Syed and Hill's (2012) investigation of Sydney property overvaluation.

The user cost of housing at the start of period t is the present value of buying one unit of housing, using it for period t, and than selling this unit of housing (Diewert, 1974; Hicks, 1939). This equals the rate of return on housing over period t, which is equivalent to the cost of renting a house for period t. This approach to measuring cost is useful because it factors in asset-class risk as well as idiosyncratic risk for homeowners.

Poterba's user cost of capital framework (Poterba, 1984) is a neoclassical investment model used to study housing demand and analyse the equilibrium imputed rental income for homeowners. An owner-occupier of real estate forgoes interest on the dwelling' s market value, incurs property taxes, incurs depreciation and maintenance costs, incurs risk from uncertainty of future house prices and gross rent movements, and benefits from the dwelling's future capital gains. The user cost of housing is calculated using Equation 3.4;

$$UC_t = r_t + \alpha_t + \delta + \gamma - \beta_t \tag{3.4}$$

where;

- UC_t is the per dollar cost of owning one unit of housing for period t (where t is measured in years),
- r_t is the risk-free interest rate for period t,
- α_t is the local property tax rate for period t,
- δ is the maintenance and depreciation rate for period t,
- γ is the required risk premium to invest in one unit of housing relative to renting, and
- β_t is the expected house price appreciation from year t to year t+1.

$$\forall t = 1, ..., 11$$

At equilibrium, the theoretical equilibrium cost of renting equals the price-rent ratio (Shiller, 2006) as shown in Equation 3.5;

$$UC_t = \frac{R_t}{P_t} \tag{3.5}$$

where;

- UC_t is the per dollar user cost of capital for period t,

– R_t is a given household's imputed rental income per unit of housing capita for period t,

– P_t is the asset price of a unit of housing capital for period t, and

– $UC_t * P_t$ is the user cost of capital for period t.

$$\forall t = 1, ..., 11$$

To evaluate the equilibrium empirically, the expression is often re-expressed as Equation 3.6;

$$\frac{P_t}{R_t} = \frac{1}{UC_t} \tag{3.6}$$

The price-rent ratio in the market should equal the inverse of the per dollar user cost. If the actual market rent is higher than the theoretical user cost ($R_t > UC_t P_t$), than it is cheaper for households to buy housing relative to renting. Since owner-occupying is more attractive than renting, this puts upward pressure on house prices and downward pressure on gross rent until equilibrium is restored. If the theoretical user cost is higher than actual market rent, the opposite argument applies. Renting will be cheaper relative to buying and this decreases pressure on house prices and increases pressure on gross rent until market equilibrium is achieved.

The equilibrium framework assumes that the price-rent ratio is the same for all types of owner-occupiers and assumes P_t and R_t are calculated for properties of equal quality. This is unlikely to hold in practice where P_t and R_t vary across age and income groups. There is a quality mismatch between median houses in the rental and owner-occupier housing markets. Furthermore, the variables used to calculate user cost aren't directly observable and approximation of these inputs creates mis-measurement bias (Verbrugge, 2008).

3.4 Empirical Evidence of Hedonic Pricing

The conceptual motivation for performing hedonic methods was first explained by Lancaster (1966) and Rosen (1974). Lancaster and Rosen broke away from the traditional approach of treating goods as direct objects and utility, and instead assumed utility is derived from the goods' characteristics and properties. In recent years, quality-adjustment of house prices has become a major focus to gain greater understanding of house price dynamics. There are two main approaches to conducting house price hedonic analysis; the hedonic imputation method and the hedonic time dummy method.

Before investigating the user of hedonic methods, I consider other methods in the literature to analyse house prices. First, transactions data on a microeconomic level can be used to quality-adjust house prices. One such application of this methodology is by Wu, Deng, and Liu (2014) who create a constant-quality house price index using transactions data for new housing units in China. The data set is obtained from the Real Estate Market Information System (REMIS) for thirty-five Chinese cities, and provides detailed characteristics and information on all new housing unit sales from 2006 onwards across China. They observe a dramatic price surge across China from 2006 to 2010. The framework provides a good method that can be employed in The Netherland's on how to collect data to construct accurate city hedonic price indexes.

Another approach to modelling house prices is a simultaneous equations framework. Chow and Niu (2013) utilise a simultaneous equations framework to analyse supply and demand for Chinese urban residential housing. Demand is equal to Equation 3.7;

$$q_t = b_0 + b_1 y_t + b_2 p_t + u_{1t} \tag{3.7}$$

Supply is equal to Equation 3.8;

$$q_t = c_0 + c_1 p_t + c_2 c_t + u_{2t} \tag{3.8}$$

In this framework, q_t is housing space per capita, y_t is real disposable income per capita, p_t is the relative price of housing, and c_t is the real construction cost. Using reduced form equations, Chow and Niu (2013) find that rapid housing price growth is well explained where income determines demand and construction costs affect supply.

Finally, Gyourko (2013) uses spatial data on US residential property to analyse the government's regulation of residential property. Gyourko finds empirical evidence that local zoning policies and land-use restrictions influence housing supply elasticity in a statistically and economically significant way. This has important implications for analysing the impact of highly intervenionist government policies on The Netherlands' property sector.

The above methods are not applicable to this thesis' investigation as they do not allow an accurate deconstruction of house prices into it's land and structure components. Hedonic regression methods provide a useful method for such analysis.

Gyourko et al (2015) create a constant-quality hedonic price index to construct price-rent and price-income ratios for China's three property tiers. This framework utilises a microeconomic data set that measures housing supply, housing demand, rent data, depreciation data, and real land prices. Using the constructed ratios, Gyourko et al (2015) find evidence of high user cost of housing in China's larger cities. This is potential evidence for poor housing affordability and strong over-valuation of property in these areas. The finding is empirically justified by considering expected future capital gains for real estate in China's larger cities.

Syed et al (2008) construct quarterly temporal and spatial hedonic price indexes for Sydney housing. The paper uses temporal fixity (Hill, 2004) to manipulate shadow prices so they are flexible across regions and time. This breaks the regression up into overlapping blocks that are spliced together. This overcomes spatial dependence in the shadow prices by spatially weighting the neighbourhood of observations. This creates more efficient estimators and corrects standard errors. House prices are than estimated using maximum likelihood estimation (Anselin, 1988). This helps overcome spatial dependence by spatially weighting the neighbourhoods of observations, which creates more efficient estimators and corrects standard errors. Furthermore, the paper uses multiple imputation techniques to solve missing data issues and to correct for heteroskedasticity (Rubin, 1987). The significance in the literature placed on accounting for spatial dependence has increased due to the influence of spatial correlation on hedonic results where house prices are obtained for neighbourhoods that share locational amenities or consist of dwellings with similar structural characteristics (Basu and Thibodeau, 1998). The method is not applied to Assen due to data limitations but would be a useful extension to my paper's analysis.

An early use of hedonic methods to create an additive decomposition model is by Bostic et al (2007) who use an additive decomposition model to demonstrate how land leverage explains the majority of variation in house price appreciation in

Kansas. Land leverage is equal to land value as a proportion of house value. The paper employs a framework similar to Davis and Heathcote's (2007) analysis of the U.S. market from 1975 to 2000. Land leverage is investigated by comparing the price of vacant land plots with prices of the same properties after houses are constructed on the vacant land plot. An alternative measure of land leverage is to use assessed values for land provided by local property tax assessment offices. This focus on land leverage has become popular in the literature with a variety of applications. An example is Bourassa et al's (2009) measurement of land leverage in New Zealand. Bourassa et al (2009) find that houses with a higher land leverage value are more price-volatile over the entire property cycle.

Building on Bostic et al's (2007) approach, Diewert et al (2015) use the hedonic imputation method to create a land and structure decomposition model called the builder's model (Equation 3.9);

$$V_n^t = \alpha^t L_n^t + \beta^1 p^t (1 - \delta^t A_n^t)(1 + \gamma R_n^t) S_n^t + \epsilon_n^t \tag{3.9}$$

Diewert et al (2015) consider linear splining and adding exogenous information to the model to find the builder's model explains 87% of house price variation in Assen from 1998 to 2003. The paper provides the motivation for the methods employed in this thesis. This thesis considers the land and structure values in Assen from 1998 to 2008 on a levels basis, which allows comparison with the index land and structure prices calculated by Diewert et al (2015). Furthermore, this thesis analyses the relative affordability of home ownership versus renting over time in Assen. The implications of house prices on housing affordability are not considered by Diewert et al (2015).

A common issue in hedonic regression analysis is how to treat missing data appropriately to avoid mis-measurement and bias. Syed et al (2008) provide a framework that uses multiple imputation techniques developed by Rubin (1987) to solve missing data issues, and use this to correct for heteroskedasticity. The paper demonstrates how to perform hedonic regressions to provide detailed analysis of the impact of interaction terms between housing characteristics, different regions and different time periods on house prices. These methods provide motivation on the modelling strategy used in this thesis and help improve model flexibility and remove substitution bias.

Another strategy that can be used to improve hedonic regression decomposition models is to use a dynamic identification strategy. Rambaldi et al (2015) create a land and structure decomposition (using a dynamic identification structure through a Kalman filter) to find land value is significantly larger proportion of house value than structure value in Brisbane and the San Francisco Bay Area. Application of the Kalman filter to the Assen data set may help improve the identification strategy for separating land and structure values separately but is not considered in this paper due to a lack of detailed location data.

The literature on residential house price movements in The Netherlands focus on using price indexes created by Statistcs Netherlands (CBS Statline). There are a variety of such studies including Kakes and Van Den End (2004) who investigate the link between stock prices and house prices, Shiller (2007) who investigates trends between house prices and home ownership, and Boelhouwer (2005) who investigates the effect of incomplete privatisation in The Netherlands on house price dynamics. The house price data used in these investigations in not valid for comparison with results in this thesis as they are not applicable in an additive decomposition context.

Using these house prices, the relative change in the affordability of owning a house can be conducted using Poterba's (1984) framework, where the marginal cost of housing services equals the marginal benefit of housing services. Poterba analyses the user cost of housing service per unit of housing, and compares this with the rate of gross housing market rent which is interpretable as the marginal benefit. In other words, individuals will consumer housing services until the marginal value of using housing services equals the marginal cost of the housing service. The user cost per unit of housing service is equal to Equation 3.10;

$$w = [\delta + K + (1-\theta)(i+\mu) - \pi_H] \tag{3.10}$$

The framework assumes all housing units depreciate at a constant rate δ and require maintenance equal to K times the total current house value. Furthermore, property tax liabilities at a rate of μ are imposed on owner-occupiers, who can deduct property taxes from their taxable income where a given individual faces the marginal income tax rate θ. Finally, owner-occupiers expect capital gains of π_H over the coming year on their house and can borrow or lend at the nominal interest rate i. Using this user cost approach provides the motivation for the measurement of housing affordability in this thesis.

Himmelberg et al (2005) use Poterba's (1984) user cost framework to measure the user cost of housing for single-family households in U.S. metropolitan areas. They find conventional measures of housing affordability in the literature such as price-rent ratios, house price growth rates and price-income ratios yield misleading results. These conventional measures of the affordability of housing are unable to indicate whether house price increases are increasing ownership costs because the price of a house is not equivalent to the annual cost of owning that house. Furthermore, calculation of the ratios is heavily dependent on assumptions of expected house price appreciation and future tax rates. This can cause significant variation in calculated price-rent ratios. Finally, house prices are more sensitive to interest rate changes when real interest rates are low or in cities where the long-run growth rate of house prices is high. In these situations, observed price growth may inaccurately provide evidence of a house price bubble. Himmelberg et al (2005) overcome these inaccuracies by imputing the annual rental cost of owning a home and evaluate this as the cost of owning a house. Using Poterba's user cost framework, Himmelberg et al (2005) find evidence of overvaluation in the owner-occupier housing market during the 1980s, and that these house prices have corrected towards the long-term trends. This indicates that overvalued houses have experienced large price decreases to correct towards market equilibrium over time. Furthermore, Himmelberg et al (2005) find that the cost of owning a house relative to renting increased in most U.S. cities from 1995 to 2004. This evidence suggests housing affordability in the rental market has improved over time.

Syed and Hill (2012) build on Syed et al's (2008) investigation by using quality adjusted price-rent ratios and observed price-rent ratios in the property market to analyse the user cost of housing in Sydney. The paper finds evidence of disequilibrium in the Sydney property market, where home ownership is overvalued. The paper notes key issues that must be considered when working with the user cost framework. Since median owner-occupied housing are of a higher quality than median rented dwellings on average (Hatzvi and Otto, 2008), bias may arise due to quality mismatches. To avoid this, price-rent ratios should be matched at the individual dwelling level. This data is not available because dwellings are sold and rented at different times. Syed and Hill (2012) use hedonic methods to estimate price-rent ratios at the individual dwelling level and assume price-rent ratios computed under the user cost framework measure the same dwelling as market price-rent ratios. Another key issue is the sensitivity of price-rent ratios to expected real capital gains on housing (Verbrugge, 2008). Syed and Hill impute expected capital gain implied by the user cost framework to measure forecasted expected capital gains.

Chapter 4
Data

4.1 Assen Housing Sector: Variable Description

My thesis uses a panel data set consisting of 6,397 sales records of detached houses in Assen from the first quarter of 1998 to the second quarter of 2008. Note that further data sources are used for user cost housing measurement. These sources are presented in a later section of this thesis. For each house sale in Assen, the data set contains corresponding quantitative and qualitative information for key physical and locational attributes. There are no missing observations or non-response issues with the initial data set (which are typically common in empirical hedonic regression studies). The information is a mixture of continuous and dummy variables.

Table 4.1: Variable Definitions

Value	Description	Measurement Units
V_n^t	Sales price for property n sold in quarter t	1000s of Euros
L_n^t	Land plot size for property n sold in quarter t	m^2
S_n^t	Floor space area for property n sold in quarter t	m^2
BP_n^t	Decade in which property n sold in quarter t is built	0 to 9
A_n^t	Decade age of property n sold in quarter t	0 to 4
R_n^t	Number of rooms for property n sold in quarter t	Units
T_n^t	Number of toilets for property n sold in quarter t	Units
F_n^t	Number of floors for property n sold in quarter t	Units
BL_n^t	Number of balconies for property n sold in quarter t	Units
D_n^t	Number of dormers for property n sold in quarter t	Units
RT_n^t	Number of roof terraces for property n sold in quarter t	Units
BT_n^t	Number of bathrooms for property n sold in quarter t	Units
P_n^t	Parking quality for property n sold in quarter t	0 to 5
MI_n^t	Inside house maintenance of property n sold in quarter t	0 to 9
MO_n^t	Outside house maintenance of property n sold in quarter t	0 to 9
SH_n^t	Garden storage quality for property n sold in quarter t	0 to 6
LR_n^t	Living room area for property n sold in quarter t	Unknown
C_n^t	Construction costs for property n sold in quarter t	Index (1998 = 1)
Q_n^t	Quarter in which property n is sold	Units

A description of the housing characteristics used in my analysis is provided in Table 4.1 $\forall$ t = 1, ..., 42 and $\forall$ n = 1, ..., 6397. This thesis analyses linear prices, since the semi-log model specification is not interpretable or valid under the additive decomposition framework.

The quarter variable is constructed from observed contract registration date. Structure size is measured using the structure's floor space area S_n^t. The mean structure floor space area is 125.72m^2, with the smallest house having a floor space area of 55m^2 and the largest house having a floor space area of 352m^2. The median and modal floor space area for detached housing in Assen is 120m^2.

The number of floors variable F_n^t is not used in my analysis due to uncertainty over whether the building floor data is measuring apartment numbers rather than number of floors.

The structure age variable A_n^t is constructed using building period data and is defined in Equation 4.1;

$$Structure\ age = 9 - Building\ period \tag{4.1}$$

The interpretation of the decade structure age is provided in Table 4.2. For example, a house built between 1960 to 1970 is assigned a value of 4 and so on. The variable measures the increase in structure price per square metre when moving from one decade structure age to the next. The median structure age is 2 (1981 to 1990) with an average of 1.99 (1981 to 1990). The largest number of houses are built from 1991 to 2000.

Table 4.2: Structure Age Description

Decade Structure Age	Value
2001 - 2008	0
1991 - 2000	1
1981 - 1990	2
1971 - 1980	3
1961 - 1970	4

$$\forall t = 1, ..., 42;$$
$$\forall n = 1, ..., 6397.$$

The interpretation of parking quality is provided in Table 4.3. For example, a house that has a garage and one carport will be assigned a value of 4. In general, the higher the parking quality value, the higher the structure price per square metre.

Table 4.3: Parking Availability Description

Parking Quality	Value
No parking	0
Parking space	1
Carport with no garage	2
Garage with no carport	3
Garage and carport	4
Garage for multiple vehicles	5

The inside maintenance variable measures the quality of maintenance performed inside a house, on a scale from bad to excellent. I assume this variable captures maintenance performed to the inside and outside of the houses' structure component, but excludes any maintenance performed to the physical land plot that the structure sits on. The scale of values for inside maintenance is shown in Table 4.4. For example, a house with reasonable to good inside maintenance is assigned a value of 6. As inside maintenance increases, this reflects a greater quality of housing structure resulting in an increase in structure price per square metre. Note that this variable does not indicate the cost or amount of maintenance performed to the inside of the structure. To enable more accurate analysis of the impact of renovation quality on structure value, data measuring the dollar value maintenance improvements to a house would be ideal to capture these effects.

Table 4.4: Inside Maintenance Description

Inside Maintenance Quality	Value
Bad	1
Bad to moderate	2
Moderate	3
Moderate to reasonable	4
Reasonable	5
Reasonable to good	6
Good	7
Good to excellent	8
Excellent	9

The outside maintenance variable measures the quality of maintenance performed to the physical land plot that the structure sits on. The variable is measured on a scale from bad to excellent as shown in Table 4.5. For example, a house with good outside maintenance is assigned a value of 7. As outside maintenance quality increases, this reflects a greater quality of land plot resulting in an increase in land price per square metre. Again, more detailed analysis will be possible if data is available on the dollar value of outside maintenance performed to a house.

Table 4.5: Outside Maintenance Description

Outside Maintenance Quality	Value
Bad	1
Bad to moderate	2
Moderate	3
Moderate to reasonable	4
Reasonable	5
Reasonable to good	6
Good	7
Good to excellent	8
Excellent	9

The garden shed variable measures the quality of garden storage space available. The variable measures whether a house has a garden shed, and what material the garden is made of. Measurement of the variable is explained in Table 4.6. For example, a house with a box shed is given a value of 6 and is assumed to have the highest quality of garden storage space available. The median and average value for garden shed is 2, indicative of a garden shed detached from the house and made of brick. Interestingly, 31% of houses do not have any garden storage space available. This model assumes that wooden garden sheds are superior in quality relative to brick garden sheds. Furthermore, garden sheds detached from the house are assumed to add more quality to the structure component of housing than garden sheds that are an extension to the main housing structure on the land plot. Indoor sheds and box sheds are higher-quality garden storage spaces, and are observed infrequently in the data. It is likely that only luxury houses have garden storage space of such quality.

For the purposes of my analysis, I ignore differences in building location such as distance to basic services and facilities, since location is unlikely to be a significant price-determining factor in this small city, and there is a lack of accurate data on location. The impact of environmental quality factors (such as neighbourhood layout), housing density measures, and the degree of urbanisation are also excluded for similar reasons.

The Assen data set is quite detailed but there are a range of characteristics not measured including landscaping, type of heating system, air conditioning, number of swimming pools, and shape of the land plots. Extensions to this thesis could consider measures of these variables to improve the accuracy of quality-adjustment measures in this thesis, and allow more flexible model comparison with other cities.

Table 4.6: Garden Storage Description

Garden Storage Quality	Value
No garden shed	0
Extension to house, made of brick	1
Detached from house, made of brick	2
Extension to house, made of wood	3
Detached from house, made of wood	4
Indoor shed	5
Box shed	6

4.2 Assen Housing: Data Cleaning

Before using the data to create house price indexes and quality-adjusted structure values, I clean the data by removing data entry errors and range outliers to minimise data bias and obtain stable coefficients. The data cleaning process proceeds as follows.

As mentioned in the Variable Description section, I exclude sales observations where the structure component of the house is older than fifty years old. The reasoning behind this is that very old houses have exponentially larger renovation expenditures relative to younger houses. Since the focus of this thesis is on estimating net depreciation and property inflation for younger structures, including these observations would create bias in the results.

There are 30 houses that sold for a price lower than 60000 Euros, and 16 houses that sold for a price greater than 550,000 observations. There are no house sales where the houses land plot size less than 70 m^2 and there are 39 sales of houses that have land plot sizes larger than 1,500m^2. There are no houses sales with structure sizes less than 50m^2 and there is 1 house sale that has a structure space larger than 400m^2. Finally, there are 14 sales of houses that have less than 2 rooms, and 9 sales of houses that have more than 9 rooms. These observations are all excluded from the hedonic regressions as range outliers. This results in 103 observations being omitted from the original data set, giving a final sample size of 6,295 house sales after data cleaning.

4.3 Assen Housing: Key Data Characteristics

The mean, standard deviation, minimum and maximum values for house sales prices and the explanatory characteristics used in this thesis are summarised in Table 4.7.

Table 4.7: Summary Statistics for Key Variables

Variable	Mean	Standard Deviation	Minimum	Maximum
V_n^t	158.67	69.69	60.13	550
L_n^t	252.28	145.72	70	1469
S_n^t	125.71	29.26	55	352
A_n^t	1.99	1.15	0	4
R_n^t	4.67	0.84	2	9
T_n^t	1.44	0.48	0	3.33
F_n^t	2.88	0.46	1	6
BL_n^t	0.07	0.26	0	2
D_n^t	0.05	0.23	0	2
RT_n^t	0.04	0.2	0	2
BT_n^t	0.97	0.3	0	2
P_n^t	1.59	1.44	0	5
MI_n^t	7.23	0.89	1	9
MO_n^t	7.21	0.86	1	9

Tables 4.8 and 4.9 summarise average house value, average land quantity and average quality-adjusted structure quantity from 1998 to 2008 in Assen. There is strong house price growth in Assen of 8.87% per annum on average from 1998 to 2008, significantly above the inflation rate. This is similar to the strong growth experienced across Drenthe as noted earlier in this thesis.

The average land quantity and the average quality-adjusted structure quantity from 1998 to 2008 is 251.81m^2 and 97.99m^2 respectively as shown in Tables 4.8 and 4.9 respectively. Land and quality-adjusted structure sizes are relatively constant over time, indicating very little change in the quantity characteristics of housing. Additionally, each quarter has approximately the same number of house sales. Since the quantities are constant over time, this helps separate the price change from quality change more easily. The strong house price growth in Assen is shown by the increasing trend in house prices from 1998 to 2008 in Figure 4.1.

The growth in house prices reflects a modest increase in market activity in the real estate sector, reflected through the steady increase in the number of transactions over time in Table 4.10. This indicates that housing supply has been relatively inelastic from 1998 to 2008.This helps keep the stock of housing constant over time, which is useful when analysing price dynamics independent of transaction flow effects. One possible explanation for the relative inelasticity in housing market transactions is that the market supply of housing was unable to react sufficiently to house price increases (Boelhouwer, 2005). An alternative explanation is that favourable tax treatment has kept high upwards pressure on house prices, resulting in inelastic supply (Van Ewijk et al, 2006). Note the 2008 figure is lower as only the first two quarters of this year are covered in the data set.

Table 4.8: House Prices and Land Quantity in Assen

Year	Average House Price (000s Euros)	Average Land Quantity (m^2)
1998	97.21	241.07
1999	118.11	260.74
2000	131.74	241.96
2001	144.45	243.51
2002	151.79	239.53
2003	163.32	254.59
2004	172.81	258.07
2005	181.47	253.18
2006	190.07	261.01
2007	195.74	266.32
2008	192.07	249.95
Average	158.071	251.812

There are large correlations between house prices (V_n^t) with land parcel size (L_n^t), structure floor space (S_n^t) and decade structure age (A_n^t) of 0.740, 0.682, and -0.351 respectively. The sales price is highly correlated with land parcel size and structure floor space as expected. The correlation coefficient between L and S is 0.590, indicating that although the effects of land and structure are separate, there is the potential for multicollinearity between land and structure.

There is strong correlation between house prices with number of rooms (R_n^t), quality of available parking (P_n^t) and quality of inside house maintenance (MI_n^t) of 0.350,

Table 4.9: Structure Quantity in Assen

Year	Average Structure Quantity (m^2)	Average Quality-Adjusted Structure Quantity (m^2)
1998	127.3	95.09
1999	125.35	95.13
2000	126.13	96.25
2001	123.01	94.32
2002	122.05	94.12
2003	125.68	97.41
2004	125.45	99.54
2005	126.09	101.31
2006	127.71	101.92
2007	127.69	100.8
2008	126.29	101.98
Average	125.705	97.988

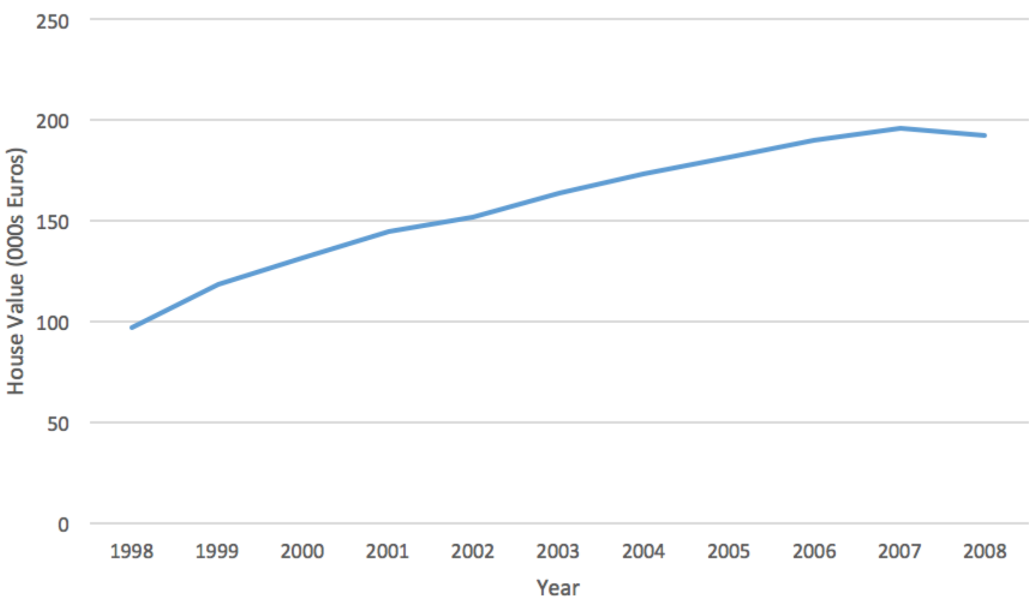

Figure 4.1: Average House Values in Assen

Table 4.10: Volume of House Transactions in Assen

Year	Number of House Sale Transactions
1998	530
1999	545
2000	559
2001	578
2002	598
2003	600
2004	607
2005	621
2006	647
2007	675
2008	335
Average	572.273

0.481 and 0.258 respectively. The correlation coefficient between S and R is 0.472. This indicates a strong positive correlation between structure floor space and number of rooms, and it is likely a wide amount of price variation attributable to R will be picked up by the S variable.

Note that the data must be cleaned before proceeding with hedonic analysis since the regression coefficients and correlation between variables differ significantly when outliers are included in the data set.

Chapter 5
Hedonic Pricing Model

The hedonic price indexes in this section are constructed using the hedonic imputation method. This allows the implicit characteristic prices to vary over time, making it more flexible than the time dummy variable method.

The regressions are run with robust standard errors and no constant term using maximum likelihood estimation. The model assumes identical suppliers of housing in Assen. Due to the rural nature of this municipality, the assumption seems reasonable. The assumption will need to be relaxed and is also not likely to be prudent in hedonic investigations of areas that have a large proportion of unit structures or significant zoning restrictions.

5.1 Preliminary Hedonic Model Form

The simplistic representation of the hedonic regression model incorporates land quantity, L_n^t, and structure quantity, S_n^t, for the sale of property n in a given period t. The two constant quality prices in period t are the price of land per square metre, α^t, and the price of structure floor space per square metre, β^t. The hedonic regression is of the form shown in Equation 5.1;

$$V_n^t = \alpha^t L_n^t + \beta^t S_n^t + \epsilon^t; \tag{5.1}$$

$$\forall n = 1, ..., N(t);$$
$$\forall t = 1, ..., T.$$

Land value is equal to the land price per metre squared, α^t, multiplied by the land plot size, L_n^t. The structure value is than easily computed as the house value minus the land value. This process is used to calculate land value and structure value throughout this paper.

Table 5.1: Land Prices and Structure Prices in Assen

Year	Land price per square metre	Structure price per square metre
1998	0.2028	0.3827
	(0.0068)	(0.0149)
1999	0.1891	0.5563
	(0.0084)	(0.0198)
2000	0.2983	0.472
	(0.0104)	(0.0217)
2001	0.2533	0.6743
	(0.0104)	(0.0229)
2002	0.3020	0.6531
	(0.0010)	(0.0212)
2003	0.2315	0.8333
	(0.0097)	(0.0223)
2004	0.2565	0.8656
	(0.0102)	(0.0235)
2005	0.2477	0.9468
	(0.0105)	(0.0238)
2006	0.2682	0.9498
	(0.0114)	(0.0259)
2007	0.2362	1.0491
	(0.0099)	(0.0237)
2008	0.2520	1.0344
	(0.0146)	(0.0323)
Average	0.2542	0.7585
	(0.0044)	(0.0099)

The land and structure prices are shown in Table 5.1. Note that I report standard errors in brackets throughout the paper. The model has an adjusted R^2 of 0.9413. Structure floorspace and land plot size are economically and statistically significant at the 1% significance level. Structure prices are higher than land prices, and increase at a faster rate than land prices. As a result, structure value increases faster relative to land value as illustrated in Figure 5.1. The implication of this is structure value increases as a proportion of total house value over time, shown in Figure 5.2.

The model parameter interpretations for this basic model and the expanded model are shown in Table 5.2, and complement the variable descriptions provided earlier in the Data section.

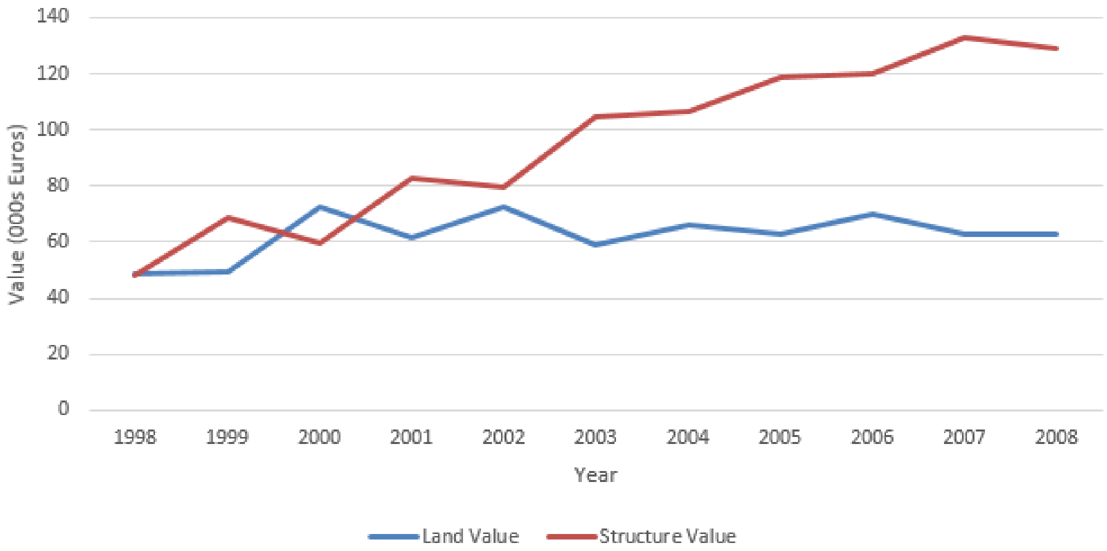

Figure 5.1: Land Value and Structure Value

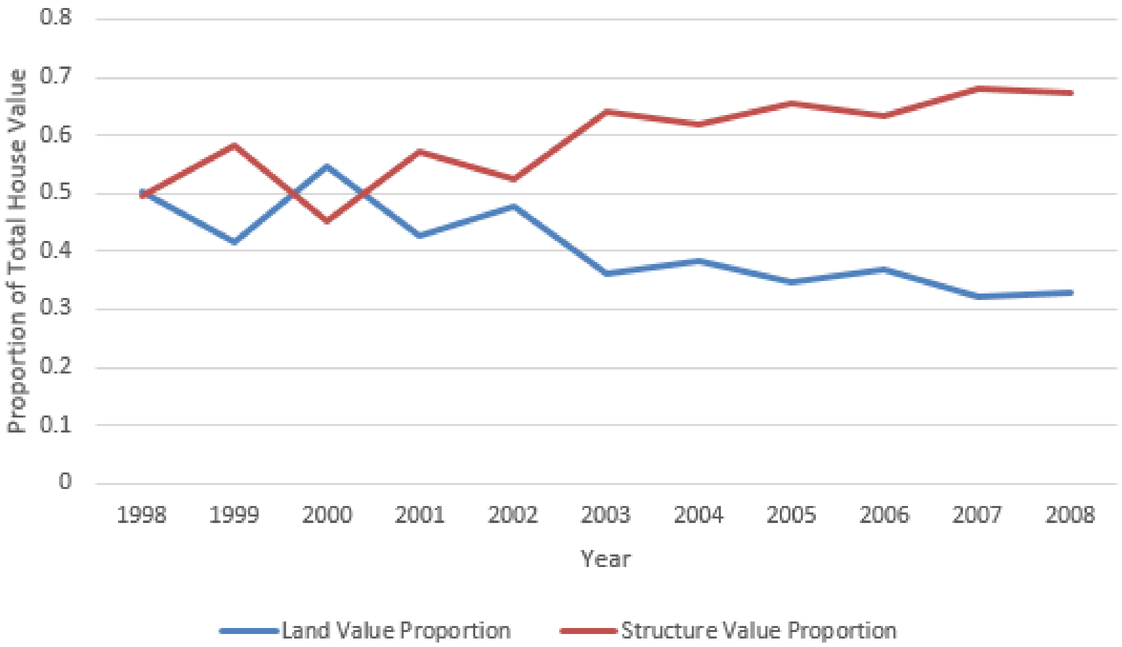

Figure 5.2: Land Value Proportion and Structure Value Proportion

Table 5.2: Basic Builder's Model: Variable and Parameter Descriptions

Variable	Description	Measurement Units
V_n^t	Sales price for property n sold in period t	000s of Euros
L_n^t	Land plot size for property n sold in period t	m^2
S_n^t	Structure floor space for property n sold in period t	m^2
A_n^t	Decade age of property n sold in period t	0 to 4
α^t	Estimated land price per metre square in period t	000s of Euros
β^t	Estimated structure price per metre squared in period t	000s of Euros
δ^t	Estimated decade net depreciation rate in period t	Percentage of Total House Value

5.2 The Basic Builder's Model

The preliminary hedonic regression model used in the Preliminary Hedonic Model Form subsection treats each square metre of structure as equal regardless of the building's age. Using this regression is likely to yield inflated structure values over time since depreciation and age deterioration effects are not accounted for, and the Assen detached housing data set does not exclusively consist of sales of new houses. Thus, the preliminary hedonic model form will only produce reliable results if all the houses in the data set contain new structures (in other words, are built between 2000 and 2008).

I now expand the regression model to include a structure age variable that accounts for depreciation and deterioration effects over time. Introducing the age variable creates the quality-adjusted hedonic empirical relationship in Equation 5.2;

$$V_n^t = \alpha^t L_n^t + \beta^t(1 - \delta^t A_n^t)S_n^t + \epsilon^t; \tag{5.2}$$

$$\forall n = 1, ..., N(t);$$
$$\forall t = 1, ..., T,$$

where A_n^t is the structure's age (decades) and δ^t is the net depreciation rate (decade) as the structure ages one year. The net depreciation rate measures average gross depreciation less average real renovation expenditure and is expected to be approximately 0.5% to 1.5% per annum. The term δA increases as building age increases, and $\beta(1 - \delta A)$ is the adjustment required to obtain the quality-adjusted structure floor space area.

Table 5.3: Land Prices, Structure Prices and Depreciation Rate in Assen

Year	Land price per square metre	Quality-adjusted Structure price per square metre	Depreciation Rate
1998	0.1993	1.0713	0.1301
	(0.0060)	(0.0188)	(0.0080)
1999	0.1988	1.0949	0.1297
	(0.0075)	(0.0228)	(0.0087)
2000	0.2935	1.0950	0.1399
	(0.0089)	(0.0237)	(0.0079)
2001	0.2591	1.1313	0.1415
	(0.0084)	(0.0237)	(0.0066)
2002	0.2972	1.0922	0.1094
	(0.0086)	(0.0226)	(0.0064)
2003	0.2351	1.0847	0.0860
	(0.0088)	(0.0244)	(0.0067)
2004	0.2638	1.1182	0.1125
	(0.0081)	(0.0210)	(0.0052)
2005	0.2454	1.0953	0.0860
	(0.0092)	(0.0092)	(0.0056)
2006	0.2818	1.1333	0.1163
	(0.0088)	(0.0221)	(0.0050)
2007	0.2726	1.1325	0.1098
	(0.0078)	(0.0196)	(0.0047)
2008	0.2706	1.1085	0.0929
	(0.0120)	(0.0285)	(0.0068)
Average	0.2561	0.9451	0.1140
	(0.0086)	(0.0215)	(0.0065)

The land and structure prices are shown in Table 5.3. The model has an adjusted R^2 of 0.9788, which is a slightly better fit than the previous model. Structure floor space area, land parcel area, and structure age are statistically and economically significant at the 1% significance level. Again, structure price per square metre of structure space is significantly higher than land price per square metre of land area. Estimated structure value is slightly lower now as expected, since deterioration effects are being captured as shown in Figure 5.3. This results in a slightly lower structure value proportion of total house value (Figure 5.4). Overall, structure values are still increasing as a proportion of house value over time.

I compare my basic builder's model results with Diewert et al's (2015) analysis to check for consistency. This involves converting my average land and structure

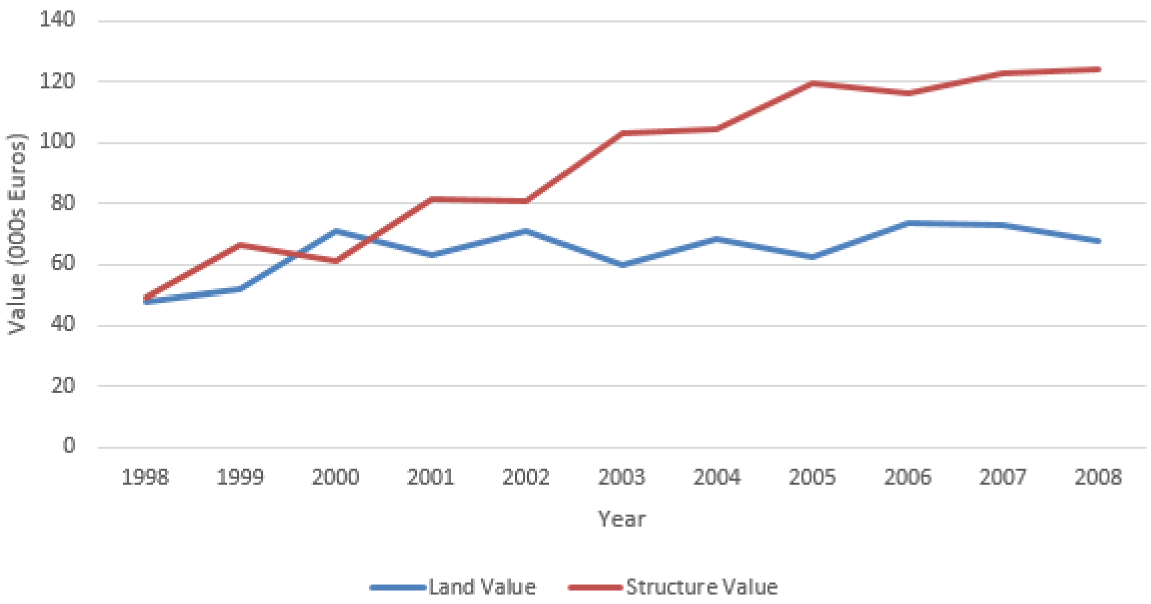

Figure 5.3: Land Value and Structure Value

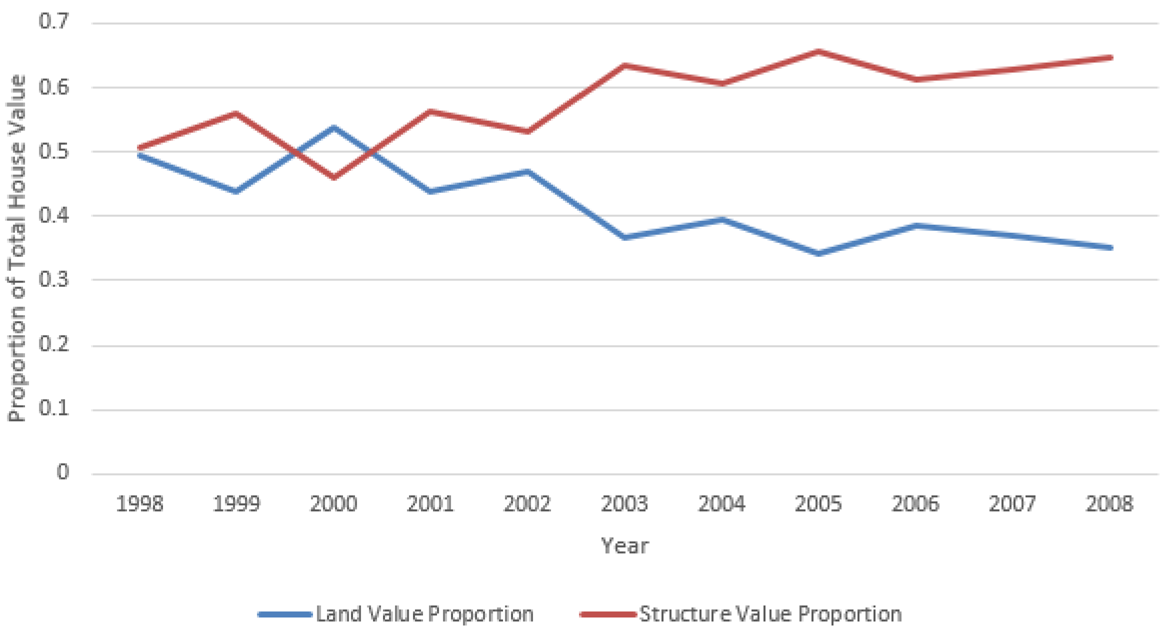

Figure 5.4: Land Value Proportion and Structure Value Proportion

quantities into aggregate values, and converting the structure price into the quality-adjusted structure price (which involves adjusting structure price for depreciation effects). The land and structure quantities in my Assen data set are quite similar to those of Diewert et al (2015) as shown in Table 5.4 but are not identical, due to differences in data cleaning and the original set of data observations. Note I only report 2003 average values for this comparison since Diewert et al's (2015) study does not consider from 2003 quarter three onwards.

By using the additive decomposition framework, I compute the land and structure prices and values for Diewert et al's (2015) estimates and compare these with my results in Tables 5.5 and 5.6 respectively. I find that my land and structure values are also consistent over time with those extrapolated using Diewert et al's (2015) index analysis.

Table 5.4: Comparison of Data Set with Diewert et al (2015)

	Land Quantity m^2	Diewert Land Quantity	Quality-Adjusted Structure Quantity m^2	Diewert Quality-Adjusted Structure Quantity m^2
1998	127768	152756	50395.26	60169.2
1999	142101	156646	51845.8	62019.3
2000	135256	157224	53802.89	64478.7
2001	140747	168871	54515.1	67637.5
2002	143236	180637	56281.01	70086.1
2003	152756	83732	58445.63	34990.1
2004	156646		60420.69	
2005	157224		62914.89	
2006	168871		65941.54	
2007	179765		68037.84	
2008	83732		34162.46	
Average (2003)	140310.7	149977.7	54214.29	59896.82

The result seems counter-intuitive compared to findings in the literature for the U.S., Australia and other developed economies. The literature indicates that land leverage is responsible for driving house value movements in these developed countries. However, accounting for the unique topography of Assen and the unique characteristics of The Netherland's housing market, the results estimated here can be interpreted intuitively.

Table 5.5: **Comparison of Land and Structure Prices with Diewert et al (2015)**

	Land Price per m^2	Diewert Land Price per m^2	Quality-Adjusted Structure Price per m^2	Diewert Quality-Adjusted Structure Price per m^2
1998	0.1993	0.2543	0.6902	0.9718
1999	0.1988	0.2599	0.9212	1.0425
2000	0.2935	0.2579	0.868	1.1135
2001	0.2591	0.2729	1.1899	1.1395
2002	0.2972	0.2829	1.0261	1.1679
2003	0.2351	0.2827	1.1537	1.1577
2004	0.2638		1.2866	
2005	0.2454		1.2991	
2006	0.2818		1.4115	
2007	0.2726		1.4699	
2008	0.2706		1.3849	
Average (2003)	0.2472	0.2685	0.9748	1.0988

Table 5.6: **Comparison of Land and Structure Values with Diewert et al (2015) Extrapolated Results**

Year	Land Value (000s Euros)	Diewert Land Value (000s Euros)	Quality-Adjusted Structure Value (000s Euros)	Diewert Quality-Adjusted Structure Value (000s Euros)
1998	48.06	61.31	49.16	35.91
1999	51.84	67.78	66.28	50.33
2000	71.01	62.39	60.73	69.34
2001	63.1	66.46	81.35	77.99
2002	71.18	67.77	80.61	84.01
2003	59.86	71.97	103.46	91.35
2004	68.08		104.72	
2005	62.13		119.34	
2006	73.54		116.53	
2007	72.59		123.15	
2008	67.64		124.43	
Average (2003)	60.84	66.28	73.6	68.16

Assen is geographically situated in a flat, featureless plain where there is a lack of natural barriers to expansion for residential housing. This influences supply-demand dynamics in the residential housing sector by keeping land prices low and near their farmland equivalent values. The continual increase in house prices can be attributed to record-low mortgage rates and high domestic incomes which is likely to have influenced median consumer behaviour, by inducing consumer's to spend a greater amount of money (but the same relative proportion of their total income) on the structure component of housing over time. This is a likely explanation for the observed sharp increase in structure values in Assen.

5.2.1 Constant Depreciation Calculation

The quality adjusted structure quantity in quarter t, S^t, equals the sum of the properties sold in that quarter adjusted into new structure units. This is expressed in Equation 5.3;

$$S^t = \sum_{n \epsilon N(t)} (1 - \delta^t A_n^t) S_n^t \tag{5.3}$$

The depreciation rates are quite volatile and range from 8.60% to 14.15% of total house value from 1998 to 2008, as shown in Figure 5.5. To minimise this volatility, it is appropriate to use the average depreciation rate for quality-adjustment purposes (extrapolated from the yearly depreciation rates calculated in the basic builder's model section). This yields an average decade net depreciation rate δ^t is 11.40%, or 1.14% per annum, which is well within the expected range.

The coefficient δ is interpreted as the sample net depreciation rate as the structure's age increases by one decade. I assume a constant depreciation rate over time to calculate the land and structure values in the additive decomposition framework, for all years in the data.

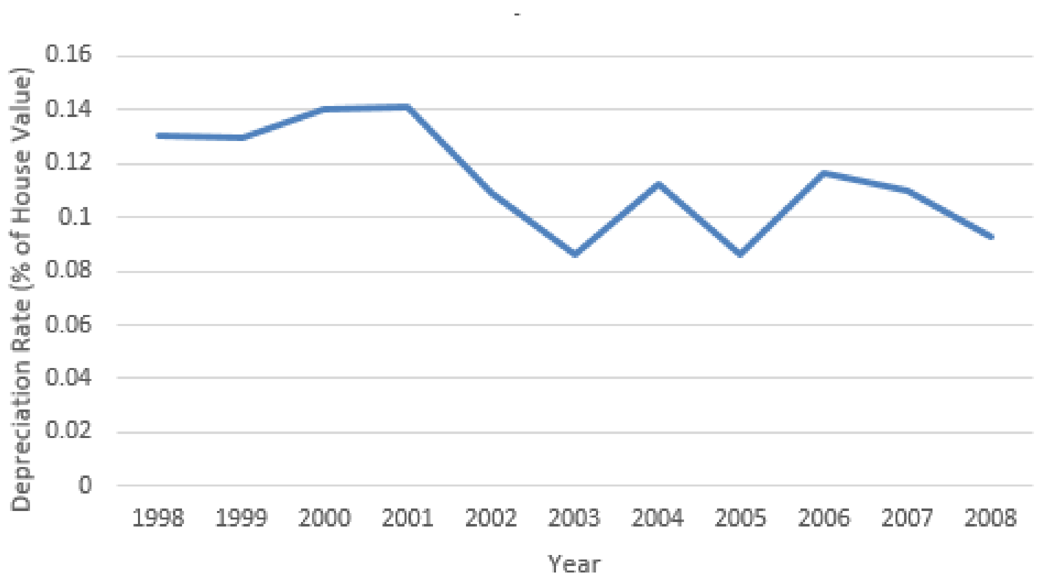

Figure 5.5: Net Decade Depreciation Rate

5.3 Creating the Basic Builder's Model as One Regression

The basic builder's model can be estimated on the pooled data for all time periods using the hedonic time dummy approach. This uses dummy variables to represent time periods and yields the same coefficient estimates as the hedonic imputation method. The time dummy coefficients are interpreted as the average difference in price relative to the base quarter, controlling for other housing characteristics.

Using the hedonic time dummy method involves regressing Equation 5.4 for the pooled data of the quarterly sample S(1), ..., S(42) ∀ t = 1, ..., 42;

$$V_n^t = \alpha^t L_n^t + \sum_{t=1}^{42} \gamma^t D_n^t + \beta^t (1 - \delta^t A_n^t) S_n^t + \epsilon^t; \tag{5.4}$$

$$\forall n = 1, ..., N(t);$$
$$\forall t = 1, ..., T,$$

The hedonic time dummy method yields the time dummy coefficients after being exponentiated and indexed to the base quarter, $\hat{\beta}^t$ and $\hat{\gamma}^t$ $\forall t = 1, ..., 42$. The hedonic time dummy coefficients are provided in Figure 5.6 (where 1998 quarter 1 is set as the base quarter).

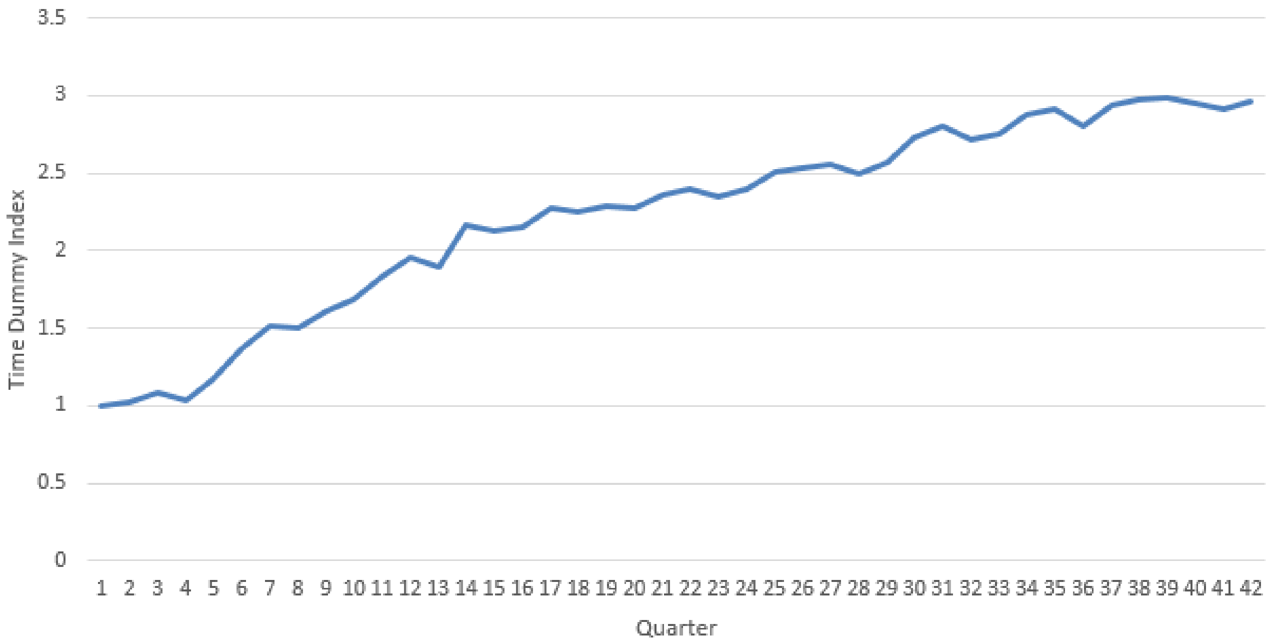

Figure 5.6: Hedonic Time Dummy Method: General House Price Inflation

The hedonic time dummy method is not the preferred method in this paper due to inaccuracies it creates in performing an additive decomposition of house prices. The hedonic time dummy method does not indicate how much of structure value and land value is captured by this general price inflation measure. Furthermore, using the hedonic time dummy method does not allow the characteristics' parameters to change over time. Parameter variation is a key factor in accurately measuring land value and structure value over time.

Nevertheless, it should be noted the hedonic time dummy method does help preserve the degrees of freedom by pooling the data (which results in increased model efficiency and lower standard errors).

Chapter 6
Hedonic Pricing Under Linear Splining of Land Plot Size

Weighting the sample of houses traded can potentially make them more representative for the total population of houses sold. This involves running an OLS regression on the data set after it has been pooled and weighted. This method is not used in this paper, since it introduces heteroskedasticity to the model (assuming constant variance of the error term over time).

Instead, I use an alternative strategy that employs sample stratification techniques. This involves stratifying the sample into several splines and running separate OLS regressions on each strata. The stratum-specific hedonic indexes are weighted using sales weights to construct an overall RPPI more representative of the population of total houses sold.

6.1 Hedonic Price Analysis: Linear Splining with One Breakpoint

The basic builder's model in Chapter 5 was restricted in it's ability to capture the empirical observation that houses that have larger sized plots sell for a lower price per unit area than houses that have smaller sized land plots (Francke, 2008). I use a spline model to allow the price of large land parcels to drop relative to smaller land parcels, under the assumption that builder's face a piecewise linear schedule of prices per unit of land when they purchase a land plot.

I first implement a simple linear spline model with one breakpoint to divide the land parcel data into two equally-sized groups (where the breakpoint chosen is the median lot size of 209 m^2). The rationale for testing the spline model is shown in the scatter plot of land parcel size and house transaction price in Figure 6.1, where house prices increase at a decreasing rate as land parcel size increases (particularly in the upper region of the graph when land plot sizes are above 900 m^2). This indicates a potential statistically and economically significant change in the mean price of a

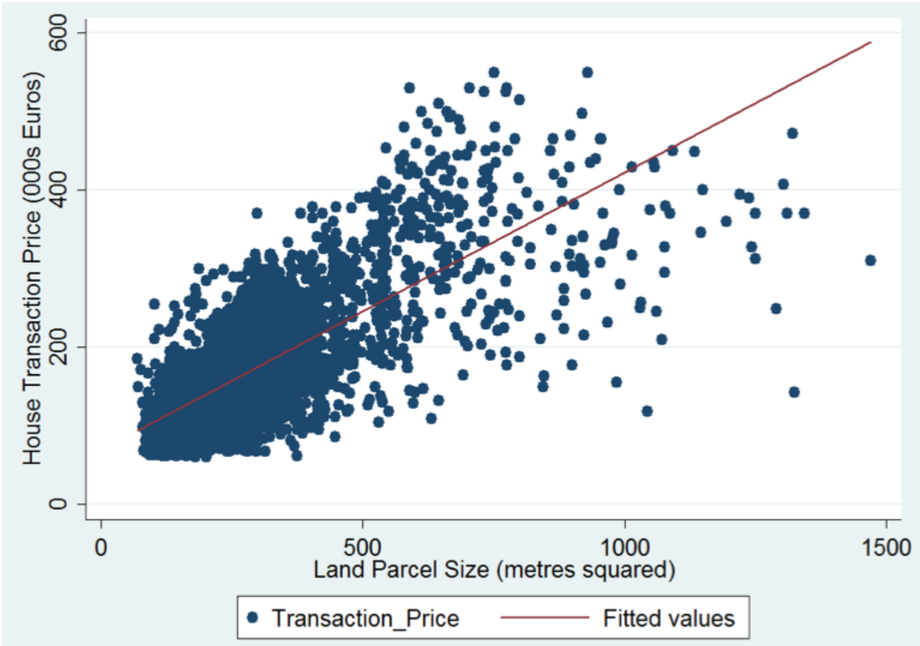

Figure 6.1: Land Parcel Size versus Transaction Price

unit of land over different parcel sizes, although the concentration of smaller land plot sizes may result in an insignificant result.

For a given observation n in period t associated with a below median land parcel size, the regression model estimates Equation 6.1:

$$V_n^t = \alpha^t L1_n^t + \beta^t(1 - \delta A_n^t)S_n^t + \epsilon_n^t; \tag{6.1}$$

$$\forall t = 1, ..., 42;$$
$$\forall n \epsilon N(t);$$
$$L < 210.$$

For an observation n in period t associated with an above median land parcel size, the regression model estimates Equation 6.2:

$$V_n^t = \alpha^t + L2_n^t + \beta^t(1 - \delta A_n^t)S_n^t + \epsilon_n^t; \tag{6.2}$$

$$\forall t = 1, ..., 42;$$
$$\forall n \epsilon N(t);$$
$$L \geqslant 210.$$

The model has an adjusted R^2 of 0.9790. The coefficients are all different from zero as expected. The land price per square metre for land plot sizes under 210m^2 is 269.7 Euros and the land price per square metre for land plots above 210m^2 is 255.7 Euros. The difference is statistically significant at the 1% significance level, and is economically significant when considering the Euro value of transactions (where the median house price is 158,070 Euros over the 42 quarter period). This provides evidence of a structural shift in the effect of land plot size on house value using two splines. The values of land in each spline can be obtained by assuming L1 and L2 are the same for all properties that have land parcel sizes in that spline region.

Table 6.1: Hedonic Regression Land and Structure Prices with Two Linear Splines

Year	L1 per square metre (000s Euros)	L2 per square metre (000s Euros)	Structure price per square metre (000s Euros)	Depreciation rate (%)
1998	0.153	0.2009	0.6132	0.1173
	(0.0231)	(0.0171)	(0.0403)	(0.0069)
1999	0.2113	0.1981	0.716	0.1333
	(0.033)	(0.0245)	(0.0097)	(0.0084)
2000	0.283	0.2946	0.6929	0.137
	(0.0347)	(0.018)	(0.0547)	(0.0075)
2001	0.2933	0.2555	0.8827	0.1496
	(0.0233)	(0.0302)	(0.0455)	(0.0089)
2002	0.2962	0.2974	0.8437	0.1092
	(0.0271)	(0.0173)	(0.0416)	(0.0072)
2003	0.295	0.2325	0.9123	0.0984
	(0.0468)	(0.0188)	(0.0734)	(0.0091)
2004	0.2292	0.265	1.0932	0.1051
	(0.0296)	(0.0164)	(0.0482)	(0.0086)
2005	0.299	0.2449	1.0394	0.0947
	(0.0342)	(0.0266)	(0.0581)	(0.0082)
2006	0.3078	.2811	1.1123	0.1213
	(0.0303)	(0.0179)	(0.0454)	(0.0075)
2007	0.3112	0.273	1.1541	0.1162
	(0.0453)	(0.0159)	(0.0628)	(0.0093)
2008	0.2878	0.2693	1.1471	0.0956
	(0.0431)	(0.0361)	(0.0662)	(0.0127)
Average	0.2697	0.2557	0.9279	0.1162

6.2 Hedonic Price Analysis: Linear Splining with Two Breakpoints

I now implement a linear spline model with two breakpoints. This model differentiates between small land parcel sizes (S), regular land parcel sizes (M), and large land parcel sizes (L). The two breakpoints for this piecewise linear regression are 170 and 270 metres squared, and are chosen so that the land parcels are split into three equally-sized groups.

I denote the set of observations n that belong to groups S, M and L in period t as N_S(t), N_M(t), and N_L(t) respectively.

For an observation n in period t associated with a small lot size, the regression model estimates Equation 6.3:

$$V_n^t = \alpha_S^t L_n^t + \beta^t(1 - \delta A_n^t)S_n^t + \epsilon_n^t; \tag{6.3}$$

$$\forall t = 1, ..., 42;$$
$$\forall n \epsilon N_S(t).$$

The equation to estimate house prices for the observations with small lot sizes is identical to Equation 6.1. The estimated parameters for this equation are α^t, β^t and δ for t = 1, ..., 11.

For an observation n in period t associated with a regular lot size, the regression model estimates Equation 6.4:

$$V_n^t = \alpha_S^t(170) + \alpha_M^t(L_n^t - 170) + \beta^t(1 - \delta A_n^t)S_n^t + \epsilon_n^t; \tag{6.4}$$

$$\forall t = 1, ..., 42;$$
$$\forall n \epsilon N_M(t).$$

The estimated parameters for this equation are α_S^t, α_M^t, β^t and δ for t = 1, ..., 11.

For an observation n in period t associated with a large lot size, the regression model estimates Equation 6.5:

$$V_n^t = \alpha_S^t(170) + \alpha_M^t(270 - 170) + \alpha_L^t(L_n^t - 270) + \beta^t(1 - \delta A_n^t)S_n^t + \epsilon_n^t; \tag{6.5}$$

$$\begin{aligned} \forall t = 1, ..., 42; \\ \forall n \epsilon N_L(t); \\ L \geqslant 270. \end{aligned}$$

The estimated parameters for these equations (excluding Equation 6.3, which is identical to Equation 6.1) are α_S^t, α_M^t, α_L^t, β^t and δ $\forall$ t= 1, ..., 11. These new parameters have the following interpretations:

- α_S^t is the value of extra marginal addition of land in quarter t for a small land parcel;
- α_M^t is the value of extra marginal addition of land in quarter t for a regular-sized land parcel;
- α_M^t is the value of extra marginal addition of land in quarter t for a large land parcel.

The average prices for large, regular and small lot sizes are calculated using Equations 6.6, 6.7 and 6.8:

$$P_{LS}^t = \frac{V_{LS}^t}{L_{LS}^t}; \tag{6.6}$$

$$P_{LM}^t = \frac{V_{LM}^t}{L_{LM}^t}; \tag{6.7}$$

$$P_{LL}^t = \frac{V_{LL}^t}{L_{LL}^t}, \tag{6.8}$$

$$\forall t = 1, ..., 11.$$

The regression results are presented in Table 6.2. The series here is smoother and looks more reasonable but there is still clear evidence of multicollinearity between the land and structure price. The regression results are statistically significant at the 1% significance level but the difference in land prices by lot size is economically insignificant. This model has an adjusted R^2 of 0.9796. The land prices for a small land plot, medium land plot and large land plot per square metre are on average 222.1 Euros, 334.3 Euros and 235.3 Euros respectively from 1998 to 2008. This provides greater detail of a structural shift in land prices per square metre, where the land price per square metre increases for small and regular land plots, but decreases for larger land plots.

Table 6.2: Hedonic Regression Land and Structure Prices with Three Linear Splines

Year	LS per square metre (000s Euros)	LM per metre (000s Euros)	LL per metre (000s Euros)	Structure price per square metre (000s Euros)	Depreciation rate (%)
1998	0.0666	0.2607	0.1764	0.6991	0.1015
	(0.0322)	(0.0214)	(0.0213)	(0.0481)	(0.0068)
1999	0.1066	0.3649	0.1600	0.7729	0.1071
	(0.0512)	(0.0270)	(0.0295)	(0.0682)	(0.0092)
2000	0.2585	0.3354	0.2792	0.7094	0.1331
	(0.0386)	(0.0246)	(0.0229)	(0.0577)	(0.0078)
2001	0.2192	0.3752	0.2224	0.9398	0.1356
	(0.0397)	(0.0292)	(0.0365)	(0.0581)	(0.0085)
2002	0.3098	0.2905	0.2992	0.8299	0.1120
	(0.0315)	(0.0213)	(0.0232)	(0.0459)	(0.0072)
2003	0.2669	0.3136	0.2186	0.9281	0.0942
	(0.0609)	(0.0264)	(0.0230)	(0.0841)	(0.0094)
2004	0.1914	0.2979	0.2505	1.1210	0.0996
	(0.0399)	(0.0233)	(0.0210)	(0.0566)	(0.0082)
2005	0.2171	0.3725	0.2125	1.1032	0.0837
	(0.0563)	(0.0266)	(0.0341)	(0.0741)	(0.0086)
2006	0.2897	0.3200	0.2723	1.1239	0.1185
	(0.0420)	(0.0255)	(0.0242)	(0.0560)	(0.0073)
2007	0.2753	0.3675	(0.2554	1.1693	0.1116
	(0.0538)	(0.0274)	(0.0191)	(0.0698)	(0.0092)
2008	0.2421	0.3793	0.246	1.1692	0.0914
	(0.0604)	(0.0352)	(0.0456)	(0.0789)	(0.0125)
Average	0.2221	0.3343	0.2353	0.9605	0.1080

6.3 Hedonic Price Analysis: Linear Splining with Nine Breakpoints

Finally as a robustness check, I create ten splines by equally-weighted percentiles to run a piecewise linear model with 9 splines. The parameters can be interpreted and defined similarly to the definitions in the Hedonic Price Analysis: Linear Splining with Two Breakpoints subsection, except here the coefficient on each parameter L1 to L10 measures the value of extra marginal addition of land in quarter t for an increase in land plot size between nine breakpoints. This yields the regression coefficients in Tables 6.3 and 6.4, with an adjusted R^2 of 0.9806. Breaking the model down into ten splines does not produce economically meaningful results for all splines, where some splines are estimated to have negative land prices per square metre. Additionally, the results here are not significant at the 1% significance level. The problem in data-overfitting due to the inclusion of too many parameters renders advanced techniques such as adaptive spline-fitting unreliable with the Assen house price data set.

To conclude this Chapter, the splining analysis indicates there is a non-linear effect of land plot size on house price. The additive decomposition model is able to accurately capture this. The results above also indicate large data variability and the likely presence of multicollinearity between land and structure prices, which is a common problem in analysing house prices using a hedonic methodology.

Table 6.3: Hedonic Regression Land and Structure Prices for Ten Splines

Year	L1 per metre (000s Euros)	L2 per metre (000s Euros)	L3 per metre (000s Euros)	L4 per metre (000s Euros)	L5 per metre (000s Euros)	L6 per metre (000s Euros)
1998	0.0980	-0.2621	0.4397	-0.3063	0.5037	0.2517
	(0.0413)	(0.2483)	(0.3687)	(0.2709)	(0.1989)	(0.1071)
1999	0.1502	0.1190	-0.4441	0.1235	0.4330	0.2819
	(0.0529)	(0.3299)	(0.3988)	(0.3085)	(0.1364)	(0.1726)
2000	0.3048	0.0409	-0.2455	0.0036	0.4240	0.3754
	(0.0441)	(0.5324)	(0.4050)	(0.3496)	(0.1986)	(0.1187)
2001	0.3165	-0.9034	0.5498	-0.0738	0.2885	0.5131
	(0.0420)	(0.3768)	(0.5553)	(0.3533)	(0.1723)	(0.1287)
2002	0.3986	-0.8559	0.8878	0.0798	0.2028	0.4203
	(0.0381)	(0.2465)	(0.4490)	(0.2754)	(0.1966)	(0.1475)
2003	0.3803	-1.1885	0.7012	-0.0313	0.3853	0.1708
	(0.0751)	(0.3546)	(0.4020)	(0.3142)	(0.1390)	0.1540
2004	0.2398	-0.1481	0.0368	0.2259	0.2550	0.3816
	(0.0495)	(0.2604)	(0.4403)	(0.2714)	(0.1208)	(0.1378)
2005	0.3336	-0.4735	-0.1580	0.4876	0.3757	0.2400
	(0.0564)	(0.2723)	(0.3485)	(0.3381)	(0.1276)	(0.1373)
2006	0.3577	-0.5940	0.3391	0.2676	0.3772	0.1220
	(0.0462)	(0.3149)	(0.3125)	(0.2109)	(0.1263)	(0.2199)
2007	0.4099	-0.6614	0.1544	0.2054	(0.3318)	0.5110
	(0.0560)	(0.2396)	(0.3104)	(0.2054)	(0.2171)	(0.1942)
2008	0.3578	-1.1957	0.5611	0.2405	-0.0574	0.6813
	(0.0692)	(0.6015)	(0.5364)	(0.3215)	(0.3324)	(0.2586)
Average	0.3043	-0.5566	0.2566	0.1111	0.3200	0.3590

Table 6.4: Hedonic Regression Land and Structure Prices for Ten Splines

Year	L7 per metre (000s Euros)	L8 per metre (000s Euros)	L9 per metre (000s Euros)	L10 per metre (000s Euros)	Structure price per metre (000s Euros)
1998	0.0356	0.5623	0.2648	0.1508	0.6742
	(0.1455)	(0.2402)	(0.0779)	(0.0315)	(0.0544)
1999	0.5783	-0.3090	0.4517	0.1028	0.7453
	(0.1722)	(0.1713)	(0.0815)	(0.0428)	(0.0646)
2000	0.3465	0.4320	0.2424	0.2767	0.6871
	(0.2484)	(0.1977)	(0.1132)	(0.0333)	(0.0602)
2001	0.2851	0.2170	0.4413	0.1889	0.8954
	(0.1948)	(0.1885)	(0.1087)	(0.0443)	(0.0553)
2002	0.4101	0.3917	0.1417	0.3212	0.7948
	(0.1701)	(0.1653)	(0.1072)	(0.0344)	(0.0492)
2003	0.5314	0.2340	0.3505	0.1832	0.8794
	(0.2067)	(0.2146)	(0.1052)	(0.0344)	(0.0901)
2004	0.1089	0.4938	0.2767	0.2290	1.0989
	(0.2257)	(0.1857)	(0.0898)	(0.0306)	(0.0580)
2005	0.3983	0.3644	0.4347	0.1544	1.0239
	(0.1865)	(0.1726)	(0.0907)	(0.0426)	(0.0675)
2006	0.6931	0.0197	0.4779	0.2305	1.0981
	(0.2730)	(0.2421)	(0.1041)	(0.0330)	(0.0571)
2007	0.2938	0.2542	0.5765	0.1745	1.0822
	(0.1953)	(0.1548)	(0.0797)	(0.0246)	(0.0667)
2008	0.6152	0.1600	0.3091	0.2250	1.1186
	(0.3513)	(0.2718)	(0.1771)	(0.0735)	(0.0777)
Average	0.3906	0.2564	0.3607	0.2034	0.9180

Chapter 7
Hedonic Pricing with Exogenous Construction Cost Data

The models in the previous chapters displayed a large degree of data variability and multicollinearity between land and structure prices. This multicollinearity may be responsible for providing erratic estimates for these variables (due to inconcistent standard errors). The results in previous sections indicated that a large increase in land price was matched by a large decrease in structure prices, and vice versa. This can be seen quite clearly by comparing the land and structure value trend in the basic builder's model presented earlier. When viewing the graphs, it also becomes apparent the model is still displaying a slight tendency to fit data outliers (even after data-cleaning).

Using exogenous construction cost data for new constructions may help remove this multicollinearity. This approach is justified by the significant correlation found between construction costs of new houses and fluctuations in U.S. house prices (Abraham and Hendershott, 1996). Additionally, Diewert and Shimizu (2013) deal with the multicollinearity issue by introducing a construction cost index to the regression model. Diewert and Shimizu incorporate construction cost data by using the following regression model in Equation 7.1;

$$P = \beta C(1 - \delta A)B + PL + \epsilon \tag{7.1}$$

where C is the construction cost index.

It should be noted the approach may create a pricing mis-match where construction costs of new houses significantly underestimate house price fluctuations (Meen, 2002). This occurs where housing supply is inelastic and is unable to meet changes in demand for residential property efficiently. Alternatively, house price developments may actually be influenced more heavily by existing houses as opposed to new houses (Meen, 2002).

To deal with the multicollinearity problem, I incorporate exogenous information on

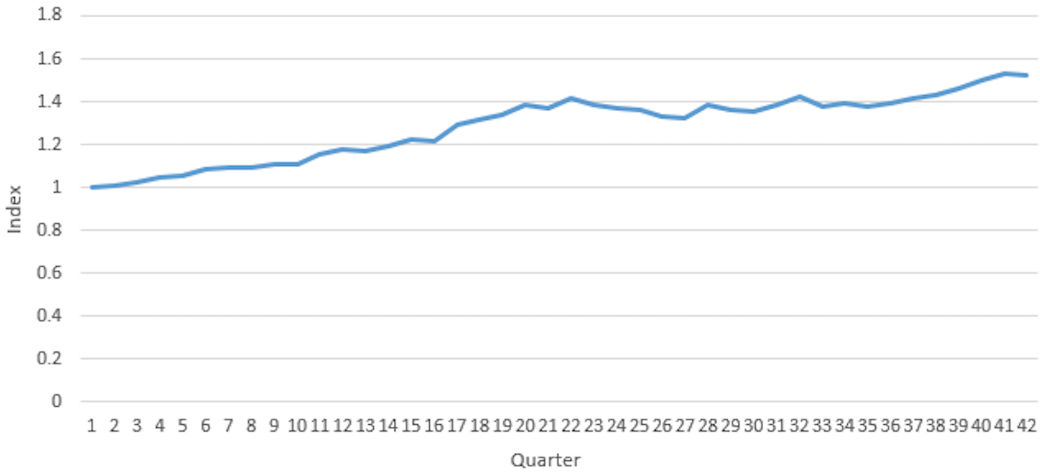

Figure 7.1: Netherland's Construction Cost Index

new house building costs using the 'New Dwelling Output Price Indices, Building Costs, 2005 = 100, Price Index: Building costs including VAT' series, available from Statline Netherlands. I re-index this series so that the base quarter becomes 1998, quarter 1. The construction cost data measures national constructions for new houses in The Netherlands. I assume price movements for house sales in Assen are equal to the national construction cost price movements for new houses. The construction cost index is provided in Figure 7.1. The graph indicates that construction costs have increased marginally over time. I will now examine whether including the construction cost index (which represents a nationwide growth rate) helps explain the price change in quality-adjusted structure values in Assen.

Using this data, the constant quality structure parameter β^t for t = 2, ..., 42 can be estimated using Equation 7.2;

$$\beta^t = \beta^1 p^t; \tag{7.2}$$

$$\forall t = 2, ..., 42,$$

where p^t is the estimated construction cost price index and where β^1 is a constant parameter that transforms the construction cost index into a value per square metre.

The exogenous construction cost data is included in the model by running the regression in Equation 7.3;

$$V_n^t = \alpha^t L_n^t + \beta_1 p^t (1 - \delta^t A_n^t) S_n^t + \epsilon_n^t \tag{7.3}$$

Table 7.1: Hedonic Regression Land and Structure Prices Including Exogenous Construction Costs

Year	Land Price per m^2	Structure Price per m^2	Depreciation Rate (%)
1998	0.1986	0.5389	0.1284
	(0.0060)	(0.0184)	(0.0081)
1999	0.1970	0.6817	0.1286
	(0.0074)	(0.0209)	(0.0086)
2000	0.2902	0.6044	0.1389
	(0.0088)	(0.0206)	(0.0077)
2001	0.2576	0.7733	0.1400
	(0.0084)	(0.0195)	(0.0065)
2002	0.2974	0.6303	0.1085
	(0.0087)	(0.0170)	(0.0065)
2003	0.2351	0.7125	0.0864
	(0.0088)	(0.0177)	(0.0067)
2004	0.2661	0.7737	0.1126
	(0.0081)	(0.0156)	(0.0053)
2005	0.2440	0.8045	0.0855
	(0.0092)	(0.0174)	(0.0056)
2006	0.2819	0.8280	0.1162
	(0.0088)	(0.0160)	(0.0050)
2007	0.2739	0.8280	0.1099
	(0.0078)	(0.0135)	(0.0048)
2008	0.2707	0.7642	0.0929
	(0.0120)	(0.0186)	(0.0048)
Average	0.2557	0.7218	0.1135

Table 7.2: Land and Structure Values when Exogenous Construction Costs are Included

Year	House Price (000s Euros)	Land Value (000s Euros)	Structure Value (000s Euros)
1998	97.215	47.881	49.334
1999	118.112	51.376	66.736
2000	131.736	70.226	61.509
2001	144.451	62.733	81.717
2002	151.786	71.246	80.54
2003	163.321	59.843	103.477
2004	172.805	68.672	104.133
2005	181.468	61.777	119.691
2006	190.071	73.569	116.502
2007	195.739	72.953	122.786
2008	192.071	67.658	124.413
Average	158.070	64.358	93.713

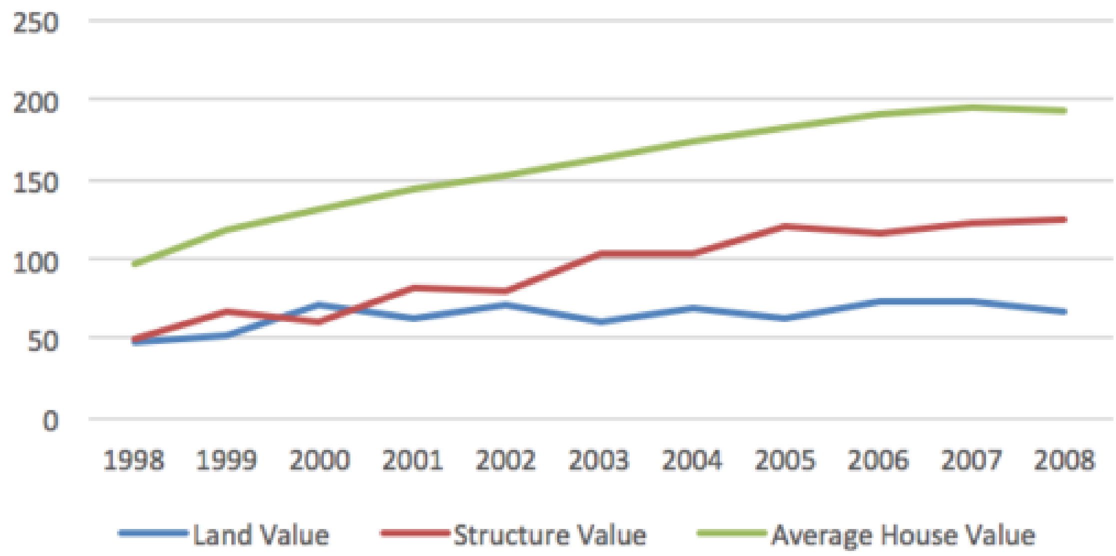

Figure 7.2: Land Value, Structure Value and House Prices

Diewert et al (2015) find that including exogenous information produces a reasonable decomposition of house values into it's land and structure components, and helps remove multicollinearity. My land and structure price per square metre estimates in Table 7.1 indicate that by including construction cost data, estimated structure value will be slightly lower relative to land value than estimated in the basic builder's model (this is verified by the land and structure values in Table 7.2). This model has an adjusted R^2 of 0.9789, and has removed significant multicollinearity between land and structure prices. As shown in Figure 7.2, overall structure value still increases at a faster rate than land value and from 1998 to 2008, the proportion of house value explained by structure value increases from 51% to 65% as expected. This increase is particularly the case from 2003 onwards, where structure value as a percentage of house value increases from 53% to 65%, reflecting structural changes in the Dutch housing market around this time. The trend in proportion fluctuations over time is provided in Table 7.3 for completeness.

There are likely to be further errors in measuring land quality and structure quality which are attributable to other important price-determining characteristics, locational factors not included in this thesis' analysis, imperfect measurement of variables, and data recording issues. These may also help explain a significant amount of the price volatility. I will explore the impact of other important price-determining characteristics in Chapter 8 and note the inaccuracies caused by the other mis-measurement issues.

Table 7.3: Movement in Land Value and Structure Value as a Proportion of House Prices

Year	Land Proportion percent	Structure Proportion percent
1998	0.4925	0.5075
1999	0.4350	0.5650
2000	0.5331	0.4669
2001	0.4343	0.5657
2002	0.4694	0.5306
2003	0.3664	0.6336
2004	0.3974	0.6026
2005	0.3404	0.6596
2006	0.3871	0.6129
2007	0.3727	0.6273
2008	0.3523	0.6477
Average	0.4164	0.5836

Chapter 8
Significance of Other Land and Structure Quality Characteristics

The aim of this chapter is to construct more accurate price indexes by accounting for additional housing characteristics, in an attempt to create better quality adjustments and decrease unit value bias. Including other important price-determining characteristics is also a more parsimonious model improvement tool to using linear splining of house prices. The additional price-determining characteristics tested in this section are the number of rooms, the availability of parking. the quality of inside and outside maintenance performed to the house, quality of garden storage space, and non-linear effects of land and structure size.

I expect structure quality to increase as the quality of parking availability increases. The parking availability term is included in the regression in a multiplicative fashion to capture the assumption it is subject to the same depreciation that influences the entire structure component. I also assume parking availability only affects structure quality with no effect on land quality, which seems reasonable as the parking spaces involve garages which are additions to the houses' structure component. My model captures an increase in the price of structure per metre squared as the quality of available parking increases by running the regression in Equation 8.1;

$$V_n^t = \alpha^t L_n^t + \beta_1 p^t (1 - \delta^t A_n^t)(1 + \lambda P_n^t) S_n^t + \epsilon_n^t \tag{8.1}$$

My regression results support this intuition and indicate that parking availability has a statistically significant impact on structure price per square metre at the 1% significance level for all time periods. The model has an adjusted R^2 of 0.9804. My results in Table 8.1 indicate that the availability of parking has a significant economic impact on housing price. More specifically, increasing average available parking quality by 1 unit (as defined in the data section) increase the average structure price per square metre by 53.9 Euros.

Table 8.1: Hedonic Regression Prices with Parking Included

Year	Land price per m^2	Structure price per m^2	Depreciation rate (%)	Parking price per unit
1998	0.1786	0.5066	0.1143	0.0702
	(0.0067)	(0.0179)	(0.0079)	(0.0119)
1999	0.1663	0.6008	0.1078	0.1008
	(0.0079)	(0.0205)	(0.0082)	(0.1282)
2000	0.2508	0.5480	0.1122	0.0978
	(0.0095)	(0.0197)	(0.0076)	(0.0123)
2001	0.2286	0.7265	0.1268	0.0634
	(0.0091)	(0.0194)	(0.0064)	(0.0094)
2002	0.2781	0.6116	0.1004	0.0355
	(0.0097)	(0.0171)	(0.0065)	(0.0084)
2003	0.2082	0.6613	0.0750	0.0629
	(0.0092)	(0.0177)	(0.0064)	(0.0089)
2004	0.2468	0.7470	0.1019	0.0321
	(0.0090)	(0.0162)	(0.0056)	(0.0069)
2005	0.2211	0.7720	0.0771	0.0441
	(0.0095)	(0.0171)	(0.0054)	(0.0064)
2006	0.2555	0.7968	0.1060	0.0371
	(0.0099)	(0.0163)	(0.0051)	(0.0068)
2007	0.2668	0.8116	0.1068	0.0152
	(0.0083)	(0.0150)	(0.0049)	(0.0062)
2008	0.2497	0.7370	0.0844	0.0335
	(0.0130)	(0.0195)	(0.0068)	(0.0090)
Average	0.2319	0.6837	0.1012	0.0539

I also test whether the quality of inside maintenance to a house increases structure value. This maintenance is assumed to include renovations and basic fixations that experience the same depreciation effects as the overall structure component, and are assumed to only affect the structure component of the house. Including this variable involves running the regression in Equation 8.2;

$$V_n^t = \alpha^t L_n^t + \beta_1 p^t (1 - \delta^t A_n^t)(1 + \theta M I_n^t)(1 + \lambda P_n^t) S_n^t + \epsilon_n^t \tag{8.2}$$

The regression results support my intuition at the 1% significance level for all time periods, shown in Table 8.2. The model has an adjusted R^2 of 0.9813. Including inside maintenance to the regression has an economically significant impact on house prices, where structure price increase by 110.14 Euros per unit increase in inside maintenance quality. Note that the structure price per square metre reported in Table 8.2 is significantly lower on average, reflecting the idea that a lot of this value increase is being captured by the inside maintenance variable.

Performing similar methods, I test outside maintenance quality, number of bathrooms, number of toilets, and garden storage quality. Each variable is included in a similar fashion to parking, where it is added as a multiplicative term to the land or structure price per square metre. Garden storage quality and outside maintenance quality are assumed to only affect land quality. The number of bathrooms and number of toilets are assumed to only affect structure quality, where I also assume that depreciation affects bathrooms and toilets at the same rate it changes overall house structure value. Overall, including these variables in the hedonic regressions indicated they are statistically and economically insignificant in the final builder's model at the 5% significance level. The number of rooms and number of bathrooms are likely to be insignificant as a majority of their effect is captured by including the structure floor space area. Garden storage quality is not found to be significant due to the relatively homogenous nature of garden storage facilities for Assen houses.

I now test for a non-linear relationship between the price-determining characteristics and house prices. The first effect I test is between building size and transaction price by including a land parcel size squared variable, ${L^2}_n^t$. This highlights the idea that increasing the building size won't continue to increase the price indefinitely, and at some turning point will start to have a diminishing effect on price. Similarly, the age of the building may be squared to account for the idea that price changes non-linearly with changes in age. I test for this specification's statistical and economic significance by including the variable ${A^2}_n^t$. My regression results indicate that land

Table 8.2: Hedonic Regression Prices with Inside Maintenance Included

Year	Land price per m^2	Structure price per m^2	Depreciation rate (%)	Parking price per unit	Inside Maintenance Quality per unit
1998	0.1787	0.1638	0.0927	0.0601	0.2609
	(0.0064)	(0.0516)	(0.0091)	(0.0112)	(0.1189)
1999	0.1657	0.4192	0.0983	0.0970	0.0553
	(0.0078)	(0.0660)	(0.0092)	(0.0127)	(0.0278)
2000	0.2496	0.4064	0.1056	0.0936	0.0460
	(0.0095)	(0.0563)	(0.0081)	(0.0122)	(0.0236)
2001	0.2280	0.5119	0.1202	0.0604	0.0551
	(0.0090)	(0.0645)	(0.0068)	(0.0093)	(0.0227)
2002	0.2774	0.2906	0.0868	0.0308	0.1442
	(0.0094)	(0.0510)	(0.0070)	(0.0082)	(0.0467)
2003	0.2069	0.4432	0.0634	0.0598	0.0625
	(0.0091)	(0.0529)	(0.0071)	(0.0087)	(0.0218)
2004	0.2394	0.4559	0.0885	0.0261	0.0854
	(0.0088)	(0.0488)	(0.0060)	(0.0065)	(0.0226)
2005	0.2144	0.5479	0.0660	.0431	0.0544
	(0.0096)	(0.0558)	(0.0061)	(0.0062)	(0.0184)
2006	0.2525	0.4980	0.0938	0.0328	0.0798
	(0.0096)	(0.0512)	(0.0055)	(0.0065)	(0.0210)
2007	0.2667	0.2613	0.0857	0.0139	0.2733
	(0.0077)	(0.0573)	(0.0053)	(0.0058)	(0.0874)
2008	0.2406	0.4344	0.0712	0.0348	0.0946
	(0.0129)	(0.0726)	(0.0074)	(0.0087)	(0.0376)
Average	0.2291	0.403	0.0884	0.0502	0.1101

squared has a statistically significant (but economically meaningless impact) since the coefficient on land squared is on average -0.0001 during the 11 year period.

I now compare my results to those obtained by Diewert et al (2015). In their paper, Diewert et al (2015) reason that as the number of rooms increases, the quality of the structure will increase. Thus, the price per meter squared of a structure should increase as the number of rooms increases. This is tested using the following regression in Equation 8.3;

$$V_n^t = \alpha^t L_n^t + \beta_1 p^t (1 - \delta^t A_n^t)(1 + \Omega R_n^t) S_n^t + \epsilon_n^t \tag{8.3}$$

Diewert et al (2015) find that including the number of rooms in the regression has an economically and statistically significant impact on structure value. Including the number of rooms variable in this manner captures the effect of the number of rooms taking out the effect of room number captured by including the structure floor space variable. My regression results are inconsistent with the finding of Diewert et al. I find that the number of rooms variable is significant at the 1% significance level in some years and insignificant at the 10% significance level for other years. Although this contradicts the findings of Diewert et al (2015), it makes intuitive sense because the majority of the impact of number of rooms is being captured by structure floor space area and inside house maintenance. This is supported by the findings of Palmquist (1984) that indicate structure size does not have a linear effect on house prices (where Palmquist finds that construction costs don't increase proportionally as structure size increases and the number of rooms effect should be fully captured by structure floor space).

Finally, I note that Coulson (1992) finds significant volatility in large structure prices in the US, indicating that the structure price should be non-constant structure price per square metre. Testing the non-linearity of the impact of structure floor space would provide a useful extension to this thesis but is not considered here, since I assuming the additive decomposition framework holds for determining house value.

8.1 Final Builder's Model

The final builder's model used to calculate land value and structure value for Assen housing based on the regression results in this section is shown by Equation 8.4;

$$V_n^t = \alpha^t(1 - \gamma L_n^t)L_n^t + \beta_1 p^t(1 - \delta^t A_n^t)(1 + \theta M I_n^t)(1 + \lambda P_n^t)S_n^t + \epsilon_n^t \tag{8.4}$$

Running this regression on the Assen data set and aggregating results, I find that including land parcel size (in a non-linear fashion), structure floor space, age of a structure, and parking availability quality explain 88% of house price variation. The model has an adjusted R^2 of 0.9822. The final regression output is shown in Table 8.3. Note land squared price per square metre is not reported in the table but is included in the regression, and has a coefficient of -0.0001 with a standard error of 0.0000 on average. Thus, including land squared in the model improves the functional form of the model (and yields different regression results as shown in Table 8.3).

Note that the Appendix contains the LR test results between the basic builder's model and final builder's model. The result indicates that adding parking, inside maintenance quality, and land squared have a statistically significant improvement on the model's fit.

The land and structure values are shown in Figure 8.1 and indicate that land and structure equally account for approximately 50% of house value over time. The proportion of house value explained by land value over time has stayed relatively constant. This result makes intuitive sense and indicates that land policy in Assen has managed to maintain land and structure value constant over time (adjusting for inflation), which is part of their policy objective in regards to housing affordability. Before proceeding to the user cost analysis, I will mention a key limitation of this thesis' coverage. An economically significant improvement to this thesis would be to evaluate and adjust for the desirability of land using fixed effects analysis, where a probability measure of flood risk in The Netherland's is applied and combined with data on how close a city is to water and key environmental hazards. I ignore these effects in my thesis, noting key limitations in the Assen data set.

Table 8.3: Hedonic Regression Prices for Final Builder's Model

Year	Land price per m^2	Structure price per m^2	Depreciation rate (%)	Parking price per unit	Inside Maintenance Quality per unit
1998	0.2384	0.1895	0.1079	0.0669	0.4801
	(0.0153)	(0.0549)	(0.0111)	(0.0137)	(0.3597)
1999	0.2787	0.2524	0.1190	0.1277	0.1041
	(0.0174)	(0.0655)	(0.0114)	(0.0185)	(0.0558)
2000	0.2696	0.3771	0.1085	0.0967	0.0525
	(0.0213)	(0.0628)	(0.0089)	(0.0133)	(0.0272)
2001	0.3363	0.3852	0.1394	0.0658	0.0766
	(0.0170)	(0.0656)	(0.0082)	(0.0112)	(0.0334)
2002	0.3138	0.2465	0.0926	0.0340	0.1779
	(0.0203)	(0.0553)	(0.0079)	(0.0089)	(0.0650)
2003	0.2974	0.3502	0.0771	0.0606	0.0866
	(0.0224)	(0.0572)	(0.0085)	(0.0099)	(0.0321)
2004	0.2992	0.3762	0.0973	0.0259	0.1131
	(0.0191)	(0.0539)	(0.0069)	(0.0071)	(0.0325)
2005	0.3551	0.3788	0.0809	.0358	0.0965
	(0.0232)	(0.0612)	(0.0075)	(0.0073)	(0.0339)
2006	0.3360	0.4155	0.1042	0.0358	0.0971
	(0.0195)	(0.0534)	(0.0064)	(0.0073)	(0.0273)
2007	0.4136	0.3693	0.1065	0.0111	0.3917
	(0.0195)	(0.0579)	(0.0068)	(0.0069)	(0.1748)
2008	0.4000	0.3654	0.0928	0.0347	0.1820
	(0.0365)	(0.0813)	(0.0102)	(0.0104)	(0.0907)
Average	0.2291	0.3205	0.1024	0.0541	0.1689

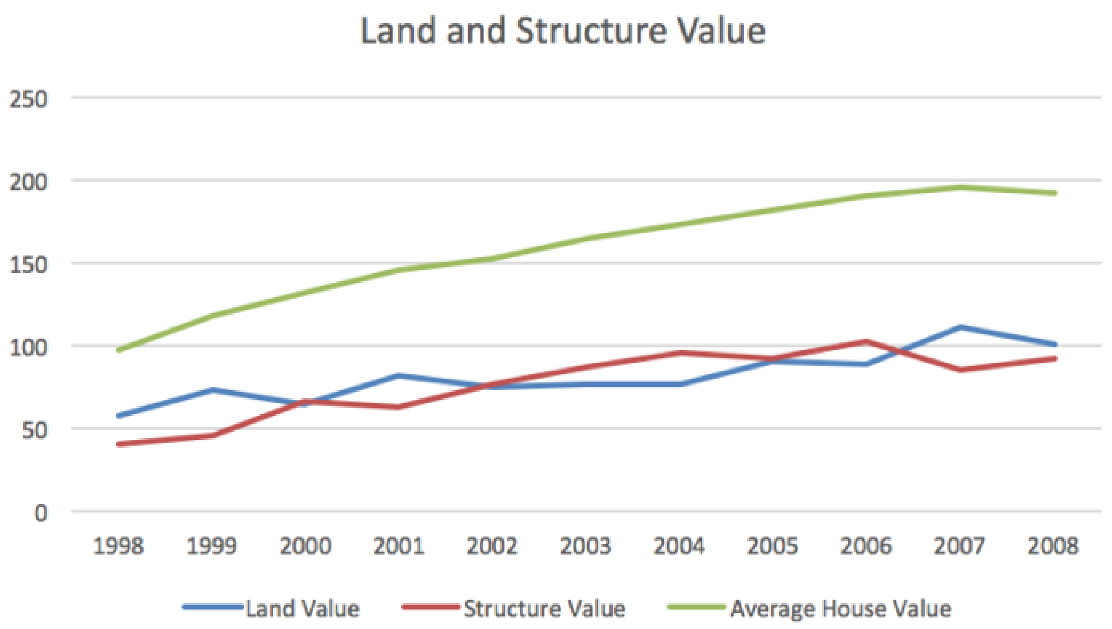

Figure 8.1: Final Builder's Model: Land Value and Structure Value versus House Value

Chapter 9
Investigating the User Cost of Residential Property

I use an asset-market model on sales of detached residential properties to analyse short-run and long-run housing affordability in Assen. This utilises Poterba's (1984) user cost of capital framework. Comparison with expected empirical results from the literature will also be discussed.

9.1 Additional Data for User Cost of Housing Calculation

The following subsections delve into additional data required to calculate the user cost of housing in Assen. Note that the data listed here are only estimates and further investigation using more accurate data is highly advised.

9.1.1 Marginal Income Tax Rate

I will quickly introduce The Netherland's income tax system to provide context in which to analyse these user cost figures. The full deductibility of mortgage payments from an individual's personal income tax remains a key incentive for investing in The Netherlands housing market. The Netherlands' has a partly progressive tax rate which has become less progressive from 1998 to 2008. Historically, individuals in The Netherland's highest income tax bracket had a marginal income tax rate of 72%. This has gradually decreased over time, down to 60% in 1990 and 52% in 2001. The marginal income tax brackets in 2014 were 33.5%, 42% and 52%.

Note in Poterba's (1984) framework that property tax is deducted from an owner occupier's taxable income. The property tax rates used in my analysis are already adjusted for this deduction and therefore, I do not include an explicit marginal income tax term in my user cost model.

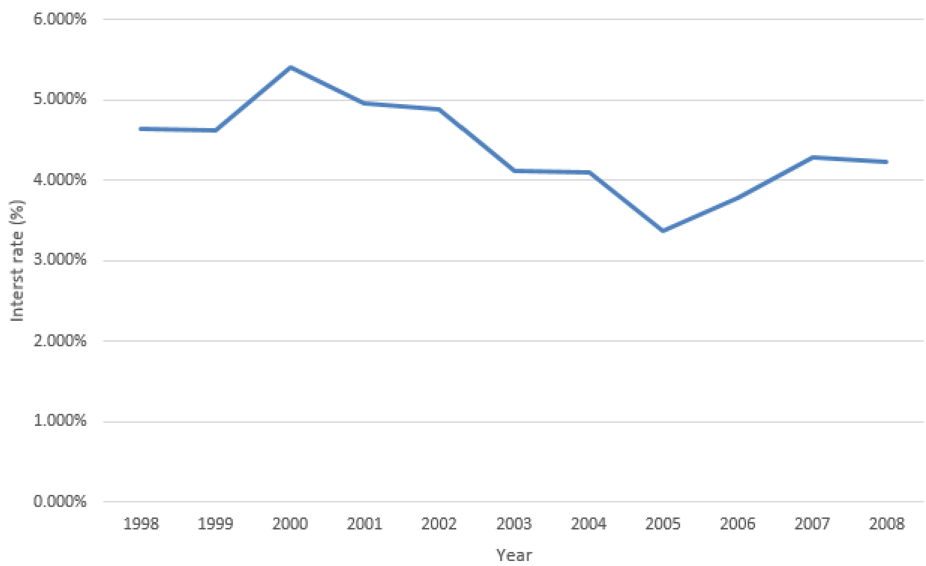

Figure 9.1: 10-year interest rate on Netherland's government bonds

9.1.2 Risk-Free Interest Rate

The risk-free interest rate measures the interest an owner-occupier of housing forgoes on the dwelling's market value. The risk-free interest rate is obtained from the annual interest rate on Netherland's government bonds (this data is readily accessible from the FRED database). The long-term interest rate is 4.36% on average over this time period and fluctuates only marginally on an annual basis between 3.3% and 5.3%, as shown in Figure 9.1.

9.1.3 Property Tax Rate

An owner-occupier of real estate incurs a property tax liability arising from contractual ownership of the piece of real estate. In The Netherlands, the property tax rate is determined on a local municipality level. Taxation can vary significantly between different regions and over time. There are also complications in calculating the rate of property tax, as there is an additional taxation system for different infrastructural support systems such as water-level management, water cleaning, and waste management that complements the standard land tax rate.

The property tax rate in Assen is estimated using an adjustment to the property tax levy on owner-occupied housing in Amsterdam in 2014 and 2015. Using these tax levies, I compute the growth rate between these time periods and interpolate a property tax growth rate for the period 1998 to 2008 in Amsterdam on an annualised basis. I assume that the Assen property tax rate is equal to the property tax rate in Amsterdam, and that the Assen property tax rate follows the same growth pattern

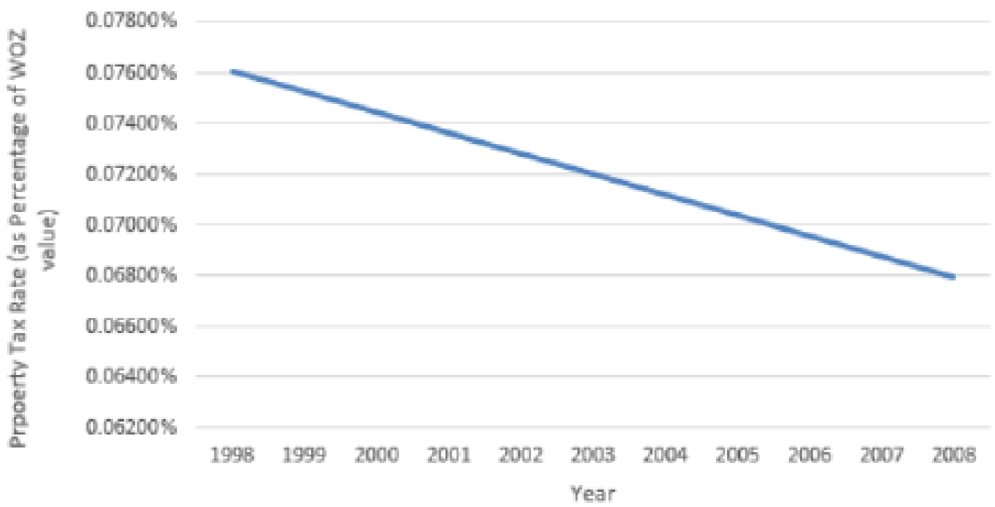

Figure 9.2: Assen Property Tax Rate

and fluctuations over time. Using Amsterdam data is desirable as data on real estate rates and costs are more readily available for Amsterdam relative to smaller cities in The Netherlands like Assen.

The property tax rate for Assen fluctuates between 0.06795% and 0.07605% of WOZ value, with an average property tax rate of 0.07200% of WOZ value. The WOZ value is a term used in The Netherlands to compute the amount of house value that is assessable for local and provincial taxation purposes.

The graph of the property tax rate in Assen is provided in Figure 9.2. The property tax rate appears to decrease linearly from 1998 to 2008, indicating a decrease in property tax costs for owner-occupiers.

9.1.4 Maintenance and Depreciation Costs

The maintenance and depreciation rate per annum for property in Assen is estimated to be 2.5% per annum. I assume this value based on the annual depreciation rate used by Himmelberg et al (2005), who based their motivation for assuming this value by referring to analysis conducted on housing depreciation rates by Harding et al (2004). The same depreciation rate has been assumed elsewhere in the literature, such as by Syed and Hill (2012).

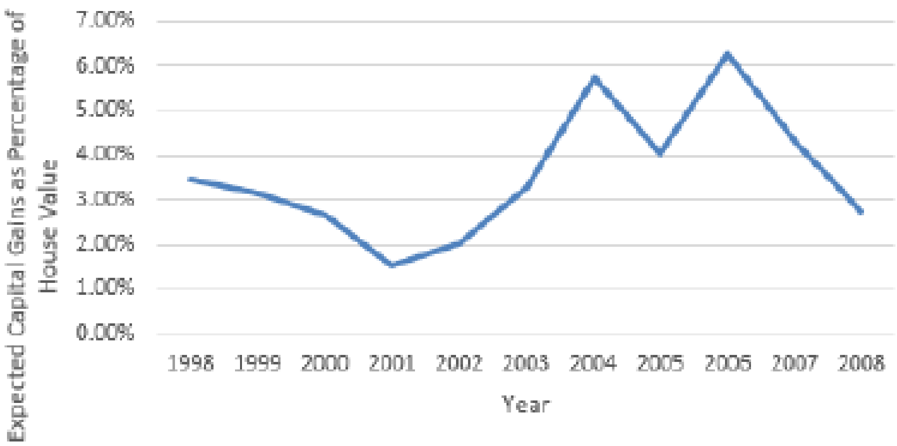

Figure 9.3: Expected Capital Gains for Assen Residential Housing

9.1.5 Risk Premium of Home Ownership

The risk premium of owning a unit of housing relative to renting is assumed to be 2.5% per annum, using the framework and assumptions of Flavin and Yamashita (2002). The same rate has been assumed in the literature, including papers by Himmelberg et al (2005) and Syed and Hill (2012).

Flavin and Yamashita (2002) construct an asset allocation line of portfolio inclusive of housing, which allows comparison of the bond-to-stock ratio with the proportion of financial assets in stocks to measure the risk premium.

Note this estimate for risk premium may be too high because it does not factor in the insurance value of owning a house in hedging risk. Nevertheless, choosing an alternative value has been found to have little effect on user cost over time (Himmelberg et al, 2005).

Th risk premium measure could be improved in future analysis by generalising the model to allow the relative risk of home ownership versus renting to vary over time.

9.1.6 Expected Capital Gains

The expected house price appreciation is constructed from 1 year ahead forecasted expected capital gains in Assen (which are calculated using the house prices from my data set). The fluctuations in these expected appreciations is provided in Figure 9.3. The expected capital gains fluctuate between 1.8% and 6.1% per annum with an average of 3.56% per annum. This expected capital gain rate seems reasonable given the strong growth in The Netherland's property sector and strong population density growth in The Netherlands.

9.2 Applying Poterba's Framework to Assen Housing

The user cost of housing for a given time period t is calculated using Equation 9.1;

$$UC_t = r_t + \alpha_t + \delta_t + \gamma_t - \beta_t \tag{9.1}$$

where;

- UC_t = per dollar cost of owning one unit of housing for period t,
- r_t = 10-year interest rate on Netherland's government bonds for period t,
- α_t = property tax rate for period t,
- δ = maintenance and depreciation rate for housing,
- γ = risk premium of owning a unit of housing relative to renting, and
- β_t = 1-year forecasted expected capital gain for Assen.

It is appropriate to keep the values δ and γ constant since they are just expectations. These variables are kept in the regression. An alternative approach would be to take these variables out of the equation (since they are constant over time) and analyse percentage changes in user cost over time. However, the focus of this thesis is to find evidence of changes in housing affordability over time in levels terms, which provides justification to keep these variables in the user cost calculation.

Note that mortgage interest payments are accounted for in this framework since mortgage interest payments on owner-occupied housing in The Netherlands is fully deductible.

Using this framework, I calculate the theoretical equilibrium user cost of capital shown in Figure 9.4. The theoretical equilibrium user cost of housing decreased from 1999 to 2006 from 5.9% to 2%, before increasing back up to 6.1% by 2008.

Rents in the social rental sector tend to be 70% of the maximum rent allowed for a dwelling. The responsibility for the affordability of housing is shared between the

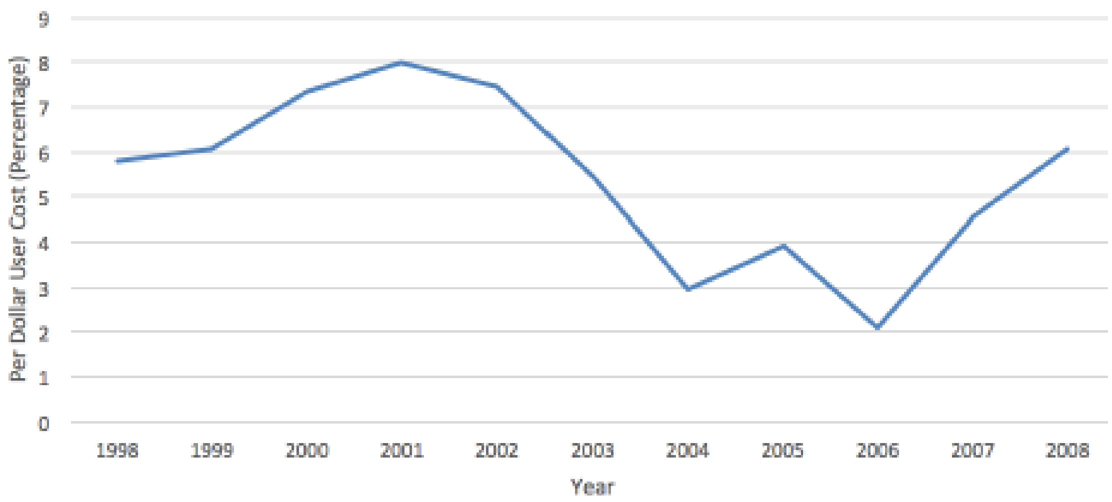

Figure 9.4: Theoretical Equilibrium User Cost of Housing

government and the social rental sector (Haffner and Boumeester, 2010). As there are not many dwellings with a market rent, this may be an indication of the market rent that is actually achievable on average. This may also be the effect of the large number of dwellings on the market that are offered for social rent and effectively subsidised via rent regulation.

Housing allowances influence the gross rent level for households in the rental sector. The average housing allowance in 2006 was 148 Euros per month for each recipient (Ministry of VROM, 2007).

9.3 Theoretical versus Market User Cost

The user cost of housing over one year at equilibrium should equal the cost of renting housing over the year. This equilibrium condition is expressed in Equation 9.2;

$$R_t = u_t P_t \tag{9.2}$$

The theoretical market equilibrium is where user cost $= \frac{rent}{price}$. In words, the user cost is equal to the inverse of the price-rent ratio. The framework is interpreted as follows. If actual market rent exceeds theoretical market rent, than home ownership is more affordable relative to renting a house. This occurs where the market rent is greater than the theoretical gross market rent. If market rent is represented by MR_t, than this relationship can be defined by Equation 9.3;

$$MR_t > p\,UC \tag{9.3}$$

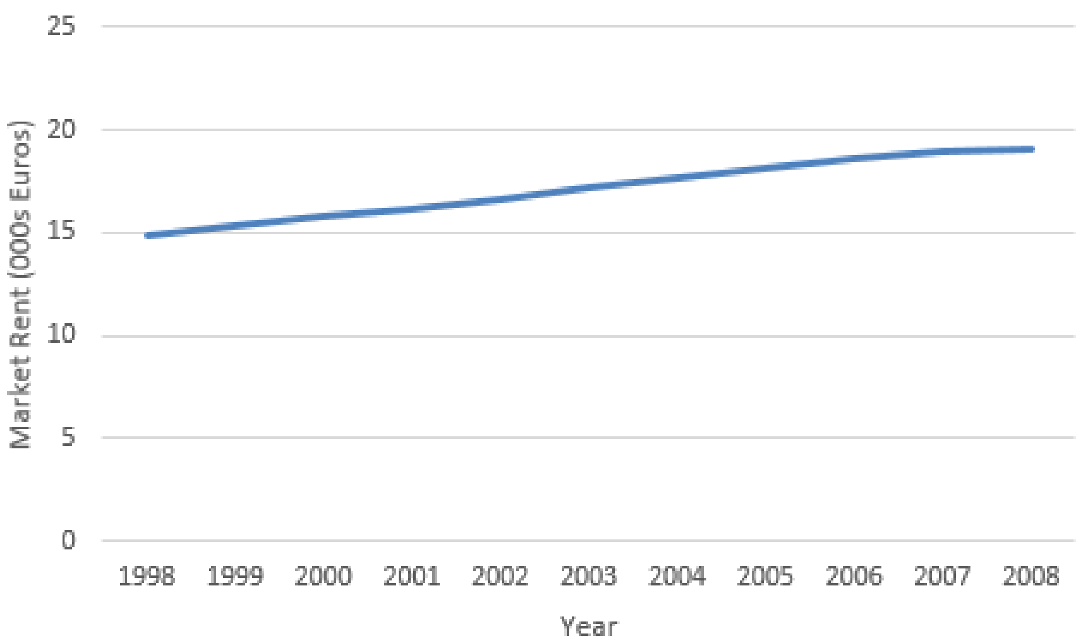

Figure 9.5: Assen: Market Rent for Housing

The actual market rent data is obtained using the growth rate of the Harmonised Index of Consumer Prices: Actual Rentals for Housing for Netherlands, and applying this to the monthly rent observed in Amsterdam. This rental series is shown in Figure 9.5.

The disequilibrium between the theoretical user cost and market user cost is provided in Figure 9.6. Home ownership has better affordability relative to renting in The Netherlands over time. Home ownership has also become relatively cheaper to renting over time. Interestingly, disequilibrium in the market increases from 2003 to 2008. This reflects increasing costs in The Netherlands rental market, which is consistent with the government's increase in the gross rent level for renters and the abolition of in subsidies provided to housing associations to provide social rental housing.

It is interesting to note that rents for social housing are significantly lower than for private housing in The Netherlands. Thus, when applying the framework to other countries the user cost will need to be adjusted for comparison.

Also, the gross rent level for renters is controlled by each municipality. This makes it difficult to accurately measure the difference between social housing rents and market rents. The government has regulated rents since World War 2, and has

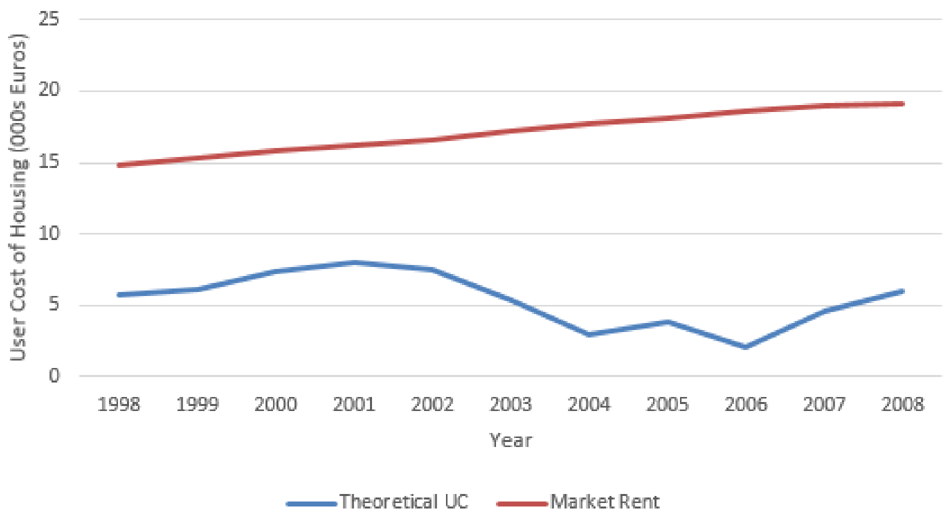

Figure 9.6: Theoretical versus Market User Cost of Housing

enforced a maximum rent cut-off of 615 Euros per month. The average rental level in The Netherlands in 2002 was 508 Euros per month, with the average rent in the social rental sector equal to 353 Euros per month in 2002.

Since 2002, the government has decreased regulation in the housing by allowing landlords to increase gross rent by a larger amount. It is likely rent levels have increased since 2002, but there is a lack of certainty on this matter due to the lack of publicly available information on these trends. Furthermore, the government's decreased regulation has benefited the private sector by significantly increasing rental income for landlords providing social and private housing, but has come at a cost to The Netherland's governments financial stability by increasing the government's financial burden for providing housing allowances.

Chapter 10
Implications for the Real Estate Sector

The use of the additive decomposition framework to decompose house prices into land and structure components has implications for central banks in measuring land and capital stocks more accurately. Regulators will also need to understand and account for this framework, and commercial developers will be able to use the decomposition to provide additional housing sector information to their clients. This will continue the trend in the industry towards revamping hedonic price index methodologies, such as Core Logic. A major consideration for regulators is how to go about backtracking price indexes to obtain accurate measures for market updates and national accounts, and to understand the value of the different components of housing.

The paper finds that the Netherlands' government has been effective in using real estate market policies to slowly decrease the financial burden on the government over time. The social housing sector has been decentralised and is now funded by housing associations. The government has also provided housing associations greater flexibility to prioritise housing issues at a localised level. Additionally, housing associations are able to access the Central Housing Fund established in 1995 to help financially weak associations. The decreased regulation of the social rental sector has changed the role of housing associations. In the 1980s, housing associations focused on increasing social housing stock and providing moderate rental yields for good quality housing. There was great expansion of housing stock across The Netherlands and little competition for middle income earners.

Since 2000, housing associations have started to set rental yields near the equilibrium market level. Housing associations now have greater access to capital markets. Combined with historically low interest-rates in the Dutch economy, this has resulted in housing associations significantly increasing new construction of owner-occupied houses. As housing has become more accessible, middle income households have continued to leave the rental market to the owner occupier market. This is supported by my user cost results which indicate home ownership is more affordable relative to renting. This trend in housing market movement and the changing role of housing associations is an area for future research.

New roles are being considered for housing associations including environmental management around dwellings, providing houses for non-traditional clients such as the elderly and students, and provide facilities such as schools and shops. Additionally, many housing associations have begun to invest at the neighbourhood level by offering extra services like insurance, neighbourhood centres and environmental maintenance. This improves the quality of life in these neighbourhoods and keeps property prices high. A key research area is to analyse how housing associations have reacted to market changes.

As demonstrated in this paper, houses prices have appreciated quite quickly in Assen. This appreciation trend is consistent across The Netherlands, which has resulted in significant housing affordability issues for low income earners and first-home buyers. Decreasing the gap between the rental market and owner-occupier market is currently a key concern for policymakers. This was addressed in June 2006 in the Vision for Housing Market policy announcements, which involves subsidised loans to first-home buyers (Dekker, 2006). This raises an important policy consideration for municipal governments and housing associations in how to set the gross market rent. This can be answered by using econometric methods to predict the drift in important variables used to measure house prices and user cost, with a focus on the impact of economic changes on home ownership affordability for low-income earners. This is crucial as low income earners represent 30% of all households in The Netherlands. Low income earners in this context are identified as individuals with a taxable income below 33,000 Euros.

One major challenge for the Dutch housing sector in the coming decades is urban renewal control. A lot of housing stock was built in the post-war period and needs to be replaced and refurbished. To renew housing stock, this will require an urban renewal program which will be expensive in the short-run and will require prudent financial management.

Another policy area to consider is the government's taxation policy. The government has kept mortgage interest payments for owner occupation fully deductible from income tax. Although this has helped the government achieve it's national policy of promoting home ownership over social renting, it is likely mortgage interest tax relief on owner-occupied dwellings has pushed house prices in The Netherland's up quite significantly. Renters spent on average 15.5% of disposable income on housing in 1982, and this grew to 21% by 1994. At the same time, buying a house has comparatively cheap due to record-low mortgage interest rates. This has created a massive tenure shift of households with moderate and higher income to buy housing and this effect persists today.

There are also implications from financial market changes. There are now a greater variable of mortgage products available, which has resulted in record high debt levels in The Netherlands. Gross expenditure is expected to change in the Netherlands, as land supply becomes less elastic and house prices continue to rise. There is uncertainty over how this will influence competition in The Netherlands real estate sector. A further area to investigate the lag in supply of new dwellings in Assen in response to housing shortages, and how this influences housing affordability.

Sustaining the financial position of housing associations is a key policy issue for The Netherlands government. To develop the real estate sector, a system that allows housing associations to self-regulate needs to be established. The Ministry for Housing in The Netherlands has also identified improving internal supervision and developing benchmarks to better manage the performance of housing associations, and as an alternative to self-regulation.

Finally, the user cost results can be improved by explicitly factoring in subsidised rents for social housing (which are significantly lower than for private housing). Since these rents are controlled by each municipality, it is difficult to accurately measure the difference between social and market rents. Obtaining better data for rent levels in the Netherlands is a key priority,

Chapter 11
Concluding Remarks

This thesis runs hedonic regressions on the sales of detached houses in Assen from 1998 to 2008 through an additive decomposition framework. The additive decomposition framework models house prices into it's land and structure values separately. This provides greater understanding of house price dynamics and has potential application in the commercial sector and for statistical agencies in creating quality-adjusted price indexes. This thesis has found evidence that structure value has increased more quickly than land value over time.

The theoretical rent calculated under Poterba's user cost framework is lower than actual market rent reflecting disequilibrium in the housing sector, where home ownership has become more affordable relative to renting. This provides evidence of a potential 'bubble' in Assen's rental market.

The thesis' findings have direct policy implications for the government in achieving it's goal of creating a competitive market for residential housing, and improving the qualitative aspects of housing. An example is reconsideration of social housing subsidies, zoning laws, and the NMG Scheme. The additive decomposition also has many potential uses in the commercial sector and for regulators to gain a more accurate insight into house price dynamics.

Chapter 12
Appendix

Likelihood Ratio (LR) test of Basic Builder's Model and the Final Builder's Model:

The LR test compares the goodness of fit between the basic builder's model and the final builder's model. The ratio can be interpreted as how many times more likely the data is under one model than the other. The LR test is calculated using Stata and involves evaluating the following expression;

$$LR = -2ln\,\frac{L(m1)}{L(m2)} = 2(ln(m2) - ln(m1)) \tag{1}$$

where;

- m1:

$$V_n^t = \alpha^t L_n^t) + \beta^t(1 - \delta^t A_n^t)S_n^t + \epsilon_n^t \tag{2}$$

- m2:

$$V_n^t = \alpha^t(1 - \gamma L_n^t)L_n^t + \beta_1 p^t(1 - \delta^t A_n^t)(1 + \theta MI_n^t)(1 + \lambda P_n^t)S_n^t + \epsilon_n^t \tag{3}$$

- H_0: m1 fits the data
- H_1: m2 fits the data
- Assumption: m1 nested in m2
- LR $\chi^2(3) = 3085.97$
- Probability $> \chi^2 = 0.0000$

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