THE APPLICATION OF PROPERTY VALUE MODELS TO ASSESS GOVERNMENT HOUSING POLICY: A NELSON MANDELA BAY CASE STUDY

By

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Promoter: Prof. M. du Preez

DECLARATION

I, Michael Charles Sale (198319030), hereby declare that this thesis for Doctor Commercii is my own work and that it has not previously been submitted for assessment or completion of any postgraduate qualification to another University or for another qualification. However, the following articles, conference proceedings and working papers, based on this research have appeared:

The impact of social housing developments on nearby property prices: a Nelson Mandela Bay case study. Co-authored with M du Preez. Forthcoming. *South African Journal of Economics*.

Determining the impact of a low-cost housing development on nearby property prices using discrete choice analysis. Co-authored with M du Preez. (2012). *Studies in Economics and Econometrics*, 36(2):23-35.

Appropriate management of social housing: a possible solution for the NIMBY syndrome. (2012). Paper presented at the 2012 South African Institute for Management Scientists (SAIMS) conference at the University of Stellenbosch.

Determining the effect of social housing developments on adjacent property prices: an application of a spatial hedonic model. (2011). Paper presented at the 2011 biannual conference of the Economic Society of South Africa (ESSA) at the University of Stellenbosch.

Determining the impact of a low-cost housing development on nearby property prices using discrete choice analysis. Co-authored with M du Preez. (2012). ERSA Working Paper, No. 265.

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EXECUTIVE SUMMARY

Two developments that may impact house prices have dominated the residential property landscape in South Africa in recent years, namely government's planned social housing developments and residential property value assessments carried out by local municipalities across South Africa for property tax purposes.

Social housing developments are often plagued by "local opposition", who argue that subsidised housing units may have a negative effect on adjacent non-subsidised residential housing. Negative preconceptions of social housing form the basis of this argument, which is commonly referred to as the "not-in-my-backyard" (NIMBY) syndrome. International studies conducted have, however, produced mixed results with some concluding that social housing developments lead to a reduction in nearby property prices, whilst others conclude that they lead to an improvement in surrounding property values. Currently, the state of the South African economy and demographics are limiting previously disadvantaged, poor peoples' access to affordable and safe housing, and for this reason the basis of the NIMBY rationale deserves closer attention. In order to test the validity of the NIMBY rationale, this study examines, by means of the hedonic price method, the effect of an existing housing establishment catering for low-income earners (the Walmer/Gqebera Township) on adjacent property values in the suburb of Walmer, Port Elizabeth, Nelson Mandela Bay in the Eastern Cape.

The study concludes that the low-cost housing development exerts a negative impact on the property values of nearby houses - the average owner of a non-subsidised residential property in Walmer would be willing to pay between R38 033 and R46 898 to be situated 200 metres further away from the Walmer Township. This conclusion is subject to three qualifications. The first is that the Walmer Township is not a recognised social housing development but merely a proxy for one. The second qualification is that a relatively small data set was used in this study and only one social housing development was considered. The third qualification is that the study period is from 1995 to 2009, which necessitated the adjustment of market prices to constant 2009 rands. For this purpose, data from the Port Elizabeth and Uitenhage section of the ABSA house price indices were used. It was not possible to disaggregate the indices further to obtain a Walmer-specific index. It is possible that an imperfect correlation exists between the Walmer property trend and the metropolitan (Port Elizabeth and Uitenhage) trend used in this study.

Based on the results of this doctoral investigation it is recommended that a monthly rebate on property rates of between R269.40 and R332.19 be implemented for affected Walmer residents. This amount could be sufficient to mitigate the capital loss associated with proximity to the Walmer Township. In terms of the management of social housing projects, it is strongly recommended that the following occur in order to alleviate the NIMBY syndrome: existing dwellings should be renovated, tenants should be monitored, dwellings should be appropriately designed and maintained, the composition of the host neighbourhood should be assessed and the image of social housing should be improved. With regard to the renovation of dwellings, social housing site preference should be given to existing structures in need of renovation, as positive externalities are associated with the renovation of such properties. The monitoring of tenants needs to take place in order to ensure that the financial and behavioural obligations of the tenants are met, and that informal "shack dwellings" do not materialise on site, and finally, that tenant default rates remain low. The appropriate management of these projects will also aid in combating the perception that social housing developments lead to private residential property devaluation.

In respect of residential property value assessments, many homeowners have recently argued that there is very little equivalence between the municipality's valuations and true market values. This study uses, *inter alia*, the hedonic price model to investigate the accuracy of the Nelson Mandela Bay Municipality's 2007/2008 valuation roll. The investigation was limited to the valuation roll applicable to the Walmer neighbourhood. The study finds that there is, on average, a 13.89 percent difference between market prices and the 2007/2008 municipal assessed values. In addition, this study finds that an attribute-based hedonic price model produces property price predictions that are more in line with true market values. This finding is subject to two qualifications. The first qualification is that only the Walmer neighbourhood's assessed values were considered, thus limiting the findings. The second qualification is that a relatively small data set was used.

Keywords:
Residential property values, property rates, social housing, hedonic price model, random utility model.

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CHAPTER ONE: INTRODUCTION

1.1 THE NATURE OF THE PROBLEM

This thesis investigates the effects of government provided social housing on adjacent residential property prices and the accuracy of municipal valuations for property tax purposes using a hedonic price model. The locus of this study is the Walmer Township[1] development and the adjacent neighbourhood of Walmer situated in Port Elizabeth, Nelson Mandela Bay, Eastern Cape. Despite the fact that the proposed social housing developments in the Nelson Mandela Bay area have been extensively debated, no formal empirical research has been conducted to corroborate or dispel the assertion that social housing developments reduce the market prices of nearby residential properties. This is an important policy question for two main reasons. Firstly, individual house ownership, coupled with retirement savings, make up the bulk of wealth most employed persons in South Africa have accumulated over their working lives (Luus, 2003; Fife, 2005). Although there are no formal data, the value of the South African residential property market, which consists of about seven million formal dwellings, was estimated at approximately R750 billion in 2002 (Luus, 2003; Luiz & Stobie, 2010). However, a more recent study of the South African property market estimated this value to be closer to R4.9 trillion in 2010, with the bulk of this value (R3 trillion) originating from residential property (New research values South Africa's property sector at R4.9 trillion, 2012). The economic significance of homeownership among the employed South African population means that changes in residential house values because of, *inter alia*, government regulation and housing policy, could be of great concern due to the wealth effects that may occur as a result of these house value changes. Secondly, due to the legacy of Apartheid, South Africa faces a severe problem of access to decent and affordable housing for poor, previously disadvantaged people in areas in close proximity to recreational amenities, schools, shops and work places.

The claim by local residents that social housing developments may lead to reductions in neighbouring property values (i.e. negative externalities) forms the basis of the "not-in-my-backyard" syndrome (NIMBY) as social housing projects are often referred to as "localised undesirable land uses" (LULUs) (Cummings & Landis, 1993; Iglesias, 2002). Residential properties are unique assets as they cannot be diversified among locations. Changes in nearby land use represent an uninsurable risk and, unless the change is perceived to be positive, these changes are likely to be met with resistance from local residents (Fischel, 2001).

[1] The Walmer Township is also referred to as the Gqebera Township.

Many international studies have attempted to estimate the effect of social housing[2] on surrounding property values (Nourse, 1963; Guy, Hysom & Ruth, 1985; Cummings & Landis, 1993; Lyons & Loveridge, 1993; Goetz, Lam & Heitlinger, 1996; Briggs, Darden & Aidala, 1999; Carroll & Clauretie, 1999; Galster, Tatian & Smith, 1999; Lee, Culhane & Wachter, 1999; Colwell, Dehring & Lash, 2000; Santiago, Galster & Tatian, 2001; Cummings, DiPasquale & Kahn, 2002; Ellen & Voicu, 2006). These studies use varied analysis techniques and arrived at rather contradictory conclusions. What does, however, emerge from this collection of studies is a weak consensus indicating support for the negative externality theory (Lyons & Loveridge, 1993). There is, however, a paucity of studies that address the urban land use issue, and more specifically, the social housing issue in South Africa. This thesis aims to fill this gap.

In addition to social housing and its effect on surrounding residential property prices, another important issue regarding residential property relates to the question of whether a municipality's residential property valuations for property tax purposes reflect the properties' true market values. These property valuations have a direct effect on residential property owners' wealth, since monthly property rates are, in part, determined by them. Many homeowners have recently argued that there is very little equivalence between municipal valuations and true market values. This controversy is evidenced by the complaints and objections received by various municipalities regarding their valuation rolls. For example, the uMngeni (Howick) Municipality received a total of 2 194 objections relating to the 2008 valuation roll, representing 10 percent of the total properties valued (Jansen, 2011). The eThekweni Metropolitan Municipality received approximately 55 000 objections and the valuation roll "was widely condemned for allocating incorrect values and having glaring omissions" (Mbonambi, 2012). In Nelson Mandela Bay, for example, residents of the suburb of Walmer lodged a total of 396 objections, representing an objection rate of approximately 15 percent (Weyers, 2011). These objections highlight the fact that many properties may have been valued incorrectly, leading to incorrect property tax calculations (Municipal Valuation Roll Chaos, 2009).

The main objective of this thesis was to examine the effect of a housing development catering for low-income earners on adjacent property prices, using the Walmer Township as a case study. The approach taken to achieve the primary goal was to apply the hedonic price model. The hedonic price model was chosen for two reasons. Firstly, the model is well founded in utility theory and has been used extensively in property value studies to uncover

[2] This thesis defines social housing as housing provided by non-profit or government agencies for households of low incomes or with particular needs.

house characteristics that contribute significantly to the price of a house (Lyons & Loveridge, 1993). Secondly, if it is found that social housing has a negative effect on surrounding property prices, the hedonic price model has the ability to estimate welfare effects (Lyons & Loveridge, 1993). A secondary objective was to investigate the accuracy of the Nelson Mandela Bay Municipality's 2007/2008 property valuations of residential properties in the Walmer neighbourhood carried out for property tax purposes. The hedonic price model developed to achieve the first (primary) goal was also used for predictive purposes in order to achieve the second (secondary) goal. Both an in-sample and an out-of-sample prediction was generated using the hedonic price model.

1.2 OBJECTIVES OF THE STUDY

The objectives of this study were to:

- Provide a critical examination of the current social housing policy in South Africa with special reference to the target market for social housing, as well as the type of subsidised housing options available to low-income earners in South Africa.
- Provide a critical discussion of the Nelson Mandela Bay Municipality's property rates valuation policy.
- Provide a theoretical description of property value models with special emphasis on the hedonic price model and how it is operationalised in order to test the negative externality hypothesis and predict property prices.
- Provide a review of the international literature on the effects of social housing developments and the like on residential property values.
- Apply the hedonic price model in order to determine the effect of a low-cost housing establishment located in the Walmer Township on the property prices of houses located in the adjacent Walmer neighbourhood.
- Apply an alternative property value model, namely the random utility model, in order to serve as a validity test of the hedonic price model's results.
- Employ the hedonic price model estimated as a predictive equation for house prices in the suburb of Walmer, Nelson Mandela Bay in order to assess the accuracy of municipal valuations.
- Provide conclusions and recommendations based on the results of the analyses carried out.
- In addition, the study will add to the very small body of urban land use economics research conducted in South Africa.

1.3 ORGANISATION OF THE THESIS

The foundation for the economic analysis of the thesis is laid in Chapters One and Two. Chapter One describes the study site, comprising of the suburb of Walmer and the Walmer Township, and provides the rationale for using this township as a proxy for an existing social housing development. Chapter Two provides a critical discussion of the government's current social housing policy and the Nelson Mandela Bay Municipality's property valuation rates policy. Chapter Three presents the theory of and estimation procedures for commonly applied property value models. The theory of welfare measurement (in the context of property value models) is also discussed. Chapter Four reviews selected international literature on the effects of social housing on adjacent property prices. Chapter Five presents the results of a variety of simple hedonic price models. All these models employ standard functional forms and omit the spatial effect of residential properties. The use of functional forms with limited flexibility and the omission of a spatial autoregressive term are major shortcomings of these simple models. Chapter Six presents the results of an extended hedonic price model which addresses the shortcomings of the base models estimated in Chapter Five. More specifically, it incorporates the use of flexible functional forms (i.e. Box-Cox transformations) and also takes the spatial nature of residential property into account. Chapter Six also presents the results of the estimation of the random utility model of house choice. This serves as a validity test of the hedonic price model's results. Following this, a policy discussion on social housing and municipal rates estimation is presented. This discussion draws on the results of the extended hedonic price model. Conclusions are drawn and recommendations made in Chapter Seven.

1.4 THE WALMER NEIGHBOURHOOD AND TOWNSHIP AND THE RATIONALE FOR SELECTING THE TOWNSHIP AS A PROXY FOR A SOCIAL HOUSING DEVELOPMENT

Although several under-utilised erven[3] in areas[4] throughout Nelson Mandela Bay have been identified as ideal sites for the Social Housing Programme, none of these projects have been developed so far. As a result, a proxy for a social housing development was used in this study.

Selecting an appropriate proxy for a social housing development in Nelson Mandela Bay was one of the main challenges of this study. More specifically, the main challenge in

[3] Erven can be defined as areas of land earmarked for building purposes.

[4] Sites already approved by the National and Provincial Departments of Human Settlements include the Inner City, Lower Baakens, Walmer, Mount Croix, Despatch CBD, Uitenhage CBD, New Brighton and William Moffet (Social Housing Boost for Nelson Mandela Bay, 2009).

defining the study area for the purposes of this study was to find an existing housing development, in the absence of recently constructed social housing developments, that (1) caters for low-income earners, (2) is located in close proximity to a residential neighbourhood, and (3) is comparable to a typical social housing development as proposed by the South African government. The only viable option was the Walmer Township.

1.4.1 PHYSICAL LOCATION OF THE STUDY AREA (WALMER AREA)

Figure 1.1 shows a map of the Walmer neighbourhood as well as the location of the Walmer Township.

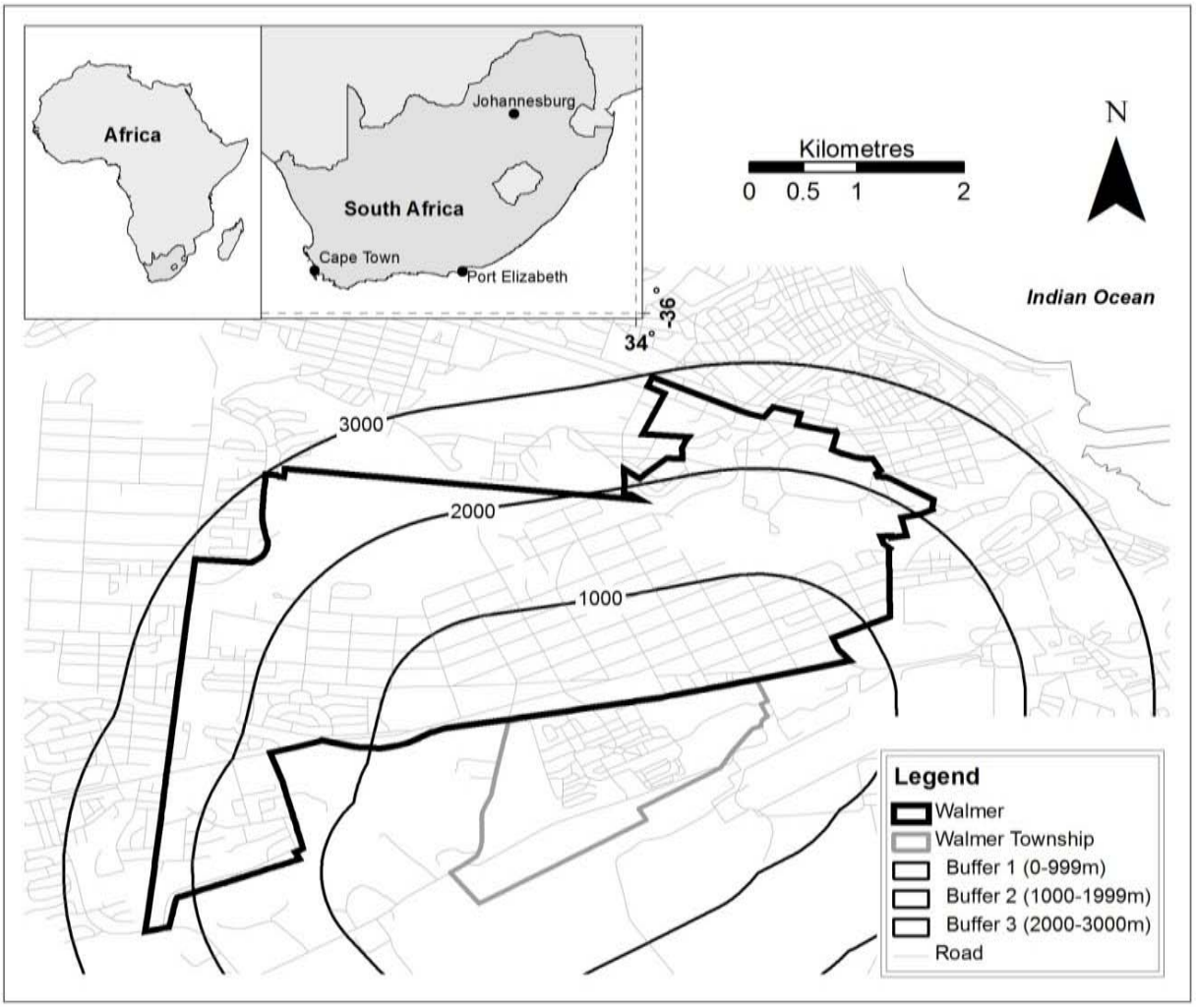


Figure 1.1: The geographical location of the Walmer neighbourhood and the Walmer Township

Average pricing bands for the properties in the Walmer neighbourhood are also shown – these indicate how market prices rise the farther away the property is situated from the Walmer Township. More specifically, the average residential property price (in 2009 rands)

located within buffer one (0m - 999m) is R1 131 284. The average price increases to R1 590 012 for homes situated within the second buffer (1000m – 1999m), and finally, the average price is R1 774 328 for homes situated within the third buffer (2000m – 3000m) (South African Property Transfer Guide, 2011). These values are substantially higher than the 2009 average house price of R816 121 for Nelson Mandela Bay as a whole. This suggests that the Walmer neighbourhood is one of the more affluent suburbs within the Nelson Mandela Bay region.

The upmarket Walmer neighbourhood is situated approximately 10 minutes by vehicle from Port Elizabeth's main beaches. The suburb is home to longstanding Port Elizabeth families and its history dates back to the early 1800s. Various amenities are located in close proximity to it. These include the Port Elizabeth airport, the Walmer Park shopping centre, the little Walmer Golf Club, and various primary and high schools. The area is well catered for in terms of residential property. Free standing homes, townhouse complexes, security complexes and guesthouses can be found in the area. Table 1.1 provides population and housing statistics for the neighbourhood of Walmer, Nelson Mandela Bay.[5]

Table 1.1: Population and housing statistics for the Walmer neighbourhood

	Count	Percent
Total population	10 500*	100
Total housing units	2 625	100
Formal dwellings	2 625	100
Informal dwellings	0	0
Backyard shacks	0	0

Note: *assuming an average of four persons per household
Source: South African Property Transfer Guide (2011)

The Walmer Township (situated adjacent to the Walmer neighbourhood) is Nelson Mandela Bay's oldest township and is unique since it was designated to be inside a "whites only" area under the Apartheid Group Areas Act of 1955. The Apartheid regime unsuccessfully attempted to remove the township. The removal was strongly resisted by township residents as well as residents of the Walmer neighbourhood. Table 1.2 provides 2007 population and housing statistics for the Walmer Township.

[5] Unfortunately, more comprehensive socio-economic data is not available for the suburb of Walmer. This is due to the fact that census data in the Nelson Mandela Bay Metropolitan area are disaggregated into wards and not suburbs. The suburb of Walmer forms part of ward 3 of the Metro (along with the Walmer Township and Greenshields Park). For this reason, it was impossible to differentiate between the suburbs within ward 3.

Table 1.2: Population and housing statistics for the Walmer Township

	Count	Percent
Total population	11 880	100
Total housing units	2 919	100
Formal dwellings	497	17
Informal dwellings	2 219	76
Backyard shacks	203	7

Source: Development Partners (2007)

1.4.2 SIMILARITES BETWEEN THE WALMER TOWNSHIP AND PROPOSED SOCIAL HOUSING

The rationale for using the Walmer Township as a proxy for a completed social housing development is based on four arguments, namely physical and cost similarities, social integration similarities, similarities in respect of public perceptions and resident similarities.

1.4.2.1 PHYSICAL AND COST SIMILARITIES

Existing low-cost housing units typically consist of one, two or three bedrooms, with each unit consisting of an open plan living area and kitchenette that includes a sink and preparation area (Project Review Series, 2009). These physical characteristics are very similar to those found in existing residential properties in the Walmer Township (South African Property Transfer Guide, 2011).

The Walmer Township enjoys a vibrant formal property market. More specifically, an analysis of the traded properties in the township for the period 2005 to 2009 revealed an average sales price of R80 720 (South African Property Transfer Guide, 2011). With regard to social housing, current estimates of the price per social housing unit vary. Total development costs of the Haven Hills South project in East London, for example, amounted to R29 000 000, resulting in an average cost per unit of roughly R112 403 (Project Review Series, 2009). The Nelson Mandela Metropolitan Municipality is due to commence construction of 269 semi-detached houses for the residents of Silverton, New Brighton. The estimated cost of this project is in the region of R18 000 000, implying a cost per unit of R66 914 (Housing Project Launched in New Brighton, 2010). These costs per unit are more or less in line with the average price of a property in the Walmer Township.

1.4.2.2 SOCIAL INTEGRATION SIMILARITIES

Another important similarity between the Walmer Township and proposed social housing developments is that the Walmer Township can be viewed as a socially integrated housing

development.[6] More specifically, the Walmer Township is situated in close proximity to many amenities in Port Elizabeth that are of use to its residents. These amenities include shopping centres (Walmer Park, Moffat on Main and 6th Avenue), a police station (Walmer Police Station) and bus routes. In addition to these amenities, many residents of the Walmer Township are relatively close to their places of work, many in walking distance.

1.4.2.3 PUBLIC PERCEPTION SIMILARITIES

In addition to the physical, cost and social integration similarities between the Walmer Township and the proposed social housing developments, there are also potential social similarities. These similarities are largely based on public perceptions of social housing developments. Residents situated in close proximity to proposed social housing developments often express concern that the effects of the social housing development "can spill over its borders to be borne by the entire community" (Pendall, 1999). To gauge public perception to proposed social housing developments in the Nelson Mandela Bay areas feedback from the Mount Road Social Housing Development public participation process was used. It revealed that the public perception is that the development would be detrimental to the Mount Croix area. More specifically, the public expressed concern that the development would result in an upsurge in crime and that low-income tenants would encourage theft in the area. The public also expressed concern that the development would lead to overcrowding and a general disturbance of peace in the area (Mount Road Social Housing Development: Public Participation Process, 2011). These perceptions are not dissimilar to the social ills afflicting the Walmer Township and surrounding areas, with the Walmer Township being associated with high levels of crime (Dames, 2010).

1.4.2.4 RESIDENT SIMILARITIES

The Walmer Township is occupied by residents who closely resemble those targeted for social housing initiatives, specifically in terms of household income. In terms of the income criterion, households earning below R7 500 per month qualify for social housing (Social Housing Policy for South Africa, 2005). Table 1.3 provides monthly household income levels for the residents of the Walmer Township.

[6] A socially integrated social housing development can be defined as a development located in urban areas of economic opportunity (Social Housing Policy for South Africa, 2005).

Table 1.3: Monthly household income levels for residents of the Walmer Township

Monthly household income	Percentage of residents
No income	2.3
R1 – R200	10.9
R201 - R500	8.5
R501 – R800	10.1
R801 – R1 500	41.9
R1 501 – R2 500	21.7
R2 501 – R3 500	3.1
R3 501 – R4 500	0
R4 501 – R6 000	0
R6 001 – R8 000	1.6
R8 001 – R10 000	0
R10 000 and above	0
TOTAL	100

Source: Development Partners (2007)

As is evident from Table 1.3, the majority (98.4 percent) of residents in the Walmer Township earn less than R7 500.

Based on these findings, it is felt that the Walmer Township acts as a suitable proxy for the proposed social housing developments in Nelson Mandela Bay.

1.5 SYNOPSIS OF CHAPTER ONE

Chapter One has laid the foundation for the thesis. A brief context of the study's problem statement was outlined, goals stated and the organisation of the thesis discussed. In addition, the study area has been defined and the rationale for using the Walmer Township as a suitable proxy for a social housing development has been explained.

CHAPTER TWO: POLICIES GOVERNING SOCIAL HOUSING DEVELOPMENTS AND MUNICIPAL PROPERTY VALUE ASSESSMENTS IN SOUTH AFRICA

2.1 INTRODUCTION

Many of South Africa's citizens live in informal settlements, which often consist of substandard housing and where the provision of basic services, such as potable water and sanitation, is often limited (Tissington, 2011). In addition to this, there are many dysfunctionalities present in South Africa which exacerbates the housing problem. These include issues of an economic, spatial and social nature. From an economic perspective, South Africa's unemployment rate is high, with the official rate currently estimated at 24.9 percent (Stats SA, 2012). Economic inequality is also an issue in South Africa, with South Africa's Gini index estimated at 67.4[7] (Stats SA, 2012). The spatial dysfunctionalities exist largely because in most South African cities the poor often live in locations that are far removed from vibrant economic growth points (Social Housing Policy for South Africa, 2005). These individuals often have to spend a large part of their working day commuting to and from work and are also situated far from other amenities, such as shopping centres, police stations and community centres. The social dysfunctionalities present in South Africa are largely intertwined with the economic and spatial issues. For example, high levels of unemployment often contribute to high levels of crime. A possible solution to the housing dilemma and one which could address the aforementioned dysfunctionalities is the provision of state subsidised housing (also referred to as social housing). The provision of this type of housing is seen as one of the government's main priorities and challenges (National Treasury, 2009).

To aid and guide government's actions in this regard, a Social Housing Policy was formulated and promulgated in May, 2005 (Social Housing Policy for South Africa, 2005). This policy defines social housing to be "a housing option for low-to-medium income persons that is provided by housing institutions, and that excludes immediate individual ownership" (Social Housing Policy for South Africa, 2005). However, as mentioned in Chapter One, there are opponents to this type of housing who argue that these developments may lead to negative externalities, such as reductions in the value of homes situated adjacent to social housing developments. The latter are broadly classified as LULUs. In turn, these LULUs may lead to the NIMBY syndrome, which leads to inefficient resource allocation as the costs are borne locally while the benefits are distributed more broadly (O'Hare, 1977).

[7] An index of 0 represents perfect equality, while an index of 100 represents perfect inequality.

A separate issue that affects residential property owners are the valuations performed by local municipalities for property rates purposes. These valuations are important to individual property owners as monthly property rates are, in part, determined by these valuations. In terms of the Municipal Property Rates Act (2004), hereafter referred to as the "Rates Act", these property valuations are meant to reflect a property's true market value. Chapter Two aims to shed some more light on the policies that govern social housing and property valuations for rates purposes.

2.2 A DESCRIPTION OF THE NIMBY SYNDROME

The term NIMBY was coined in the 1980s and has continued to play a large role in policy research and practice (Schively, 2007). This term characterises the social response to facilities that are "undesirable", sometimes referred to as LULUs. Facilities that may lead to the NIMBY syndrome include social housing developments, drug treatment centres, mental health facilities, detention centres, homeless shelters, prisons, power plants, wind turbines, and landfills (Cummings & Landis, 1993; Pendall, 1999; Fischel, 2001; Iglesias, 2002; Green, Malpezzi & Seah, 2002; Schively, 2007; du Preez, Menzies, Sale & Hosking, 2012). Those opposed to such facilities may argue that the facility is unnecessary or that it belongs in another area, citing the potential decline in property values as the primary concern (Popper, 1985; Lyons & Loveridge, 1993; Schively, 2007). This concern forms the basis of the NIMBY argument – the effects of the facilities "can spill over its borders to be borne by the entire community" (Pendall, 1999). In terms of social housing, residents that are established in a particular suburb may perceive proposed social housing to be associated with unsightly structures, unsavoury residents, and increased crime (Pendall, 1999). These perceptions, in turn, lead to fears that property values will decline.

Social housing advocates, however, claim that opponents expressing NIMBY sentiments are acting in a selfish and greedy manner (Koebel, Lang & Danielson, 2004). However, the literature reveals that NIMBY attitudes are far more complex than this characterisation suggests. More specifically, a study by Pendall (1999) analysed NIMBY concerns in 182 developments of various types in San Francisco in the 1980s. The study found that of the 182 developments, social housing generated only one NIMBY concern, with the majority of community concerns stemming from environmental issues (Pendall, 1999). This finding suggests that social housing is not alone when it comes to community resistance and opposition, reinforcing the notion that homeowners will oppose any form of land use that is perceived to generate negative externalities. Another study by Fischel (2001) suggested that homeowners expressing a NIMBY sentiment are acting in a rational manner as opposed to a selfish and greedy manner (Fischel, 2001). This is due to the fact that land use adjacent to

residential property is classified as an uninsurable risk. Therefore, it is rational for homeowners to want to reduce this risk by opposing undesirable land use (Fischel, 2001).

The severity of the NIMBY problem varies considerably with the type of project that is being proposed and geographical proximity (Dear, 1992; Iglesias, 2002). In terms of geographical proximity, "the closer residents are to an unwanted facility, the more likely they are to oppose it" (Dear, 1992; Iglesias, 2002). In terms of the type of project, the following are seen as the most important determinants of NIMBY sentiment: facility characteristics, size, operating procedures and appearance, and characteristics of the host community (Dear, 1992; Lake, 1993).

2.2.1 OVERCOMING THE NIMBY SYNDROME

NIMBY sentiment remains one of the biggest challenges facing developers of projects that are deemed to be "undesirable" by host communities (Dear, 1992; Iglesias, 2002; Koebel *et al*., 2004). It is, therefore, essential that developers of these types of projects attempt to mitigate homeowner fears. In this regard several approaches to overcoming NIMBY sentiments have been suggested. These approaches include campaigns to educate the public, home equity assurance, and project design improvements (Koebel *et al*, 2004).

2.2.1.1 CAMPAIGNS TO EDUCATE THE PUBLIC

Risks that are unfamiliar are less acceptable than risks that are familiar (Sandman, 1986). NIMBY sentiment is often driven by a lack of information and unfamiliar risk which, in turn, leads to fear (Koebel *et al*., 2004). Campaigns to educate the public about the benefits and necessity of "undesirable" projects have the ability to alleviate this fear, with effective communication being essential in order to successfully convey the message (Dear, 1992; Koebel *et al*., 2004). Communications strategies range from broad, nationwide approaches to those that target individual projects (Koebel *et al*., 2004). Developers can use a variety of media sources. These include television, radio, print media, and leaflets to increase public awareness (Dear, 1992).

2.2.1.2 HOME EQUITY ASSURANCE

As mentioned above, homeowners expressing NIMBY sentiments are acting in a rational manner in order to protect the equity they have invested in their houses (Fischel, 2001). Moreover, homeowners cannot insure against the risk of property devaluation (Fischel, 2001). However, there have been progammes in the United States that offer insurance to homeowners in the event of house value reductions (Koebel *et al*., 2004). The most well-known programme was set up in Oak Park, Illinois (Koebel *et al*., 2004). The programme

offered insurance against property devaluation, subject to a five year waiting period. These assurance programmes may also encourage property price stability since "panic sales" are reduced due to the "peace of mind" gained; the programmes are usually funded through a government entity (Koebel *et al*., 2004). However, in order to have a wider impact, it was suggested by Fischel (2001) that private insurance companies would have to offer the service (Fischel, 2001). However, there are a few barriers to private market participation. These include the difficulty in estimating the true market value of residential property and the difficulty in establishing the independent price effects of a particular land use (Fischel, 2001).

2.2.1.3 DESIGN IMPROVEMENTS

The physical design of "undesirable" facilities is often seen as a vital component of community acceptance (Koebel *et al*., 2004). However, it is often challenging for developers to design facilities that are both aesthetically pleasing and cost effective (Koebel *et al*., 2004).

In terms of social housing, two different design approaches have been recommended to assist social housing in gaining community acceptance. The first approach is high quality design and the second approach is invisibility. The high quality design approach attempts to conceal the fact that the development is of a social housing nature, by blending in the development with the surrounding residential neighbourhood (Koebel *et al*., 2004). Conversely, the invisibility approach aims for minimal exposure of the social housing development and tenants (Koebel *et al*., 2004).

2.3 THE STATE OF HOUSING PROVISION TO THE POOR IN SOUTH AFRICA

Despite the size and value of the South African residential property market, many poor, previously disadvantaged people still live in informal structures.

Currently, it is estimated that approximately 2.1 million households live in dwellings that are deemed to be inadequate[8] (Tissington, 2011).

[8] "Adequate housing" is a rather challenging concept to define, as adequate housing will depend on the specific context and situation of individual households. Nevertheless, a matrix has been developed which aids in assessing the adequacy of a housing structure according to certain key criteria (Smit, 2008). These include the adequacy of the following: location, shelter, affordability (initial outlay and running costs), services (sanitation, water and electricity), space, security, tenure security and availability. Adequate housing is also not to be viewed as a stand-alone service. Other socio-economic services are intrinsically related to housing, such as electricity, water, sanitation, human dignity and access to land.

Table 2.1 provides a breakdown of the extent of informal dwelling residency for the major urban areas in South Africa.

Table 2.1: Informal dwelling residency in major South African urban areas (2007)

Urban area	Number of households	Percentage of households living in informal dwellings
Ekurhuleni municipal area	849 349	26
Johannesburg	1 165 014	18.4
Tshwane municipal area	686 640	26.8
eThekwini municipal area	833 859	17.1
Cape Town	902 278	15.5
Rustenburg	146 542	37.3
Buffalo City	208 389	24.5
Nelson Mandela Bay	276 881	13.7
Mangaung municipal area	202 762	18.2

Source: Tissington (2011)

Compared to other major urban centres, Nelson Mandela Bay has the lowest percentage (13.7 percent) of households living in informal dwellings. At the other end of the spectrum, more than a third of Rustenburg's residents are being accommodated in inadequate housing conditions (Tissington, 2011).

Unfortunately, traditional housing and residential property markets cannot be relied upon to address the current housing shortages (Tissington, 2011). Problems inhibiting the implementation of the constitutional right to adequate housing include the following:

- Provincial under spending of housing budgets.
- Weak coordination between different government spheres in the housing delivery process causing delays in the initiation, approval, implementation and completion of housing projects.
- National to provincial budget allocation issues - this is particularly prevalent in the subsidised basic services categories, such as water and sanitation.
- Local level political infighting.
- Minimal availability of suitable, well-located land for social housing development.
- Skills shortages.
- Corruption and tender irregularities.
- Increasing construction costs (Tissington, 2011).

2.3.1 THE HOUSING BACKLOG

It is challenging to obtain accurate statistics on the current housing backlog in South Africa due to two main reasons (Tissington, 2011). These include incomplete records on house construction as well as substandard record keeping by municipalities (Tissington, 2011). Nevertheless, Table 2.2 shows the housing delivery from 1994/1995 to 2007/2008 in all nine provinces.

Table 2.2: Completed number of housing units

Province:	1994/1995-2002/2003	2003/2004	2004/2005	2005/2006	2006/2007	2007/2008	Total
Eastern Cape	187 237	27 119	37 524	19 825	16 526	12 684	300 915
Free State	87 859	16 746	16 447	20 536	19 662	12 482	173 732
Gauteng	340 331	49 034	66 738	59 310	77 044	90 886	683 343
Kwazulu-Natal	245 534	33 668	36 734	35 872	38 290	34 471	424 569
Limpopo	114 767	15 810	16 514	46 813	23 609	18 970	236 483
Mpumalanga	105 093	21 232	18 000	14 986	10 651	16 569	186 531
Northern Cape	29 231	3 787	3 598	8 667	3 880	8 686	57 831
North West	125 353	10 484	10 037	35 515	46 972	19 945	248 306
Western Cape	185 510	15 735	11 756	11 310	34 585	34 157	293 053
Total	1 420 897	193 615	217 348	252 834	271 219	248 850	2 604 763

Source: Tissington (2011)

As is evident from Table 2.2, roughly 2.6 million housing units have been supplied to nearly 11 million households (Tissington, 2011). Progress with housing provision appears to be greatest in Gauteng, with 683 343 delivered units. Gauteng is followed by Kwazulu-Natal, the Eastern Cape, the Western Cape and the North West with 424 569, 300 915, 293 053 and 248 306 units, respectively. The Northern Cape, the Free State, Mpumalanga and Limpopo are lagging in respect of housing delivery with 57 831, 173 732, 186 531 and 236 483 housing units, respectively. The government estimates that by 2014, a further 1.1 million housing units will have been delivered nationally leaving a shortage of 1 million units - the projected demand by 2014 will be 2.1 million units (Tissington, 2011).

2.4 LEGISLATION GOVERNING HOUSING PROVISION IN SOUTH AFRICA

The provision of basic housing in South Africa is enshrined in the Constitution of South Africa (1996). More specifically, Section 26 of the Constitution outlines the following:

1) "Everyone has the right to have access to adequate housing."
2) "The state must take reasonable legislative and other measures, within its available resources, to achieve the progressive realisation of this right."
3) "No one may be evicted from their home, or have their home demolished, without an order of the court made after considering all the relevant circumstances. No legislation may permit arbitrary evictions" (Tissington, 2011).

Government, thus, has a "duty to work progressively towards ensuring all South Africans have access to secure tenure, housing, basic services, materials, facilities and infrastructure on a progressive basis" (National Housing Code, 2009). The primary piece of housing legislation in South Africa is the Housing Act (No. 107 of 1997), hereafter referred to as the "Act", which provides for a sustainable housing development process.

2.4.1 THE HOUSING ACT

The Act lays down general principles for all spheres of government in respect of the provision of housing and states that priority must be given to the housing needs of the poor. In terms of the Act, housing development is defined as "the establishment and maintenance of habitable, stable and sustainable public and private residential environments to ensure viable households and communities in areas allowing convenient access to economic opportunities, and to health, educational and social amenities in which all citizens and permanent residents of the Republic will, on a progressive basis, have access to: permanent residential structures with secure tenure, ensuring internal and external privacy and providing adequate protection against the elements; and potable water, adequate sanitary facilities and domestic energy supply" (Tissington, 2011).

2.4.2 ROLES AND RESPONSIBILITIES OF THE VARIOUS TIERS OF GOVERNMENT

Each tier of the South African Government has certain responsibilities when it comes to the provision of housing. National government is tasked with facilitating the national housing development process. This is done by formulating a national housing policy. Monitoring of progress is also the responsibility of national government and this is done with the guidance of the National Housing Code.

The role of the next governmental tier, the provincial government, is the administration of the National Housing Code, which was published in 2000. It provides the policies driving the National Housing Programmes. These National Housing Programmes can be categorised into financial, incremental, and social and rental housing programmes. Financial programmes are defined as programmes that facilitate immediate access to housing goods and services (Department of Human Settlements, 2007). Incremental programmes are programmes that aid access to housing opportunities through a phased process (Department of Human Settlements, 2007). Social and rental housing programmes promote urban reintegration by facilitating access to rental housing (Department of Human Settlements, 2007).

The final tier (local municipalities) must implement the housing objectives set out by national government, and in doing so, ensure that the constitutional rights of citizens within the relevant metro are satisfied (Tissington, 2011).

2.5 HOUSING OPTIONS AVAILABLE TO THE POOR IN SOUTH AFRICA

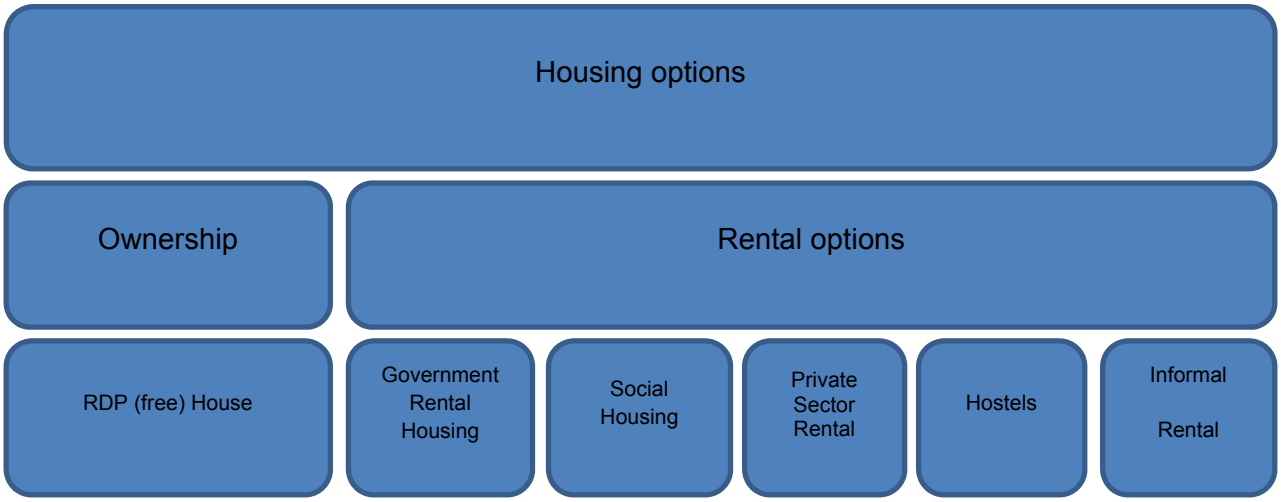
In an attempt to address the housing shortages described above, the South African Government embarked on a programme of developing low-cost housing as part of its Reconstruction and Development Programme (RDP). This programme began after the 1994 elections with the goal of providing more housing units to the poor (Barry, Dewar, Whittal, & Muzondo, 2007). Under this system, the National Housing Subsidy Scheme (NHSS) provided capital subsidies to qualifying households (with full home ownership taking place).[9] Over the period 1994 to 2001, approximately 1.1 million low-cost houses were built (Tissington, 2011).

This programme has, however, been plagued by a number of problems which have slowed its progress substantially (Tissington, 2011). Many RDP sites have essentially become residential dormitories, with many beneficiaries choosing to trade their houses and return to informal settlements that are situated closer to places of work (Tissington, 2011). Although a mandatory lock-in period of 8 years is in force, approximately 11 percent of beneficiaries have traded their RDP houses before the expiration of the lock-in period since 2005. More than 50 percent of these transactions have values that were between R5 750 and R17 000 (Tissington, 2011). In addition to these problems, the existing RDP housing programme suffers from another important failure: the failure to address the re-integration of the population (a spatial dysfunctionality).

In order to address these problems and the rising housing backlog, a major shift in housing policy took place in 2004 with the implementation of the Breaking New Ground (BNG) policy. This policy emphasised rental housing as a form of tenure, in line with international best practices, which shows that a combination of rental and ownership options is more effective than one mode alone in delivering housing to the poor (Department of Human Settlements, 2004). The various housing options available to poor and middle-income households are summarised in Figure 2.1.

[9] The 2009 General Household Survey (conducted by Stats SA) reveals that approximately 12.8 percent of households in South Africa live in state subsidised dwellings with approximately 13.8 percent on the waiting list (Stats SA, 2009).

Figure 2.1: Housing options available to the poor in South Africa



Source: Sobuza (2010)

Government rental housing is provided by different spheres of government and is aimed at low-income households. No new government rental housing has been built over the past two decades and the stock of this form of housing is decreasing as units continue to be bought privately under the discount benefit scheme (Martin & Nel, 2002). Social housing is aimed at low-to-middle-income households and is generally provided by non-governmental institutions. Private sector rental is rental accommodation provided on a commercial basis. Hostels are primarily intended to provide accommodation for single people. This form of rental housing is, however, plagued by social disruption and crime (Martin & Nel, 2002). Informal rental is accommodation provided by households for social reasons (Martin & Nel, 2002).

2.6 SOCIAL HOUSING IN SOUTH AFRICA

Social housing is a relatively new concept in South Africa (A Toolkit for Social Housing Institutions, 2010). Plans to provide affordable accommodation options for low-income earners in South Africa officially commenced in 1996, with the establishment of the National Housing Finance Corporation (NHFC) (A Toolkit for Social Housing Institutions, 2010). The primary goal of the NHFC was to ensure the development and appropriate funding of institutions offering a variety of tenure options for residential purposes. Over the next 12 years, various policy and legislative procedures were developed, which resulted in the Social Housing Act (No. 16 of 2008), which seeks to establish and promote a sustainable housing environment.

The two primary objectives of social housing are to contribute to the restructuring of South African society in order to address economic, social and spatial dysfunctionalities and to

improve and contribute to the overall functioning of the housing sector in order to widen the range of housing options available to the poor (Social Housing Policy for South Africa, 2005). In terms of addressing the spatial aspect, social housing complexes are ideally located in specific, defined localities which have been identified as areas of opportunity. Currently, individuals deemed to be poor often live in areas which are removed from the vibrant economic growth spots. Social housing seeks to alleviate this problem by ensuring that the poor are not pushed out to marginalised areas of South Africa's cities (Social Housing Policy for South Africa, 2005). Social housing also has the ability to aid in job creation and economic revitalisation, partly in the form of construction of these social housing complexes. The extent of economic revitalisation will, in part, depend on the size and nature of the specific housing complex. Finally, social housing may also have the ability to address many of the social issues facing households currently living in informal dwellings, as well-managed social housing projects aid in the stabilisation of areas prone to crime (Social Housing Policy for South Africa, 2005).

Government's social housing policy is underpinned by the following guiding principles:

- Through the social, physical and economic integration of housing, urban restructuring must be promoted, primarily in urban and inner city areas. In terms of this principle, social housing is seen as being capable of contributing to urban restructuring. This is particularly relevant in urban areas. More specifically, social housing projects must have the ability to connect low-income individuals to various urban amenities. This means that these projects must be established in areas where income generating opportunities and various facilities and amenities are in close proximity to residents (Social Housing Policy for South Africa, 2005).
- Well-managed housing options for the poor must be promoted. This guiding principle seeks to drive social housing in the direction of increasing the number of housing options for the poor. At present, substandard housing is often the only option for low-income individuals. Social housing seeks to address this issue with this principle (Social Housing Policy for South Africa, 2005).
- Local housing demand must be taken into account. Social housing needs to respond to the unique situations of households. As household needs may differ (depending on the area) social housing needs to take these differences into account and area-specific social housing projects must be promoted (Social Housing Policy for South Africa, 2005).

- The economic development of low-income communities must be supported. Social housing projects must be established in areas where job opportunities are present. In addition to this, the specific locations of social housing projects must aid in supporting SMME's (small, medium and microenterprises) (Social Housing Policy for South Africa, 2005).
- The creation of quality living environments for low-income households must be nurtured. Not only should social housing projects address the accommodation needs of low-income households, quality living environments must also be created. Adequate space must also be provided and the design and structure of the units need to contribute to the aesthetic appeal of the area (Social Housing Policy for South Africa, 2005).
- The creation of viable and sustainable projects must be promoted. This is an essential guiding principle and states that social housing projects must be financially viable. The appropriate management of these projects is essential in order to ensure that informal "shack dwellings" do not materialise on site and good management practices will contribute to low tenant default rates (Social Housing Policy for South Africa, 2005).
- The involvement of residents must be facilitated. The purpose of this guiding principle is to ensure that residents are fully aware of their housing options and can thus make informed decisions. Prior to occupancy, residents need to participate in training and information sharing sessions (Social Housing Policy for South Africa, 2005).
- All spheres of government must be included. The participation of all spheres of government must be done in a manner that promotes efficiency. Local government plays an integral role in the success of social housing and has a significant part to play in the identification of appropriate sites (Social Housing Policy for South Africa, 2005). In order to help address some of the housing provision problems outlined in Section 2.3, local municipalities are allowed to become developers of social housing. Each municipality must include a housing chapter in its Integrated Development Plan (IDP) and through accreditation, are able to perform housing related functions traditionally carried out by provincial and national government. These functions include subsidy budget planning and the administration and management of priority programmes. The aim of this is to eventually give municipalities full control over these functions with provincial and national government fulfilling a monitoring role. The rationale for this is further backed up by the fact that, at present, "limited powers are given to municipalities in housing

delivery, despite the significant responsibilities they hold for the provision of infrastructure and the long term management of settlements" (Tissington, 2011).

- Social housing must operate within the provisions of the Constitution. Social housing projects need to comply with the requirements of fairness and equitable competition as laid out in the Constitution (Social Housing Policy for South Africa, 2005).

2.6.1 THE TARGET MARKET FOR SOCIAL HOUSING

Taking the above guiding principles into account, a specific target market (potential recipients of social housing) needs to be identified. One of the objectives of social housing is to provide accommodation options to individuals who cannot afford market rental rates and would like to be located in an urban area. As was discussed in Chapter One (see Section 1.4.2.4), social housing is aimed at households deemed to be low-to-middle-income which are broadly defined as households that earn between R1 500 and R7 500 per month (Social Housing Policy for South Africa, 2005). Table 2.3 provides income classifications and the respective subsidy types.

Table 2.3: Income classifications and subsidy types

Classification	Income	Subsidy
Middle-income	R3 500 – R7 500	Rental
Low-income	R1 500 – R3 500	Rental and partly subsidised ownership
Poor	<R1 500	Fully subsidised ownership
Destitute	0	Fully subsidised ownership

Source: Sobuza (2010)

According to Table 2.3, households earning between R3 500 and R 7 500 per month qualify for a rental subsidy. However, according to Stats SA's 2005/2006 Income and Expenditure survey, 55 percent of all renting households in South Africa earn less than R3 500 per month, 27 percent earn less than R1 500 per month and 14 percent earn less than R850 per month (Stats SA, 2007). The majority of households currently renting in South Africa can thus be classified as poor or low-income.

Among those households looking for affordable rental options are the following:

- Individuals opting for the flexibility and mobility that renting allows.
- Persons looking at rental housing as a first phase to eventual ownership.
- Households who simply cannot afford inner city residential property prices.

- Individuals requiring short term accommodation.
- Broken households where alternative accommodation is a matter of urgency.
- Singles with dependents.
- Single persons seeking to co-habit.
- Persons currently living in informal settlements.

Indications are that the demand for this type of housing will increase significantly (Social Housing Policy for South Africa, 2005).

2.6.2 AN EXAMPLE OF A COMPLETED SOCIAL HOUSING DEVELOPMENT IN SOUTH AFRICA

Examples of completed social housing projects in South Africa include BG Alexander (Hillbrow, Johannesburg), Botlhabela Village (Alexandra Far East Bank, Sandton), Candella Road (Durban), Elangeni (Inner City, Johannesburg), Hope City (Mpumalanga), Skyview (East London) and Haven Hills South (East London) (Project Review Series, 2009)[10].

Table 2.4 presents a summary of completed social housing projects and provides information on their respective locations.

[10] The Nelson Mandela Bay Municipality is due to commence construction of 269 semi-detached houses for the residents of Silverton, New Brighton. The estimated cost of this project is in the region of R18 000 000, implying a cost per unit of R66 914 (Housing Project Launched in New Brighton, 2010).

Table 2.4: Social housing projects in South Africa

Project Name	Date Completed	City	Location	Surrounding residential neighbourhoods
Elangeni	July 2002	Johannesburg	Inner City	Inner city
Hope City	October 2002	Middleburg	Middleburg, Mpumalanga	Located 4km south east of the centre of Middleburg
Haven Hills South	June 2003	East London	Haven Hills	Haven Hills, Buffalo Flats, Braelyn, Amalinda.
Skyview	February 2006	East London	City centre	Southernwood
Candella Road	January 2008	Durban	Bonella, 6km from Durban CBD	Cator Manor, Bonella
Botlhabela Village	February 2008	Johannesburg	Alexandra Far East Bank, Sandton	Marlborough Gardens, Kelvin.
Signal Hill	August 2008	Pietermaritzburg	Pietermaritzburg, Kwazulu Natal	Signal Hill
BG Alexander	February 2009	Johannesburg	South side of Hillbrow, inner city	Hillbrow, Berea
Newkirk and Castle Mansions	March 2009	Johannesburg	Eastern parts if the inner city	Inner city

Source: Project Review Series (2009)

A closer examination of the Haven Hills South project in East London, for example, reveals the following: the vision of the project was to "provide social housing in a township environment" and was identified by the Buffalo City Municipality (BCM) as a pilot initiative to develop an integrated urban living environment, aimed at individuals who would qualify for social housing (Project Review Series, 2009). The complex is situated 7 kilometres from the East London CBD. This project commenced in July 2002 and was completed and occupied in June 2003. In accordance with the Social Housing Policy for South Africa, low-income earners qualified on a rental basis. The project consists of 258 units ranging from one to three bedroom units. The sizes of the one, two and three bedroom units, respectively, are 25m², 35m² and 45m². Each unit comes standard with an open plan living area and kitchenette that includes a sink and preparation area. Aluminum window frames and a stable front door were fitted to each unit. Tenants are charged a monthly rental of R950, R1451 or R1551, respectively, for a one, two or three bedroom unit. The average maintenance cost per unit is approximately R96 per month. Facilities and amenities include play areas for children, pre-paid water and electricity and one parking bay per unit (Project Review Series, 2009). Current estimates of the price per social housing unit vary. Total development costs of the Haven Hills South project in East London, for example, amounted to R29 000 000, resulting in an average cost per unit of roughly R112 403 (Project Review Series, 2009).

2.7 THE NELSON MANDELA BAY MUNICIPALITY'S VALUATION AND PROPERTY RATES POLICY

2.7.1 BACKGROUND

The Rates Act stipulates that all municipalities ensure that all properties falling within their municipal jurisdiction be subjected to a valuation process. According to the Rates Act, the Nelson Mandela Bay Municipality needs to prepare a new valuation roll every four years[11] for the purpose of determining municipal rates (Nelson Mandela Bay Municipality: 2010/2011 Property Rates Policy, 2011). These municipal rates provide the necessary funds in order to provide services that benefit the community within a municipality. These services include: construction and maintenance of streets, roads, sidewalks, lighting and storm water drainage facilities, building and operating clinics, parks, recreational facilities, cemeteries and municipal administration (Nelson Mandela Bay Municipality: 2010/2011Property Rates Policy, 2011).

Approximately 1.3 million people inhabit the Nelson Mandela Bay Municipal area and are housed in a wide variety of property types. Many of these properties have never been formally valued and the main purpose of the valuation procedure was to achieve equity in the property tax system. Table 2.5 provides a broad indication with regard to the types of properties within the metro.

Table 2.5: Rateable properties within the Nelson Mandela Bay Metro

Property Category	Estimated number of properties
Single residential (SR)	200 000
Sectional title (SC)	20 000
Non-residential commercial or industrial	30 000
Previously unrated	16 064
Total	**266 064**

Source: Weyers (2011)

Furthermore, the Rates Act states that a municipality must designate a person as municipal valuator. This may be one of the municipal officers or a person in private practice (Municipal Property Rates Act, 2004). If the municipality decides to secure the services of a contractor, an open, transparent and competitive process must be adhered to. For the purposes of the 2007/2008 valuation[12] (the specific valuation roll considered in this study) the Nelson

[11] Supplementary valuations are undertaken twice during each financial year. Additional supplementary valuations can take place at the discretion of the CFO (Weyers, 2011).

[12] The valuations applicable in this study became effective (for property rates purposes) on 1 July 2008.

Mandela Bay Municipality outsourced the valuation task, which was awarded to eValuations (Weyers, 2011).

The specific objectives of the contractor, as stipulated by the Nelson Mandela Bay Municipality can be summarised as follows:

- The valuation of all properties within the Nelson Mandela Bay Municipality.
- The compilation of a general valuation roll and a supplementary valuation roll.
- The provision of a concomitant rates policy.
- The provision, installation and implementation of a computer assisted mass appraisal (CAMA) system.
- Training and transfer of knowledge and skills to Nelson Mandela Bay Municipality personnel relevant to the competent use of the CAMA system and the maintenance of the valuation roll.
- The integration of the CAMA system with existing NMMM systems (e.g. billing and GIS).
- The development and implementation of a system to manage appeals and objections.
- The provision, installation and implementation of a financial modeling tool to enable running of various “what if” financial scenarios.
- Delivery to the municipality of all software and documentation representing the final configuration as agreed by the tenderer and municipality (Weyers, 2011).

2.7.2 GUIDING PRINCIPLES

A thorough compilation of guiding principles has been established in order to assist municipalities with the rating of municipal property. Impartiality, fairness, equity and bias-free estimates are the core values that need to be adhered to when rating property as well as when setting criteria for exemptions, reductions, and rebates (Nelson Mandela Bay Municipality: 2011/2012 Property Rates Policy, 2011).

The rating of property should be implemented in the following manner:

- The rating should be developmentally orientated.
- A stable and buoyant revenue stream should result from property ratings. This aids in ensuring a sustainable local government with the municipality having discretionary control over the funds.
- The rating of property should aid in supporting socio-economic development within the municipal jurisdiction.
- The property rates assessments process should be conducted with simplicity, uniformity and certainty.
- The rating of property should take into account the need for an efficient and user-friendly billing system.
- Land management should be promoted in a sustainable manner.
- The rating of property should contribute to achieving the aims and objectives of both local and national government (Nelson Mandela Bay Municipality: 2011/2012 Property Rates Policy, 2011).

The municipality has the discretion to offer exemptions, rebates and reductions in certain instances. When looking at certain cases, the following areas have been identified as potentially qualifying for exemptions, rebates and reductions: income of the owner of the property, source of income of the owner and employment status of the owner. In addition, public benefit organisations, indigent households, disabled persons, pensioners, sporting bodies, municipal owned property, state owned property, protected critical biodiversity areas and disaster affected areas may qualify for rebates and exemptions. These exemptions, rebates and reductions are offered in order to accommodate indigent persons, less affluent pensioners and public service providers (Nelson Mandela Bay Municipality: 2011/2012 Property Rates Policy, 2011). These rebates are shown in Table 2.6.

Table 2.6: Applicable rebates

Annual Household Income	Rebate (percent)
Less than 2 annual state pensions	100
Between 2 annual state pensions and R37 550.99	85
Between R37 551 and R46 620.99	70
Between R46 621 and R55 690.99	55
Between R55 691 and R64 640.99	40
Between R64 641 and R73 700.99	25
Between R73 701 and R82 660	10

Source: Nelson Mandela Bay Municipality: 2011/2012 Property Rates Policy (2011)

2.7.3 VALUATION FORMULA AND DATA USED

Municipal rates are calculated according to the following equation:

Monthly general rates = (market value – reduction)*rating factor/12……..…..(2.1)

The market value in Equation 2.1 refers to the market value of the property as determined by the municipality. The reduction is determined by the category of owner. The following criteria are used in this regard: income of the owner, source of income of the owner, employment status of the owner and use of the property. The category of property also infuences the rates levied (the rating factor). This is based on the use, ownership and geographical area. The following broad categories of properties[13] are recognised: residential property, industrial property, business/commercial property, farm property (residential, business/commercial and industrial), smallholding property (residential, business/commercial and industrial), public service infrastructure property, public benefit organisations property, vacant land, game parks and agricultural property (Nelson Mandela Bay Municipality: 2011/2012 Property Rates Policy, 2011).

For the purposes of the 2007/2008 valuation, the Nelson Mandela Bay Municipality supplied the contractor with the following property information: existing GIS data, existing valuation records and rolls (in Alchemy format), existing aerial photographs and existing building plans. The following data were also made available in the case of single residential properties: property ID, property description/category, property use, owners details, physical address, erf[14] size, dwelling size, sale information, garage area, granny flat area, servants

[13] This study focuses on residential property, which is formally defined as "land owned by a person or entity which is zoned for single family houses, multi-family apartments, townhouses, condominiums and/or co-ops" (Brooks & Tsolacos, 2010).

[14] Erf can be defined as a plot of land marked off for building purposes. The terms erf, plot and yard can be used interchangeably.

quarters area and swimming pool if applicable. Additional data collected for the 2007/2008 valuation roll included information on the security system, view, topography, roof covering, condition and number of stories (Smoothey, 2011; Weyers, 2011).

2.7.4 COMPLAINTS PROCEDURE

Individual home owners may argue that there is little equivalence between a property's true market value and the valuation determined by a municipality. For this reason, and in terms of the Rates Act, all municipalities must establish a board of appeal. The main functions of this board are to review the decisions made by the municipal valuator and to hear and decide appeals against these decisions. The appeals board must consist of a chairperson with the relevant legal qualifications and experience in justice administration (Municipal Property Rates Act, 2004).

If an individual has an objection with the rates levied (due to an incorrect valuation or rating category), the individual may appeal the decision made by the municipal valuator. If this appeal is successful, the appropriate adjustment will take place. In terms of the processing of these objections, the municipal valuator must consider all objections within a prescribed procedure, decide on objections based on fact and adjust or add to the valuation roll accordingly. If an upward/downward adjustment of more than 10 percent takes place, the municipal valuator must provide the municipal manager with written reasons for the discrepancy (Municipal Property Rates Act, 2004). In addition to this, the municipal manager must submit all relevant documentation (including the valuator's decision) to the appeal board. The matter then lies with the appeal board, which must confirm, amend or revoke the valuator's decision. The chairperson of the appeal board must ensure that the valuation roll is adjusted accordingly.

Individuals who have lodged complaints must be notified in writing of the valuator's decision. The individual then has 30 days to apply to the municipal manager for the reasons behind the decision, which must be accompanied by a prescribed fee. An appeals process is also available to individuals who have laid objections and are not satisfied with the decision. As mentioned in Chapter One, a total of 396 objections were received for the suburb of Walmer in respect of the 2007/08 valuation roll. This represents approximately 15 percent of the rateable residential properties in Walmer (Weyers, 2011).

2.8 CONCLUSION

Chapter Two highlighted that the negative sentiment expressed by surrounding property owners, namely the NIMBY syndrome, was one of the challenges facing the government's

social housing programme. This sentiment needs to be addressed if the constitutional right to adequate housing is to be ensured. The chapter further described South Africa's urgent need to increase the housing options available to the poor and provided a short description of the current social housing policy in South Africa.

Chapter Two also discussed the policy guiding residential property valuations for property tax purposes. These valuations need to be as close to true market value as possible in order to meet the conditions as stipulated in the Rates Act. The information generated in this chapter is used in Chapter Six to contextualise the policy discussion. The next chapter (Chapter Three) provides a theoretical overview of property value models.

CHAPTER THREE: A THEORETICAL OVERVIEW OF PROPERTY VALUE MODELS

3.1 INTRODUCTION

The analysis of property markets has enabled researchers to estimate prices for goods that are not traded in traditional markets based on the fact that housing and other real estate constitute differentiated products (Freeman, 1979; Day, 2001; Diewert, 2003; Palmquist, 2005). These non-market goods often exhibit a public good nature and include, among others, open space, water and air quality, and proximity to social housing.

Three alternative property value methods exist, namely the hedonic price model, the repeat-sales model and discrete choice models (Freeman, 1979; Palmquist, 1992; Chattopadhyay, 1998, 2000). Individual choice theory and a model of the equilibrating forces of the housing market form the foundation of all these models (Rosen, 1974; Palmquist, 1991, 2005; Day, 2001; Diewert, 2003; Coulson, 2008).

The international literature reveals that the most commonly applied property value technique is the hedonic price model (Humavindu & Stage, 2003; Deaton & Hoehn, 2004; Palmquist, 2005; Anderson & West, 2006; Bayer, Keohane & Timmins, 2009; Walsh, Milon & Scrogin, 2011). The word "hedonic" stems from the Greek work "hedone" which means enjoyment (Picard, Antoniou & De Palma, 2010). This terminology was first used by Court (1939) who conducted an automobile study (Court, 1939; Palmquist, 2005). However, Lancaster's (1966) paper entitled "A new approach to consumer theory" provided the first reachable theory for hedonic price modelling. The essence of this approach is that the characteristics of consumption goods (not the goods themselves) provide utility to individuals. However, it is the goods (not the characteristics) that are traded in traditional markets. The attractiveness of the hedonic price model is that it allows for the recovery of implicit prices of the attributes (both market and non-market) inherent in consumption goods. Following the Lancaster (1966) study, Griliches (1971) performed a study on automobile demand and managed to popularise the technique (Griliches, 1971; Palmquist, 2005). Rosen's (1974) seminal paper entitled "Hedonic prices and implicit markets: product differentiation in pure competition" then paved the way for a plethora of hedonic price studies.

The hedonic price model is commonly applied to property markets in order to value both market and non-market housing characteristics (Palmquist, 1991, 2005). Many studies have used the hedonic price model to estimate the effect of air pollution on house prices (Smith & Deyak, 1975; Kiel & McClain, 1995; Chattopadhyay, 1999; Beron, Murdoch & Thayer, 2001). Other non-market applications of this method include estimating the relationship between

house prices and hazardous waste sites, water pollution, school quality, open space, crime rates, and airport noise (Hoehn, Berger & Blomquist, 1987; Kohlhase, 1991; Nelson, Genereux & Genereux, 1992; Black, 1999; Hite, Chern, Hitzhusen & Randall, 2001; Irwin, 2002; Ihlanfeldt & Taylor, 2004; Linden and Rockoff, 2008; Pope, 2008; du Preez & Lottering, 2009).

The repeat-sales model is a variant of the hedonic price method that is used to infer willingness to pay values for housing characteristics. In contrast to the hedonic price model, this model takes advantage of a time series of sales prices of houses where the structural characteristics have not changed over time (Palmquist, 1982; 2005; Freeman, 2003). Model specification and estimation in the repeat-sales model is simpler than in the hedonic price model because characteristics that have remained unchanged can be omitted from the analysis (Palmquist, 1982, 2005; Freeman, 2003). Despite this simplicity, hedonic price models are far more popular than repeat-sales models (Clapham, Englund, Quigley & Redfearn, 2006).

An alternative property value method, known as the discrete choice method, argues that individuals' choices are discrete instead of continuous in house characteristics. Discrete choice models consist of the random bidding model and the random utility model. The random bidding model seeks to predict the type of individual with the highest bid for a house in an equilibrium allocation (the model assumes that houses are eventually owned by households with the highest bids) (Ellickson, 1981; Lerman & Kern, 1983; Chattopadhyay, 1998; Palmquist, 2005). Application of the random bidding model to residential choice is limited (Chattopadhyay, 1998). The random utility model, on the other hand, assumes that the individual selects the dwelling that provides the highest utility in a choice set of houses (McFadden, 1978; Chattopadhyay, 2000; Palmquist, 2005). Following McFadden's (1978) seminal paper, which suggested the use of a random utility model in housing choice studies, the model has been commonly applied (Quigley, 1976; 1985; Friedman, 1981; Longley, 1984; Cropper, Deck, Kishor & McConnell, 1993; Nechyba & Strauss, 1998; Chattopadhyay, 2000).

3.2 THE HEDONIC PRICE MODEL

3.2.1 UNDERLYING THEORY

As mentioned above, the majority of property models are devoted to residential housing, a differentiated product (Freeman, 1979; Cropper *et al*., 1993; Leggett & Bockstael, 2000; Fullerton & Villalobos, 2011). This means that, although each housing unit is different from the next, houses are generally traded in the same market (essentially a market group)

(Nicholson, 2004; Palmquist, 2005). This further implies that price homogeneity will not exist in housing markets as each unit differs (Nicholson, 2004; Palmquist, 2005). These differences include, but are not limited to, differences in house specific characteristics, differences in locational characteristics and differences in neighbourhood characteristics. Thus, differences in the sales prices of houses are due to differences in their characteristics and individuals' preferences for these characteristics (Freeman, 1979; Epple, 1987; Palmquist, 2005). A further implication of product differentiation is that the market offers a wide variety of choices (Rosen, 1974; Freeman, 1979; Sheppard, 1999; Day, 2001).

It is generally accepted that most housing markets are driven by houses currently available on the market, thus implying perfectly inelastic supply in the short run (Palmquist, 1991, 2005).[15] Thus, the prices of existing houses are determined by demand conditions. In the discussion that follows, the house supply will be assumed to be fixed and the focus will be on the market equilibrium and the consumer side of the market. No theoretical complications arise by ignoring the producer side of the market (Palmquist, 1991, 2005; Sheppard, 1999; Day, 2001; Diewert, 2003; Freeman, 2003).

3.2.1.1 THE HEDONIC PRICE FUNCTION

The first stage of the hedonic analysis is to estimate the hedonic price function. In accordance with Rosen (1974), a house can be completely described by a vector of its characteristics (including structural, locational, neighbourhood, and environmental characteristics):

$$\boldsymbol{z} = (z_1, z_2, .., z_n) \qquad (3.1)$$ [16]

where z_i $(i = 1, 2, \ldots, n)$ represents the amount of any one of the characteristics of a house. All services provided by the house to the household are described by the vector $\boldsymbol{z}$ (Day, 2001). Since the market offers a wide variety of differentiated houses, the choice among various combinations of $\boldsymbol{z}$ is treated as continuous (Rosen, 1974; Day, 2001; Freeman, 2003; Palmquist, 2005). It is assumed that each house characteristic is treated as an

[15] If the researcher deems it necessary to incorporate the construction of new houses into the hedonic price model, house price determination would also include building costs and the profit maximising decisions of firms (Palmquist, 2005).
[16] Vectors are represented by boldface letters. For example, $\mathbf{X} = x_1, x_2, \ldots, x_n$.

“economic good” as opposed to an “economic bad”. Consumers thus place positive marginal valuations on the characteristics (Rosen, 1974; Day, 2001).

The vector of characteristics making up a house determines its market price:

$P = P(\boldsymbol{z}) = P(z_1, z_2, \ldots, z_n)$……...……..…...(3.2)

Equation 3.2 is known as the hedonic price function and represents the equilibrium price schedule in a competitive market (Rosen, 1974; Freeman, 1979; Palmquist, 1991, 2005; Sheppard, 1999; Diewert, 2003; Coulson, 2008). If it were possible to move characteristics between houses, arbitrage activities would ensure constant marginal implicit prices for the characteristics and a linear hedonic price function would emerge (Rosen, 1974; Freeman, 1979; Palmquist, 1991, 2005). Since it is impossible to break up the characteristics of a house and enjoy each characteristic separately (one must enjoy the unit as a whole) the marginal implicit prices are not necessarily constant (Day, 2001). For example, a house with two bedrooms is not the same as two houses with one bedroom (it is impossible to live in two houses simultaneously). This means that the marginal implicit prices may depend on the quantity of the characteristic (the marginal implicit price of a bedroom will most likely be higher for the house with one bedroom than for the house with two bedrooms). For this reason, the hedonic price function does not necessarily take on a linear functional form (Rosen, 1974; Freeman, 1979; Palmquist, 1991, 2005). A typical hedonic price function is shown in Figure 3.1.

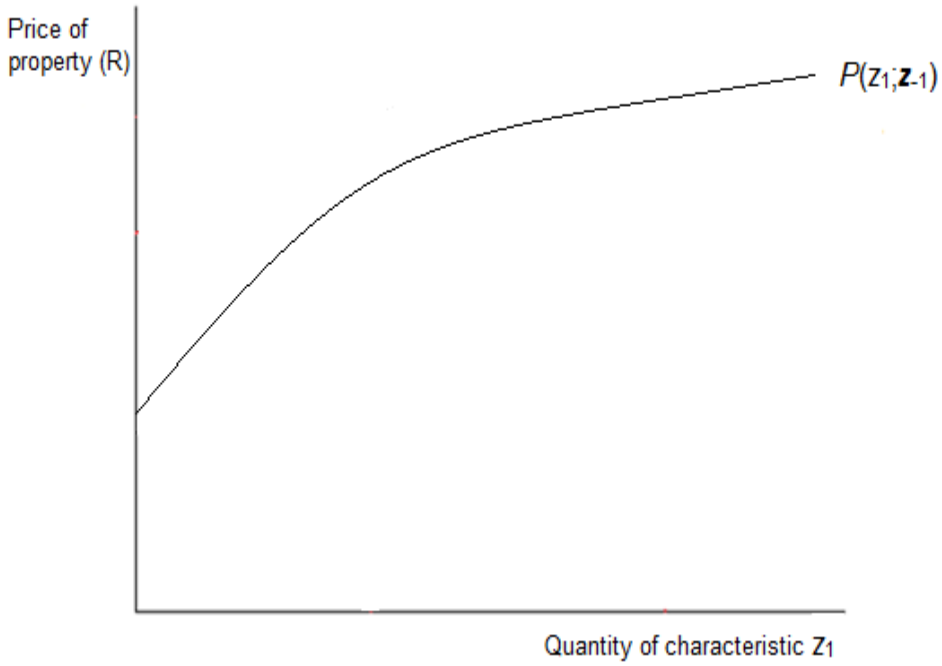


Figure 3.1: The hedonic price function
Source: adapted from Rosen (1974)

Figure 3.1 displays the hedonic price function for a specific house characteristic, z_1. All other house characteristics are held constant and $\boldsymbol{z}_{-1}$ represents the vector of these characteristics (Rosen, 1974; Sheppard, 1999; Day, 2001; Diewart, 2003). As is evident from Figure 3.1, the price of a house increases as the quantity of z_1 increases. However, the hedonic price function increases at a diminishing rate. This implies that the marginal implicit price of characteristic z_1 is not constant and the additional value created by increases in z_1 declines. This concept can be further highlighted by examining the marginal implicit price function for a specific housing characteristic. The marginal implicit price for a characteristic is derived by partially differentiating the hedonic price function in respect of the characteristic in question:

$$p_{z_i} = \frac{\partial P(\boldsymbol{z})}{\partial z_i} \quad \text{.....(3.3)}$$

Figure 3.2 displays the marginal implicit price function for characteristic z_1.

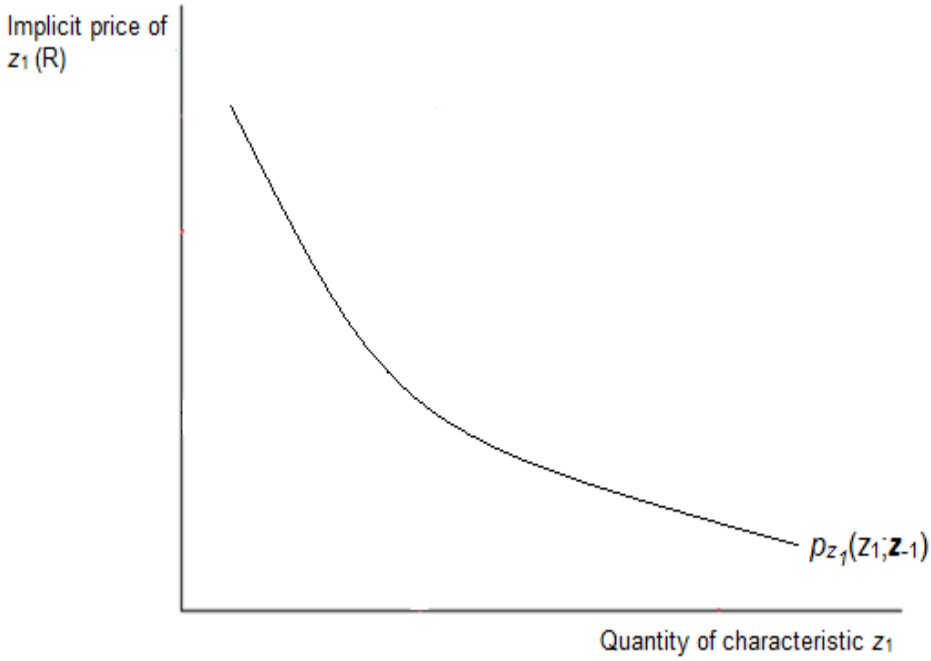


Figure 3.2: Marginal implicit price function for characteristic z_1
Source: adapted from Day (2001)

The marginal implicit price function depicted in Figure 3.2 corresponds with the hedonic price function in Figure 3.1. At low levels of z_1, the marginal implicit price of z_1 is high. This declines as the quantity of the characteristic increases (Rosen, 1974; Palmquist, 1991, 2005; Day, 2001; Freeman, 2003).

3.2.1.2 UTILITY MAXIMISATION AND INDIVIDUAL CHOICE

Utility maximising individuals base their housing decisions on the hedonic price function, along with their individual utility functions (Rosen, 1974; Sheppard, 1999; Day, 2001; Coulson, 2008). Rosen's (1974) utility maximising model is based on two important assumptions. The first assumption is that individuals have no effect on the hedonic price function through their actions (since they are price takers). However, they can influence the price they pay for a house based on the characteristics they select (Rosen, 1974; McConnell & Phipps, 1987; Palmquist, 1991, 2005). The second assumption is that consumers are only interested in the purchase of a single house.[17]

[17] If more than one house is purchased by a consumer, the assumption is that the second (or third house) was purchased for different reasons (i.e. as an investment property or a holiday house). In this case, the transaction would enter the utility function as a separate entry (Rosen, 1974; Palmquist, 1991, 2005).

Individuals select a house that provides them with the highest level of utility. More specifically, each individual's decision involves the maximisation of a utility function:

$U(z_1, z_2, \ldots, z_n, x, \boldsymbol{\alpha})$……(3.4)

where: $\boldsymbol{z}_i$ (i = 1, 2,…,n) = house characteristics.

x = a non–housing numeraire good (Hicksian composite good representing all other goods).

$\boldsymbol{\alpha}$ = socio-economic variables that differ across individuals (Rosen, 1974; Freeman, 1979; Palmquist, 1991, 2005; Sheppard, 1999; Day, 2001).

The utility function is assumed to be strictly concave and is based on the assumptions of completeness, transitivity and continuity[18] (Rosen, 1974; Nicholson, 2004; Palmquist, 1991, 2005).

The utility function is subject to the individual's budget constraint:

$y = P(\boldsymbol{z}) + x$……..(3.5)

where: y = an individuals normalised income (Rosen, 1974; Palmquist, 1991, 2005; Sheppard, 1999; Day, 2001; Freeman, 2003).

In Equation 3.5 normalisation of prices and income is achieved by dividing by the price of x (Rosen, 1974; Palmquist, 1991, 2005; Sheppard, 1999; Day, 2001; Freeman, 2003). Maximisation of the utility function (Equation 3.4) subject to the budget constraint (Equation 3.5) can be achieved by using the Lagrangian multiplier technique (Nicholson, 2004). The Lagrangian function is specified as follows:

$L = U(z_1, z_2, \ldots, z_n, x, \boldsymbol{\alpha}) + \lambda\,(y - x - P(\boldsymbol{z}))$……..…..(3.6)

[18] The assumption of completeness means that individuals are fully aware of the options available to them (Nicholson, 2004). The transitivity assumption states that an individual's choices are internally consistent (Nicholson, 2004). The assumption of continuity allows the researcher to analyse individuals' responses to small changes in income and prices (Nicholson, 2004).

The first order conditions are:

$\frac{\partial L}{\partial z_i} = U_{z_i} - \lambda P_{z_i} = 0 \qquad i = 1, 2, \ldots, n$ ……(3.7)

$\frac{\partial L}{\partial x} = U_x - \lambda = 0$ ……(3.8)

$\frac{\partial L}{\partial \lambda} = y - x - P(\boldsymbol{z}) = 0$ ……(3.9)

where: U_{z_i} = the partial derivative of the utility function with respect to characteristic z_i.

U_x = the partial derivative of the utility function with respect to the non-housing numeraire good.

P_{z_i} = the marginal implicit price of characteristic z_i (Rosen, 1974; Nicholson, 2004).

By rearranging Equations 3.7 and 3.8 (in order to eliminate Lambda) the condition necessary for utility maximisation is revealed - the marginal rate of substitution between a characteristic and the numeraire must be equated to the marginal implicit price of the characteristic for optimal choice:

$U_{z_i}/U_x = p_{z_i}(z_i;\boldsymbol{z}_{-i})$ ……(3.10)

This condition can be further illustrated by introducing Rosen's (1974) bid function. The slope of the bid function is the ratio of the marginal utilities from the utility function (U_{z_i}/U_x). Consider the utility function for a housing characteristic, z_1, and the numeraire good, x. This utility function is implicitly defined as:

$u = U(z_1, z_2, \ldots, z_n, x, \boldsymbol{\alpha})$ ……(3.11)

The utility function is also consistently increasing in the numeraire good, x (Rosen, 1974; Palmquist, 1991, 2005; Day, 2001). Therefore, $u = U(z_1, z_2, \ldots z_n, x, \boldsymbol{\alpha})$ can be inverted to arrive at:

$x(\boldsymbol{z}, u, \boldsymbol{\alpha})$ ……(3.12)

In this form, the utility function indicates how much a household with characteristics, $\boldsymbol{\alpha}$, must spend on the numeraire good, x, in order to achieve the level of utility, u, in a house with characteristics, $\boldsymbol{z}$ (Day, 2001).

Recall that households' choices are constrained by their income. The bid can be defined as:

$\theta = y - x$……..……(3.13)

The bid function, θ, is thus implicitly defined as:

$U(y - \theta, z_1, z_2, \ldots, z_n; \boldsymbol{\alpha}) = u$……...…….……..……..….(3.14)

where: $\theta = \theta(\boldsymbol{z}, u, y, \boldsymbol{\alpha})$.

The bid function represents the maximum amount that an individual would be willing to pay for a house with the characteristics, $\boldsymbol{z}$, in order to achieve utility, u, with a limited income, y (Rosen, 1974; Bartik, 1987; Day, 2001).

Implicitly differentiating Equation 3.14 results in the following:

$\theta_{z_i} = U_{z_i}/U_x > 0$……...(3.15)

$\theta_u = -1/U_x < 0$……..……..….(3.16)

$\theta_y = U_x/U_x = 1$…….…….....(3.17)

$\theta_{z_i z_i} = U_{z_i z_i} U_x^2 - 2U_{z_i x} U_{z_i} U_x + U_{xx} U_{z_i}^2 < 0$…….…...(3.18)

Equations 3.15, 3.16, 3.17 and 3.18 imply that the bid function is increasing in z_i although at a diminishing rate and is governed by the properties of the utility function (Rosen, 1974; Day, 2001; Coulson, 2008). More specifically, Equation 3.15 indicates that the bid will increase following an increase in the characteristic z_i (holding income and utility constant) (Rosen, 1974; Palmquist, 2005; Coulson, 2008). The slope θ_{z_i} is comparable to the utility maximising condition of equating the marginal rate of substitution between two goods with the ratio of the goods' prices (Nicholson, 2004). Equation 3.16 reveals that if income and characteristic z_i are held constant, the only way for an individual to increase utility is to increase consumption of good x. This implies a lower bid ($\theta = y - x$) (Rosen, 1974; Day, 2001; Palmquist, 2005; Coulson, 2008). Equation 3.17 states that if utility levels and good x are held constant, any increase in income must result in a rand-for-rand increase in the bid (Rosen, 1974; Palmquist, 2005; Coulson, 2008). Equation 3.18 shows that the marginal bid for z_i decreases as the quantity of z_i increases (Rosen, 1974; Palmquist, 2005; Coulson, 2008).

The above discussion can be represented graphically. Figure 3.3 displays indifference curves for a housing characteristic, z_1, and the numeraire good, x, along with the corresponding bid functions.

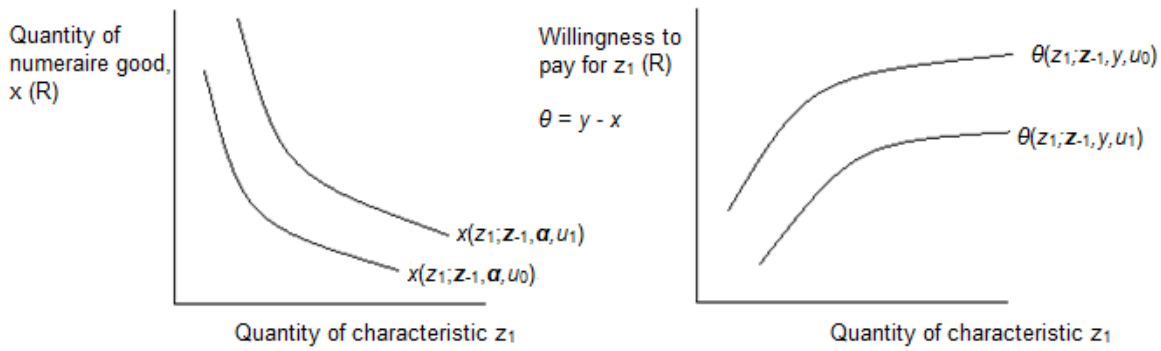


Figure 3.3: Indifference curves and the bid function
Source: adapted from Day (2001)

In Figure 3.3, the left hand panel displays a set of indifference curves, showing combinations of z_1 and x that generate the same level of utility. The slope of the indifference curve ($-U_{z_1}/U_x$) indicates the marginal rate of substitution between characteristic z_1 and x (Day, 2001; Nicholson, 2004; Coulson, 2008). The right hand panel displays the corresponding bid functions which still define indifference relationships. The bid curves depict combinations of house characteristic z_1 and respective payments for which the individual is indifferent. The slope of the bid function is identical to the slope of the indifference curve, but with the opposite sign (U_{z_1}/U_x). This ratio represents the condition necessary for optimal housing location (as per Equation 3.10).

Utility is maximised where the slope of the hedonic price function is equal to the slope of the bid function (the point of tangency). This can be seen in Figure 3.4, which displays the classic Rosen (1974) diagram.

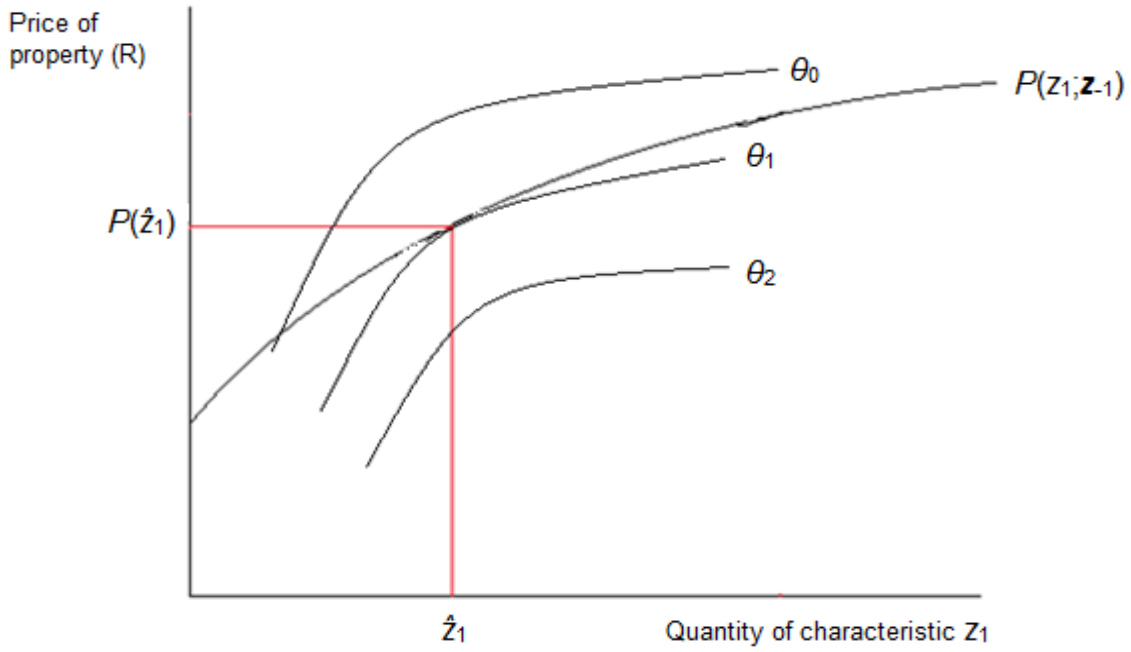


Figure 3.4: The hedonic price function and bid functions
Source: adapted from Rosen (1974)

Figure 3.4 displays one housing characteristic, z_1 (the others are held constant) on the x-axis and house prices on the y-axis. Line $P(z_1;\mathbf{z}_{-1})$ represents the equilibrium hedonic price function.[19] Individual bid functions are also shown in Figure 3.4. The individual bid function depends on the preferences and income of an individual. For example, an individual represented by bid function θ_1, would be willing to pay $P(\hat{z}_1)$ for the house with a level of the particular attribute at $\hat{z}_1$. At this point of tangency, the marginal rate of substitution between the house characteristic and the composite good is equal to the marginal implicit price of the characteristic (i.e. this individual is maximising utility) (Rosen, 1974; Palmquist, 1991, 2005; Sheppard, 1999; Day, 2001; Freeman, 2003; Coulson, 2008). Bid contour θ_0 represents a lower level of utility and bid contour θ_2 represents a higher level of utility. These bid contours would differ for different individuals, as the bid contours are determined by income and other socio-economic characteristics (Rosen, 1974; Palmquist, 1991, 2005; Freeman, 2003). The utility maximisation process (with the budget constraint) can also be shown in Figure 3.5.

[19] Typically, this is concave in nature, reflecting the diminishing returns associated with a particular attribute, although linear or convex hedonic price functions are not impossible (Palmquist, 2005).

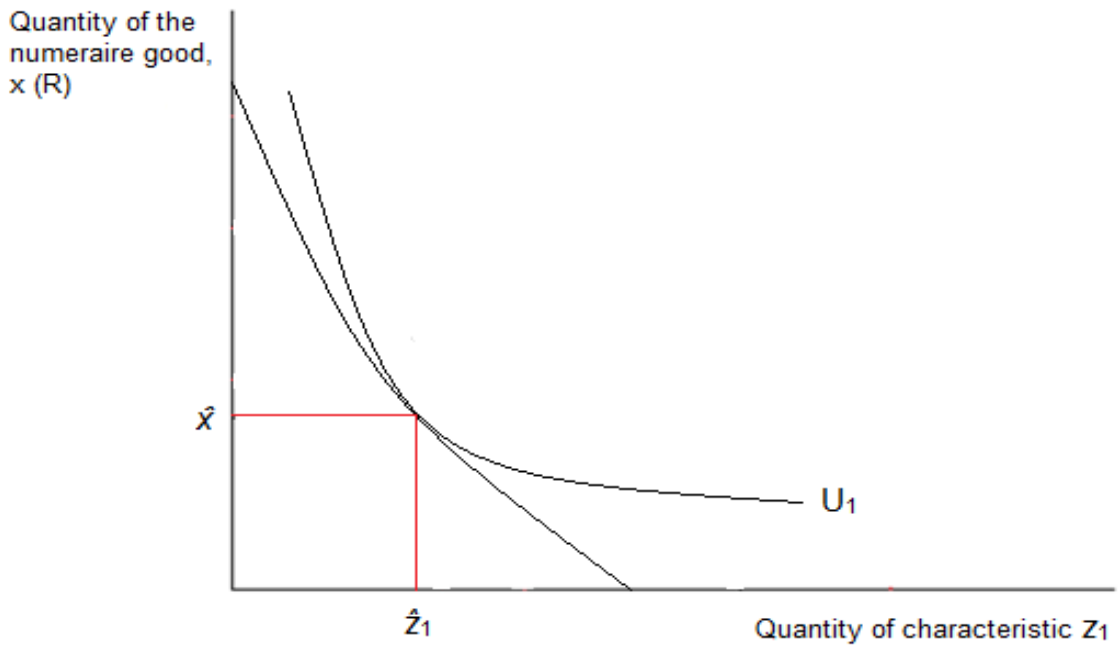


Figure 3.5: Utility maximisation
Source: adapted from Palmquist (2005)

In Figure 3.5, the marginal rate of substitution (of the house characteristic for the non-housing numeraire good) is equal to the slope of the budget constraint. At this point of tangency, utility is at its maximum (Day, 2001; Nicholson, 2004; Palmquist, 2005).

3.2.1.3 THE THEORY OF DEMAND CURVE ESTIMATION IN HEDONIC PRICE MODELS

The second stage of the hedonic analysis entails estimating the underlying demands for the housing characteristics (Rosen, 1974; Sheppard, 1999; Day, 2001; Freeman, 2003; Coulson, 2008). This step has proven to be challenging due to issues surrounding identification and endogeneity (Palmquist, 1991, 2005; Brown & Rosen, 1982; Mendelsohn, 1987; Haab & McConnell, 2002). These issues are discussed in greater detail in Sections 3.2.4.1.1 and 3.2.4.1.2, respectively.

In terms of demand estimation, it was suggested by Rosen (1974) that the marginal willingness to pay function, hereafter referred to as the MWTP function (which depends on the level of utility but not income), is the inverse compensated demand function (which depends on income but not utility) (Rosen, 1974; Palmquist, 1991, 2005; Sheppard, 1999; Day, 2001; Coulson, 2008). The MWTP function is the partial derivative of the bid function and indicates how much an individual is willing to pay for an additional unit of a characteristic, so as to maintain the same level of utility (Rosen, 1974; Palmquist, 1991, 2005; Day, 2001; Coulson, 2008).

This is given by:

$$b_{z_i}(z_i, \boldsymbol{z}_{-i}, \boldsymbol{\alpha}, u) = \frac{\partial(z,y,\alpha,u)}{\partial z_i} \quad \text{.....(3.19)}$$

Equation 3.19 is also the inverse compensated demand function (Rosen, 1974; Day, 2001; Freeman, 2003). In equilibrium, the implicit price of characteristic z_i is equated to the MWTP function (Palmquist, 1991, Day, 2001; Freeman, 2003). This can be seen by examining Figure 3.6.

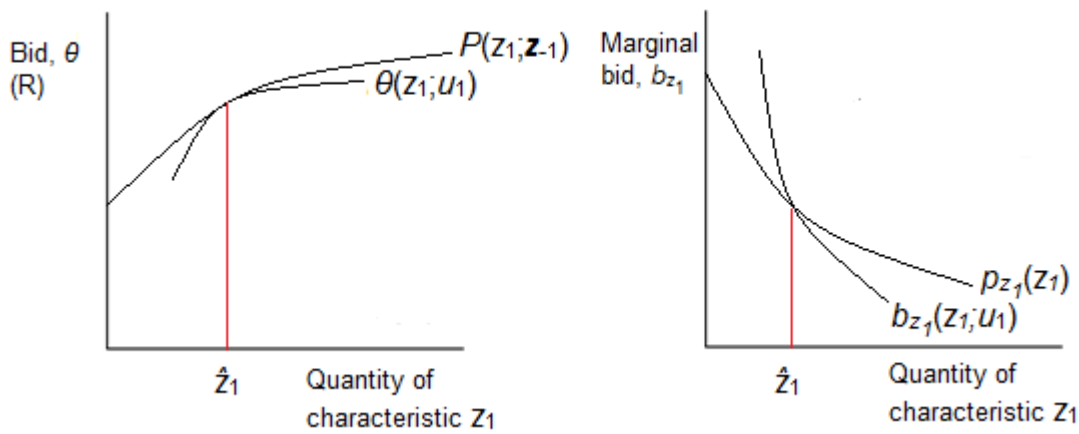


Figure 3.6: Optimal characteristic levels using the hedonic price function and the corresponding MWTP function
Source: adapted from Day (2001)

The left hand panel in Figure 3.6 displays the hedonic price function and the bid function. The right hand panel displays the corresponding marginal implicit price function and the MWTP function. As is evident from the panel on the right, an individual selects $\hat{z}_1$ units of characteristic z_1 (where the marginal implicit price curve intersects the MWTP function). At levels lower than $\hat{z}_1$ the MWTP is greater than the marginal implicit price and at levels higher than $\hat{z}_1$ the opposite is true. This analysis results in a measure of the price and the MWTP for z_i. Although this provides some information on the MWTP function, it does not directly reveal the function (Freeman, 2003; Day, 2001). The MWTP function (the inverse compensated demand curve) is revealed in the second stage of the hedonic analysis by using information on the marginal implicit prices (Palmquist, 1988, 1991; Day, 2001; Freeman, 2003). However, any number of curves could pass through the equilibrium point depicted in Figure 3.6 (Brown & Rosen, 1982; Murray, 1983; McConnell & Phipps, 1987). The identification of the MWTP function is thus dependent on knowing an individual's marginal bids at different levels of z_i (Day, 2001). The alternative to this is to obtain data

from a variety of markets (Day, 2001). Estimating the MWTP function using different markets requires the researcher to estimate separate hedonic price functions in each market (Day, 2001). Ideally, the households in each separate market should have similar incomes and socio-economic characteristics (Day, 2001). Different demand and supply conditions will lead to different marginal implicit prices for a specific characteristic. From this, the inverse uncompensated demand function can be estimated:

$b^d{}_{z_i}(z_i;y)$……..……(3.20)

The inverse uncompensated demand function is observed in market behaviour whereas the inverse compensated demand function is not (Day, 2001). However, these two functions will be very similar (Willig, 1976; Day, 2001). The two functions will be identical in the presence of linear hedonic price functions and quasilinear preferences (Day, 2001). Due to the similarities of the two functions, the inverse uncompensated demand function provides a good approximation of the MWTP function and is thus used to evaluate the welfare effects of changes in characteristics (Day, 2001). This discussion has assumed that the hedonic price function is linear and thus marginal implicit prices for characteristics are constant. This is often not the case and it is impossible to derive the inverse uncompensated demand curve in the traditional manner when the hedonic price function is non-linear (Day, 2001). More specifically, a regression of marginal implicit prices against the characteristic of choice, other characteristics, and income will not yield a downward sloping uncompensated demand curve (Day, 2001).

Fortunately, it is possible to derive the uncompensated inverse demand function for a characteristic by linearising the budget constraint around the optimal choice of characteristics (Murray, 1983; Palmquist, 1988, 2005). The linearised budget constraint is defined by constant marginal implicit prices and a mythical income[20] (Murray, 1983; Day, 2001; Palmquist, 2005). Effectively, the bundle of housing characteristics chosen by an individual facing a non-linear hedonic price function would be identical to the bundle chosen with the mythical income facing a linear hedonic price function (Hall, 1973; Murray, 1983; Palmquist, 1988, 2005; Day, 2001). Thus, by linearising the budget constraint the inverse uncompensated demand curve can be derived. The derivation of the linearised budget constraint is illustrated in Figure 3.7.

[20] Mythical income is also referred to as hypothetical income.

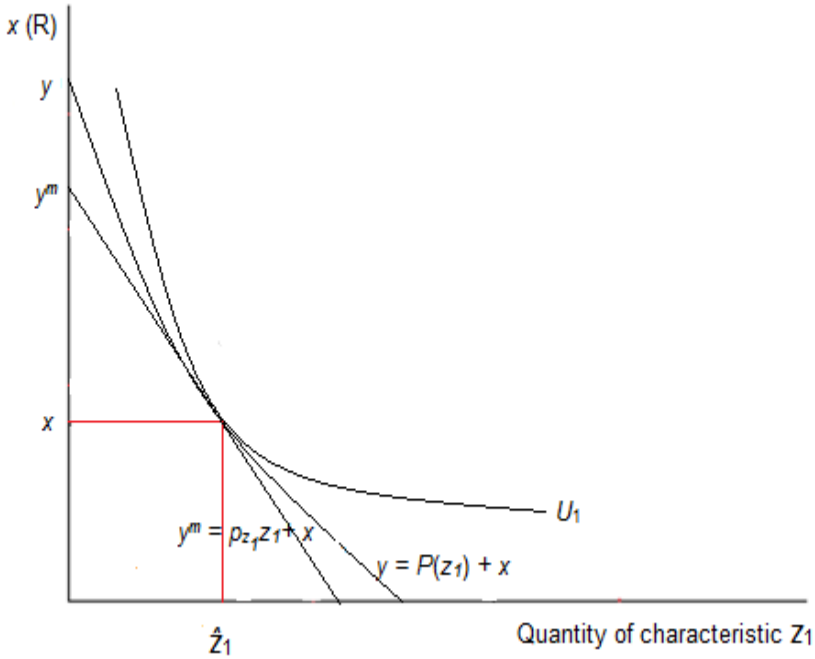


Figure 3.7: Linearising the budget constraint
Source: adapted from Palmquist (2005)

In Figure 3.7, an individual with a non-linear budget constraint depicted by $y = P(z_1) + x$ selects a house with $\hat{z}_1$ units of characteristic z_1. This is where the budget constraint is tangent to the utility function. If it is imagined that the implicit price associated with this optimal choice was constant (i.e. resulting from a linear hedonic price function) it is possible to construct a linear budget constraint tangent to the utility function with a slope of $\hat{p}_{z_1}$ (Murray, 1983; Day, 2001). The intercept of this mythical budget constraint is the individual's mythical income (y^m in Figure 3.7) (Murray, 1983; Day, 2001). The mythical income is calculated according to the following:

$$y^m = y - P(\hat{\boldsymbol{z}}) + \sum_{i=1}^{n} \hat{p}_i \hat{z}_i \qquad (3.21)$$

Following this, it is now possible to estimate the inverse uncompensated demand curve by regressing the marginal implicit prices against the quantities of z_1, other characteristics and the calculated mythical income (Day, 2001; Palmquist, 2005). This is given by the following:

$$\hat{p}_{z_1} = b_{z_1}(\hat{z}_1, \hat{\boldsymbol{z}}_{-1}, y^m, \boldsymbol{\alpha}) \qquad (3.22)$$

From the inverse demand curve, welfare estimates can be calculated.[21]

3.2.2 THEORY OF HEDONIC WELFARE MEASUREMENT

This section addresses the issue of how information on prices and preferences, extracted from the hedonic price function, can be used to provide aggregate welfare measurements when changes in housing characteristics or environmental amenities take place.

Measuring welfare changes in hedonic price models is difficult due to the adjustments that property owners and suppliers are likely to make in response to changes in house characteristics (Bartik & Smith, 1987; Bartik, 1988; Palmquist, 1988; Day, 2001; Freeman, 2003). Effectively, the main goal of hedonic analyses is to establish what these changes do to the overall well-being of property owners and suppliers (Bartik & Smith, 1987; Bartik, 1988; Palmquist, 1988; Day, 2001; Freeman, 2003). Household well-being is defined in terms of utility and supplier well-being is defined in terms of profits. From the supplier point of view, changes in welfare due to changes in environmental characteristics can be evaluated in terms of changes in profits (Δ Prof). In terms of households, the change in utility following a change in characteristics would allow one to evaluate welfare effects. Unfortunately, it is not possible to ask households how their utility has changed following a change in characteristics (Bartik & Smith, 1987; Bartik, 1988; Palmquist, 1988; Day, 2001; Freeman, 2003). Thus, in order to evaluate household welfare changes a monetary compensating measure (which takes the household's current utility as the baseline) must be employed (Bartik & Smith, 1987; Bartik, 1988; Palmquist, 1988; Day, 2001; Freeman, 2003). The two monetary compensating measures are WTP and WTA. The former measure is used when an environmental improvement takes place and the latter measure is used when there is a reduction in environmental quality (Bartik, 1988; Day, 2001; Freeman, 2003).

The nature of the environmental change will also influence the way welfare effects are estimated. Broadly speaking, environmental changes can be classified as localised or non-localised (Palmquist, 1992; 1988; 2005; Day, 2001; Freeman, 2003). If the change affects a large part of the market, then one could conclude that the environmental change is non-localised in nature (for example, air pollution). This would result in a shift in the hedonic price function (as many sub-markets will be affected) (Bartik, 1988; Palmquist, 1988, 2005; Day, 2001). Alternatively, the environmental change may only have an effect on a small section

[21] However, in many cases, the second stage simply mirrors the first stage. This is known as the identification problem (Brasington & Hite, 2005). For this reason, many researchers have abandoned the second stage (demand curve estimation) and welfare estimates are inferred from the actual hedonic price function (Haab & McConnell, 2002).

of the entire market (for example, proximity to a social housing development). In this case, the environmental change is not large enough to affect the market clearing marginal implicit prices and the hedonic price function remains unchanged (Bartik, 1988; Palmquist, 1992; 2005; Day, 2001; Freeman, 2003).

Another issue that deserves consideration is the response of individuals when facing an environmental change. Individuals have two options: they can choose to remain in their current dwelling, or they can choose to re-locate (Bartik & Smith, 1987; Bartik, 1988; Palmquist, 1992; 2005; Day, 2001; Freeman, 2003). Factors that individuals consider when facing these options include moving costs and time considerations (Bartik & Smith, 1987; Bartik, 1988; Palmquist, 1992; 2005; Day, 2001; Freeman, 2003).

Since the changes discussed above are non-excludable and nondepletable, this effectively means that these changes are public goods (Bartik & Smith, 1987; Freeman, 2003). The desirability of these changes can be evaluated by comparing the marginal cost of the change with the marginal value. The marginal value is the sum of each affected individual's MWTP at the existing housing equilibrium (Bartik & Smith, 1987; Bartik, 1988; Palmquist, 1988; Freeman, 2003). Thus, for characteristic z_i, the aggregate marginal welfare change (w_{z_i}) is given by (where the subscript j represents the jth individual's MWTP):

$$w_{z_i} = \sum_{j=1}^{n} b_j = \sum_{j=1}^{n} \left(\frac{\partial P(\boldsymbol{z})}{\partial z_i}\right)_j \qquad (3.23)$$

The marginal benefit estimates derived from Equation 3.23 are relatively simple to calculate (Freeman, 2003).

3.2.2.1 HOUSEHOLD WELFARE CHANGES FROM A LOCALISED AMENITY IMPROVEMENT

In the case of a change in a localised amenity, where the number of sites affected is small relative to the total size of the market, the hedonic price function does not shift (Bartik & Smith, 1987; Palmquist, 1992). The estimation of the MWTP function is not required and benefits can be measured by the change in property prices from the hedonic price function (Palmquist, 1992). For the purposes of illustrating this, consider two hedonic price functions denoted by $P^b(\boldsymbol{z})$ and $P^a(\boldsymbol{z})$, respectively. The hedonic price function, $P^b(\boldsymbol{z})$ represents the equilibrium function before any amenity improvements take place and $P^a(\boldsymbol{z})$ represents the situation after any amenity changes have taken place (Day, 2001). If the amenity change is

too small to cause a shift of the hedonic price function, $P^b(\boldsymbol{z}) = P^a(\boldsymbol{z})$. This can be seen in Figure 3.8.

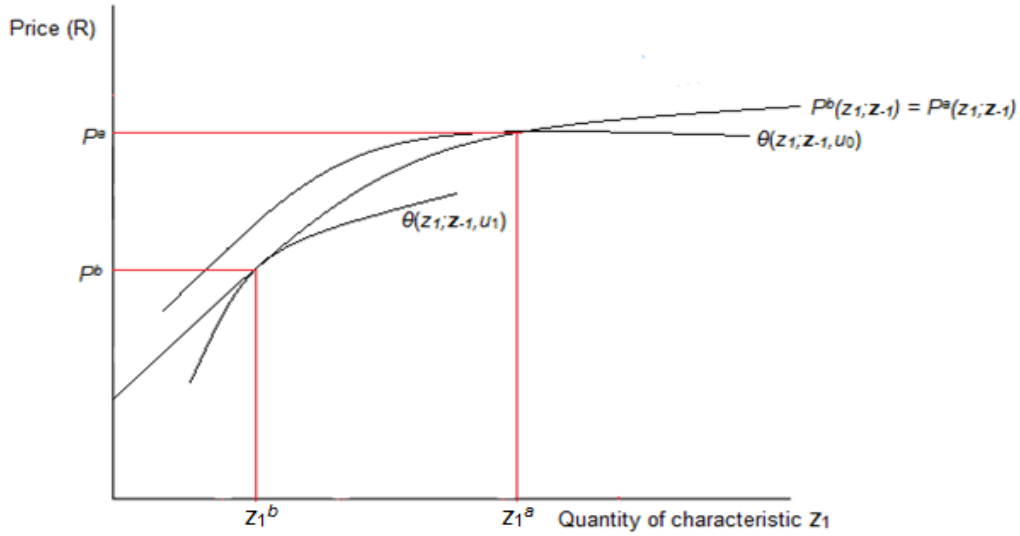


Figure 3.8: An amenity improvement when the hedonic price function remains unchanged
Source: adapted from Day (2001)

Figure 3.8 focuses on just one property in the area experiencing an amenity improvement. The initial level of characteristic z_1 is represented by z_1^b and the property commands a price of P^b. At this level of z_1^b and price of P^b the bid function is tangent to the hedonic price function and utility is maximised (Palmquist, 1988, 2005; Day, 2001; Freeman, 2003). Assume that characteristic z_1 increases from z_1^b to z_1^a. This leads to an increase in the price of the house from P^b to P^a. The owner of the property experiences an increase in wealth due to the change in characteristic z_1. However, if the individual occupying the house is renting it then he or she is made worse off due to the increase in rent associated with the increase in the house price (Palmquist, 1988; 1992; 2005; Day, 2001; Freeman, 2003). Continuing to occupy the house (now associated with z_1^a units of characteristic z_1) leads to a reduction in utility for the renter from u_1 to u_0. However, if moving is costless, the occupant could simply move to a house associated with the original level (z_1^b). Such a move would return the individual to the original level of utility. In this case, the increase in wealth experienced by the owner is the net welfare change. The result is exactly the same if the occupant owns the house (Palmquist, 1988; 1992; 2005; Day, 2001; Freeman, 2003).

The assumption of costless moving may not be realistic. Relocating to a new house often involves costs which may be substantial. The household needs to evaluate whether the benefits of moving (thus increasing utility) outweigh the costs of moving. If this is the case, then the household will choose to relocate and the net welfare effect will be the increase in

wealth to the owner minus the relocation costs incurred by the occupant (Palmquist, 1988, 2005; Day, 2001; Freeman, 2003). If, however, the costs of moving outweigh the benefits of moving, the household will decide to stay and suffer a loss of utility. In this case, the relocation costs represent an upper bound on the welfare loss incurred by the occupant (Palmquist, 1988; 1992; 2005; Day, 2001; Freeman, 2003).This analysis is conditional upon being able to quantify relocation costs. If this is not possible, then welfare changes must be calculated by using the underlying bid functions (Bartik, 1988).

3.2.2.2 HOUSEHOLD WELFARE CHANGES FROM A NON-LOCALISED AMENITY IMPROVEMENT WITH NO ADJUSTMENT

When the change in the environmental characteristic is sufficiently large and extensive, a significant change in the vectors of the housing characteristics takes place (Bartik & Smith, 1987; Bartik, 1988; Palmquist, 1988; 1992; 2005; Day, 2001; Freeman, 2003). At least some people are now out of equilibrium and efforts to restore equilibrium will result in the formation of a new hedonic price function and marginal implicit prices (Bartik & Smith, 1987; Bartik, 1988; Palmquist, 1988; 1992; 2005; Day, 2001; Freeman, 2003). Welfare measurement is now more complex than in the case of localised changes where the hedonic price function remains unchanged (Bartik & Smith, 1987; Bartik, 1988; Palmquist, 1988; 1992; 2005; Day, 2001; Haab & McConnell, 2002; Freeman, 2003).

When a major environmental change takes place, many households may choose to relocate. However, this is not always the case and households may find it beneficial to remain in their current residences (Palmquist, 2005). If the transaction and moving costs are greater than the benefit of moving, then households tend to remain in their original location. This can also be viewed as a short-run scenario (Bartik & Smith, 1987). This situation is depicted in Figure 3.9.

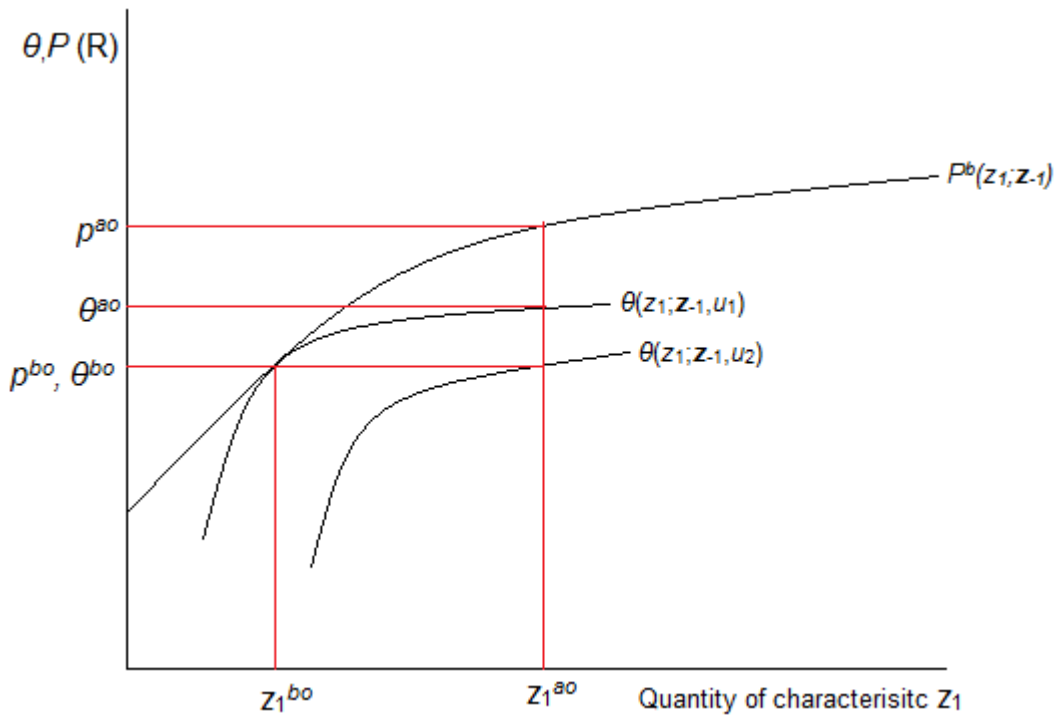


Figure 3.9: The quantity compensating surplus measure
Source: adapted from Day (2001)

In Figure 3.9 the original equilibrium level is located at the point of tangency between the original hedonic price function, $P^b(z_1;\mathbf{z}_{-1})$ and the original bid curve, $\theta(z_1;\mathbf{z}_{-1},u_1)$. At this point, z_1^{bo} units of z_1 are enjoyed and the price of the house is at P^{bo} (the superscript *bo* refers to the situation before the improvement takes place at in the individual's original house). Assume an exogenous improvement in z_1, from z_1^{bo} to t z_1^{ao}, takes place. Since this change represents a non-localised improvement, one would expect a shift of the hedonic price function. However, assuming that the individual chooses not to relocate (and further assuming that landlords do not increase the rental price at the original location), the individual continues to face the original hedonic price function (Bartik, 1988; Day, 2001). This effectively means that the individual now enjoys the new level of characteristic z_1, but continues to pay for the old level. The individual enjoys an increase in utility from u_1 to u_2. In this case the compensating measure is the individual's WTP to experience this increase in utility. This amount is known as the quantity compensating surplus (*QCS*) and is the vertical distance between the two bid functions at the new level (Bartik, 1988; Palmquist, 1988; Day, 2001; Freeman, 2003). Mathematically it is represented by:

$$QCS = \theta(z_1^{ao};\mathbf{z}_{-1}^{bo},y,\boldsymbol{\alpha},u_1) - \theta(z_1^{bo};\mathbf{z}_{-1}^{bo},y,\boldsymbol{\alpha},u_1) \quad (3.24)$$

This welfare measure only applies to households that are affected by the environmental change (since there are no adjustments in the market) (Bartik, 1988; Day, 2001). By summing these surpluses across all affected households, the total welfare effect (W_H) of the change in z_1 can be calculated:

$$W_H = \sum_{h \in H_1} QCS = \sum_{h \in H_1} \theta(z_{1_h}{}^{ao}; \boldsymbol{z}_{-1_h}{}^{bo}, y, \boldsymbol{\alpha}, u_{1_h}) - \theta(z_{1_h}{}^{bo}; \boldsymbol{z}_{-1_h}{}^{bo}, y, \boldsymbol{\alpha}, u_{1_h}) \quad (3.25)$$

Another method of deriving the *QCS* from an increase in an environmental amenity from z_1^b to z_1^a is by summing the area under each household's MWTP curve over the change in z_1 (Horowitz, 1984; Bartik & Smith, 1987; Freeman, 2003). More formally:

$$W_H = \sum_{h=1}^{n} \int_{z_1^{bo}}^{z_1^{ao}} b_h(z_{1_h}, \boldsymbol{z}_{-1_h}, u_h) dz_1 \quad (3.26)$$

This welfare measure requires information on the MWTP functions of individuals (Horowitz, 1984; Bartik & Smith, 1987; Freeman, 2003). Using the second stage uncompensated bid functions lead to an overestimate of the welfare gains associated with an increase in z_1 (Horowitz, 1984; Bartik & Smith, 1987; Freeman, 2003). However, there is a method for calculating exact welfare measures for non-marginal changes in z_1, holding all else constant (Horowitz, 1984; Bartik & Smith, 1987; Freeman, 2003). In order to illustrate this method, suppose that an individual, *j*, has an uncompensated demand curve for z_1, represented by:

$$b_j = b_j(z_1, \boldsymbol{z}_{-1}, y - P(\boldsymbol{z})) \quad (3.27)$$

In equilibrium, using the indirect utility function:

$$\frac{(\partial v/\partial z_1)}{(\partial v/\partial y)} = b_j(\cdot) \quad (3.28)$$

and for individual *j*:

$$b_j = \frac{\partial P(\boldsymbol{z})}{\partial z_1} \quad (3.29)$$

In Equation 3.28, the left hand side represents the slope of the indifference curve between *y*, z_1 and the numeraire (Horowitz, 1984; Bartik & Smith, 1987; Freeman, 2003).

Therefore, in equilibrium:

$$\frac{dy}{dz_1} = b_j(\cdot) = \left(\frac{\partial P(z)}{\partial z_1}\right)_j \quad \text{.....(3.30)}$$

Equation 3.30 can then be solved for (where C is a constant of integration):

$$y = f(z_1, \boldsymbol{z}_{-1}, C) \quad \text{.....(3.31)}$$

The benefit increase of an increase in z_1 is then represented by:

$$W_H = f(z_1^b, \boldsymbol{z}_{-1}, C) - f(z_1^a, \boldsymbol{z}_{-1}, C) \quad \text{.....(3.32)}$$

The welfare estimates for a non-marginal change in an amenity require the researcher to identify either the compensated demand function (MWTP function) or the uncompensated demand function (Bartik & Smith, 1987; Bartik, 1988; Freeman, 2003). If neither of these functions can be identified, welfare estimates are still possible by making certain assumptions about the shape of each household's MWTP curve (Bartik & Smith, 1987; Bartik, 1988; Freeman, 2003). To this end, there are three options available. The first option is to assume that the MWTP function is a horizontal line passing through the utility maximising point (i.e. the assumption of constant MWTP) (Bartik & Smith, 1987; Bartik, 1988; Freeman, 2003). In this case, a household's welfare estimate for a change in an amenity is the constant MWTP multiplied by the change in the amenity level. By summing these values over all affected individuals, an aggregate welfare estimate can be obtained (Bartik & Smith, 1987; Bartik, 1988; Freeman, 2003). The second option is to assume a linear MWTP function (Bartik & Smith, 1987; Bartik, 1988; Freeman, 2003). The assumption is that each individual's MWTP decreases linearly from the identified point to the maximum attainable level of the amenity. Here, the MWTP would be zero (Bartik & Smith, 1987; Bartik, 1988; Freeman, 2003). The third option is to assume that all individuals have the same income and preferences. In this case, the marginal implicit price function is itself the inverse demand function (Bartik & Smith, 1987; Bartik, 1988; Freeman, 2003).

3.2.2.3 HOUSEHOLD WELFARE CHANGES FROM A NON-LOCALISED AMENITY IMPROVEMENT WITH ADJUSTMENT

In the case where an improvement in a non-localised amenity takes place and moving occurs, welfare analysis becomes extremely complex (Palmquist, 2005). One approach is to look at marginal changes in amenities (even though these changes may take place over a

large area) (Bartik & Smith, 1987). The benefits of marginal amenity improvements have been shown to equal the marginal willingness to pay for the improvement at each improved site (Bartik & Smith, 1987). This implies that at any location, the integral of a series of extremely small (marginal) changes in the amenity will generate a value of a non-marginal change (Bartik & Smith, 1987; Freeman, 2003). Each occupant's willingness to pay is the value of each small change and the sum of the values for each site generates the value for all sites (Bartik & Smith, 1987; Freeman, 2003). This is given by Equation 3.33:

$$W_h = \sum_{j=1}^{n} \int_{z_1^b}^{z_1^a} [\partial P(z_1, \mathbf{z}_{-1})/\partial z_1] dq_j \quad (3.33)$$

where: $\mathbf{z}_{-1}$ = vector of all other site characteristics (constant by assumption).

j = index for locations.

This measure allows individuals to move in response to amenity changes, as it sums individuals' marginal values as the amenity is changed at each site (Bartik & Smith, 1987; Freeman, 2003). This measure can be calculated with the hedonic price function alone as each occupant's marginal willingness to pay will be equal to the marginal implicit price of the characteristic (Bartik & Smith, 1987). For this reason, knowledge of the MWTP function is not required (Bartik & Smith, 1987).

However, because the change in the amenity level is not negligible and thus causes the hedonic price function to shift, it is necessary to investigate how the hedonic price function and the marginal implicit prices change at each location as the amenity levels change (Bartik, 1988). This is a limitation of the measure described by Equation 3.33 and has prompted researchers to look for practical ways in which to measure upper or lower bounds on true welfare measures (Bartik, 1988; Freeman, 2003). Much of the progress in this regard can be attributed to Bartik (1988). Suppose that an urban area experiences a non-localised increase in an environmental amenity, where the characteristic z_1 increases from z_1^b to z_1^a. The immediate welfare effects experienced by individuals who do not move can be represented by Equation 3.25. In this case, W_H can be interpreted as a lower bound on the true measure as this does not capture welfare changes of individuals who decide to choose a different bundle of characteristics (assuming that by doing so, they perceive themselves to be better off) (Bartik, 1988; Freeman, 2003). However, the hedonic price function is likely to shift as individuals adjust to different characteristics bundles. Figure 3.10 presents this process.

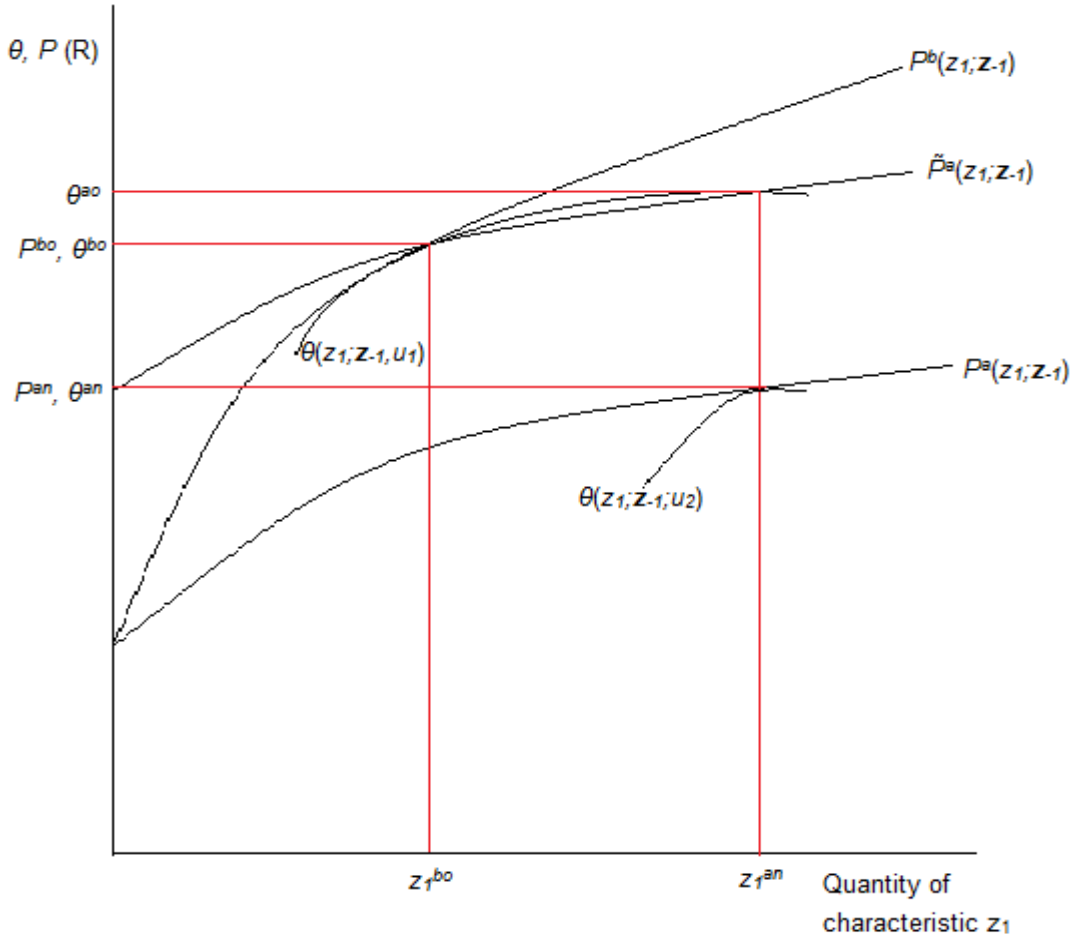


Figure 3.10: The compensating surplus measure
Source: adapted from Day (2001)

Figure 3.10 presents the scenario where a single household experiences a non-marginal change in an environmental characteristic (z_1). Initially (before the change takes place) the household maximises utility where the original hedonic price function ($P^b(z_1;\mathbf{z}_{-1})$) is tangent to the bid curve ($\theta(z_1;\mathbf{z}_{-1},u_1)$). At this point, the household enjoys z_1^{bo} units of characteristic z_1 (the superscript *bo* represents the situation before the change takes place at the original location). Following a non-localised, market-wide improvement in characteristic z_1 (from z_1^{bo} to z_1^{an}) the hedonic price function shifts downward (from $P^b(z_1;\mathbf{z}_{-1})$ to $P^a(z_1;\mathbf{z}_{-1})$). This downward shift has reduced the price of a property at any level of z_1. This is due to the fact that the increased supply of environmental quality in the market necessitates a reduction in the price per unit of the environmental quality across the entire market (Bartik, 1988; Day, 2001). The household now relocates to a new property where the new hedonic price function is tangent to the bid curve ($\theta(z_1;z_{-1},u_2)$). The household is made better off by this move. The compensating measure in this case is the amount of money that the household would be willing to pay to achieve this new level of utility and is given by the vertical distance between

the new hedonic price function and the original bid curve at the new level of z_1. This is known as the compensating surplus (*CS*) (Bartik, 1988).

The compensating surplus can be broken up into two separate components: the first component is the difference in WTP (ΔWTP) to achieve the new level of utility, at the original and new location[22] and the second component is the change in rent associated with the move (ΔP). Mathematically, the *CS* can be defined as:

$$CS = \Delta\text{WTP} - \Delta\text{P} = \{\theta(z_1^{an},\mathbf{z}_{-1}^{an};u_1) - \theta(z_1^{bo},\mathbf{z}_{-1}^{bo};u_1) - [P^a(z_1^{an},\mathbf{z}_{-1}^{an}) - P^b(z_1^{bo},\mathbf{z}_{-1}^{bo})]\} \quad (3.34)$$

The total welfare gain experienced by all households is given by the sum of the welfare gain experienced by each household in the market:

$$W_H = \sum_{h=1}^{H} CS_H = \sum_{h=1}^{H} \{\theta(z_1^{an},\mathbf{z}_{-1_h}^{an};u_{1_h}) - \theta(z_{1_h}^{bo},\mathbf{z}_{-1_h}^{bo};u_{1_h}) - [P^a(z_{1_h}^{an},\mathbf{z}_{-1_h}^{an}) - P^b(z_{1_h}^{bo},\mathbf{z}_{-1_h}^{bo})]\} \quad (3.35)$$

In addition to the welfare gains experienced by individuals, suppliers of houses may also experience welfare gains in the form of increased profits (due to additional housing expenditure) (Bartik, 1988; Freeman, 2003). There are four reasons why suppliers' profits may change following an improvement in an environmental amenity. First, supplier costs may be affected. For example, a reduction in air pollution may reduce cleaning costs. Second, a change in rent is associated with a change in amenity levels. Third, a shift of the hedonic price function will affect all suppliers (not only the suppliers whose sites were affected). Fourth, suppliers may respond to the new hedonic price function by supplying different combinations of $\mathbf{z}_{-1}$ (Bartik, 1988).

The change in supplier profits, for *N* landlords in a given area, is given by (where C(·) is the producers' cost function):

$$W_L = \Delta\text{Prof} = \sum_{l=1}^{N} [P^a(z_{1_l}^{an}, \mathbf{z}_{-1_l}^{an}) - P^b(z_{1_l}^{bo}, \mathbf{z}_{-1_l}^{bo})] - \sum_{l=1}^{N} [C^a(z_{1_l}^{an}, \mathbf{z}_{-1_l}^{an}) - C^b(z_{1_l}^{bo}, \mathbf{z}_{-1_l}^{bo})] \quad (3.36)$$

The total social benefit of the amenity improvement is given by the sum of Equations 3.35 and 3.36 over all households and landlords (Bartik, 1988).

[22] This is similar to the *QCS* discussed in the previous section.

One of the main limitations of this welfare measure is the vast amounts of data required (Bartik, 1988; Freeman, 2003). The measure requires knowledge of how the hedonic price function has shifted by the change in the amenity, as well as knowledge of how households and landlords react to this shift (Bartik, 1988).

However, if the hedonic price function remains unchanged and producers' costs are not affected, the welfare effect can be captured by Equation 3.25 (Bartik, 1988; Freeman, 2003). Encouragingly, Equation 3.25 can be viewed as the lower bound on the true benefit measure if the hedonic price function does shift. The advantage of using Equation 3.25 as a lower bound on the true welfare measure is that this measure does not require information on how households and landlords adjust (Bartik, 1988; Day, 2001).

The theoretical justification for using Equation 3.25 as a lower bound of the true benefit measure was provided by Bartik (1988), with the true benefit measure being broken down into an imaginary three stage sequence of events. The first stage is to consider an amenity change without any adjustment by consumers or producers. Equation 3.25 plus cost reductions associated with supplying existing houses at affected locations represents the welfare changes associated with this (Bartik, 1988). The second stage is to consider a shifting of the hedonic price function. However, individuals and suppliers are not permitted to make any adjustments in response to the new hedonic price function. Therefore, no net change in welfare takes place at this stage (the price changes sum to zero) (Bartik, 1988). The third stage is to permit consumers and producers to respond to the new hedonic price function. Those responding must be doing so for welfare gains.

The true benefit measure thus consists of four components, namely the WTP of households for the improvement while still at their original site (*QCS*), landlords' cost savings at stage one, the profits that landlords make at stage three and the utility that households gain at stage three (the efficiency benefits at stage two are zero) (Bartik, 1988). Since the *QCS* measure effectively ignores adjustment (and hence the benefits at stage one and three) this is viewed as a lower bound of the true benefit measure (Bartik, 1988). However, this lower bound estimate of the welfare change from an improvement in an environmental amenity is desirable for a number of reasons. First, the *QCS* measure does not require data on how households and landlords adjust to the shifting hedonic price function. Second, since the *QCS* is a household welfare measure, the need to examine the supply side of the market is eliminated. Third, the *QCS* only requires information on affected households (Bartik, 1988; Day, 2001). The accuracy of the *QCS* in measuring these welfare gains is greatest when the

adjustments to the new hedonic price function are small (Bartik, 1988; Day, 2001; Freeman, 2003).

3.2.3 DEFINING AND ESTIMATING THE HEDONIC PRICE FUNCTION

The estimation of a first-stage hedonic price function normally requires the analyst to make certain strategic decisions. These include decisions regarding market specification, the choice of the dependent variable, the selection of explanatory variables, how to address the issues of omitted variable bias and multicollinearity, time considerations, the selection of an appropriate functional form and spatial econometric issues.

3.2.3.1 MARKET SPECIFICATION

Since the hedonic price function represents a market's equilibrium prices, it is essential that the observations used to generate the function come from a single market (Palmquist, 2005). Therefore, it is important to define the market correctly, as an area treated as a single market when in fact it is actually segmented, will result in biased coefficient estimates (Palmquist, 1991; Freeman, 2003). Previous applications of the hedonic price model have defined separate markets from a few blocks apart to a nationwide market (Linneman, 1980; Butler, 1980; Palmquist, 1991). As it is difficult to determine the appropriate market size based on statistical tests, researchers have had to rely on theoretical considerations to provide assistance in defining the components of a market.

For different hedonic price functions to exist in an urban area (i.e. for a market to be considered segmented), two conditions must be met. The first condition is that the supply and demand structure must be heterogeneous across segments (Freeman, 1979, 2003; Palmquist, 1991). Either the structure of the characteristics of the actual housing units must differ or buyers must have different demand structures (Freeman, 1979, 2003; Palmquist, 1991). The second condition is that there must be minimal cross participation of buyers between the segments (Freeman, 1979, 2003; Palmquist, 1991). The second condition is only possible if there are certain barriers present (for example, geographical barriers, discrimination, or lack of information). These barriers prevent individuals in one segment from participating in the other, and therefore prevent arbitrage from occurring in the presence of different marginal implicit prices (Freeman, 1979, 2003; Palmquist, 1991). Conversely, perfect mobility on the part of buyers will eliminate differences in marginal implicit prices (Freeman, 1979, 2003; Palmquist, 1991). High moving and information costs lead to segmented markets between cities. The presence of discrimination may lead to segmented markets within cities (Palmquist, 1991). However, an individual's refusal to move to a different part of a city (based on racial or ethnic grounds) does not necessarily mean

that the individual is unable to move. For this reason, markets are not segmented due to racial or ethnic reasons in hedonic price studies (Palmquist, 1991).

The issue of market segmentation can also be addressed empirically with the use of *F*-tests by testing whether the coefficients from potential market segments are equal (Palmquist, 1991). However, the validity of these tests hinges on the use of the true hedonic specification (Palmquist, 1991). Since the theory provides little guidance with regard to specifying the hedonic price equation, an *F*-test result rejecting the hypothesis of equal coefficients could mean that the functional forms were not appropriate or the hedonic price function was specified incorrectly (Palmquist, 1991). Unfortunately, this does not provide conclusive evidence of separate markets (Palmquist, 2005).

F-tests have been used to test the hypothesis of a national housing market (Butler, 1980). A study by Butler (1980) sought to address the risks of pooling data from separate regions (effectively forming one national market). Pooling data from different regions is problematic if the underlying preferences from separate regions are vastly different. In this case, the nature of the relationships between these preferences and the constituent market could be seriously misrepresented (Butler, 1980). However, if the underlying preferences are similar, there is little harm in pooling data (Butler, 1980).

In order to test the pooling hypothesis, an *F*-test was conducted using census data for 36 cities (Butler, 1980). The results suggest that the hedonic relationships in different metropolitan areas are similar, especially for renters. More specifically, the study found that a national housing market does exist for renters. For owners this hypothesis was rejected (Bulter, 1980). However, substantial aggregation of owner markets is still possible and does little harm in terms of coefficient accuracy and the predictive power of the hedonic price equation (Butler, 1980).

Another approach to market segmentation is to consult real estate experts. Michaels and Smith (1990) tested this approach by requesting real estate agents to separate towns within a large metropolitan area into groups thought to be homogenous. Statistical tests were then performed and the results indicated that some segmentation was suitable (Michaels & Smith, 1990). More specifically, the results of the effect of hazardous waste sites on adjacent property values differed significantly when the market was considered segmented and not unified (Michaels & Smith, 1990).

It is clear that, to some extent within cities, market segmentation does exist. This makes the application of the hedonic price model more complex and it is essential that separate hedonic price functions are estimated in the presence of segmented markets (Freeman, 2003). From this, separate MWTP functions for each market can be estimated (Freeman, 2003).

3.2.3.2 CHOICE OF THE DEPENDENT VARIABLE

The majority of hedonic price studies use sales prices rather than rental prices as the dependent variable (Palmquist, 2005). This price can be interpreted as the discounted present value of the expected rental income (Freeman, 2003). This causes two complications. The first is that estimated welfare changes are usually expressed in annual flows. When house price differentials are used to estimate these welfare changes, care must be observed to convert the house price measures into the appropriate temporal dimension[23] (Freeman, 2003).

The second complication is that it might be necessary to account for expected changes in house characteristics, particularly environmental changes, when the hedonic price function is estimated. For example, house prices used to estimate the hedonic price function should be adjusted upwards if an environmental improvement is due to take place thus reflecting current conditions plus the expected improvement (Freeman, 2003).

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[23] The conversion of a house price into a rental stream is performed as follows (where r is the discount rate):

$R = P \cdot r$……(3.37)

However, rental income (R) is also subject to *ad valorem* taxation. An individual would only consider purchasing a property for investment purposes if the purchase price is less than or equal to the present discounted value of future rental income net of property taxation (Freeman, 2003). The workings of the market would thus result in the following relationship between house prices and rental income:

$P = (R - t \cdot P)/r$……(3.38)

where t is the *ad valorem* tax rate (Freeman, 2003). If property prices are known, rearranging Equation 3.38 enables the calculation of the rental income. If the relationship between property values and an environmental amenity has been estimated, the marginal benefit for a change in z_i is given by:

$W_{z_i} = \partial R/\partial z_i = (r + t) \cdot \partial P/\partial z_i$……(3.39)

The present value of this benefit stream can be represented by:

$W_{z_i}/r = (1 + t/r)(\partial P/\partial z_i)$……(3.40)

As is evident from Equation 3.40, the benefit estimate is influenced by the *ad valorem* tax rate. If the hedonic price function is defined in terms of property prices (effectively ignoring the effect of the *ad valorem* tax on rental income) the benefit estimate may be underestimated (Freeman, 2003). The size of the error can be estimated using the term t/r. For example, at a discount rate of 10 percent and an *ad valorem* tax rate of 1 percent, the error will be approximately 10 percent (Freeman, 2003).

Another important issue to address is whether the dependent variable should reflect the full price of the land and house together or whether it should reflect only the land value. Since public good amenities are location specific, but do not form part of the house structure, the amenity values should be reflected in the land alone (Freeman, 2003). However, in most property markets the land and structure are sold as one unit. The observed sales prices thus reflect both the land value and the value of the house structure (Freeman, 2003). This provides no theoretical complications but does require the hedonic price function to adequately control for house characteristics (Freeman, 2003).

The source of data on housing prices is another important consideration, with data on actual market transactions being preferable (Kiel & Zabel, 1999; Cotteleer & van Kooten, 2012). The availability of monthly rental transaction values provides an opportunity to use rental prices. However, the majority of hedonic price studies focus on residential housing which is mostly owner-occupied. The preferred source of data is thus methodically-collected data on actual sales prices of individual residential houses (Freeman, 2003).

Owner provided house price assessments provide another potential data source. However, the use of these kinds of data raises a potential issue, namely the degree of accuracy of owner provided estimates. This issue was addressed in a study by Kiel and Zabel (1999). The study compared individual home owners' estimates with the most recent sales price of the house. It was found that owners overstated values by approximately 5 percent (Kiel & Zabel, 1999).

The use of owner provided estimates was defended in a recent study by Fullerton and Villalobos (2011) by examining the correlation coefficient between owner provided estimates and actual market prices. The study found that the correlation coefficient between these two values (using market averages) was 0.99 for the study site (Fullerton & Villalobos, 2011).

Another option to obtain house data is to consider professional appraisals for property tax purposes. Assessed property values are very often more accessible and are thus frequently used in hedonic price studies (Fullerton & Villalobos, 2011; Cotteleer & van Kooten, 2012). It is important to note that the use of a dependent variable other than the actual sales price (i.e. assessed property value or owner provided estimate) may be imperfectly correlated with actual market prices (Freeman, 2003). If the errors in assessment are correlated with other variables in the model biased coefficient estimates will be present (Freeman, 2003).

The use of actual sales prices is not immune to disadvantages. The main disadvantage of using sales prices is a potential lack of data if sales do not occur frequently (Cotteleer & van Kooten, 2012). In addition to this, the threat of errors in sales price data is also present, along with the risk of distorted markets (Doss & Taff, 1996). Distorted markets occur as a result of asymmetric information and tend to be common in markets where real estate agents and lenders are dominant in the market (Doss & Taff, 1996). Real estate agents may influence the market by affecting the list price of properties and by affecting the bidding strategies of buyers. Lenders may affect the market with their lending practices (for example, by requesting large deposits from first time buyers) (Doss & Taff, 1996). Other transactions, such as trading between relatives, may not reflect true market values either. For this reason, it is recommended that all transactions that are not of arms-length should be excluded from the hedonic analysis (Cotteleer & van Kooten, 2012).

A recent study by Cotteleer and van Kooten (2012) compared the effectiveness of using assessed property values versus actual market prices when valuing non-market amenities. It was found that, while there are clear data advantages to using assessed property values, the use of actual market prices is preferred for determining the value of non-market amenities (Cotteleer & van Kooten, 2012).

3.2.3.3 CHOICE OF INDEPENDENT VARIABLES

In terms of specifying the hedonic price model, housing characteristics that matter to home buyers should be included in the model. These characteristics can be grouped into eight broad categories, namely construction and structure, internal features, external amenities, natural environmental amenities, neighbourhood and locational environmental amenities, public service environmental amenities, marketing and occupancy, and financial issues (Sirmans, Macpherson & Zietz, 2005). Table 3.1 presents the eight categories along with the characteristics within each category.

Table 3.1: Independent variables by category

Category	Variable
1	**Construction and structure:** • Erf size • House size • Age • Number of bathrooms • Number of bedrooms
2	**House internal features:** • Full baths • Half baths • Fireplace • Air-conditioning • Hardwood floors • Basement
3	**House external amenities:** • Garage • Deck • Pool • Porch • Carport
4	**Natural environmental amenities:** • Lake view • Lake front • Oceanview • "Good view"
5	**Neighbourhood and locational environmental amenities:** • Crime • Distance • Golf course • Trees
6	**Public service environmental amenities:** • School district • Public sewer
7	**Marketing, occupancy and selling:** • Assessors quality • Assessed condition • Vacant • Owner occupied • Time on the market
8	**Financial issues:** • Foreclosure • Property tax

Source: Sirmans *et al*. (2005)

Since hedonic price model specifications are often driven by data availability, it may not be possible to include all the categories presented in Table 3.1. To this end, Table 3.2 contains the top twenty characteristics used to specify hedonic price functions in previous studies, the number of times a characteristic has been used and the number of times its estimated coefficient has been positive, negative or insignificant (Sirmans *et al*., 2005).

Table 3.2: Top twenty characteristics appearing most often in hedonic price model studies

Variable	Appearances	No. of times positive	No. of times negative	No. of times insignificant
Lot Size	52	45	0	7
Ln Lot Size	12	9	0	3
Square Feet	69	62	4	3
Ln Square Feet	12	12	0	0
Brick	13	9	0	4
Age	78	7	63	8
No. Stories	13	4	7	2
No. Bathrooms	40	34	1	5
No. Rooms	14	10	1	3
Bedrooms	40	21	9	10
Full Baths	37	31	1	5
Fireplace	57	43	3	11
Air-conditioning	37	34	1	2
Basement	21	15	1	5
Garage Spaces	61	48	0	13
Deck	12	10	0	2
Pool	31	27	0	4
Distance	15	5	5	5
Time trend	13	2	3	8
Time On Market	18	1	8	9

Source: Sirmans *et al*. (2005)

As is evident from Table 3.2, age shows up most often in hedonic price studies and typically has a negative effect on price (negative 63 times out of 78 studies). Common structural characteristics used to specify hedonic price models include house size, erf size, number of bathrooms, number of bedrooms, fireplace, air-conditioning, garage, and pool. Time on the market is not frequently used, although its predominantly negative sign (only positive once out of 18 appearances) implies that the longer a house is on the market, the lower its final sale price will be (Sirmans *et al*., 2005). House prices may also be influenced by proximity to amenities (Brasington & Hite, 2005). A distance measure can be used to capture the effects of these amenities (see Table 3.2) (Sirmans *et al*., 2005). Examples include proximity to the central business district, schools, hazardous waste sites, green belts and neighbourhood parks, and social housing developments (Weicher & Zerbst, 1973; Correll, Lillydahl & Singell, 1978; Kohlhase, 1991; Nelson *et al*., 1992; Hite *et al*., 2001; Ihlanfeldt & Taylor, 2004; Nguyen, 2005).

When selecting suitable independent variables to capture the effects of environmental and locational amenities, it is important to consider how the characteristics enter into the hedonic price function (Freeman, 2003). A simple scalar measure of an amenity is generally used (Freeman, 2003). In terms of air pollution studies, this simple scalar might take the form of parts per million of an air pollutant. Proximity effects of a non-market amenity (for example, open space or greenbelts) are usually entered into the hedonic price function with a simple

linear distance measure from the property to the resource in question (Morgan & Hamilton, 2011). However, it has been argued that a network distance measure is more appropriate as this more appropriately measures residents' ease of access to the resource (Morgan & Hamilton, 2011).

More generally, the practice of using simple scalar measures has been subjected to a certain degree of criticism because it is not consistent with a restriction forced on the hedonic price function on the supply side of the housing market (Parsons, 1990). More specifically, profit maximisation on the supply side can only be captured with precision if the amenity in question is weighted by the area of the plot on which the house is located (Parsons, 1990). The restriction is that land in an area, with a given environmental amenity level, must sell for the same price per square metre, regardless of the plot size. For example, suppose an area of land consists of plots of different sizes (1 000 square metres and 2 000 square metres). If two 1 000 square metre plots sell for RX each, then one 2 000 square metre plot must sell for R2X (Freeman, 2003). This implies that the premium on plots with higher levels of the environmental amenity (the 2 000 square metre plots) must be double the premium of the 1 000 square metre lots (in order to compensate the landowner the opportunity cost of not selling two smaller plots and capturing the premium twice) (Freeman, 2003). If the weighted amenity values are not used the coefficient estimates may be biased (Parsons, 1990). Theoretically this argument is sound, although its practical application is questionable because the weighted form may not be possible in second hand markets due to potentially high costs of changing plots post development. For this reason, most empirical applications of the hedonic price model do not use weighted amenity values.

It is also important to take into account that the levels of some environmental amenities are fixed by location, for example, the distance to a public park. Other environmental amenities (for example, air quality) vary over time with changes in emissions and climatic conditions. With regard to amenity levels that vary over time, annual averages for the amenity in question are generally used as a summary statistic (Leggett & Bockstael, 2000; Freeman, 2003). However, peoples' perceptions generally govern choices reflected in property prices. Consequently, there should ideally be a close correlation between peoples' perceptions of amenity levels and the objective measures available to researchers (Freeman, 2003).

An important theoretical and practical issue to address when selecting appropriate explanatory variables is to consider the issue of disentangling the effects of different amenities on property values when measures of the amenities may be correlated. For example, when using a simple scalar distance measure to capture the proximity effects of an

amenity, is it possible to separate the effects of other amenities situated close to the amenity in question? This is an important consideration because the objective of the hedonic price model is to determine the effect of one amenity on property values. All other structural, neighbourhood and environmental amenities must be adequately controlled for (Freeman, 2003). This is discussed in greater detail in Section 3.2.3.5.

3.2.3.4 OMITTED VARIABLE BIAS

The specification of the hedonic price function can have a considerable effect on the coefficient estimates of the environmental variables concerned (Palmquist, 1991). One of the main concerns regarding the specification of a hedonic price function revolves around omitted variable bias (Kuminoff, Parmeter & Pope, 2009).

Hedonic price functions specified in the traditional manner do not address the issue of omitted variable bias (Brasington & Hite, 2005). This can limit the ability of the hedonic regression to accurately measure the MWTP for housing characteristics (Kuminoff *et al*., 2009). Neighbourhood characteristics that matter to households but have not been observed by the researcher may well be correlated with the variables of interest (or other independent variables). Examples of potential omitted variables include air pollution, the presence of shopping centres and the presence of highways.

Evaluating the implications of omitted variables in hedonic price studies is challenging because the market clearing process determines housing values and consumer welfare simultaneously (Rosen, 1974). In order to meet this challenge, Cropper, Deck and McConnell (1988) developed a theoretically consistent framework for imitating hedonic equilibria. It was found that traditional functional forms (linear, semi-log and double-log) performed best in the presence of omitted variables. More flexible functional forms were preferred when all variables were included in the model (Kuminoff *et al*., 2009). This is one of the reasons why the significant majority of hedonic price studies use traditional functional form specification (to avoid the risk of omitted variable bias).

Possible remedies to overcome omitted variable bias include zoning in on small geographical areas and collecting as much data as possible (Brasington, 2000; Brasington & Hite, 2005). An alternative method for addressing this issue is to incorporate a spatial autoregressive term in the traditional hedonic price function, as this term captures the influence of omitted variables (Brasington & Hite, 2005). These unmeasured influences help to determine the value of neighbouring houses which, in turn, are related to the subject

house. The implementation of a spatial autoregressive term is discussed further in Section 3.2.3.9.

3.2.3.5 MULTICOLLINEARITY

Multicollinearity is a common issue in hedonic price studies as house characteristics tend to be correlated (Haab & McConnell, 2002). This may pose a problem regarding the selection of explanatory variables as it is preferable to include as many housing characteristics as possible in order to reduce omitted-variable bias (Leggett & Bockstael, 2000; Tu, 2005). However, the inclusion of highly correlated variables may result in spurious regression results (Palmquist, 1991). This leads to the question of the trade-off between omitting variables that are correlated with the variable of concern (thus increasing bias) and including collinear variables (thus reducing the precision of coefficient estimates) (Freeman, 2003). Although theory does not provide thorough guidelines on this issue, it has been suggested that approaching this question systematically, using Bayesian principles, may provide some value (Atkinson & Crocker, 1987).

Concerns regarding muliticollinearity were addressed in an air pollution study by Palmquist (1983). The study analysed hedonic regressions with extensive specifications. The environmental variables of concern were measures for four different air pollutants in 14 cities. It was found that collinearity produced biased coefficient estimates in only one of the 14 cities (two air pollution measures were found to be collinear) (Palmquist, 1983). Considering that over 50 pollution coefficients were estimated in the study, this result is reassuring.

However, the variables of interest largely determine the degree of multicollinearity and in some instances it may be severe (Palmquist, 1991). For example, it may be impossible to disentangle the effects of certain environmental or locational characteristics. To illustrate this, consider an attempt to measure the effects of an urban slum on surrounding property values. Assume that the urban slum is situated in close proximity to a hazardous waste site. Both of these exert negative effects on surrounding property prices. Therefore, as distance from the sites increases, property values should rise. However, disentangling the separate effects of the urban slum and the hazardous waste site may require more than just variation in house prices and variation in distance (Haab & McConnell, 2002).

Considering the way in which the environmental attribute in question is measured may provide some relief. Morgan and Hamilton (2011) addressed the multicollinearity issue by using a network distance parameter (as opposed to a simple linear parameter) in a hedonic

price model to disentangle access and view amenities in coastal residential communities. Since network access varies independently of view, it was found that the use of this distance measure greatly reduced collinearity effects and thus access and view were separated in the hedonic price model (Morgan & Hamilton, 2011).

Ideally, diagnostic tests should be conducted in order to test for multicollinearity in hedonic price studies (Studenmund, 2006).[24]

3.2.3.6 TIME CONSIDERATIONS

The hedonic price function would display stability over time if forward markets existed in property markets, due to resultant arbitrage activities (Palmquist, 1991). This stability is not guaranteed because such forward markets do not exist in property markets (Palmquist, 1991). However, empirically it is often necessary to aggregate data from different time periods (Palmquist, 2005; Walsh *et al*., 2011). This is necessary when the number of observations in one time period is too small or there has been an environmental change over time (Palmquist, 2005).

Statistical tests of data aggregation over time are available. These are based on the same principles as the statistical tests used to determine the geographical extent of the market (*F*-tests). Aggregation of data over time was tested in this manner by Edmonds (1985). The study analysed two hedonic price functions generated from data sets originating from different time periods (1970 and 1975). It was found that the *F*-test rejected the aggregation of the two data sets (Edmonds, 1985). Furthermore, a study by Palmquist (1980) concluded that data over a 13 year time period could not be aggregated, but data over adjacent pairs of years was acceptable. Generally, *F*-tests reject aggregation if the time period in question is more than a few years (Palmquist, 2005). However, a less strict approach to aggregation using data extending over more than a few years is to compare the standard errors of the regressions in the constrained and unconstrained form (Ohta & Griliches, 1975). If there is a less than 10 percent deviation in the standard errors, aggregation of data is considered acceptable (Ohta & Griliches, 1975). This guideline has allowed hedonic price studies to aggregate data over a longer time period (Palmquist, 2005).

[24] The detection of multicollinearity involves the calculation of variance inflation factors (VIF) for the independent variables in the model. This approach looks at the extent to which a given independent variable can be explained by all other variables in the model (Studenmund, 2006). In order to test for multicollinearity VIF values need to be calculated by running ordinary least squares regressions using each independent variable as the dependent variable. If the VIF values do not exceed the threshold value of 5, then the researcher can conclude that severe muliticollinearity is not present in the model (Studenmund, 2006). If, however, the VIF values exceed 5, then severe multicollinearity is present and steps should be taken to remedy the situation.

Another temporal issue to consider is when does an environmental change have an effect on market prices? For example, does a social housing development influence property prices when the project is announced, when construction of the project begins or when tenants move in? To address this issue, the use of interaction terms is recommended (Michaels & Smith, 1990). Interaction terms are additional independent variables and are constructed by multiplying the distance of the property to the site by dummy variables. The dummy variables are specified as follows: 1 if a property sale took place within six months of the site announcement, 0 if otherwise. This interaction term captures the short term response to the announcement (Michaels & Smith, 1990). A second interaction term can also be introduced that captures the long term response. In this case, the time period for the dummy variable is specified as six months or longer (Michaels & Smith, 1990). Interaction terms can also be used to determine whether or not the effect of the environmental amenity has changed over the time period of the study (Michaels & Smith, 1990).

3.2.3.7 FUNCTIONAL FORM SELECTION

Although traditional hedonic price theory provides very little guidance on the selection of an appropriate functional form for the hedonic price function, the theory does indicate that the hedonic price function is an equilibrium situation which arises from the interaction of utility maximising individuals and profit maximising suppliers (Bender, Gronberg & Hwang, 1980; Milon, Gressel & Mulkey, 1984; Cropper *et al*., 1988; Haab & McConnell, 2002; Freeman, 2003). There is only one general restriction on the form that the hedonic price function takes - the marginal implicit price derived from the hedonic price function must be positive for an environmental amenity and negative for an environmental disamenity (Freeman, 2003). According to theory, if costless repackaging were possible (moving characteristics between houses) the hedonic price function would be linear (Palquist, 2005). However, this is not the case and the hedonic price function must rely on empirical analysis in order to determine the functional form (Palmquist, 1991).

Initial hedonic price studies employed standard linear, semi-log and log-linear functional forms, with functional form selection being conjectural in treatment (Goodman, 1978; Palmquist, 2005). Generally, a goodness-of-fit criterion was used to select an appropriate form for a specific hedonic price function (Cropper *et al*., 1988).

The use of flexible functional forms was first suggested by Goodman (1978). This flexibility came from the transformation of the dependent variable:

$P^{(\lambda)} = \frac{p^{\lambda-1}}{\lambda}$ ……..(3.41)

Equation 3.41 is the equivalent of a simple linear function for λ = 1. The functional form becomes the equivalent of semi-log specification as λ approaches zero (Freeman, 2003). A hypothesis of value between 0 and 1 would reject both the linear and the semi-log form (Goodman, 1978). This transformation has proven to fit the data better than simple linear and semi-log functional forms, since λ is often significantly different from both one and zero (Freeman, 2003).

However, this simple transformation of only the dependent variable still produces limited results in terms of flexibility (Freeman, 2003). If the primary objective of the research is welfare analysis, a functional form should be selected that most accurately estimates the marginal implicit prices of the characteristics (Cassel & Mendelsohn, 1985).

In order to increase flexibility, a quadratic Box-Cox transformation was developed by Halvorsen and Pollakowski (1981). This can be represented in parametric form by the following:

$P^{(\lambda)} = \alpha + \sum_{i=1}^{n} \beta_i z_i^{(\theta)} + 0.5 \sum_{i=1}^{n} \sum_{j=1}^{m} \gamma_{ij} z_i^{(\theta)} z_j^{(\theta)} + \varepsilon_i$ ……(3.42)

where $P^{(\lambda)} = (P^{\lambda} - 1)/\lambda$ *if* $\lambda \neq 0$ and $P^{(\lambda)} = \ln P$ if $\lambda = 0$, and $z_i^{(\theta)} = (z_i^{\theta} - 1)/\theta$ if $\theta \neq 0$ and $z_i^{(\theta)} = \ln z_i$ if $\theta = 0$.

In Equation 3.42, only positive values can be transformed. The general form of the hedonic price function includes the translog, semi-log, quadratic and simple linear form as special cases, depending on the transformation parameter estimates of λ and θ. For example, if λ = 0 and θ = 1, the semi-log hedonic price function emerges (Haab & McConnell, 2002).

The parameters (λ and θ) are generally estimated using statistical software (Haab & McConnell, 2002). The alternative to this is to identify the optimal transformation parameter values in a grid search (Palmquist, 1991; Haab & McConnell, 2002). The likelihood for the case where the quadratic terms are omitted is shown below (it is unlikely that these variables would also need to be transformed) (Haab & McConnell, 2002). The density function for the random error of the ith observation can be represented by:

$f(\varepsilon_i) = 1/\sqrt{2\pi\sigma^2}\ e(-\varepsilon_i^2/2\sigma^2)$……..(3.43)

From Equation 3.42 (dropping the quadratic terms):

$$\varepsilon_i = P^{(\lambda)} - \alpha - \sum_{i=1}^{n} \beta_i z_i^{(\theta)} \quad (3.44)$$

Therefore:

$$f\,(P^{(\lambda)} - \alpha - \sum_{i=1}^{n} \beta_i z_i^{(\theta)}) = 1/\sqrt{2\pi\sigma^2}\ e(-[P^{(\lambda)} - \alpha - \sum_{i=1}^{n} \beta_i z_i^{(\theta)}]^2/2\sigma^2) \quad (3.45)$$

The probability density function (*pdf*) for *P* becomes:

$$pdf\,(P) = P^{\lambda-1} f\,(P^{(\lambda)} - \alpha - \sum_{i=1}^{n} \beta_i z_i^{(\theta)}) \quad (3.46)$$

The log-likelihood function for *T* observations is given by:

$$\sum_{i=1}^{T} (\lambda - 1)\ln(P) - T\ln(\sigma) - \sum_{i=1}^{T} \{[P_i^{(\lambda)} - \alpha - \sum_{i=1}^{n} \beta_i z_i^{(\theta)}]^2/2\sigma^2\} \quad (3.47)$$

Welfare measures are then determined with the hedonic price function by estimating the marginal effect of a change in the environmental characteristic (Haab & McConnell, 2002).

For example, the marginal effect of a change in characteristic z_i is given by the following:

$$\frac{\partial P}{\partial z_i} = P^{1-\lambda} (\beta_i z_i^{\theta-1} + z_i^{\theta-1} \sum_{i=1}^{n} \gamma_i z_i^{(\theta)} \quad (3.48)$$

Unfortunately, complex functional forms such as the quadratic form represented by Equation 3.42 may make the challenge of identifying the effects of characteristics even more difficult due to induced collinearity (Haab & McConnell, 2002).

A study by Cropper *et al*. (1988) provided more insight into the question of functional form selection. The study conducted Monte Carlo experiments in order to test the accuracy of marginal implicit prices generated using a variety of different functional forms. Correctly specified and misspecified hedonic price functions were considered and the findings suggested that when the hedonic price function was specified correctly, the quadratic Box-Cox and the linear Box-Cox yielded the best estimates (Cropper *et al*., 1988). However, when the hedonic price function was misspecified, the simpler linear Box-Cox transformation yielded the most accurate estimates (Cropper *et al*., 1988). Since specifying the hedonic price function correctly is difficult, the results suggest that the use of linear Box-Cox

transformations is preferable (Cropper *et al*., 1988). Examples of the linear Box-Cox transformations are discussed below.

The Box–Cox model that transforms only the dependent variable (leaving the independent variables unchanged) is known as the left hand Box-Cox model (lhBC):

$\frac{P^{\lambda}-1}{\lambda} = \alpha + \sum_{i=1}^{k} \beta_i z_i + \sum_{s=1}^{j} \gamma_s D_s + \varepsilon$ for $\lambda \neq 0$ or

$\ln P = \alpha + \sum_{i=1}^{k} \beta_i z_i + \sum_{s=1}^{j} \gamma_s D_s + \varepsilon$ *for* $\lambda = 0$……...……(3.49)

The right–hand Box–Cox model (rhBC) transforms only the continuous independent variables, leaving the dependent variable unaltered:

$P = \alpha + \sum_{i=1}^{k} \beta_i \frac{Z_i^{\theta}-1}{\theta} + \sum_{s=1}^{j} \gamma_s D_s + \varepsilon$ *for* $\theta \neq 0$ or

$P = \alpha + \sum_{i=1}^{k} \beta_i \ln Z_i + \sum_{s=1}^{j} \gamma_s D_s + \varepsilon$ *for* $\theta = 0$……...…...……(3.50)

For transformation of both sides of the equation with different parameters, a more complex version is used. This transformation can be represented as

$\frac{P^{\lambda}-1}{\lambda} = \alpha + \sum_{i=1}^{k} \beta_i \frac{Z_i^{\theta}-1}{\theta} + \sum_{s=1}^{j} \gamma_s D_s + \varepsilon$ *for* λ *and* $\theta \neq 0$……..……...…..(3.51)

Equation 3.51 is referred to as an unrestricted Box–Cox model (uBC). For a restricted Box–Cox model (rBC), both sides of the equation are transformed by the same parameter.

Thus, the rBC is equal to the UBC, with the restriction that $\lambda = \theta$:

$\frac{P^{\lambda}-1}{\lambda} = \alpha + \sum_{i=1}^{k} \beta_i \frac{Z_i^{\lambda}-1}{\lambda} + \sum_{s=1}^{j} \gamma_s D_s + \varepsilon$ *for* $\lambda \neq 0$ or

$\ln P = \alpha + \sum_{i=1}^{k} \beta_i \ln Z_i + \sum_{s=1}^{j} \gamma_s D_s + \varepsilon$ *for* $\lambda = 0$……...……..…….....(3.52)

The use of the Box-Cox functional form allows the data to be accommodated in multiple functional forms (Cropper et al., 1988). Certain Box-Cox parameter values are associated

with basic functional forms, such as the linear, semi-log and double-log forms (Haab & McConnell, 2002). Table 3.3 summarises what the Box–Cox model represents, depending on the parameter value.

Table 3.3: Possible Box-Cox functional forms

Box – Cox model:	Parameter Value:	Functional Form:
Restricted Box-Cox	λ = 1	Linear
	λ = 0	Log–log
Left hand Box–Cox	λ = 0	semi–log
	λ = 1	Linear
Right hand Box–Cox	θ = 1	Linear
	θ = 0	Semi-log
	θ = -1	Reciprocal
Unrestricted Box–Cox	$\lambda = \theta$	Restricted Box–Cox
	$\theta = 1$	Left hand Box–Cox
	$\lambda = 1$	Right hand Box–Cox

Source: Williams (2008)

Since the Box–Cox regression is able to represent a variety of different functional forms, it can be used to test for the most appropriate functional form (Haab & McConnell, 2002). The Box-Cox regression can also be used as a functional form itself (Cropper *et al*., 1988).

3.2.3.8 SEMIPARAMETRIC AND NONPARAMETRIC ESTIMATION

The use of parametric estimation techniques (such as the ordinary least squares method) requires the analyst to select appropriate dependent and independent variables and to determine the appropriate functional form governing the variables and the associated parameters (Pace, 1993, 1995). To a certain extent, the Box-Cox transformations described in the previous section provide guidance on the functional form that best fits the data (Williams, 2008). However, specification errors associated with parametric estimation techniques may still adversely affect estimator performance (Pace, 1993, 1995).

A possible solution to the problems associated with specification error can be found in semiparametric and nonparametric estimation techniques (Pace, 1993, 1995; Anglin & Gencay, 1996; Bin, 2004; Palmquist, 2005). Semiparametric and nonparametric estimation techniques still require the analyst to select the appropriate variables but attention to the appropriate functional form is greatly reduced (Pace, 1993, 1995). More specifically, “nonparametric estimators produce their inferences free from a particular functional form. Semiparametric estimators produce their inferences free from a particular functional form but within a particular class of functional forms” (Pace, 1995).

The main difficulty in applying completely nonparametric estimation in a housing market setting stems from the fact that the price of a house is determined by many characteristics and very often the characteristic of interest only plays a small part in determining the overall house price. For this reason, the hedonic price equation must be specified correctly in order to obtain reliable coefficient estimates (Palmquist, 2005). Nevertheless, there have been several semiparametric and nonparametric applications to housing markets. More specifically, Pace (1993) applied the kernel nonparametric regression estimator to two different data sets. The study found that the nonparametric estimator outperformed the parametric estimator (Pace, 1993).

In another study Anglin and Gencay (1996) estimated a benchmark parametric model (which passed several common specification tests) and compared the results to a semiparametric model. The study concluded that the semiparametric model outperformed the parametric model (Anglin & Gencay, 1996).

Finally, Bin (2004) compared the predictive powers of a conventional parametric model with a semiparametric model. In terms of predictive capability, the study found that the parametric regression was inferior to the semiparametric regression for both in-sample and out-of-sample price predictions (Bin, 2004).

3.2.3.8.1 *THE ESTIMATION PROCEDURE*

Consider a model where the price of a house is determined by a vector of *n* characteristics, ***z***:

$$P = M(\boldsymbol{z}) + \varepsilon \qquad (3.53)$$

where $M(\boldsymbol{z}) = E(P \mid \boldsymbol{z})$ ……..(3.54)

Parametric estimation techniques estimate $E(P \mid \boldsymbol{z})$ in two steps: first, $E(P \mid \boldsymbol{z})$ is modelled as a function of the parameters, and second, the parameters are estimated (Pace, 1993, 1995). Nonparametric techniques estimate $E(P \mid \boldsymbol{z})$ directly (Pace, 1993, 1995). This is done by estimating the joint density ($pdf(P,\boldsymbol{z})$) and the marginal density ($pdf(\boldsymbol{z})$), dividing the former by the latter and integrating *P* times the result:

$$M(\boldsymbol{z}) = E(P \mid \boldsymbol{z}) = \int P \frac{pdf(P,z)}{pdf(z)} dP \qquad (3.55)$$

The kernel method of estimation is the most commonly used method of density estimation in the housing literature (Palmquist, 2005). For J observations, the method uses a function, $K(\cdot)$, whose value varies inversely and smoothly with w_j, where $w_j = (x_j - x_0)/h$, x_0 is the point where the density needs to be determined, x_j is a data point and h is the bandwidth (Pace, 1993, 1995; Palmquist, 2005). The bandwidth is also referred to as the dispersion of the kernel (Palmquist, 2005). For a univariate distribution the density function evaluated at x_0 is:

$$\hat{f}(x_0) = \frac{1}{hJ}\sum_{j=1}^{J} K(w_j) \qquad (3.56)$$

For a multivariate distribution:

$$K(w_j) = \prod_{k=1}^{k} K(w_{jk}) \qquad (3.57)$$

where $w_{jk} = (x_{jk} - x_{0k})/h$ and $k=1,\ldots,K$ is the index of jointly distributed variables (Palmquist, 2005).

The bandwidth, h, is crucial in nonparametric estimation, especially when small samples are used (Pace, 1993, 1995). A bandwidth that is too small leads to excessive spikiness and noise on the regression surface and one that is too large leads to a regression surface that is possibly too smooth due to the high degree of averaging (Pace, 1993, 1995).

Semiparametric estimation offers an intermediate strategy between parametric and nonparametric estimation (Anglin & Gencay, 1996).

This strategy incorporates some parametric information into the nonparametric form:

$$P = \boldsymbol{z}_a\beta + M(\boldsymbol{z}_b) + \varepsilon \qquad (3.58)$$

where: $\boldsymbol{z}_a$ = vector of characteristics entered parametrically
$\boldsymbol{z}_b$ = vector of characteristics entered nonparametrically

This form of estimation reduces the dimensionality problems associated with nonparametric methods (Palmquist, 2005).

3.2.3.9 SPATIAL ECONOMETRIC ISSUES

The transaction price of a house is determined not only by its structural and neighbourhood characteristics, but also by transaction prices of prior sales within its vicinity (Can & Megbolugbe, 1997; Brasington & Hite, 2005). This spatial relationship is appropriate because an individual will often base his/her offer bid after having researched the prior transaction prices in the surrounding area (Brasington & Hite, 2005). This practice, known as "comparable sales", is also often employed by real estate experts when trying to estimate the market value of a specific property (Can & Megbolugbe, 1997).

Earlier applications of the hedonic price method were unable to capture the effects of spatial interdependence, since the tools used to determine these effects were cumbersome and difficult to implement (Palmquist, 2005). Recently, however, significant advances have been made in spatial econometrics and spatial interdependence has become a prominent feature in many hedonic price studies (Can & Megbolugbe, 1997; Brasington & Hite, 2005; Tu, 2005).

There are two basic ways in which to incorporate spatial effects into a hedonic price model, namely a spatial error model or a spatial-lag model (Kim, Phipps & Anselin, 2003). The spatial error model is also referred to as spatial autocorrelation and the spatial-lag model is also referred to as spatial autoregression (Palmquist, 2005). Although the two specifications have different economic interpretations, they are closely related in terms of the underlying mathematics (Kim *et al*., 2003). The spatial error model assumes that there are omitted variables in the traditional hedonic price function and that these omitted variables vary spatially. Due to this, the error term in the hedonic price function has a tendency to be spatially autocorrelated (Kim *et al*., 2003). This model is appropriate when there is no theoretical spatial interaction and the researcher simply wants to address the issue of potential bias in the coefficient estimates caused by spatial autocorrelation (Kim *et al*, 2003). In contrast, the spatial-lag model assumes that, in addition to the standard independent variables determining house prices, house prices are also influenced by the spatially weighted average of house prices in the neighbourhood (Kim *et al*., 2003). This approach is appropriate when spatial interaction is present in the market (when house prices are influenced by surrounding property prices).

a) Spatial autoregression (the spatial-lag model)

The spatial autoregression approach considers spatial lags, which are defined as neighbouring properties' prices (Can & Megbolugbe, 1997; Palmquist, 2005; Tu, 2005; Brasington & Hite, 2005; Bourassa, Cantoni & Hoesli, 2007; Picard *et al*., 2010). In order to

capture these spatial lags, a spatial autoregressive term can be included in the hedonic regression (Can & Megbolugbe, 1997; Tu, 2005).

This term is introduced into the traditional hedonic price model as follows:

$$P_{it} = \beta_0 + \beta_1 \sum j W_{ij} P_{j,t-m} + \beta_2 \mathbf{z} + \varepsilon \quad (3.59)$$

where: P_{it} = transaction price of a given house *i* at time *t*.

$\mathbf{z}$ = a vector of residential property characteristics.

W_{ij} = $(1/d_{ij})/\sum j(1/d_{ij})$ (inverse function of the distance, d, between the subject property, *i*, and a prior transaction, *j*.).

$P_{j,t-m}$= price of a transaction, *j*, occurring within the prior 6 months of the subject property, *i*.

β_1 = estimated coefficient of the autoregressive term ($\beta_1 \sum j W_{ij} P_{j,t-m}$).

Once Equation 3.59 is estimated, the coefficient β_1 will provide a measure of the effects of prior neighbouring sales on the subject property (P_{it}) (Can & Megbolugbe, 1997).

Of critical importance is how W_{ij} is defined (Can & Megbolugbe, 1997; Tu, 2005). This is due to the fact that the value of W_{ij} will determine which houses should be considered neighbouring and the extent to which these houses influence the price of the specific house in question (Tu, 2005). It is assumed that the further away a neighbouring house is located from the specific house in question, the less of an influence it would have on the house in question. It is thus hypothesised that *W* is an inverse function of the distance, *d*, between the subject property, *i*, and a prior transaction, *j*. ((W_{ij} = $(1/d_{ij})/\sum j(1/d_{ij})$). In practice, it is recommended that all transactions concluded within the prior 6 months of the subject property transaction be included in the compilation of the spatial autoregressive term (Can & Megbolugbe, 1997). Exploratory work on spatial structure indicated that spatial dependencies were located within a radius of 3.2 km of the subject property (Can & Megbolugbe, 1997).

b) Spatial autocorrelation (the spatial error model)

Modelling the spatial error dependence or a spatially dependent error term is known as spatial autocorrelation and two main approaches have been followed in this regard. One approach is to directly specify the error covariance (or correlation) matrix. This is known as direct representation (Anselin & Bera, 1998; Palmquist, 2005; Bourassa *et al*., 2007). Unfortunately, this approach is limited when large data sets are used.

The lattice approach offers an alternative to direct representation. This approach models the covariance matrix of the errors parametrically and the error for each house is assumed to be influenced by the errors of certain neighbouring houses (but not all in the sample) (Palmquist, 2005; Bourassa *et al*., 2007). With this approach, neighbouring properties are specified by a spatial weights matrix. For example, if two properties (i and j) are within a certain distance of one another, the weight (w_{ij}) takes on a value of 1 (0 if the properties are further apart than the specified distance).

A more formal model of spatial autocorrelation can be presented as follows:

$$\boldsymbol{P} = \beta_0 + \beta_1 \boldsymbol{z} + \varepsilon,$$
$$\varepsilon = \lambda W \varepsilon + u \qquad (3.60)$$

where: $\boldsymbol{P}$ = a vector of transaction prices.

$\boldsymbol{z}$ = vectors of residential property characteristics.

β = coefficient estimates.

ε = error term.

λ = spatial autoregressive coefficient.

W = spatial weights matrix.

u = a vector of independent and identically distributed (i.i.d.) error terms.

In the formal model described above, the spatial weights matrix needs to be specified by the researcher (Palmquist, 2005; Bourassa *et al*., 2007; Picard *et al*., 2010). Several different approaches have been followed in this regard. One approach is to give a specific number of nearest neighbours a nonzero covariance. Alternatively, one can specify a certain maximum distance where the covariance goes from nonzero to zero (Can, 1992; Palmquist, 2005). However, using a maximum distance may lead to discontinuity in the weight at the maximum distance (Palmquist, 2005). In order to solve the discontinuity issue, the approach adopted by Pace and Gilley (1997) is recommended. Under this approach $W = 1 - (d_{ij}/d_{\max})$. As is evident from Equation 3.60, the price of a house is now a function of its characteristics and the omitted variables at neighbouring locations (Kim *et al*., 2003).

3.2.4 ESTIMATING THE DEMAND EQUATION

3.2.4.1 DEMAND ESTIMATION ACCORDING TO ROSEN (1974)

As mentioned in Section 3.2.2.1, it is possible to estimate welfare effects from the hedonic price function if the environmental change is localised (for example, the effect of social housing projects) (Palmquist, 2005). However, many environmental changes extend beyond

a local area (for example, air pollution). If environmental changes are not localised, then one can expect this to result in a new equilibrium price schedule (i.e. the hedonic price function will shift) (Palmquist, 2005). In this case, knowledge of the underlying consumer preferences or demands is required in order to calculate welfare estimates and is generally performed in two steps. Firstly, marginal implicit prices for the housing characteristics are calculated (from the original hedonic price equation). These marginal implicit prices are then combined with the quantities of the house characteristics and with socio-economic data of the consumers purchasing houses to estimate the demand function for the housing characteristics (Palmquist, 2005).

Performing the second step has plagued economists for two main reasons: firstly, the data requirements are enormous as one not only needs to gather house characteristics data, but also consumers' socio-economic data. Secondly, the estimation procedure is challenging as one is faced with the issues of identification and endogeneity (Brown & Rosen, 1982; Palmquist, 1984; 1991; 2005; Brasington, 2000; Haab & McConnell, 2002; Freeman, 2003; Brasington & Hite, 2005).

3.2.4.1.1 *IDENTIFICATION*

In Rosen's (1974) seminal article, it was suggested that because a non-linear hedonic price function provided different marginal implicit prices (a linear hedonic price function will generate only one marginal implicit price) within a single market, the demand and supply functions for a characteristic could be estimated (Rosen, 1974). However, for any one individual, only one data point on the demand function for a specific characteristic is actually observed. This data point corresponds with the marginal implicit price at the chosen level of the characteristic (Palmquist, 2005). In reality, an infinite number of demand curves could pass through this point. The other observed marginal implicit prices (generated from the non-linear hedonic price function) come from different individuals with different socio-economic characteristics (Palmquist, 1991). Unfortunately, these points do not provide sufficient information to derive the original individual's demand function for the characteristic in question and it is thus impossible to distinguish between the marginal implicit price function and the MWTP function (Brown & Rosen, 1982; Palmquist, 1991). This is known as the identification problem and is presented graphically in Figure 3.11.

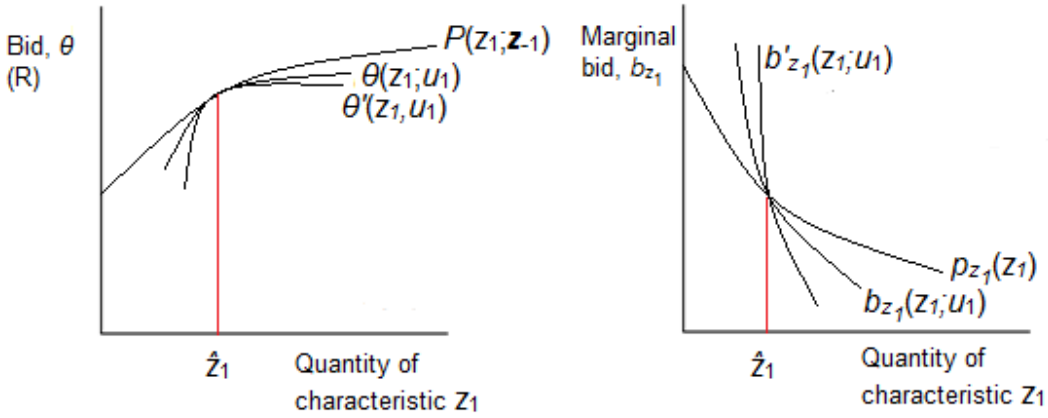

Figure 3.11: The identification problem
Source: adapted from Palmquist (1991)

The left hand panel in Figure 3.11 displays the hedonic price function ($P(z_1;\mathbf{z}_{-1})$) for characteristic z_1, along with the bid curve for an individual ($\theta(z_1,u_1)$). However, as can be seen from the panel on the left, the bid curve ($\theta'(z_1,u_1)$) is also consistent with the observed data. Indeed, any number of bid curves could be consistent with the data. The right hand panel in Figure 3.11 displays the marginal analysis of the scenario. It is evident from the right hand panel that any number of MWTP functions could pass through the observed point making it impossible to estimate the inverse demand curve without additional information.

The identification issue was highlighted by Brown and Rosen (1982) in an article that pointed out a pitfall of Rosen's (1974) procedure. This pitfall was that marginal implicit prices constructed as a function of quantities of the characteristic in question and exogenous shift variables "will not necessarily play the same role in estimation that direct observations on prices would play if they were available" (Brown & Rosen, 1982). A simple quadratic hedonic price function was used to highlight this fact, further assuming that the marginal implicit prices derived from the hedonic price function are linear in the characteristics (Brown & Rosen, 1982). In this case, combining quantities of the characteristic with other socio-economic data to try and explain the marginal implicit prices will fail to identify the structural demand function of interest (Brown & Rosen, 1982). More specifically, the parameters emerging from the second stage will simply be functions of the first stage parameters (Brown & Rosen, 1982).

There are various ways that researchers have dealt with the identification issue. One possible method of identifying the demand function is to restrict the functional form and

variables of the second stage regression (so that it is vastly different from the first stage). This can be achieved by excluding most of the house characteristics from the bid function and by specifying different functional forms for the hedonic price function and the bid function (Bender *et al.*, 1980; Palmquist, 1984; Bartik, 1988; Epple, 1987; Palmquist, 1991; Chattopadhyay, 1999; Zabel & Kiel, 2000).

However, the most widely accepted solution is the use of segmented markets (Brown & Rosen, 1982; Palmquist, 1984; Brasington, 2000; Zabel & Kiel, 2000). In the case of segmented markets, a separate hedonic price function is estimated for each metropolitan area assumed to be affected by the environmental disamenity. This will (theoretically) generate a number of different parameter estimates for the relationship between house prices and the environmental quality, thus revealing different marginal implicit prices from which the demand function can be estimated. From this, total welfare effects can be estimated (Brasington & Hite, 2005).

For example, studies by Palmquist (1984), Palmquist and Israngkura (1999) and Zabel and Kiel (2000) made use of segmented markets to analyse air quality demand. Boyle, Poor and Taylor (2000) used segmented markets to study the demand for lake water quality. In addition to these environmental studies, market segmentation has also been used to overcome identification issues in a non-environmental setting (Witte, Sumka & Erekson, 1979; Ohsfeldt, 1988).

3.2.4.1.2 *ENDOGENEITY*

Endogeneity in the second stage in hedonic price estimation arises if the hedonic price function is non-linear[25] (Palmquist, 2005). In this case, the marginal implicit prices of the housing characteristics and their attribute levels are determined concurrently via the interaction of demanders and suppliers (Murray, 1983; Mendelsohn, 1984; Palmquist, 1984; Diamond & Smith, 1985; Epple, 1987; Bartik, 1988; Chattopadhyay, 1999). Thus, when the second stage inverse demand function is estimated, the levels of characteristics will be correlated with the error term and this will result in ordinary least squares estimates that are not consistent (an important ordinary least squares assumption is non-correlation between the independent variables and the errors) (Murray, 1983; Mendelsohn, 1984; Palmquist, 1984; Diamond & Smith, 1985; Bartik, 1988; Epple, 1987; Chattopadhyay, 1999). In other words, “reverse causality” may be present with the endogenous variable.

[25] If the various functional form tests reveal that a linear function is indeed the appropriate functional form, then endogeneity is not an issue (Palmquist, 2005). However, linear functional forms often lead to inaccurate marginal implicit price estimation and are thus generally rejected by functional form tests (Williams, 2008).

In order to address the issue of endogeneity, the introduction of an instrumental variable (for the endogenous variable) is necessary. In hedonic price studies, finding a suitable instrumental variable has proven to be challenging (Bartik, 1987; Bartik & Smith, 1987; Palmquist, 1991). For an instrumental variable to be valid, it must satisfy the condition of orthogonality (i.e. it must be uncorrelated with the error term) (Palmquist, 2005; Shepherd, 2010). In addition to this, the instrumental variable must also be relevant (correlated with the endogenous variable). Additional information must also be generated by the exogenous variable (Palmquist, 2005; Shepherd, 2010). Although orthogonality tests are available, researchers generally rely on economic theory to select suitable instrumental variables (Palmquist, 2005; Shepherd, 2010). Common instrumental variables used in hedonic price studies include socio-economic variables such the square of income[26], number of children, marital status and race (Chattopadhyay, 1999).

Once suitable instrumental variables have been identified, the second stage demand curve estimation procedure is usually carried out using two-stage least squares estimation (although three-stage least squares estimation is not unusual) (Chattopadhyay, 1999). The two-stage least squares procedure eliminates the bias associated with endogenous variables in two steps: the first step eliminates the endogeneity by using truly exogenous variables (the instrumental variables) and the second step uses variables produced in the first stage (which are no longer endogenous) (Shepherd, 2010).

3.3 DISCRETE CHOICE MODELS

The use of the hedonic price model has been subjected to a certain degree of criticism when applied to housing market studies. More specifically, the "hedonic price model is based on the assumption that each housing attribute of the housing bundle is a continuous variable and that an individual can choose any point on the continuous and differentiable hedonic price function in the n-dimensional attribute space" (Freeman, 2003). This assumption is not completely realistic, and "in some respects it may seriously misrepresent the problem of choosing a bundle of housing attributes" (Freeman, 2003).

An alternative to the hedonic price model involves the analysis of discrete choices. As mentioned in Section 3.1, the two main types of discrete choice models are the random

[26] Using income, for example, could be problematic since actual income is exogenous, but adjusted income (adjusted in order to generate a linear budget constraint to allow for estimation) is endogenous (Palmquist, 1991, 2005).

utility model[27] and the random bidding model (McFadden, 1978; Chattopadhyay, 1998, 2000; Freeman, 2003; Palmquist, 2005). The former focuses on the individual's utility function and the latter investigates the individual's bid function (McFadden, 1978; Ellickson, 1981; Chattopadhyay, 1998; 2000; Freeman, 2003). Since both models allow for the estimation of the MWTP function, they can be used for welfare estimation (Lerman & Kern, 1983; Chattopadhyay, 1998; 2000; Freeman, 2003).

3.3.1 THE RANDOM UTILITY MODEL

3.3.1.1 UNDERLYING THEORY

In the random utility model, house characteristics are still vitally important to the individual, but the choice the individual makes is not continuous, but rather discrete. The individual has the same utility and bid functions and makes a discrete choice among the different housing alternatives that maximises utility (McFadden, 1978; Chattopadhyay, 2000; Palmquist, 2005).

Moreover, the random utility model views house prices as representing the market prices available to all consumers (McFadden, 1978; Palmquist, 1991, 2005). Based on this market price information (along with unique utility functions) individuals then make a choice among the available houses the market has to offer (McFadden, 1978; Palmquist, 1991, 2005; Chattopadhyay, 2000). The individual's decision to buy a specific house, for example, as opposed to other substitute houses is treated by the random utility model as a stochastic, utility-maximising choice (Parsons, Massey & Tomasi, 1999; Haab & McConnell, 2002). The model is known as a random utility model because of the presence of certain random elements. These are the inability of the researcher to know the true utility function or all the characteristics that are deemed to be important (McFadden, 1978; Chattopadhyay, 2000; Haab & McConnell, 2002; Palmquist, 2005).

More formally, the utility derived from buying house, *j,* may be described by the indirect utility function:

$$V_{ij} = V(\boldsymbol{z}_{ij}, \boldsymbol{\alpha}_i) \qquad (3.61)$$

[27] It has been shown that the random utility model is preferred over the hedonic price model when single market data is used (Cropper *et al*., 1993). Moreover, Cropper *et al*. (1993) also found that the random utility model yielded better benefit estimates of non-marginal changes compared to those obtained from the hedonic price model. Another merit of the discrete choice model is that the generation of welfare measures for non–marginal changes is relatively easy (Bartik & Smith, 1987; Palmquist, 1991; Freeman, 2003).

where:

$\mathbf{z}_{ij}$ = a vector of attributes of house *j*.
$\boldsymbol{\alpha}_i$ = a vector of individual *i*'s characteristics.

Individual *i* will buy house *j* if the utility of house *j* exceeds the utility of all other houses *k* in the choice set, where *k* = (1, 2, …, *n*). The utility consists of the sum of two parts, a systematic or observable element (V_{ij}), observable to both the researcher and the decision-maker, and a random or unobservable element (ε_{ij}), unobservable to the researcher, but known to the decision-maker:

$$U_{ij} = V(z_{ij}, x_i) + \varepsilon_{ij} \qquad (3.62)$$

The utility maximising decision is shown in Figure 3.12.

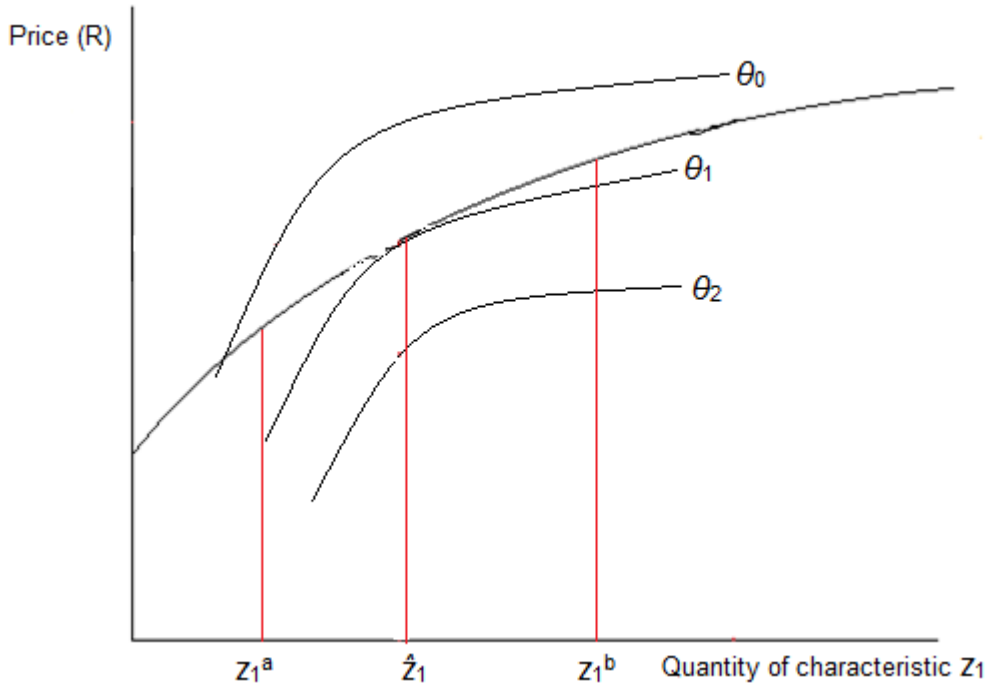

Figure 3.12: The discrete choice selection
Source: adapted from Palmquist (2005)

In Figure 3.12, the only houses available to the consumer are represented by z_1^a, $\hat{z}_1$ and z_1^b. It is clear from Figure 3.12 that the individual would select the house represented by $\hat{z}_1$, as the other two houses lie on a higher bid curve, which implies a lower level of utility. The same concept can be represented by Figure 3.13.

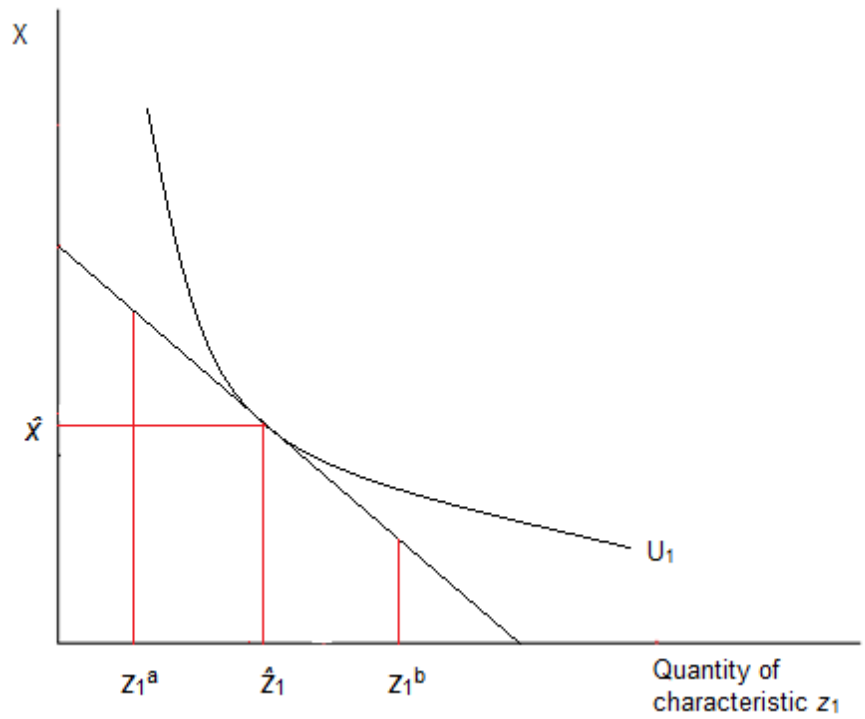

Figure 3.13: Discrete choice utility maximisation
Source: adapted from Palmquist (2005)

As can be seen from Figure 3.13, the house represented by $\hat{z}_1$ provides the highest level of utility (the other two options lie on lower indifference curves).

3.3.1.2 MODEL ESTIMATION

The random utility model may be specified in terms of a conditional logit (Haab & McConnell, 2002). The conditional logit model assumes that ε_{ij} (from Equation 3.62) is independent and has a type I extreme value distribution.

The probability, $Pr_i(j)$, that individual *i* chooses house *j* out of *n* houses is given by:

$$Pr_i(j) = \exp(V_{ij}) / \sum_{j=1}^{n} \exp(V_{ij}) \quad (3.63)$$

where: exp(·) = the antilog function.

3.3.1.2.1 *ESTIMATION ISSUES – INDEPENDENCE OF IRRELEVANT ALTERNATIVES AND SAMPLING*

a) Independence of irrelevant alternatives

The conditional logit model is based on the assumption of independence of irrelevant alternatives (IIA) (Uyar & Brown, 2005). This principle states that the relative probabilities of choosing between any two alternatives are unaffected due to the introduction or removal of other options (Haab & McConnell, 2002; Quigley, 1985). McFadden's (1974) hypothetical example clarifies this concept. Assume that commuters have two means of travelling to work. They can travel by car or they can take a red bus. Assume that these two options have equal probabilities of being selected (0.5). The relative probability of choosing the car to the red bus is thus 1. Now assume that a blue bus is introduced and commuters are indifferent as to the colour of the bus (they are perfect substitutes). It is reasonable to assume that the probability of travelling by car will be unaffected by this introduction and the probabilities of taking the red bus and the blue bus will be equal at 0.25. The relative probability of choosing the car to the red bus is now 2. However, the conditional logit model will retain the original relative probabilities between the car and the red bus. This is clearly an undesirable result. Unfortunately, the validity of the IIA assumption cannot be tested under the conditional logit setup (Quigley, 1985; Chattopadhyay, 2000).

Quigley (1985) suggested that this problem, if relevant, can be overcome by applying the nested logit model. Under this approach, individuals' housing decisions can be partitioned into several components, for example, different neighbourhoods and cities (Lerman, 1977; Friedman, 1981; Quigley, 1985; Nechyba & Straus, 1998; Bajari & Kahn, 2001; Bayer, McMillan & Rueben, 2002, Chattopadhyay, 2000). Generally, characteristics such as property taxes remain the same within a city but vary across different cities. Similarly, general living standards may vary across different neighbourhoods, but remain the same within a given neighbourhood (Chattopadhyay, 2000). These differences across cities and neighourhoods produce the "nesting structure" necessary for the nested logit model.

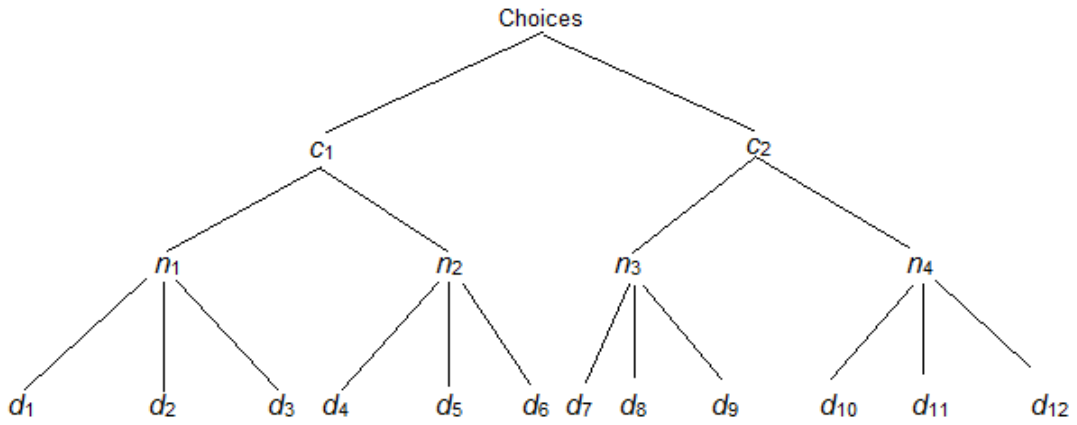

Figure 3.14: Nested structure of city, neighbourhood, and dwelling choice.
Source: adapted from Chattopadhyay (1998)

Figure 3.14 displays this nesting structure. As is evident from Figure 3.14, the choice model under the nested structure has 11 rejected dwellings, three rejected neighbourhoods and one rejected city (Chattopadhyay, 1998). This nesting structure leads to an extension of Equation 3.63 and a conditional logit model under a three-level nested structure representing the probability that individual *i* selects the kth house in the jth neighbourhood in the ith city can be written as follows:

$$Pr_i(i,j,k) = \exp(v_{iijk}) / \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} \exp(V_{iijk}) \quad (3.64)$$

b) Sampling

In order to make the conditional logit model empirically cooperative, the number of alternative choices should be small. This is a disadvantage of the model that limits its application, as a consumer normally selects a house from a large number of alternatives (Chattopadhyay, 2000). Previous studies have thus had to resort to arbitrary aggregation of dwellings to represent dwelling types (Quigley, 1976; Lerman, 1977). This may lead to biased valuations of characteristics in terms of magnitude and sign.

In order to alleviate this problem a sampling rule originally devised by McFadden (1978) can be followed. According to this rule, the researcher randomly selects a small subset of dwellings from a large number of alternatives for each consumer. The subset will thus contain the chosen dwelling and a few randomly selected dwellings not chosen by the consumer (McFadden, 1978). At the dwelling level out of N alternatives, a subset, *s,* is selected which contains *n* alternatives, such that *s* contains the chosen alternative and (n-1) rejected alternatives (Chattopadhyay, 2000). If this sampling rule is adhered to, the "uniform

conditioning property" is satisfied which leads to consistent parameter estimates (Bayer *et al*., 2002; Uyar & Brown, 2005).

3.3.1.3 WELFARE MEASUREMENT

Welfare estimation in the random utility model involves two steps. First, the coefficients need to be estimated. Following this, welfare effects can be calculated (Haab & McConnell, 2002). For example, consider the following estimation equation:

$$V_{ij} = \beta_0 + \beta_1 P_{ij} + \beta_2 z_{ij} \quad (3.65)$$

where the βs are the coefficients to be estimated, P is the price of the house and z is a house characteristic. In Equation 3.65, the calculation of the marginal implicit price (for characteristic z_i) is achieved by dividing the estimated attribute coefficient by the estimated price coefficient (i.e. β_2/β_1) (Chattopadhyay, 2000; Haab & McConnell, 2002). In order to calculate the willingness to pay for a non-marginal change the estimated implicit price is multiplied by the change necessary to bring an improvement to a site (Haab & McConnell, 2002).

The complexity of the welfare calculation largely depends on whether or not relocation to a new house takes place. If households do not relocate in response to an exogenous change (due to high moving costs), new locations do not have to be predicted and one can use the estimated utility function to calculate marginal implicit prices (Haab & McConnell, 2002; Palmquist, 2005). If relocation does occur, the equilibrium price schedule will change. Although the random utility model is unable to predict these changes, the welfare estimates calculated with the assumption that relocation does not take place still provides a lower bound estimate of the true welfare estimate (as is the case for the hedonic price model) (Haab & McConnell, 2002; Palmquist, 2005).

Cropper *et al*. (1993) compared welfare estimates derived from a standard hedonic price model with those obtained from a random utility model. Welfare measures for changes in a total of 10 housing characteristics were calculated. These characteristics included both neighbourhood characteristics and house specific characteristics. The study calculated welfare measures for a 25 percent and a 100 percent change in the characteristics. It was found that the random utility model provided more accurate welfare estimates than the hedonic price model. The study concluded that for non-marginal changes the random utility model is superior (when single market data are used) since it is difficult to accurately

estimate the demand functions for specific characteristics (the identification problem) when using the hedonic price model (Cropper *et al.*, 1993).

3.3.2 THE RANDOM BIDDING MODEL

3.3.2.1 UNDERLYING THEORY

The theoretical underpinnings of the random bidding model were developed by Ellickson (1981) with modifications performed by Lerman and Kern (Ellickson, 1981; Lerman & Kern, 1983; Palmquist, 1991, 2005). The random bidding model differs considerably from the random utility model as it seeks to model housing market equilibrium (whereas the random utility model is based on individual utility maximisation when faced with different houses in a choice set) (McFadden, 1978; Ellickson, 1981; Palmquist, 1991, 2005). More specifically, the random bidding model offers predictions as to the type of household who possesses a winning bid for a house with a given set of characteristics, bearing in mind that there are a finite number of households (Ellickson, 1981; Chattopadhyay, 1998; Palmquist, 2005). The application of the random bidding model requires that households be divided into homogenous types (Ellickson, 1981; Chattopadhyay, 1998). Socio-economic variables such as income, race and family size are used to determine the differences between household types (Ellickson, 1981; Chattopadhyay, 1998). In the random bidding model "the utility maximisation problem is solved to obtain the individual's bid function, that is, the bid as a function of the housing attributes and income, holding utility constant" (Freeman, 2003). A formal description of the model is presented by the following bid function:[28]

$$\theta = \theta(\boldsymbol{z}, u, y, \boldsymbol{\alpha}) \qquad (3.66)$$

Following Ellickson's (1981) notation[29], and assuming that households can be grouped into homogenous types based on income, socio-economic characteristics and utility, the bid for a household *h* within type *t* can be written as:

$$\theta_{ht} = \Psi_t(\boldsymbol{z}) + \varepsilon_{ht} \qquad (3.67)$$

where: Ψ_t = the common bid function for type *t.*

ε_{ht} = an individual specific error term associated with unobserved tastes of household *h* within type *t*.

[28] The notation used here was defined in Section 3.2.1.2.
[29] The common bid function is denoted by the Greek letter psi (Ψ).

The random bidding model assumes that houses go to the winning bidder, therefore it is necessary to calculate the maximum bid among households of type *t* (Ellickson, 1981; Chattopadhyay, 1998). This maximum bid is given by:

$$\underset{h \in G_t}{\text{Max}}\ \theta_{ht} = \Psi_t(z) + \underset{h \in G_t}{\text{Max}}\ \varepsilon_{ht} = \Psi_t(z) + \varepsilon_t^* \quad (3.68)$$

where: G_t = the set of households of type *t*.

The probability that a type *t* household will own a house with characteristics *z* is then given by Equation 3.69:

$$\Pr(t/z) = \Pr[\Psi_t(z) + \varepsilon_t^* \geq \Psi_{t'}(z) + \varepsilon_{t'}^* \text{ for all } t' \neq t] \quad (3.69)$$

3.3.2.2 MODEL ESTIMATION

Since the ε_t's in Equation 3.69 are assumed to be independent, Equation 3.69 has an extreme value distribution (McFadden, 1974; Ellickson, 1981; Lerman & Kern, 1983; Chattopadhyay, 1998; Palmquist, 2005). This enables Pr(*t*/*z*) (i.e. Equation 3.69) to be written in the multinomial logit form (McFadden, 1974; Ellickson, 1981; Lerman & Kern, 1983; Chattopadhyay, 1998; Palmquist, 2005):

$$\Pr \frac{t}{z} = e^{\Psi_t(z)} / \sum_{t' \in T} e^{\Psi_{t'}(z)} \quad (3.70)$$

The multinomial logit model represented by Equation 3.70 is under-identified (Ellickson, 1981; Lerman & Kern, 1983; Chattopadhyay, 1998). Therefore, the bid function coefficients (i.e. the parameters of Ψ_t in Equation 3.67) must be normalised to zero for one consumer type (Ellickson, 1981; Lerman & Kern, 1983; Chattopadhyay, 1998), which makes it impossible to estimate the absolute values of the parameters in Equation 3.67.[30] The inability to fully identify the parameter vectors limits the model in terms of estimating willingness to pay for various characteristics of the housing bundle (Ellickson, 1981).

[30] Only differences in the parameters between consumer types can be estimated (Ellickson, 1981).

3.3.2.3 WELFARE MEASUREMENT – THE LERMAN AND KERN (1983) MODIFICATION

After a modification by Lerman and Kern (1983), welfare measurement became possible (Lerman & Kern, 1983). This modification is based on the fact that the sales price of the house can be assumed to equal the winning bid. With this additional piece of information the entire set of parameters can be identified. In the Lerman and Kern (1983) modification, the price paid for the house is denoted by *P*. This information allows computation of the probability density of the following event:

$$\{\Psi_t(z) + \varepsilon_t^* = P \text{ and } \Psi_{t'}(z) + \varepsilon_{t'}^* \leq P \text{ for all } t' \neq t\} \quad (3.71)$$

If it is again assumed that the ε_t 's are independent, then

$$f(P - \Psi_t(z)) \prod_{t' \neq t} F(P - \Psi_{t'}(z)) \quad (3.72)$$

where: $F(\varepsilon_t^*) = \exp[-e^{-\omega\varepsilon_t^*}]$

$f(\varepsilon_t^*) = \omega e^{-\omega\varepsilon_t^*} \exp[-e^{-\omega\varepsilon_t^*}]$

ω = the scale parameter of the disturbances.

Therefore, Equation 3.72 becomes:

$$\omega e^{-\omega(P - \Psi_t(z))} \prod_{t' \neq t} \exp[-e^{\omega(P - \Psi_{t'}(z))}] \quad (3.73)$$

The likelihood function (based on Equation 3.73) for a household of type *t* (denoted by *t*(*n*)) occupying house *n* (*n*=1,2,…,*N*) is:

$$L = N\log\omega - \omega \sum_{n=1}^{N} (P_n - \Psi_{t(n)}(z_n)) - \sum_{n=1}^{N} \sum_{t'=1}^{T} e^{-\omega(P_n - \Psi_{t'}(z_n))} \quad (3.74)$$

The parameters of the right hand side of Equation 3.74 can be estimated using maximum likelihood (Lerman & Kern, 1983). Since these parameters can be fully identified, the model can be used to infer willingness to pay values for changes in house characteristics. More specifically, for any household of type *t*, the difference in bid associated with a change in a characteristic can be interpreted as the willingness to pay for the change (Lerman & Kern, 1983).

Chattopadhyay (1998) compared the results of a standard hedonic regression with those obtained from the random bidding model. The study used data from the Chicago housing

market and concluded that the benefit estimates obtained from the hedonic price model were similar to those obtained from the random bidding model (Chattopadhyay, 1998). For the random bidding model, households were divided into four types (using two income categories and two family size categories). The study concluded that the random bidding model is particularly useful if the WTP for characteristics by different types of households is required (Chattopadhyay, 1998).

3.4 THE REPEAT-SALES MODEL

3.4.1 UNDERLYING THEORY

The repeat-sales model, a variant of the standard hedonic price model, was developed by Bailey, Muth and Nourse (1963) and was modified by Palmquist (1982). The model has primarily been used to generate real estate price indexes (Case & Quigley, 1991; Clapp & Giaccotto, 1992). However, there have been a few applications of the method to infer welfare estimates (Palmquist, 1982; 2005; Kohlhase, 199; Gatzlaff & Smith, 1993).[31]

The model uses repeat sales of houses that have experienced an environmental change between sales (Palmquist, 1982; 2005; Freeman, 2003; Benoit & Lanoie, 2007). An important requirement of the model is that other characteristics of the house, with the exception of age and the general real estate price level, have remained unchanged (Palmquist, 1982; 2005; Freeman, 2003, Benoit & Lanoie, 2007). Herein lies the major advantage of the repeat-sales model – data requirements are substantially reduced since characteristics that have remained unchanged can be excluded from the model (Palmquist, 1982; 2005; Gayer & Viscusi, 2002; Freeman, 2003; Benoit & Lanoie, 2007).[32]

3.4.2 MODEL ESTIMATION AND WELFARE MEASUREMENT

The relationship between traditional hedonic regressions and repeat-sales estimates can be explained by revisiting a standard hedonic price model:

$$P_{t'} = P\,(z_1, z_2, \ldots, z_n, E_{t'}, A_{t'}) \qquad (3.75)$$

[31] Previous studies have used the repeat-sales method to determine the impact of the construction of train stations, highways, and hazardous waste sites.

[32] However, if it is discovered that significant changes in structural characteristics between sales have occurred, it is necessary to screen the data in order to eliminate problematic observations (Palmquist, 1982; Gayer & Viscusi, 2002).

where: z_i (i = 1, 2,…,n) = house characteristics

$E_{t'}$ = the environmental variable.

$A_{t'}$ = the age of the house at the time of the sale.

t' = the date of the sale.

For the purposes of the repeat-sales method, an unspecified general functional form is hypothesised (Palmquist, 1982; 2005; Gayer & Viscusi, 2002; Benoit & Lanoie, 2007). However, there are certain mild restrictions – changes in environmental variables and the general real estate price level must be expressed in percentage terms, and house prices must be assumed to depreciate geometrically with age (Palmquist, 1982). These restrictions allow Equation 3.75 to be rewritten as:

$$P_{t'} = B_{t'}g(z_1, z_2,\ldots,z_n)\exp(\gamma E_{t'})\exp(-\delta A_{t'})\exp\varepsilon_{t'} \quad (3.76)$$

where: $B_{t'}$ = a true but unknown real estate index at the time of sale.

γ = a parameter to be estimated.

δ = a parameter to be estimated.

$\varepsilon_{t'}$ = an error term.

g = the characteristics function (can be left unspecified) (Palmquist, 1982).

It is essential that there are at least two sales for each property. A house thus has an earlier sale in year t (Palmquist, 1982; 2005; Gayer & Viscusi, 2002; Freeman, 2003; Benoit & Lanoie, 2007):

$$P_t = B_t g(z_1, z_2,\ldots,z_n)\exp(\gamma E_t)\exp(-\delta A_t)\exp\varepsilon_t \quad (3.77)$$

It is then possible to calculate the ratio of the prices at the two sales:

$$R^*_{tt'} = P_{t'}/P_t = B_{t'}/B_t = \exp[\gamma(E_{t'}-E_t)]\exp[-\delta(A_{t'}-A_t)]\exp(\varepsilon_{t'}-\varepsilon_t) \quad (3.78)$$

In Equation 3.78 the characteristics function (g) cancels out on the assumption that the house characteristics have remained unchanged between the two sales (Palmquist, 1982; 2005; Gayer & Viscusi, 2002; Freeman, 2003). Unfortunately, "the difference in age of the house at the two sales is an exact linear combination of the year dummy variables that would be used in estimating the B_i" (Palmquist, 1982). This means that the estimation of Equation 3.78 will be unreliable. However, by using an independent depreciation estimate in

order to adjust for the depreciation which took place between the two sales, this problem can be overcome. This adjustment is only necessary if the researcher wishes to generate an index. If the focus of the study is on welfare estimates (and not index generation) it is possible to proceed without the adjustment. In this case, the age variable can be eliminated from Equation 3.78. This does not affect the coefficient estimate of the environmental variable (γ) (Palmquist, 1982; 2005; Gayer & Viscusi, 2002).

In order to estimate Equation 3.78 (after omitting the age difference variable) one can take the natural log of both sides (Palmquist, 1982; 2005; Gayer & Viscusi, 2002). This yields:

$$r_{tt'} = -\beta_t + \beta_{t'} + \gamma E_{tt'} + \nu_{tt'} \qquad (3.79)$$

where: $r_{tt'}$ = the natural log of $R_{tt'}$

β_t = the natural log of B_t

$\beta_{t'}$ = the natural log of $B_{t'}$

$E_{tt'}$ = $E_{t'} - E_t$

$\nu_{tt'}$ = $\varepsilon_{t'} - \varepsilon_t$

The effect of marginal changes of an environmental variable on house prices is given by the coefficient estimate γ in Equation 3.79 (Palmquist, 1982). The effect of a non-marginal change (ΔE) is given by:

$$c = \exp(\hat{\gamma}\,\Delta E) - 1 \qquad (3.80)$$

Unfortunately, a major drawback of the repeat-sales model is the potential of sample selection bias (Case, Pollakowski & Wachter, 1991; Clapp, Giaccotto & Tirtiroglu, 1991; Cho, 1996; Hwang & Quigley, 2004). Some types of properties may trade more frequently than others, and will thus be over-represented in the sample.[33] This may result in a biased index. For example, if cheaper houses sell more frequently but more expensive houses experience slower price appreciation, a repeat-sales index will tend to have an upward bias (Handbook on Residential Property Prices, 2011). There are various reasons why cheaper properties tend to have a higher turnover rate. The transaction costs on cheaper properties are lower

[33] Clapp *et al*. (1991) found no evidence of systematic differences between the repeat-sales sample and the full sample, arguing that prices for the repeat sample grew at the same rate as for the full sample due to arbitrage. Furthermore, a study by Meese and Wallace (1997) concluded that the use of a repeat sample was representative of all sales during the sample period in question.

and are thus traded more frequently. Cheaper houses are also used more frequently for the buy-to-let market (Handbook on Residential Property Prices, 2011).

Although the assumption of the other hedonic coefficients being constant over time may not hold true, the repeat-sales model substantially reduces data costs and potential variable misspecification (Freeman, 2003).

3.5 CONCLUSION

The diversity of property value models available to researchers has been highlighted in this chapter with an emphasis placed on the way individuals value housing characteristics. In this context, the hedonic price model is well entrenched in the literature and is the most popular method to infer willingness to pay for changes in housing characteristics. A variant of the hedonic price model, namely the repeat-sales method is used mainly to generate real estate price indexes as opposed to valuing changes in non-market housing characteristics.

The discrete choice models discussed in this chapter have been less commonly applied. Their application is often used as a validity check to compliment hedonic price studies. This complimentary role has the potential to enhance hedonic price applications that seek to determine welfare estimates caused by environmental and locational changes.

The majority of international studies regarding social housing use the hedonic price model. Chapter Four provides international examples of applying the hedonic price model in the context of social housing.

CHAPTER FOUR: A REVIEW OF THE INTERNATIONAL LITERATURE

4.1 INTRODUCTION

Chapter One highlighted one of the main challenges facing social housing developments, namely "local opposition" who argue that these structures may lead to reductions in the market values of adjacent residential houses. Many international studies have attempted to address this issue (Nourse, 1963; Guy *et al*., 1985; Cummings & Landis, 1993; Lyons & Loveridge, 1993; Goetz *et al*., 1996; Briggs *et al*., 1999; Carroll & Clauretie, 1999; Lee *et al*., 1999; Galster *et al*., 1999; Colwell *et al*., 2000; Santiago *et al*., 2001; Cummings *et al*., 2002; Iglesias, 2002; Ellen & Voicu, 2006). Chapter Four presents a review of these thirteen studies. All of these studies explicitly focus on the type of effect social housing exerts on property values. The methodology used in the majority of these studies is regression analysis (hedonic pricing).[34] Only one study, the earliest one, uses price trend comparisons between test and control sites. Most of the studies employed distance to social housing as a key variable, and some studies included a spatial dimension.

4.2 NOURSE (1963) STUDY

The study by Nourse (1963) is credited as one of the earliest studies examining the effects of social housing on surrounding property values (Goetz *et al*., 1996). At the time of the study, housing reformers often claimed that decent housing (as opposed to slums) meant less crime, less juvenile delinquency, lower policing costs, better health and lower death rates (Nourse, 1963). Many people were thus of the opinion that social housing led to increases in surrounding property values. However, no actual scientific evidence was available at the time to substantiate this claim. The main purpose of this study was to scientifically examine this claim (Nourse, 1963).

The technique used in the study was to measure the improvement (or degradation) of the environment by measuring the change in the land values of the neighbourhood in which a social housing project was established. The economic value of location was measured by analysing the land value plus improvements (land value alone could not be used as less than 10 percent of the land in the study area was vacant). Thus, the only prices available for the study were for land and improvements (Nourse, 1963).

The study area consisted of eight St. Louis, Missouri public housing projects. These were arranged into three neighbourhoods. A social housing neighbourhood was defined as the

[34] Not all of the studies reviewed provided the hedonic price equation.

area surrounding each project. This area was defined as a minimum of two blocks (to insure adequate sales for an index) and a maximum of three blocks (as the distance decay effect would begin to materialise at greater distances) (Nourse, 1963). The three neighbourhoods were called A, B and C. Neighbourhood A had four social housing projects in its vicinity, B had two projects and C had two projects. Three control neighbourhoods were also defined and called A_1, B_1 and C_1, respectively. This was one of the main difficulties of the study – to find suitable areas that were comparable to the public housing neighbourhood in every respect, with the exception of the project. This was impossible and other neighbourhood differences were thus also analysed (Nourse, 1963).

In order to compare the social housing neighbourhoods and the control neighbourhoods, data on the following characteristics were obtained: the total number of dwelling units, the percentage of units that were occupied, the percentage of occupied units that were tenant occupied, the percentage of units that were built prior to 1900, the percentage of units that were built between 1900 and 1919, the percentage of units with comprehensive plumbing, the percentage of units with more than 1.5 persons per room, average monthly rental, household income, employment status of the head of the household, and the occupation of the head of the household. These data were obtained from the 1940, 1950, and 1960 censuses. Most of the control neighbourhood characteristics were the same as in the social housing neighbourhoods.

Real estate price indexes were then constructed for the three social housing neighbourhoods and the three control neighbourhoods, using sales data from the Real Estate Abstract of the Assessor's office of the City of St. Louis over the period 1937 to 1959. A total of 5 044 initial and final transactions were considered. The residential demand was similar in areas A and B, with the exception of area C, where a disproportionate amount of purchases were made by trucking companies (with 11.2 percent of sales attributed to trucking companies as opposed to 0.3 percent and 0.6 percent for areas A and B, respectively) (Nourse, 1963).

The results of the study indicated that there were no significant differences in the trend of prices in areas A and A_1, and B and B_1. For this reason, the study found that social housing had no effect on surrounding property values in areas A and B. The trend of prices was higher in area C than in area C_1. However, the higher price trend in area C (compared to C_1) was attributed to trucking demand (and not social housing). The study, thus, concluded that social housing did not result in a rise in surrounding residential property prices.

4.3 GUY, HYSOM AND RUTH (1985) STUDY

Guy *et al*. (1985) conducted a case study in order to determine the effect of social housing on adjacent (non-subsidised) property values. The main purpose of the study was to enhance the literature on social housing (at the time, very little scholarly research on the topic was available) (Guy *et al*., 1985). Two below-market interest rate (*BMIR*) housing projects (social housing) in Fairfax County, Virginia (suburban Washington, D.C.) were considered for the study. The method of application was the hedonic price method (Guy *et al*., 1985).

The study area comprised four middle-income townhouse clusters in Fairfax County, Virginia. This area was selected due to the high degree of homogeneity between the clusters. This provided a unique opportunity as the clusters were part of the same community but varied in distance from the social housing units. Apart from the community similarities, the clusters were also very similar with respect to several value-influencing externalities. These externalities included proximity to highways, schools, and public facilities. In addition, all four clusters were subjected to the same property tax rates (Guy *et al*., 1985).

The hedonic price equation took a linear functional form. The dependent variable used in the study was the actual sales price on units in all four clusters. The independent variables included the following: distance to the social housing project (*BMIR*), a dummy variable indicating whether or not the unit was an end unit (*Endunit*), number of bedrooms (*Bedrooms*), a dummy variable indicating the presence of a basement (*BSMT*), and a series of time trend variables. The time trend variables were incorporated into the model because sales took place over the period 1972 to 1980. The time trend variables were specified as follows: *T*1 (1 if the sale occurred in 1972 and 0 otherwise), *T*2 (1 if the sale occurred in 1973 and 0 otherwise), etc. The sample consisted of a total of 861 sales transactions.

The regression model (estimated using ordinary least squares) was specified as follows:

$$P = B_0 + B_1 BMIR + B_2 Endunit + B_3 Bedrooms + B_4 BSMT + B_5 T2 + B_6 T3 + B_7 T4 + B_8 T5 + B_9 T6 + B_{10} T7 + B_{11} T8 + B_{12} T9 \quad (4.1)$$

The results of the analysis revealed an R-squared[35] value of 0.88, indicating a model with exceptionally good fit. All the coefficients were statistically significant at the 5 percent level (or higher). The positive and statistically significant coefficient for *Endunit* implied that end units sold at a premium over interior units. The number of bedrooms coefficient was also (predictably) positive. The coefficient on the basement variable revealed that units with a basement also sold at a premium. The variable of interest (*BMIR*) had a coefficient of 1.57. This implied that the further away a unit was from the subsidised housing project, the higher its price *ceteris paribus*.

The study provided strong statistical evidence that proximity to subsidised housing had a negative effect on surrounding property prices. However, it was conceded that, while other external value influences were controlled for, the possibility existed that some other external influence was being measured by the *BMIR* variable (Guy *et al*., 1985).

4.4 CUMMINGS AND LANDIS (1993) STUDY

In an application of the hedonic price model, Cummings and Landis (1993) sought to determine the effect of Holloway Terrace (a 42-unit condominium project catering for the elderly in San Francisco, California) on surrounding residential property prices. The purpose of this study was to test the validity of the NIMBY hypothesis.

The complex is located on the site of a former school in San Francisco's Ingleside neighbourhood and also features a community centre. The townhouses (which comprise 2 and 3 bedroom units) were initially sold for under $100 000. This was well below neighbouring sales prices at the time (Cummings & Landis, 1993). The townhouses also featured patios, fireplaces and attached garages. The City of San Francisco provided assistance to first time home buyers, and this, combined with low-interest bond financing, enabled families earning less than $23 000 per annum to purchase a unit.

A total of 612 single-family home sales were considered in the study. The sales price of each home was used as the dependent variable in the regression analysis. These sales took place over the time period 1985 to 1992. Of the 612 observations, 150 homes were located within half a mile of the project, 61 were located within a quarter of a mile of the project and nine were located within an eighth of a mile of the project.

[35] Some of the studies reviewed did not provide an adjusted R-squared value. In these cases, only the R-squared value is reported on in Chapter Four.

Five independent variables were included in the regression analysis, namely the size of the house (*SQFT*), the number of bathrooms and bedrooms (*BATHS* and *BEDS,* respectively), the size of the erf (*LOTSIZE*), the age of the house (*AGE*), and finally, distance of the house from Holloway Terrace. The distance variable was recorded as a dummy variable in the study. Three zones were created in this regard. The first zone was a radius of an eighth of a mile (*Emile*). If the house was located within this zone, it was coded as "1", if not, "0". The second zone was a radius of a quarter of a mile (*Qmile*) and the third was a radius of half a mile (*Hmile*). The coding process for these zones followed the same procedure as for the first zone (Cummings & Landis, 1993). The regression model took the following general form:

*CPRICE*90 = *f* (*SQFT*, *LOTSIZE*, *BATHS*, *BDRMS*, *AGE*, *Hmile*, *Qmile*, *Emile*)……..……(4.2)

The results of the regression revealed the following information: the number of bedrooms, bathrooms, the size of the house and the size of the erf all had a statistically significant effect on house prices, with *t*-statistics of 2.268, 2.220, 5.608 and 9.982, respectively. Age did not appear to be a statistically significant predictor of house prices. Furthermore, the most important variable included in the study (the distance variable) was statistically insignificant in all three cases, with *Emile*, *Qmile* and *Hmile* displaying *t*-statistics of 0.431, -1.079 and 0.878, respectively. This result suggests that Holloway Terrace had no effect on surrounding residential property prices, thus dispelling the NIMBY argument in this case.

4.5 LYONS AND LOVERIDGE (1993) STUDY

Another study which set out to test the NIMBY syndrome was undertaken in Ramsay County, Minnesota by Lyons and Loveridge (1993). The study attempted to estimate what property owners would be willing to pay to have an increase or a decrease in social housing situated near them. In addition to this, the study also estimated hedonic prices for different spatial distributions of the social housing (Lyons & Loveridge, 1993).

A total of 120 federally subsidised housing projects in Ramsay County were considered for the study. In addition, the researchers defined 16 variables of interest relating to the social housing units. These variables included information on the presence (number of projects and number of actual units), the spatial pattern (distance between the non-subsidised housing units and social housing units), value (average per unit value of the social housing units), tenant type, and finally, the subsidy type.

Data on 128 010 non-subsidised residential housing units were collected from the Ramsay County Department of Property Taxation and Records (Lyons & Loveridge, 1993). For computational ease, this was reduced to a sample of 25 percent (n = 26 503). The data included both structural and locational attributes of each housing unit, with the dependent variable being the assessed value of each housing unit. For each housing unit in the sample, distances to each of the 120 subsidised projects in the county were computed. The distances were then separated into five radii, ranging from 300 feet to two miles. Distances greater than two miles were discarded. The regression equation used in the study was specified in quadratic form:

$$P = \alpha + \beta S + \beta_L L + \gamma_1 NLOCS + \lambda_1 NLOCS^2 + \gamma_2 MAINDIS + \lambda_2 MAINDIS^2 + \varepsilon \quad (4.3)$$

where: *S* = structural characteristics.

L = locational characteristics.

NLOCS = number of subsidised locations within the radius.

MAINDIS = weighted mean distance between the non-subsidised house and all subsidised locations weighted by the number of units at each location.

The regression equation was estimated using ordinary least squares. The interpretation of the quadratic coefficients is as follows: if consumers are willing to pay more for the attribute in question, then γ should be positive and λ should be negative. Conversely, if consumers are willing to pay more to have less of the attribute present, γ should be negative. The sign of λ depends on the assumption of diminishing marginal values. It thus follows that if the coefficients of the first order terms of *NLOCS* and *MAINDIS* are negative, the subsidised units are in fact negative externalities and owners of non-subsidised units would be willing to pay to have less of these units situated nearby (Lyons & Loveridge, 1993).

An analysis of the results reveals that both *NLOCS* and *MAINDIS* were insignificant at the 300 foot radius. The reason for this result is the small number of houses which have subsidised housing within 300 feet (123 out of 25 603) (Lyons & Loveridge, 1993). Looking at the spatial variable, *MAINDIS*, for the quarter mile radius to the two mile radius, statistically significant coefficients were estimated, although they were too small in magnitude to imply any real impact (in financial terms) (Lyons and Loveridge, 1993). The *NLOCS* coefficients were all statistically significant from the quarter mile to the two mile radius and ranged in value from -$1585 (quarter mile) to -$609 (two mile).

These findings appear to be consistent with the NIMBY hypothesis and imply that owners of non-subsidised housing would be willing to pay to have less subsidised housing units situated nearby. The findings are also consistent with the diminishing distance effect (diminishing effect at larger radii) with the coefficient on *NLOCS* becoming smaller as the radius is increased.

4.6 GOETZ, LAM AND HEITLINGER (1996) STUDY

The study by Goetz *et al*. (1996) examined the impact of subsidised multi-family homes on urban neighbourhoods in Minneapolis, Minnesota. The study focused on the relationship between subsidised housing and three neighbourhood vitality dimensions, namely surrounding property values, crime and the overall "fit" of the project. According to Goetz *et al*. (1996), earlier studies seeking to highlight the impact of subsidised housing compared neighbourhoods with subsidised housing to "control" neighbourhoods without such projects. This approach would be virtually impossible today given the stark differences between lower income suburbs (where subsidised projects are typically placed) and more affluent suburbs (where these projects are generally not placed). Thus, finding neighbourhoods where the only difference in neighbourhood characteristics is the presence of subsidised housing would prove to be challenging. To overcome this problem a hedonic price model was employed which allows for the impact of the subsidised housing project to be isolated and analysed (Goetz *et al*., 1996).

The study area comprised a total of 23 multi-family projects developed by non-profit community development corporations (CDCs) in the central neighbourhoods of Minneapolis. A hedonic price function for all residential properties in the central neighbourhood of Minneapolis was estimated. Data on 14 structural variables were gathered from records of the City of Minneapolis Assessor's office. In addition to the structural variables, 12 neighbourhood variables were added. These variables provided a measure of the social, economic and physical characteristics of the neighbourhood. The independent variable of interest in this case was "distance to privately-owned, publicly subsidised housing". The dependent variable used in the study was the 1994 assessed property value because the use of actual sales prices may have limited the sample size (if not enough transactions have taken place in the study period). A total of 22 156 observations were used to estimate the hedonic price equation.

The hedonic results revealed an adjusted R-squared value of 0.590. The coefficients of all the variables estimated in the study were statistically significant, with bedrooms, bathrooms, building area, fireplace, garage, pool, age and condition reporting p-values of 0.000, 0.001,

0.000, 0.000, 0.000, 0.000, 0.000 and 0.000, respectively. In addition to this, all of these coefficients conformed to *a priori* expectations and displayed the correct signs. The critical variable, namely "distance to privately-owned, publicly subsidised housing", had a coefficient of -0.82 and a p-value of 0.000, indicating statistical significance. As the inverse of the distance from the non-subsidised house to the subsidised project was measured, the negative coefficient reveals that proximity to the subsidised project had a negative impact on property values (Goetz *et al*., 1996). These findings suggest that proximity to privately-owned, publically subsidised housing resulted in a decline in surrounding property values to the tune of approximately $0.82 per foot.

The findings of this study are consistent with the NIMBY hypothesis, although it was stressed by Goetz *et al*. (1996) that few critics have an objection to social housing from a social welfare perspective. In fact, most agree that subsidised housing is one of the only ways to ensure that low-income families have access to safe, decent and affordable housing in today's market place. The objections, thus, stem from the suitability of social housing in a particular neighbourhood (Goetz *et al*., 1996).

4.7 BRIGGS, DARDEN AND AIDALA (1999) STUDY

In this study, Briggs *et al*. (1999) addressed the issue of scattered-site public housing in the neighbourhoods of Yonkers, New York by examining the effect of seven social housing developments on surrounding property prices. The rationale for the study was based on increased hostility towards court-ordered desegregation of public housing in the 1990s (Briggs *et al*., 1999).

The scattered-site social housing considered for the study by Briggs *et al*. (1999) was constructed between 1990 and 1993, with occupancy taking place between 1992 and 1994 (Briggs *et al*., 1999). The 200 units are spread across seven sites and comprise two and three bedroom townhouses. The brick units have small, private backyards and are built in such a manner so as to blend in with the surrounding areas (Briggs *et al*., 1999). Tenants were selected by the Yonkers Municipal Housing Authority from two groups: 50 percent from current residents and 50 percent from households on the waiting list. Once households met certain income, family composition and payment history requirements, the selection was made by lottery.

The method used by Briggs *et al*. (1999) was the hedonic price method. The study area comprised the seven scattered-site public housing projects in Yonkers, New York. Real estate data were obtained from the Multiple Listings Sales Books for state. The dependent

variable used in the study was the actual sales price. The study period was from 1985 to 1996. Time trend variations were controlled for by creating a series of dummy variables. The independent variables consisted of a number of house specific structural characteristics and proximity characteristics. The structural characteristics included age, number of rooms, number of bathrooms, interior size and erf size. In terms of the proximity variables, GIS software was used to create circular buffers around the seven scattered-site housing projects. Dummy variables were then created to indicate whether the subject property was situated within one-quarter mile of any of the seven projects. In addition, dummy variables were also created to indicate "whether each sale took place before or after the announcement and occupation of the scattered-site housing project" (Briggs *et al*., 1999).

A total of 3 101 observations were used to generate the hedonic price equation. This equation was of linear functional form and robust standard errors were estimated for the coefficients in order to correct for heteroskedasticiy (Briggs *et al*., 1999).

All structural characteristics were statistically significant in the hedonic price model and an adjusted R-squared of 0.74 was reported. The model investigated price differentials relating to overall proximity to scattered-site public housing (any of the seven sites). Three coefficients were estimated in this regard: before the site announcement[36] (β_1), prior to occupancy (β_2), and post occupancy (β_3). These were price differentials relative to the remaining area within the census tract (Briggs *et al*., 1999). The proximity coefficients themselves did not isolate the presence of the scattered-site public housing project. In order to determine the effect of the scattered-site public housing project, the difference between pre-event (β_1) and post-event coefficients (β_2) was determined. In addition, the difference between β_2 and β_3 was also calculated to determine if post occupancy had an effect on property prices. A statistically significant difference between two coefficients indicated a reliable effect of the scattered-site public housing project (Briggs *et al*., 1999).[37]

The study concluded that no significant differences between the respective coefficients were present, indicating that neither the announcement nor occupancy of the scattered-site social housing projects had an effect on surrounding property values. This result was attributed to good housing management and the early involvement of public officials and police in mitigating home owner fears (Briggs *et al*., 1999).

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[36] All seven projects were known to the public about five years prior to the start of construction.
[37] For example, in order to capture the "announcement effect", the null hypothesis was defined as:

H_o: $\beta_1 - \beta_2 = 0$

4.8 CARROLL AND CLAURETIE (1999) STUDY

The research conducted by Carroll and Clauretie (1999) investigated the transitory effects of public and senior housing on nearby residential property values. The study was unique in that it not only tested for the effect of the establishment, but it also tested for the duration of the impact.

The social housing considered for the study included 13 affordable housing projects catering for low-income residents in Clark County, Nevada. Of the 13 projects, three catered for senior citizens while the remaining 10 were designed for family living (Carroll & Clauretie, 1999). Eight of the properties were brand new buildings, built solely for the purpose of low-income housing and five were acquired by the Clark County Housing Authority. The projects ranged in size from small four unit complexes to large-scale complexes consisting of 356 units (Carroll & Clauretie, 1999). The projects provided a good mix in terms of size, age, purpose and nature of conversion to low-income use (new or existing).

The hedonic price model was used to determine the effects of the 13 projects on surrounding property prices. In order to estimate the hedonic price equation, data on 6 321 residential properties in Clark County, Nevada (the study site) were gathered. The dependent variable used in the study was the actual sales price and the study period was from 1968 to 1997. All sales prices were adjusted to constant 1983 dollars. The following independent variables were included in the analysis: age of house, number of bathrooms, number of bedrooms, number of rooms, size of house, erf size, the presence of a fireplace, the presence of a garage, the presence of a pool, and the distance to a public or senior housing project. In addition to these variables, it was also recorded whether or not the sale occurred prior or subsequent to the establishment of the project. Finally, data on the socio-economic characteristics of the neighbourhood were also collected, along with data on the actual low-income project (in terms of its size, whether or not is was owned by the county or by a private entity, the profit motive of the project owner, whether or not the project was new or existing, and whether the project was for family or senior citizens) (Carroll & Clauretie, 1999). The socio-economic data were collected to determine if factors such as racial composition of the census tract and the resident status (owner versus tenant) had an effect on property prices (Carroll & Clauretie, 1999).

The basic hedonic price equation estimated in the study was:

$P_{ijt} = f\,(X_i, S_j, D_{ij}, PR_j)$……..……(4.4)

where: P_{ijt} = Sales price of the ith house near the jth project.

X_i = Vector of characteristics of the ith house.

S_j = Vector of socio-economic variables in the census tract of project *j.*

D_{ij} = Distance of the ith house from the jth project (in feet).

PRj = Vector of the characteristics of the project.

In total, six different double-log hedonic price equations were estimated using the ordinary least squares method of estimation. The first equation consisted only of the house specific characteristics and a time trend variable. This model was run simply to generate a standard hedonic price equation. The results of this model mirrored the usual hedonic results with all house-specific characteristics displaying the correct signs. With the exception of the number of rooms, the coefficients of all house-specific characteristics were statistically significant. The model reported an adjusted R-squared value of 0.433 (Carroll & Clauretie, 1999).

The second equation added socio-economic characteristics of the census tract, specifically the log of the percentage of black residents and the log of the percentage of owner-occupied houses. This model had an adjusted R-squared value of 0.478 and found that for each doubling of the proportion of black residents, property prices declined by 5 percent. A doubling of the proportion of owner-occupied units was found to increase property prices by 7.4 percent (Carroll & Clauretie, 1999).

The third equation introduced 12 indicator variables. These indicator variables identified 12 of the 13 census tracts in which the projects (and the neighbouring properties) were located. This model reported an adjusted R-squared value of 0.497 and weakened the effect of the socio-economic variables introduced in the second equation (Carroll & Clauretie, 1999).

The fourth equation incorporated the proximity variables. The log of the distance of the residential unit to the low-income housing project (current or future) was included (*LFEET*). In addition to this variable, an interaction term (*AFTERLFEET*) was also created. This interaction term was set equal to zero if the property was purchased before the low-income project was established and equal to the log of the distance between the residential property and the low-income project if the property was purchased subsequent to the opening of the project. The coefficient of the first distance variable was insignificant, implying that the project had no effect on adjacent property values until it was opened (i.e. there was no “announcement effect” on residential property prices). However, the interaction term was statistically significant. More specifically, property values increased by approximately one percent for each doubling of distance from a current low-income housing project. This

version of the model reported an adjusted R-squared value of 0.499 (Carroll & Clauretie, 1999).

The fifth equation incorporated a variable measuring the time (in days) between the sale of the residential property and the opening of the project (*SOLD*). If the sale occurred before the project opening, this variable was a negative number and if the property was sold after the project opening, it was positive. The coefficient of the *SOLD* variable implied that properties appreciated by approximately 0.009 percent each day after the opening of the project. An interaction term was also created. This term was the product of *LFEET* and *SOLD*. By dividing this interaction term's coefficient by the coefficient of the interaction term in the fourth equation, it was determined that property values took an average of 391 days to return to their original values (Carroll & Clauretie, 1999).

The sixth equation incorporated the low-income housing project characteristics. These variables were included to determine the effect of the type of low-income housing project on surrounding property values. It was determined that bigger projects (in terms of units) had a greater effect on property values. Projects aimed at senior citizens also tended to exert a greater negative effect on property values than those catering for families. The profit motive of the project owner and the age of the project also played a role. Newer projects had less of a negative effect than older projects and for-profit projects also had a lesser negative effect than not-for-profit projects (Carroll & Clauretie, 1999).

The findings of this study had important policy implications as it investigated not only the effect of low-cost housing, but also the time taken for the effects to diminish. The findings suggested that although low-cost housing had a negative effect on surrounding property values, this effect was temporary and property prices generally recovered after about a year. In addition to this, the results also suggested that the type of low-income housing projects also plays a role in determining their effects of surrounding property prices. New projects were found to be better than converted apartment buildings and for-profit projects are better than not-for-profit ones.

4.9 GALSTER, TATIAN AND SMITH (1999) STUDY

The study by Galster *et al*. (1999) analysed the sales prices of single-family homes surrounding Section 8 Certificate Sites. The study focused on the effect of these sites in different census tracts. Four specific questions were addressed by the study: Firstly, does the occupancy of an apartment by a Section 8 household cause a significant reduction in the sales prices of adjacent residential houses? Secondly, does any price impact vary within 2 000 feet of the Section 8 site? Thirdly, does any price impact vary with the number of Section 8 sites and units occupied? Fourthly, does any price impact vary across different types of neighbourhoods?

Baltimore County was chosen as the study area and the method used to address the research questions was the hedonic price method. A total of 43 361 residential homes sales were considered for the study. These sales took place over the period 1991 to 1995. A total of three hedonic price equations were estimated. The dependent variable used in the regressions was the actual sales price. All three models included the usual house characteristics typical of hedonic price studies, with the key housing attribute being the proximity to a Section 8 site (Galster *et al*., 1999). Three proximity measures were defined: houses located within 500 feet of a Section 8 site, houses situated between 501 and 1000 feet of a Section 8 site, and houses situated between 1001 and 2000 feet of a Section 8 site (Galster *et al*., 1999). An additional proximity measure was also defined, namely the number of subsidised tenants within *x* feet of the residential home (Galster *et al*., 1999). The regression models were structured in a manner so as to create the equivalence of a pre/post experiment, by comparing the level and trend of house prices in a neighbourhood both before and after a site was occupied by tenants.

The first regression model tested for effects of both price level shift and price trend slope alteration in the three impact areas defined by the proximity measures. This model implicitly assumed that the impact of proximity was invariant to the number of sites. The second model relaxed this assumption by allowing the post occupancy shift variable to assume the number of occupied Section 8 sites at the given distance at the time of sale (Galster *et al*., 1999). The third model used the number of actual units (not sites). The semi-log functional form was used in the estimation of all three models.

The models performed well, with each model reporting an adjusted R-squared value of 0.79. All structural, census tract, and price trend control variables displayed coefficients that were statistically significant and had the hypothesised signs (Galster *et al*., 1999). The results of the regressions indicated that neighbourhoods into which Section 8 sites were introduced

were valued less and had lower rates of appreciation than other neighbourhoods with no Section 8 sites situated close by (within 1000 feet) (Galster *et al*., 1999). This means that there was a tendency for Section 8 sites to be located in less desirable areas.

With regard to the effect of Section 8 sites on surrounding property values, properties within 500 feet of a Section 8 site were positively affected, provided the number of sites was less than six. With a larger number of sites, the net impact on prices was negative (Galster *et al*., 1999). A similar result was obtained when analysing the effect of the number of units on adjacent property prices. These results indicated that a 500 foot proximity to less than eight units resulted in a positive effect on adjacent property prices. However, when more units were located within 500 feet, the effect on adjacent property prices was negative (Galster *et al*., 1999). The results for the 1001 to 2000 foot ring indicated that the presence of Section 8 sites had a negative effect on property prices (Galster *et al*., 1999). The study found that positive impacts from close proximity to Section 8 sites only occurred in certain types of neighbourhoods. These neighbourhoods generally had higher house prices, real house price appreciation and were occupied predominantly by whites (Galster *et al*., 1999). Negative price impacts were confined to "vulnerable" areas (Galster *et al*., 1999).

Based on these findings, the study concluded that Section 8 subsidised housing has the potential to generate positive externalities in more affluent areas. These positive externalities were attributed to exterior improvements to the rental building. However, if too many Section 8 households or sites are clustered within vulnerable areas, negative price impacts will occur (Galster *et al*., 1999). It was recommended that policies should be devised that direct Section 8 households away from vulnerable neighbourhoods.

4.10 LEE, CULHANE AND WACHTER (1999) STUDY

Lee *et al*. (1999) applied the hedonic price method to examine the effect of federally assisted housing units on surrounding property values. The study used Philadelphia as its locus and sought to determine the differential effects of federally assisted housing programmes on real estate prices.

The following housing programmes[38] were included in the analysis: public housing developments, public housing scattered-sites, Federal Housing Administration (FHA) housing, Section 8 New Construction and Rehabilitation housing, Section 8 certificates and

[38] Many of the housing programmes are unique to the study site (United States of America). Those comparable to social housing in South Africa include Section 8 certificates and vouchers (which do not involve ownership and are thus comparable to the rental option in South Africa) and public housing developments.

vouchers[39], and Low-Income Housing Tax Credit (LIHTC) housing. Public housing developments were further differentiated by building type (high-rise, low-rise), programme type (family, senior), development size (large, small), and era (built before or after 1980).

Data for the study came from a variety of sources, including the U.S. Department of Housing and Urban Development and the Philadelphia Planning Commission. All the locational data were obtained using GIS software. The sales price and property-specific data were sourced from the Board of Revision of Taxes in Philadelphia. The dependent variable used in the study was the actual sales price. Sales time was restricted to the period between 1989 and 1991 and was applicable only to single residential stands (townhouse/condominium data were removed). The final data set comprised of 18 062 observations (Lee *et al*., 1999). As with most hedonic price studies, the model assumed that the value of a property was a function of property specific attributes, the period of the sale, the neighbourhood quality, locational amenities and the proximity of the property to federally assisted housing projects. Property specific independent variables included erf size, living area size, house type (dummy variables for semi-detached and row house), garage (dummy), masonry (dummy), and stone (dummy). Locational variables included distance from the CBD and dummy variables for living within 1/4, 1/2, or 1 mile of a river or park.

In the study, federally assisted housing units were aggregated by 1/8 or 1/4 mile radii around individual property sales. More specifically, the following variables were employed: *DOPUB*125 (dummy variable for public housing development within 1/8 mile radius; *DPUB*250 (dummy variable for public housing development within 1/4 mile radius; *DOPUB*250 (dummy variable for public housing development within 1/4 mile radius, excluding those within 1/8 mile radius); *NUS*8*C*250 (total number of Section 8 certificate and voucher units within 1/4 mile radius). Controlling for demographic, housing and amenity variables, these data were regressed on sale prices from 1989 to 1991, in order to tease out the effect of the federally assisted units on property values.

In total, four different hedonic price models were run, all using ordinary least squares estimation. The first model (Model I) tested the impacts of several types of public housing, but excluded the neighbourhood quality control variables. These variables were included in the second model (Model II). The third model (Model III) provided more detailed characteristics of the public housing development, and finally, the fourth model (Model IV)

[39] The Section 8 certificates and vouchers programme increases housing options for very low-income families. Families apply to a local public housing authority (LPH). The LPH then pays the difference between 30 percent of the household income and the unit's rent (Section 8 Rental Certificate Programme, 2012).

tested for the diminishing effect of public housing, by comparing developments within 1/8 mile and 1/4 mile radii.

The results of the regressions revealed that both public housing and Section 8 certificate and voucher units had a statistically significant negative effect on surrounding property values. In the case of public housing, this effect diminished with distance – the *DOPUB*125 coefficient was -0.4 and the *DOPUB*250 coefficient was -0.2, with both coefficients significant at the 1 percent level (Model I estimate). When the neighbourhood quality control variables were added (Model II), the coefficient estimates were reduced (to -0.067 and -0.033, respectively). However, the overall model fit was improved with this addition, with the R-squared value increasing from 0.55 to 0.72. This finding provided evidence that spatial effects should be included in the model. With regard to the Section 8 certificate and voucher units, the coefficient estimates ranged between -0.008 and -0.002 (depending on the model). Although all four coefficient estimates were significant at the 1 percent level, their magnitudes were modest (Lee *et al*., 1999), suggesting a negligible negative effect on surrounding property values.

Using Philadelphia as its locus had a limiting effect on the degree to which the results of the study could be applied at a national level, although this approach did result in a number of advantages (Lee *et al*., 1999). Firstly, the study was able to capitalise on available GIS data. Secondly, this approach allowed for the addition of spatial variables that have the ability to control for neighbourhood characteristics.

4.11 COLWELL, DEHRING AND LASH (2000) STUDY

The effect of group homes on adjacent residential property prices was tested in a study by Colwell *et al*. (2000). The study focused on group homes catering for individuals with developmental, mental and physical disabilities, as individuals suffering from these afflictions have been moved from state institutions to group homes. This process of decentralisation has been occurring since the 1970s in the United States of America and the rationale for this is that group homes are seen as a more humane and cost effective option (Cowell *et al*., 2000).

The study focused on seven group homes established by the DuPage County Health Department. These homes were opened during the period 1987 to 1994. The homes typically cater for individuals suffering from schizophrenia, mood disorders and severe depression. Typically, households situated adjacent to group homes catering for individuals with mental illnesses express safety concerns (Bartels & Lisatowicz, 1995).

The study site comprised a sample of 641 residential property sales across the seven neighbourhoods where the group homes were established (Colwell *et al*., 2000). In order to determine the "announcement effect", data for the prior six year period were also collected. In the study, "announcement" was defined as the time when adjacent property owners were made aware of plans to establish a group home in their neighbourhood (Colwell *et al*., 2000). In order to examine the effect of the event (announcement of the group home) the observations were overlapped throughout time. This ensured that all group home announcements occurred at time 0 (Colwell *et al*., 2000) Price level shifts at the time of the announcement were then examined.

House specific data included the following: sales price (dependent variable), house size, age, number of bathrooms, erf size and erf frontage (independent variables). Spatial specific data included proximity to the group home and whether or not the group home would be visible from the subject property (visibility was established by consulting plot maps of the area). Colwell *et al*. (2000) defined a circular neighbourhood with the group home at the centre producing a radius of 1 500 feet. The central hypothesis of the study was that residential properties situated within a group home neighbourhood would experience a decline in value following the announcement of the construction of a group home (Colwell *et al*., 2000).

Two hedonic price models (of the double-log functional form) were estimated in order to test this hypothesis: the first model made use of a dummy variable for sight (coded 1 if the group home would be visible from the subject property and 0 if otherwise); the second model incorporated distance variables. More specifically, the second model tested whether residential properties situated less than 200 feet from the group home experienced a decline in value (Colwell *et al*., 2000).

The results of the analysis revealed that subsequent to the announcement of the construction of a group home, residential properties situated within sight of the group home experienced a decrease in value of 10.5 percent (this finding being significant at the 1 percent level) (Colwell *et al*., 2000). In respect of the model incorporating a proximity measure, the finding was similar. More specifically, residential houses situated within 200 feet of the group home experienced a decline in value of up to 24 percent (significant at the 2.5 percent level).

4.12 SANTIAGO, GALSTER AND TATIAN (2001) STUDY

The study conducted by Santiago *et al*. (2001) tested the NIMBY hypothesis, specifically to determine if rehabilitated housing had a negative effect on surrounding residential homes (Santiago *et al*., 2001).

The study area consisted of scattered-site housing in the city of Denver. Scattered-site housing came about as a result of inadequacies of large-scale public housing projects (Hogan, 1996). These inadequacies included increased criminal activity, concentrated poverty, increased social and spatial isolation of the poor, and a rise in negative behaviour (high school desertion, out-of-wedlock childbearing and withdrawal from the labour market). In order to address these issues, policy makers promoted the development of low-density, geographically dispersed assisted housing. These developments later became known as scattered-site housing. The city of Denver began operating the programme of "dispersal" in 1969. Initially, 100 single-family and duplex units were acquired at foreclosure sales. These units were then renovated and occupied by tenants. During the 1990s, a further 500 units of existing property in Denver was acquired by the public housing authority (Santiago *et al*., 2001).

For the study, sales price data for home sales in Denver were obtained for the period 1987 to 1997. These data were obtained from a private vendor and included the following information: street address, sales price, date of the sale, size of the house (square footage), size of the erf (square footage), number of rooms, type of construction, and age (Santiago *et al*., 2001). Data on a total of 43 361 sales were collected. Data on 167 public housing programmes that opened during the period 1987 to 1995 were obtained from the Housing Authority of the City and County of Denver.

A total of three hedonic price models (of semi-log functional form) were estimated in the study. The ordinary least squares method of estimation was used. The first model measured the proximity of a residential house to any subsidised housing sites. The second model measured the proximity of a house to the number of subsidised sites and the third model looked at proximity to the number of actual subsidised units. In order to capture this proximity effect, dummy variables were created. In order to specify the dummy variables, concentric rings were created, expanding as follows: 0 – 500 feet, 501 – 1000 feet, and 1001 – 2000 feet from a subsidised site. The data was then captured accordingly for each specific house (Santiago *et al*., 2001). In addition to this, the study captured the effects of neighbouring properties by introducing an autoregressive term (Can & Megbolugbe, 1997; Santiago *et al*., 2001).

The results of the analysis revealed a positive relationship between house prices and subsidised housing units, thereby dispelling the NIMBY hypothesis (in this case). Possible reasons provided by Santiago *et al*. (2001) for the positive amenity effect of the rehabilitated housing included the characteristics of the facility, the management and the tenants. More specifically, subsidised housing that is aesthetically pleasing and well managed may result in positive neighbourhood spill over effects. Specific recommendations provided by Santiago *et al*. (2001) for future rehabilitated housing programmes include the following: renovation of dwellings, the establishment of impaction standards, the monitoring of tenants, the maintenance of dwellings, collaboration of neighbourhood groups and improving the image of dispersed housing (Santiago *et al*., 2001). Santiago *et al*. (2001) does, however, acknowledge that caution must be taken when interpreting the findings as the results are applicable to a specific site and thus cannot be applied at a national level (as unique study site characteristics need to be taken into account).

4.13 CUMMINGS, DIPASQUALE AND KAHN (2002) STUDY

Cummings *et al*. (2002) examined the effects of promoting inner city homeownership in the City of Philadelphia, by looking at the gains, in terms of structure and community attributes, that residents receive as they moved from renting to owning. This homeownership promotion formed part of the Philadelphia community strategy and was expected to increase economic activity within the inner city, resulting in net welfare gains (Cummings *et al*., 2002). Inner city homeownership was also expected to result in an increase in surrounding property values. By analysing property prices adjacent to homeownership promotion sites, the study was able to test this hypothesis.

Two Nehemiah developments in Philadelphia were considered for the purposes of this study, namely, West Philadelphia Nehemiah and West Poplar Nehemiah. These developments were subsidised by the City of Philadelphia and offered newly constructed homes at well below cost to previously renting residents. Funding came from the Nehemiah Housing Opportunity Grants Programme (NHOP), which is a national programme. The latter enables the United States Department of Housing and Urban Development to make grants to non-profit organisations that, in turn, provide loans to qualifying families purchasing subsidised homes. Construction of the West Philadelphia project began in 1994 and was completed in 1997. The project consisted of 135 units. Qualifying households purchased these homes at considerably less than it cost to build them (Cummings *et al*., 2002). The West Poplar project was built in 1996 and consisted of 176 units. Again, construction costs were considerably higher than purchase prices (Cummings *et al*., 2002).

Although residents received brand new units, these units are located in some of the highest poverty census tracts in the city of Philadelphia. In order to determine how the lives of residents changed after switching from renting to owning, the study analysed data on over 8 000 households that participated in the Settlement Grant Programme from 1993 to 1997. The data came from the Settlement Grant database (Cummings *et al*., 2002). These grant holders did not form part of the Nehemiah projects and were thus considered the control group. Census data on 86 grant recipients who purchased homes in either the West Philadelphia or West Poplar projects was then analysed. It was found that the census tracts housing the Nehemiah developments had populations with considerably lower incomes, lower house values, less education, and lower homeownership. Unfortunately, the Settlement Grant database did not contain information on the homes' physical attributes. These data were required in order to compare the homes of the Nehemiah projects with those in the control group. To obtain these data, a total of 476 households were surveyed. Four hundred of these households were non-Nehemiah residents. It was found that the Nehemiah households enjoyed an increase in the number of rooms, bedrooms, and bathrooms. Off-street parking and air-conditioning was also gained by most Nehemiah residents. It was clear that, while Nehemiah residents enjoyed structural gains, community sacrifices were made. The Nehemiah projects, thus, offered a mixed opportunity, with excellent structures being located in a low quality of life community (Cummings *et al*., 2002).

As mentioned above, the actual price paid for homes by the Nehemiah residents was substantially less than the construction cost. The difference was made up by the public subsidy (Cummings *et al*., 2002). In order to quantify the value of the structural gains enjoyed by the Nehemiah residents (and to measure the social benefits of Nehemiah) a standard hedonic price approach was employed, using data obtained from the surveys. A semi-log model regression equation was estimated using the ordinary least squares method of estimation. The dependent variable was the actual sales price and the independent variables included a number of structural (number of rooms, number of bathrooms, the presence of air-conditioning, the presence of a garage, the presence of sound proof walls, and the presence of leaks) and community characteristics (class room size in census tract, murder rate per 1 000 persons in census tract, and distance from city hall) (Cummings *et al*., 2002). Using the predicted hedonic price equation, it was found that the average house in the Nehemiah developments was valued at 23 percent less than the actual purchase price. The social benefits of the Nehemiah projects were measured by multiplying the change in house-specific attributes experienced from the Nehemiah move by the implicit prices obtained from the hedonic price regression. These values were then summed over the housing attributes. A value of $10 496 per household was estimated, which was

considerably less than the subsidies provided (the difference between purchase price and cost).

In order to determine whether this loss was offset by other benefits, additional hedonic price regressions were estimated to determine the impact of the Nehemiah developments on nearby property prices. In order to do this, property price appreciation in the Nehemiah census tracts was compared to two sets of control groups. The first census tract control group was located more than 1.2 miles from the Nehemiah census tract, but had similar socio-economic characteristics. The second census control group also had similar socio-economic characteristics, but shared a border with at least one Nehemiah census tract. The hedonic price equation took the following form:

$$P_{ijt} = \beta_1 X_{ijt} + \beta_2 Z_j + \beta_3 Year_t + \beta_4 Nehemiah_j + \beta_5 Nehemiah_j * Post + \beta_6 Control_j + \beta_7 Control_j * Post + \varepsilon_{ijt} \quad (4.5)$$

where: *P* = log of home *i*'s price in census tract *j* at time *t.*

X = structural characteristics.

Z = community characteristics.

Year = set of year dummy variables.

Nehemiah = dummy variable indicating if property is in Nehemiah census tract

Control = dummy variable indicating if property lies in a control track.

Both the Nehemiah and the control variables were interacted with a time dummy "*post*". This indicated whether the Nehemiah developments had been built at the time of the house sale (Cummings *et al*., 2002). Data on 146 053 transactions were collected to generate the hedonic price equation.

The results of the hedonic price estimation revealed that a home situated in the Nehemiah tract experienced a 12 percent increase in price after the Nehemiah complexes were constructed, whereas the homes in the first control group appreciated by 22.3 percent. This indicated that the price appreciation was less in the Nehemiah census tract. In the second control group, homes appreciated by 9 percent, although this value was not statistically different from the Nehemiah census tract appreciation (Cummings *et al*., 2002).

The study concluded that the positive impact of the Nehemiah developments on the surrounding community was negligible and it was recommended that alternative types of

place-based subsidies should be considered (Cummings *et al*., 2002). Alternatives recommended included land clearance and site-improvement, which could achieve the goal of urban renewal at a lower cost (Cummings *et al*., 2002).

4.14 ELLEN AND VOICU (2006) STUDY

There is an increasing trend in the United States of federal, state and local governments turning to the non-profit sector to deliver housing programmes. The main justification for this is that affordable housing developed by non-profit organisations results in greater neighbourhood spillover benefits than housing developed by other providers (Walker, 1993; O'Regan & Quigley, 2000). The study by Ellen and Voicu (2006) compared the neighbourhood spillover effects of city-supported rehabilitation of rental housing undertaken by non-profit developers with those generated by for-profit developers in New York City. In order to measure these benefits, the study analysed increases in neighbouring property prices.

There are several reasons why neighbourhood spillover effects might differ across sectors. The reason provided by Ellen and Voicu (2006) is that non-profit firms have less to gain than for-profit firms by economising on construction costs. This implies that projects built by for-profit firms might deteriorate more quickly than those built by non-profit firms. In addition, for-profit firms may have an incentive to economise on maintenance that does not affect the value of the asset (but may have an adverse effect on the surrounding neighbourhood). Any positive neighbourhood spillover effects would, thus, diminish over time in the case of the projects built by the for-profit developers (Ellen & Voicu, 2006). Another reason for possible differences in neighbourhood spillover effects has to do with the tenant mix. Non-profit firms may be more likely to select needier tenants (in terms of income), which may result in a reduction of positive neighbourhood spillover effects (Ellen & Voicu, 2006).

The hedonic price method was used in the study to compare prices of properties situated close to subsidised housing sites with those situated further away but still located within the same general neighbourhood (census tract). A "difference-in-difference" approach was then used to compare the magnitude of this difference before and after the completion of the project (Ellen & Voicu, 2006). Impacts on property value were also tested by sector (for-profits versus non-profits). The hedonic price model estimated in the study was specified as follows:

$$\ln P_{icdt} = \beta_0 + \beta_1 X_{it} + \beta_2 W_c + \beta_3 inRing_i + \beta_4 inRingD_i + \beta_5 PostRing_{it} + \beta_5 PostRing_{it} D_i + \beta_6 TPost_{it} + \beta_7 I_{dt} + \varepsilon_{it} \quad (4.6)$$

where: lnP_{icdt} = log of home *i*'s price in census tract *c*, in community district *d*, and in quarter *t*.

X_{it} = structural characteristics.

W_c = series of census tract fixed effects.

The ring variables were described as follows: *inRing* variables were dummy variables indicating if the property was located within 1000 feet of a subsidised site (current or future) (Ellen & Voicu, 2006). Separate *inRing* variables were included for large projects (more than 100 units) and small projects (100 units or less). Separate *inRing* variables were also created for projects developed by non-profit and for-profit developers. These variables were also interacted with D_i (the distance between the subject property and the nearest subsidised project). The *PostRing* dummy variables indicated whether the property was located within 1000 feet of a completed subsidised project. The final ring variable (*TPost*) indicated the number of years between the date of sale of the subject house and the project completion date. This allowed the project impacts to vary over time (Ellen & Voicu, 2006).

In order to estimate Equation 4.6, data on 43 417 subsidised housing units were obtained from New York City's Department of Housing Preservation and Development. For each subsidised unit, the data included the project location, the completion date, the building structure, the development's name, the type of intervention (new construction or rehabilitated, and whether units were rental or owner-occupied (Ellen & Voicu, 2006). House characteristic and sales data were then collected on residential properties over the period 1980 to 1999 across 1 606 census tracts and 48 community districts. A total of 293 789 transactions were considered for the study (Ellen & Voicu, 2006). Finally, distances from each residential property to the nearest subsidised housing development were calculated using GIS techniques.

The estimated hedonic price regression model produced an R-squared value of 0.86, which can be considered high. All of the structural variables had significant coefficients displaying the hypothesised signs. All of the *inRing* dummy variables were statistically significant and negative. More specifically, properties situated within 1 000 feet of an incomplete project sold for between 19 and 37 percent less than those situated outside of the 1 000 foot ring. This result was not surprising as many of the projects involved the rehabilitation of derelict buildings. Thus, prior to completion, a disamenity effect was experienced (Ellen & Voicu, 2006). This negative effect was larger for larger sites and also larger for non-profit sites.

The interaction variables were all statistically significant with positive coefficients. This implies that the pre-completion disamenity effect declined with distance from the site. The impact estimates (*PostRing* variables) were all statistically significant and positive. This means that completed subsidised projects generated positive spillover effects, and shrunk the gap between house prices situated close to the subsidised sites and those situated further away. Comparisons were also made between large and small projects and for-profit and non-profit developments. The results indicate that the positive effects of completed projects were similar for large projects regardless of whether they were built by for-profit developers or non-profit developers. However, for small projects (100 units or less), the positive spillover effects were smaller if the project was developed by non-profit developers.

The study found that both non-profit and for-profit rehabilitation projects generated positive neighbourhood spillover effects. However, on smaller projects, the benefits generated by non-profits were smaller than those generated by for-profit developers. This may be due to capacity issues that often challenge smaller non-profit developers. The study recommended that the US government continue to allocate funds to both non-profit and for-profit developers, as positive neighbourhood spillover effects of rehabilitated public housing are present.

4.15 A SYNOPSIS OF THE STUDIES REVIEWED

Table 4.1 presents a synopsis of key information of the studies reviewed.

Table 4.1: Summary of international studies

Author(s)	Year	Study site	Number of housing projects considered	Housing Programme	Sample size	Dependent variable	Number of independent variables	Incorporation of key independent variable	Functional form of hedonic price equation	Time period	Time considerations	Spatial autoregressive term	Relationship with property values
Nourse [40]	1963	St. Louis, Missouri	8 projects, arranged into 3 neighbourhoods	Public housing	5 044 residential properties	Not applicable	Not applicable	Not applicable	Not applicable	1937 - 1959	Not applicable	Not applicable	None
Guy, Hysom and Ruth	1985	Fairfax County, Virginia	4 projects	Below-market-interest-rate housing	861 residential properties	Sales price	12	Linear distance	Linear	1972 - 1980	Time trend dummy variables for each year	No	Negative
Cummings and Landis	1993	San Francisco, California	1 project	42-unit condominium catering for families and seniors	612 residential properties	Sales price	8	Dummy variables using 3 radii ranging from 1/8 mile to 1/2 mile	Linear	1985 - 1992	Sales price converted to 1990 dollars using the CPI	No	None
Lyons and Loveridge	1993	Ramsay County, Minnesota	120 projects	Subsidised housing	26 503 residential properties	Assessed value	47	Linear distance	Quadratic	1991	Not applicable	No	Negative
Goetz, Lam and Heitlinger	1996	Minneapolis, Minnesota	23 Projects	Privately-owned and publicly subsidised housing	22 156 residential properties	Assessed value	26	Linear distance	Linear	1994	Not applicable	No	Negative
Briggs, Darden and Aidala	1999	Yonkers, New York	7 sites	Scattered-site public housing	3 101 residential properties	Sales price	7	Dummy variable indicting whether subject property was within 1/4 mile of any of the 7 projects	Linear	1985 - 1996	Time trend dummy variables for each year	No	None
Carroll and Clauretie	1999	Clark County, Nevada	13 projects	Combination of affordable housing aimed at senior citizens and families	6 321 residential properties	Sales price	34	Linear distance	Double log	1968 - 1997	Sales price converted to 1983 dollars	No	Negative
Galster, Tatian and Smith	1999	Baltimore County	Not provided	Section 8 certificates	43 361 residential properties	Sales price	Not provided	Dummy variables using 3 radii ranging from 500 feet to 2000 feet	Semi-log	1991 - 1995	Time trend dummy variables for each year	Yes	Mixed

[40] The study by Nourse (1963) made use of test versus control area methodology. For this reason, estimation issues common to the hedonic price model are not applicable in this case.

Table 4.1 continued

Author(s)	Year	Study site	Number of housing projects considered	Housing Programme	Sample size	Dependent variable	Number of independent variables	Incorporation of key independent variable	Functional form of hedonic price equation	Time period	Time considerations	Spatial autoregressive term	Relationship with property values
Lee, Culhane and Wachter	1999	Philadelphia, Pennsylvania	Not provided	Public housing, scattered-site public housing	18 062 residential properties	Sales price	40	Dummy variables using 2 radii ranging from 1/8 mile to 1/4 mile	Semi-log	1989 - 1991	Time trend dummy variables for each year	No	Negative
Colwell, Dehring and Lash	2000	DuPage County	7 group homes	Group homes	641 residential properties	Sales price	26	Dummy variable indicting whether subject property was within 1500 feet of any of the 7 projects	Double log	1987 - 1994	Not specified	No	Negative
Santiago, Galster and Tatian	2001	Denver, Colorado	167 projects	Scattered-site public housing	43 361 residential properties	Sales price	Not provided	Dummy variables using 3 radii ranging from 500 feet to 2000 feet	Semi-log	1987 - 1997	Time trend dummy variables for each year	Yes	Positive
Cummings, DiPasquale and Kahn	2002	Philadelphia, Pennsylvania	2 projects	Subsidised housing	146 053 residential properties	Sales price	17	Dummy variable coded as “1” if subject property was located in subsidised census tract and “0” othersise	Semi-log	1986 - 1997	Time trend dummy variables for each year	No	None
Ellen and Voicu	2006	New York City	Not provided	Public housing	293 789 residential properties	Sales price	28	Dummy variable indicting whether subject property was within 1000 feet of a subsidised unit	Semi-log	1980 - 1999	Not specified	No	Positive

Table 4.1 shows that the majority of the studies had substantial sample sizes, which ranged from 612 residential properties to 293 789 residential properties. In most cases, sample sizes were driven by data availability. All of the studies made use of data provided by various municipal sources. These sources included census data, local government property taxation records and records from local property assessors' offices.

Table 4.1 also indicates the diverse nature of social housing, with specific projects including public housing, below-market-interest-rate housing, housing aimed at families and seniors, privately-owned and publicly subsidised housing, scattered-site public housing, and Section 8 certificates. The number of social housing projects considered for each study varied from one to a total of 167 projects, thus highlighting the unique nature of each study site.

According to Table 4.1, the majority of the studies used the actual sales price as the dependent variable. Only two studies used the assessed value of the property, citing the increased sample size as the reason. In terms of addressing the temporal aspect of residential house sales, most of the studies adjusted current sales prices to constant prices (for example, by using an inflation related index) or by incorporating time dummy variables.

The average number of independent variables included in the hedonic price studies presented in Table 4.1 was 24.5. The minimum number of independent variables was 7 and the maximum was 47. The high number of independent variables included in some of the studies is due to the inclusion of socio-economic census tract data as social housing projects may exert a differential impact on surrounding property values according to the socio-economic character of the neighbourhood (Carroll & Clauretie, 1999). The variable of interest (the proximity measure) was either entered into the hedonic price equation as a simple linear distance measure or social housing "neighbourhoods" were created. In the latter cases dummy variables were used to indicate whether or not the subject residential property was located within the neighbourhood. The radii used to create these "neighbourhoods" ranged from 500 feet to 2 400 feet. The value of following this approach is that the effect of distance decay can be measured.

All of the studies modelled the hedonic price equation in terms of the standard functional forms (linear, semi-log or double log). Flexible functional form selection based on Box-Cox transformations was not employed in any of the studies and the effect of neighbouring properties (i.e. by introducing a spatial autoregressive term) was only taken into account in two of the studies.

In terms of the relationship between social housing and surrounding property values, it is evident from Table 4.1 that the answer to the research question "does affordable housing have an effect on surrounding property values" is location and project specific. More specifically, of the 13 studies reviewed in this chapter, six revealed a negative relationship, two revealed a positive relationship and the remaining five found that social housing either had no effect or the effect was mixed. However, these studies did reveal under which circumstances property values are more likely to be detrimentally affected. More specifically, the likelihood of social housing having a negative effect on surrounding property values increases when the quality, design, and management of the social housing are poor (Santiago *et al*, 2001). In addition to this, social housing that is clustered in nature also increases the likelihood of the project emerging as a negative externality (Galster *et al*., 1999).

4.16 LIMITATIONS OF THE STUDIES

The 13 studies reviewed in Chapter Four had certain limitations, some specific and some general. A couple of study-specific limitations are discussed first. A specific limitation of the Nourse (1963) study was that a price trend comparison between a test and control group methodology was employed. This may prove to be problematic because "one can never be certain that the control area is exactly like the study area in all relevant characteristics" (Nourse, 1963). A specific limitation of the Lyons and Loveridge (1993) and Goetz *et al*. (1996) studies was that assessed values were used as the dependent variable, rather than actual sales prices. This limited the findings of these studies since assessed values may be imperfectly correlated with actual market prices (Freeman, 2003; Cotteleer & van Kooten, 2012).

A general limitation of the studies that employed regression analysis (all, except the Nourse (1963) study) was that only standard functional forms were employed. None of the studies investigated the use of flexible functional form selection (i.e. Box-Cox transformations). Standard functional forms do not necessarily provide the best fit for the data which, in turn, may compromise the accuracy of the results (Williams, 2008). In addition to this, none of the studies employed alternative estimation techniques (for example, discrete choice methods) in order to serve as a validity test of the hedonic price model's results.

Another general limitation was that most of the studies, with the exception of the Galster *et al*. (1999) and Santiago *et al*. (2001) studies, did not include a spatial autoregressive term when specifying the hedonic price equation. This omission limited the robustness of the regression results since it is well known that the transaction price of a house is influenced by

the transaction prices of neighbouring properties within its vicinity (Can & Megbolugbe, 1997; Brasington & Hite, 2005).

Finally, a limitation of most of the studies was that, in the cases where a negative effect was reported, the results did not shed light as to why the social housing project had this effect.

4.17 CONCLUSION

Chapter Four provided a review of the international literature on the effects of social housing on surrounding property prices. In total, 13 studies were reviewed, with the results of each study varying greatly. This suggests that each social housing project (and study site) is unique and that caution must be applied when interpreting the results. Although most of the studies did not provide explicit reasons as to why social housing had a negative effect on surrounding property values, four points can be extracted from the literature. Firstly, characteristics about the social housing project play a large role in determining the effect on property values. More specifically, social housing projects that are poorly designed and managed may exert negative effects on adjacent property values. Secondly, the composition of the neighbourhood in which the social housing project is located is important. Social housing is more likely to lead to reductions in adjacent property values when it is clustered and when it is situated in disadvantaged neighbourhoods. Thirdly, when negative effects exist, they tend to be small. Finally, a need for further studies exists in order to address the limitations discussed in Section 4.16.

The following chapter (Chapter Five) presents the estimation results of a variety of basic hedonic price models.

CHAPTER FIVE: ESTIMATING A BASIC HEDONIC PRICE MODEL

5.1 INTRODUCTION

Chapter Five presents the results of three different specifications of the hedonic price model. The first model (Model 1) follows the Leggett and Bockstael (2000) specification[41] – the data set employs a municipal assessed value of the structure instead of actual housing characteristics. In contrast, Models 2 and 3 use housing characteristics as explanatory variables. Models 2 and 3 differ in terms of their dependent variable selection - Model 2 employs an assessed value as the dependent variable[42], whereas Model 3 employs the actual sales price as the dependent variable.[43] In all cases, the models were estimated using the standard linear, semi-log and double-log functional forms. In addition to this, diagnostic tests were conducted in order to test for the presence of multicollinearity and heteroskedasticity. All models were estimated using Stata Version 11.0.

5.2 MODEL 1: THE LEGGETT AND BOCKSTAEL (2000) SPECIFICATION

5.2.1 THE DATA

Data on the 2007/2008 assessed values of properties were purchased from the Nelson Mandela Bay Municipality. Historical sales price data for residential property stands in the neighbourhood of Walmer, Nelson Mandela Bay that were traded at least once during the period 1995 to 2009 were also obtained.[44] These data were purchased from the South African Property Transfers Guide (SAPTG). Data from the ABSA house price index (Port Elizabeth and Uitenhage) were then used to adjust assessed values and house prices to 2009 constant rands to control for real estate market fluctuations. Adjusting sales prices to control for house price inflation is a relatively common approach when the data originate from different years (Cummings & Landis, 1993; Carroll & Clauretie, 1999; Leggett & Bockstael, 2000; Cho, Bowker & Park, 2006; Cotteleer & van Kooten, 2012).

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[41] The use of this specification is rare. Only one published example could be found in the international hedonic literature.

[42] A specification recently used by Fullerton and Villalobos (2011) and Cotteleer & van Kooten (2012). The Fullerton and Villalobos (2011) study investigated the effect of street widths and proximity to border crossings on house prices in the El Paso metropolitan economy, which includes cities from Texas and New Mexico, United States of America. The Cotteleer and van Kooten (2012) study investigated the effects of open space amenities on surrounding property values in the Saanich Peninsula, British Columbia, Canada. In both cases, the hedonic price equation was modelled with only one functional form (double-log in the Fullerton and Villalobos (2011) study and linear-log in the Cotteleer and van Kooten (2012) study).

[43] This specification is preferable (Kiel & Zabel, 1999; Cotteleer & van Kooten, 2012).

[44] All transactions that were not arms-length ones were excluded from the analysis. Some property transactions are conducted for reasons other than profit maximisation. In the SAPTG database three pieces of information are provided which could reveal property deals that were not at arms-length, namely the price, the seller, and the buyer. For example, a property was sold by a person to his trust for an amount of R40.

The Walmer neighbourhood has a total of 2 625 residential properties and a total of 1 326 transactions took place from 1995 to 2009 (excluding repeat sales) (South African Property Transfer Guide, 2011). The population in this study was, thus, limited to the 1 326 transactions that took place over the study period. Of these transactions, a simple random sample of 289 was drawn.[45]

5.2.2 A DEFINITION OF THE VARIABLES INCLUDED IN MODEL 1

Table 5.1 provides definitions of the variables used in Model 1.

Table 5.1: Variable mnemonics and definitions of the variables used in Model 1

Variable	Definition	Unit of measurement	Expected sign
Dependent variable			
Sales_price	Actual sales price	Constant 2009 rands	
Independent variables			
Assessed_value	Municipal valuation	Constant 2009 rands	+
Dist_wal	Distance of house to the Walmer Township	Metres	+

The variable of interest (distance to the Walmer Township) was measured (to the nearest metre) using Google Maps. All distances were measured from the same point, on the outer border of the Walmer Township. A network distance measure was employed (as opposed to a simple linear measure) as it has been argued that this measure more appropriately measures residents' access to the site in question (Morgan & Hamilton, 2011). The hypothesised sign for both independent variables included in Model 1, namely the assessed value and the distance to the Walmer Township, was positive.

5.2.3 DESCRIPTIVE STATISTICS OF THE VARIABLES INCLUDED IN MODEL 1

Table 5.2 provides a summary of the descriptive statistics of the variables used in Model 1.

[45] The sample size was determined by employing the following equation:

$n = N/(1 + Ne^2)$……(5.1)

where: n = sample size
N = population size
e = level of precision

Using Equation 5.1, the sample size was determined with a level of precision of 5.2 percent, which ensured a representative sample from the population, because the generally accepted level of precision for representative samples is 10% or less (Fink, 2003).

Table 5.2: Descriptive statistics of the variable used in Model 1 (n = 289)

Variable	Min	Max	Mean	Standard deviation
Sales_price	193 600	6 106 180	1 598 464	792 270
Assessed_value	737 100	5 915 000	1 833 161	626 638
Dist_wal	500	3 200	1 780	566

As can be seen from Table 5.2, the average sales price in the sample is R1 598 464 and the average assessed value is R1 833 161. The average house is located 1 780 metres away from the Walmer Township. The closest house is situated 500 metres away from the Walmer Township while the furthest house is situated 3 200 metres away from the Walmer Township.

5.2.4 RESULTS OF THE HEDONIC PRICE ESTIMATION – MODEL 1

Table 5.3 presents the results of the first hedonic price estimation (Model 1).[46]

Table 5.3: Regression results of Model 1 (n = 289)

Variable	Model		
	Linear	Semi-log	Double-log
Constant	-108544.2 (153751)	13.21 (0.09)	0.68 (1.05)
Assessed_value	0.83[a] (0.95)[e]	0.00000044[a] (0.00000005)[e]	0.88[a] (0.074)[d]
Dist_wal	103.5[b] (48.27)[e]	0.00008[b] (0.00003)[e]	0.109[c] (0.066)[d]
R-squared	0.46	0.36	0.37
Adjusted R-squared			0.36
F-statistic	52.04	51.32	83.84

Notes: [a] Significant at the 1 percent level
[b] Significant at the 5 percent level
[c] Significant at the 10 percent level
[d] Standard errors in parentheses
[e] Robust standard errors in parentheses

The estimation results from Model 1 conform to *a priori* expectations. More specifically, the coefficient of the key independent variable (distance to the Walmer Township) was statistically significant across all three models and displayed a positive sign (property values in Walmer increase as distance from the Walmer Township increases, *ceteris paribus*). The coefficient on the assessed value independent variable was also statistically significant across all three models and it had the expected sign. The R-squared values for the linear

[46] Diagnostic tests were conducted in order to test for the presence of multicollinearity and heteroskedasticity. The computed variance inflation factors (VIFs) – a test for multicollinearity – did not exceed the threshold value of 5 indicating that there was no severe multicollinearity (for all three models). The Breusch-Pagen test for heterskedasticity was also conducted for all three models. The Chi-squared test statistics were 100.05 and 14.81 for the linear and semi-log models, respectively, which exceeded the critical value of 4.61, meaning that the null hypothesis of constant variance was rejected in these cases. It was, thus, concluded that heteroskedasticity was present in the linear and semi-log models. In order to correct for heteroskedasticity, the robust standard errors for the coefficients were calculated. The double-log model Chi-squared test statistic was 4.05, which did not exceed the critical value (4.61), indicating that heteroskedasticity was not present in the double-log model.

and semi-log models[47] were 0.46 and 0.36, respectively, and the adjusted R-squared value for the double-log model was 0.36. This means that less than half the variation in house prices was explained by the two independent variables.

These results differ from the results obtained in the Leggett and Bockstael (2000) study. More specifically, the R-squared[48] values for the linear, semi-log and double-log models were 0.76, 0.69 and 0.73, respectively, in the Leggett and Bockstael (2000) study. A possible explanation for these dissimilarities is that the Leggett and Bockstael (2000) specification included a number of distance variables (for example, distance to the nearest marina and distance to the nearest sewage treatment plant), which may have improved the overall predictive power of the hedonic price model. The key independent variable in the Leggett and Bockstael (2000) study (median fecal coliform concentration in the year of sale) was significant across all models. The same result was obtained in this study (see Table 5.3).

Despite the attractiveness of using an assessed value as a proxy for actual housing characteristics (in the form of data advantages which often allow for increased sample sizes), there is a major limitation associated with this method - the potential for incorrect assessments (Haab & McConnell, 2002). If these assessments are measured with error, the coefficient on the assessed value will be attenuated. In addition, other coefficient estimates may also be contaminated (Haab & McConnell, 2002). For this reason, "it is far better to include the housing-specific attributes rather than the assessed value of the structure" (Haab & McConnell, 2002). Since using the assessed value as a proxy for housing characteristics is not a preferred hedonic price model specification, Model 1 will not be considered further in Chapter Five, except for comparative purposes.

5.3 MODEL 2: A HEDONIC PRICE MODEL WITH HOUSING CHARACTERISTICS

In contrast to Model 1, Model 2 employed actual housing characteristics as explanatory variables and made use of the assessed value as the dependent variable. This is a relatively common approach and has been used in recent applications of the hedonic price method to estimate the value of open space and externalities (Fullerton & Villalobos, 2011; Cotteleer & van Kooten, 2012). Although actual property values are preferred (as they reflect how people allocate their money and, therefore, how they value property attributes), assessed value

[47] Since the linear and semi-log versions of Model 1 were corrected for heteroskedasticity, their adjusted R-squared values are not reported.
[48] The adjusted R-squared values were not reported in the Leggett and Bockstael (2000) study.

estimates are often more readily available and have frequently been used as a substitute for actual property prices (Darling, 1973; Doss & Taff, 1996; Lee, Taylor & Hong, 2008).

5.3.1 THE DATA

Since Model 2 used the actual housing characteristics as the independent variables, the sample size was smaller than in Model 1. This was because a lack of house characteristic data on the municipal database necessitated the physical collection of data. Information on the structural characteristics of houses in the Walmer neighbourhood was collected via personal interviews during January 2010. A simple random sample of 170 properties was drawn.[49]

5.3.2 A DEFINITION OF THE VARIABLES INCLUDED IN MODEL 2

The selection of appropriate structural and neighbourhood characteristics was guided by the Sirmans *et al*. (2005) study. A total of 11 independent variables were thought to influence house prices in the Walmer neighbourhood, namely the number of bedrooms, the presence of a garage, the presence of air-conditioning, the number of bathrooms, the age of the house, the size of the erf, the number of stories, the presence of an electric fence, the presence of a swimming pool, the distance to the Walmer Township and the distance to the nearest school. Table 5.4 presents definitions of these variables, along with the hypothesised signs.

[49] The sample size was determined by employing Equation 5.1, with a level of precision of 7.2 percent. The sample response rate was 100 percent.

Table 5.4: Variable mnemonics and definitions of the variables used in Model 2

Variable	Description	Unit of measurement	Expected sign
Dependent variable			
Assessed_value	Municipal valuation	Constant 2009 rands	
Independent variables			
Bed	Number of bedrooms	Number of	+
Garage	Whether or not a garage is present	Yes = 1 No = 0	+
Aircon	Whether or not air-conditioning is present	Yes = 1 No = 0	+
Bath	Number of bathrooms	Number of	+
Age	Age of house	Years	-
Erf_size	Size of the erf	Square metres	+
Stories	Number of stories	Number of	+
Elec_fence	Whether or not an electric fence is present	Yes = 1 No = 0	+
Swim	Whether or not a swimming pool is present	Yes = 1 No = 0	+
Dist_wal	Distance of house to the Walmer Township	Metres	+
Dist_school	Distance of house to the nearest school	Metres	-

In terms of structural characteristics, the number of bedrooms, the presence of a garage, the presence of air-conditioning, the number of bathrooms, the erf size, the number of stories, the presence of an electric fence, and the presence of a swimming pool were all expected to have positive impacts on house prices. With regard to the neighbourhood characteristics (distance to the nearest school and distance to the Walmer Township), proximity to the nearest school was expected to have a positive impact on house prices and proximity to the Walmer Township was expected to have a negative effect. As these proximity effects were measured in metres, the hypothesised sign for distance to the nearest school was negative (i.e. the further away a house is situated from the nearest school, the lower its price is expected to be, *ceteris paribus*), whereas the hypothesised sign for distance to the Walmer Township was positive (i.e. the further away a house is situated from the Walmer Township, the higher its price is expected to be, *ceteris paribus*).

5.3.3 DESCRIPTIVE STATISTICS OF THE VARIABLES INCLUDED IN MODEL 2

Table 5.5 provides a summary of the descriptive statistics of the variables used in Model 2.

Table 5.5: Descriptive statistics of the variables used in Model 2 (n = 170)

Variable	Min	Max	Mean	Standard deviation
Sales_price	193 600	4 926 800	1 626 395	774 758
Assessed_value	500 500	3 976 700	1 784 135	600 255
Structural characteristics				
Bed	2	8	3.6	0.91
Garage	0	1	0.81	0.40
Aircon	0	1	0.25	0.46
Bath	1	7	2.67	1.09
Age	1	80	55.45	21.85
Erf_size	380	4 600	1 776	629
Stories	1	2	1.18	0.39
Swim	0	1	0.8	0.401
Elec_fence	0	1	0.26	0.44
Neighbourhood characteristics				
Dist_wal	500	3 200	1 799	599
Dist_school	140	3 200	1 469	679

The average house in the sample has 3.6 bedrooms, 2.67 bathrooms, is 55.45 years old, has an erf size of 1776 square metres, has 1.18 stories, and is located 1469 metres from the nearest school and 1799 metres from the Walmer Township. The majority of houses in the sample have a garage and a swimming pool, although less than half of the houses have air-conditioning or electric fencing. The average sales price is R1 626 395 and the average assessed value is R1 784 135.[50]

5.3.4 RESULTS OF THE HEDONIC PRICE ESTIMATION – MODEL 2

Table 5.6 presents the results of using an assessed value as the dependent variable (i.e. Model 2).[51]

[50] These values are slightly different to the values reported on in Table 5.2. This is due to the different sample sizes in Models 1 and 2.

[51] As with Model 1, diagnostic tests were conducted in order to test for the presence of multicollinearity and heteroskedasticity. The computed variance inflation factors (VIFs) did not exceed the threshold value of 5 (for all three models) indicating that there was no severe multicollinearity present (for all three models). According to the Breusch-Pagen test, the Chi-squared test statistic was 25.18 for the linear model which exceeded the critical value of 17.28, indicating the presence of heteroskedasticity. Robust standard errors for the coefficients were calculated in this case. The semi-log and double-log Chi-squared test statistics were 0.12 and 3.7, respectively, which did not exceed the critical value (17.28), indicating that heteroskedasticity was not present in these models.

Table 5.6: Regression results: Model 2 (n = 170)

	Model		
Variable	**Linear**	**Semi-log**	**Double-log**
Constant	-87872.14 (221012.7)[e]	13.45 (0.118)[d]	11.2 (0.52)[d]
Structural Characteristics			
Erf_size	535.96[a] (77.35)[e]	0.00027[a] (0.00003)[d]	0.23[a] (0.043)[d]
Age	1839.15 (1988.4)[e]	0.00077 (0.0009)[d]	0.0006 (0.00097)[d]
Stories	236269.1[b] (104662.5)[e]	0.119[b] (0.05)[d]	0.109[b] (0.055)[d]
Bath	70848.12 (46770.94)[e]	0.036[c] (0.02)[d]	0.05[b] (0.022)[d]
Bed	-23524.19 (45425.02)[e]	-0.008 (0.026)[d]	0.015 (0.028)[d]
Swim	84038.74 (69134.56)[e]	0.06 (0.05)[d]	0.09[c] (0.054)[d]
Aircon	131321.2 (89113.55)[e]	0.091[b] (0.041)[d]	0.097[b] (0.045)[d]
Garage	54500.07 (76940.98)[e]	0.05 (0.05)[d]	0.07 (0.054)[d]
Elec_fence	227486.3[a] (80153.03)[e]	0.13[a] (0.043)[d]	0.133[a] (0.047)[d]
Neighbourhood characteristics			
Dist_Walmer	178.82[a] (54.49)[e]	0.0000953[a] (0.0000357)[d]	0.15[a] (0.056)[d]
Dist_school	-61.48 (56.44)[e]	-0.00004 (0.000032)[d]	-0.025 (0.037)[d]
R-squared	0.54	0.51	0.41
Adj R-squared		0.48	0.37
F-statistic	12.54	14.99	9.99

Notes: [a] Significant at the 1 percent level
[b] Significant at the 5 percent level
[c] Significant at the 10 percent level
[d] Standard errors in parentheses
[e] Robust standard errors in parentheses

The following independent variables were significant at the 10 percent level (or better): erf size, stories, electric fence and distance to the Walmer Township. The presence of an air conditioner was statistically significant in the semi-log and double-log models. The signs of these variables are consistent with *a priori* expectations presented in Table 5.4. The R-squared value for the linear model was 0.54 and the adjusted R-squared values for the semi-log and double log models were 0.51 and 0.41, respectively. This implies that approximately half the variation in the assessed values was explained by the house characteristics included in the model. It is also clear from the data presented in Table 5.6 that the Walmer Township has a statistically significant negative effect on property values in Walmer.

The benefit of including house specific characteristics in the hedonic price model can be emphasised by assessing the results of the linear functional form[52] (Haab & McConnell, 2002). For example, the coefficient estimate of 535.96 for erf size indicates that the marginal assessed value of an additional square metre is about R535.96, whilst distance to the Walmer Township has an assessed value of about R178.82 per additional metre in distance.[53]

The results obtained from Model 2 differ from the results obtained in a recent application of the hedonic price model, which employed the same specification. More specifically, the results of the Fullerton and Villalobos (2011) study revealed a model with an extremely good fit (an adjusted R-squared value of 0.87 was reported). However, the statistical significance of one of the key independent variables (distance to the nearest border crossing) was questionable, with the *t*-statistic for this regressor falling below the 5 percent level (Fullerton & Villalobos, 2011). The coefficient of the other key independent variable (street width) was statistically significant at the 5 percent level (Fullerton & Villalobos, 2011). The results of another recent study, which also employed the same specification, are more in line with the results presented in Table 5.6. More specifically, the results of the Cotteleer and van Kooten (2012) study revealed an R-squared value of 0.58. Moreover, the key independent distance variables were all statistically significant at the 10 percent level, or better (Cotteleer & van Kooten, 2012).

5.4 MODEL 3: THE USE OF ACTUAL SALES PRICES AS THE DEPENDENT VARIABLE AND HOUSING CHARACTERISTICS AS THE INDEPENDENT VARIABLES

The third hedonic price estimation (Model 3) used the actual sales price as the dependent variable and housing characteristics as independent variables. In all other respects, the model is identical to Model 2. Table 5.7 presents the results of this approach.[54]

[52] This functional form directly reveals the implicit prices of the house characteristics through the estimated coefficient.
[53] This interpretation of these coefficients should not be regarded as a comparison of their relative importance.
[54] As with Models 1 and 2, diagnostic tests were conducted in order to test for the presence of multicollinearity and heteroskedasticity. The computed variance inflation factors (VIFs) did not exceed the threshold value of 5 indicating that there was no severe multicollinearity present for all three models. According to the Breusch-Pagen test, the Chi-squared test statistic was 44.28 for the linear model which exceeded the critical value of 17.28, indicating the presence of heteroskedasticity. Robust standard errors for the coefficients were calculated in this case. The semi-log and double-log Chi-squared test statistics were 0.11 and 0.09, respectively, which did not exceed the critical value (17.28), indicating that heteroskedasticity was not present in these models.

Table 5.7: Regression results: Model 3 (n = 170)

	Model		
Variable	**Linear**	**Semi-log**	**Double-log**
Constant	-740535.3 (302674.1)[d]	12.76 (0.174)[c]	9.57 (0.73)[c]
Structural Characteristics			
Erf_size	580.57[a] (85.62)[d]	0.0003[a] (0.00005)[c]	0.299[a] (0.06)[c]
Age	876.43 (1900.7)[d]	-0.0004 (0.0013)[c]	-0.0005 (0.0013)[c]
Stories	278600.5[b] (144698.1)[d]	0.17[b] (0.74)[c]	0.156[b] (0.077)[c]
Bath	61209.5 (50148.42)[d]	0.046 (0.03)[c]	0.053 (0.31)[c]
Bed	-315 (57275)[d]	0.024 (0.038)[c]	0.048 (0.039)[c]
Swim	364337.9[a] (87333.02)[d]	0.308[a] (0.073)[c]	0.343[a] (0.75)[c]
Aircon	6010.76 (129618.7)[d]	0.002 (0.06)[c]	0.01 (0.063)[c]
Garage	41360.15 (74847.6)[d]	-0.007 (0.073)[c]	0.0033 (0.075)[c]
Elec_fence	279153.4[b] (116840.9)[d]	0.14[b] (0.63)[c]	0.156[b] (0.066)[c]
Neighbourhood characteristics			
Dist_Walmer	198[a] (63.8)[d]	0.00013[b] (0.00005)[c]	0.2[a] (0.078)[c]
Dist_school	25.59 (62.08)[d]	0.000002 (0.00005)[c]	0.016 (0.052)[c]
R-squared	0.48	0.48	0.44
Adj R-Squared		0.45	0.40
F-statistic	11.22	13.39	11.38

Notes: [a] Significant at the 1 percent level
[b] Significant at the 5 percent level
[c] Standard errors in parentheses
[d] Robust standard errors is parentheses

Erf size, stories, the presence of a swimming pool, the presence of an electric fence and distance to the Walmer Township had statistically significant coefficients across all three models. Furthermore, the coefficients on these variables all displayed the hypothesised signs. The R-squared value for the linear model was 0.48 and the adjusted R-squared values for the semi-log and double log models were 0.48 and 0.44, respectively, implying that roughly half of the variation in market prices was explained by the independent variables.

In order to compare models 2 and 3, it was necessary to investigate the statistical differences between the two models.

5.5 STATISTICAL DIFFERENCES: MODEL 2 VERSUS MODEL 3

Previous studies have attempted to compare coefficient estimates for non-market amenities using regression equations with different dependent variables (Nicholls & Crompton, 2007; Bowman, Thompson & Colletti, 2009). These studies, however, did not develop test statistics in order to compare these estimates. Only one study could be found in the international literature that developed test statistics for this comparison – the study by Cotteleer and van Kooten (2012). The analysis presented below follows the Cotteleer and van Kooten (2012) approach closely.

In order to test for statistical differences between assessed values and sales prices, the correlation coefficient between the assessed values and the sales prices was calculated. Histograms for the distribution of sales prices and assessed values were also constructed and a paired *t*-test was performed. In addition to this, a Seemingly Unrelated Regression (SUR) model was estimated to test for significant differences between Models 2 and 3.

5.5.1 METHODS

5.5.1.1 CORRELATION COEFFICIENT

The correlation coefficient, *r*, is a measure of the strength of the linear relationship between two variables (Studenmund, 2006). This is defined as:

$$r = cov(X,Y)/S_xS_y \qquad (5.2)$$

where: *cov* = sample covariance

S_x = sample standard deviation of variable X

S_y = sample standard deviation of variable Y

The correlation coefficient will always lie between -1 and 1 (Keller, 2011). A value of -1 indicates a perfect negative relationship, a value of 0 indicates no relationship and a value of 1 indicates a perfect positive relationship (Keller, 2011).

5.5.1.2 PAIRED *T*-TEST

A paired *t*-test is used to determine whether or not there is a significant difference in two population means. In order to conduct a paired *t*-test, it is necessary to pair the observations in one of the samples with the observations in the other (Shier, 2004). The relevant *t*-statistic is calculated as follows:

$t = \bar{d} / SE(\bar{d})$……..……..(5.3)

where: $\bar{d}$ = the mean difference

SE = the standard error of the mean difference

The *t*-statistic is then used to test the null hypothesis that no significant difference in the mean values is present (Shier, 2004).

5.5.1.3 SEEMINGLY UNRELATED REGRESSION (SUR) AND THE WALD STATISTIC

A SUR model involves pairing the actual sales prices and assessed values and specifying a regression model for each of the properties for which both values are available (Cotteleer & van Kooten, 2012). By analysing both equations in one model, the relevant test statistic can be derived (i.e. the Wald statistic).

Generally, the SUR model specifies the mth of M equations for the ith of N individuals as follows:

$P_{im} = x'_{im}\beta_m + \varepsilon_{im,} \qquad m = 1, \ldots, M, i = 1, \ldots, N,$……...……..……...(5.4)

where: x_{im} = regressors that are assumed to be exogenous

β_m = $K_m \times 1$ parameter vectors

ε_m = an error term

P_m could, for example, represent the ith individual's expenditure on house m and x_{im} could, for example, represent a matrix of house attributes. In order to estimate the SUR model, observations over both equations and individuals are combined (Cameron & Trivedi, 2005). If independence over i is assumed, all equations for a given individual are first stacked (Cameron & Trivedi, 2005).

The process of stacking M equations for the ith individual produces the following:

$$\begin{bmatrix} P_{i1} \\ \vdots \\ P_{iM} \end{bmatrix} = \begin{bmatrix} \mathbf{x}'_{i1} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \ddots & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{x}'_{im} \end{bmatrix} \begin{bmatrix} \beta_1 \\ \vdots \\ \beta_M \end{bmatrix} \begin{bmatrix} \varepsilon_{i1} \\ + \\ \varepsilon_{iM} \end{bmatrix} \quad \ldots\ldots(5.5)$$

which represents the following form:

$$\boldsymbol{P}i = \mathbf{X}_i \beta + \varepsilon_i \qquad (5.6)$$

where: P_i and ε_I = $M \times 1$ vectors with m^{th} entries P_{im} and ε_{im}

$\boldsymbol{X}_i$ = $M \times K$ matrix with m^{th} row $[\mathbf{0 \ldots x'}_{im} \mathbf{\ldots 0}]$

β = $[\beta'_1 \ldots \beta'_M]' = K \times 1$ vector where $K = K_1 + \ldots K_M$.

Given the definitions of $\boldsymbol{X}_i$ and $\boldsymbol{P}_i$ it can be shown that $\hat{\beta}_{SOLS}$ is:

$$\begin{bmatrix} \hat{\beta}_1 \\ \vdots \\ \hat{\beta}_M \end{bmatrix} = \begin{bmatrix} \left[\sum_{i=1}^{N} \mathbf{x}_{i1}\mathbf{x}'_{i1}\right]^{-1} \sum_{i=1}^{N} \mathbf{x}_{i1}\boldsymbol{P}_{i1} \\ \vdots \\ \left[\sum_{i=1}^{N} \mathbf{x}_{iM}\mathbf{x}'_{iM}\right]^{-1} \sum_{i=1}^{N} \mathbf{x}_{iM}\boldsymbol{P}_{iM} \end{bmatrix} \qquad (5.7)$$

which implies that system OLS (SOLS) is identical to separate equation-by-equation OLS (Cameron & Trivedi, 2005). In cases where all M equations have the same regressors, the efficient estimator is single equation OLS (Greene, 2011). Alternative estimators include the feasible generalised least squares (GLS) estimator[55] and the maximum likelihood estimator[56] (Cameron & Trivedi, 2005)

Once the SUR model has been estimated, the Wald statistic[57] can be calculated to test whether the restriction $\beta_1 = \beta_2$ holds (i.e. the Wald statistic tests the hypothesis that coefficients in the equation with actual market prices as the dependent variable are equal to the coefficients in the equation with assessed values as the dependent variable (Cotteleer & van Kooten, 2012)).

[55] In many cases the feasible GLS estimator is more efficient compared to systems OLS but it collapses to OLS if precisely the same regressors are present in each equation.
[56] Stata Version 11.0 uses the maximum likelihood estimator to estimate SUR models.
[57] The Wald statistic can be calculated in Stata Version 11.0.

More formally,

$H_o : \beta_1 = \beta_2$

$H_a : \beta_1 \neq \beta_2$

where: β_1 = the estimated coefficients for the sales prices equation

β_2 = the estimated coefficients for the assessed values equation

5.5.2 RESULTS

It was first considered whether or not there were any significant differences between sales prices and assessed values. The correlation coefficient for the 170 observations was 0.79, indicating an imperfect overlap. Actual sales prices are generally lower than assessed values, although sales prices have a larger standard deviation (see Table 5.5). This is also apparent from Figures 5.1 and 5.2.

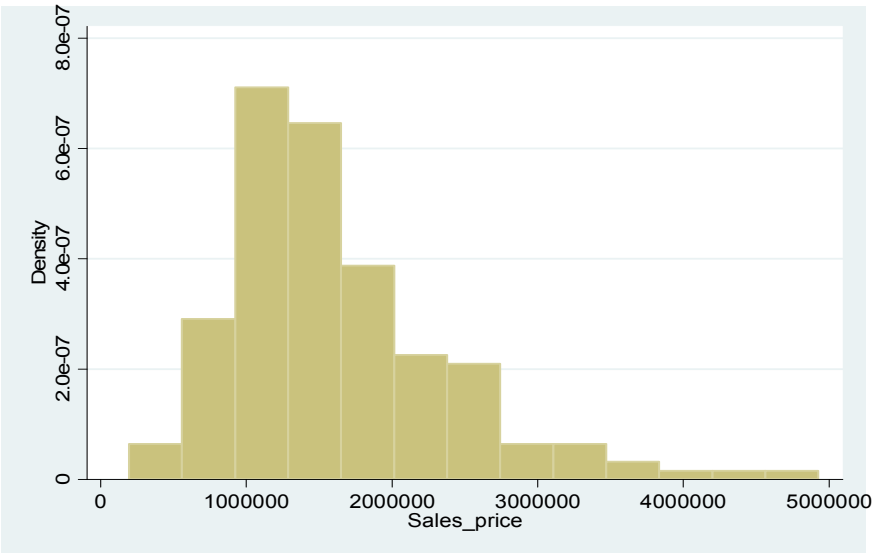

Figure 5.1: Sales price distribution

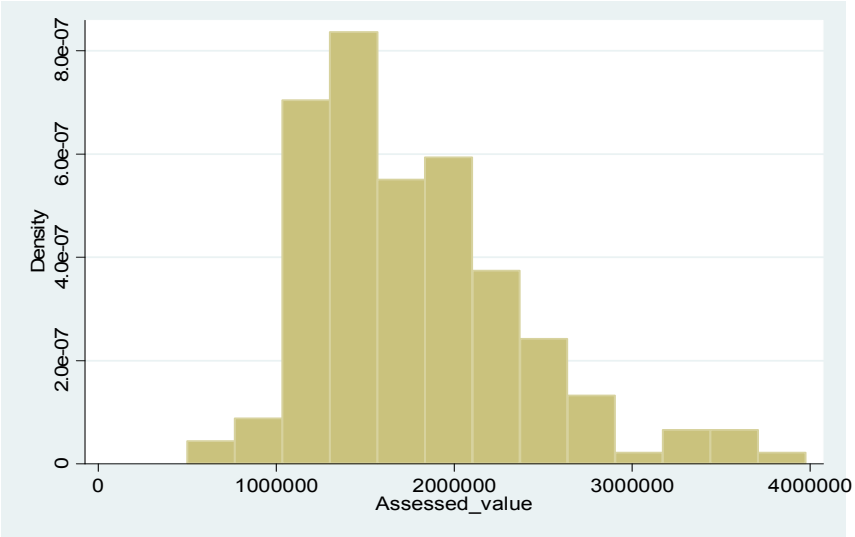

Figure 5.2: Assessed value distribution

As can be seen from Figures 5.1 and 5.2, the distribution of the assessed values has fewer observations in the tails of the distribution compared to actual sales prices.

In addition to the histograms presented above, kernel densities for sales prices and assessed values were estimated. These are presented in Figures 5.3 and 5.4.

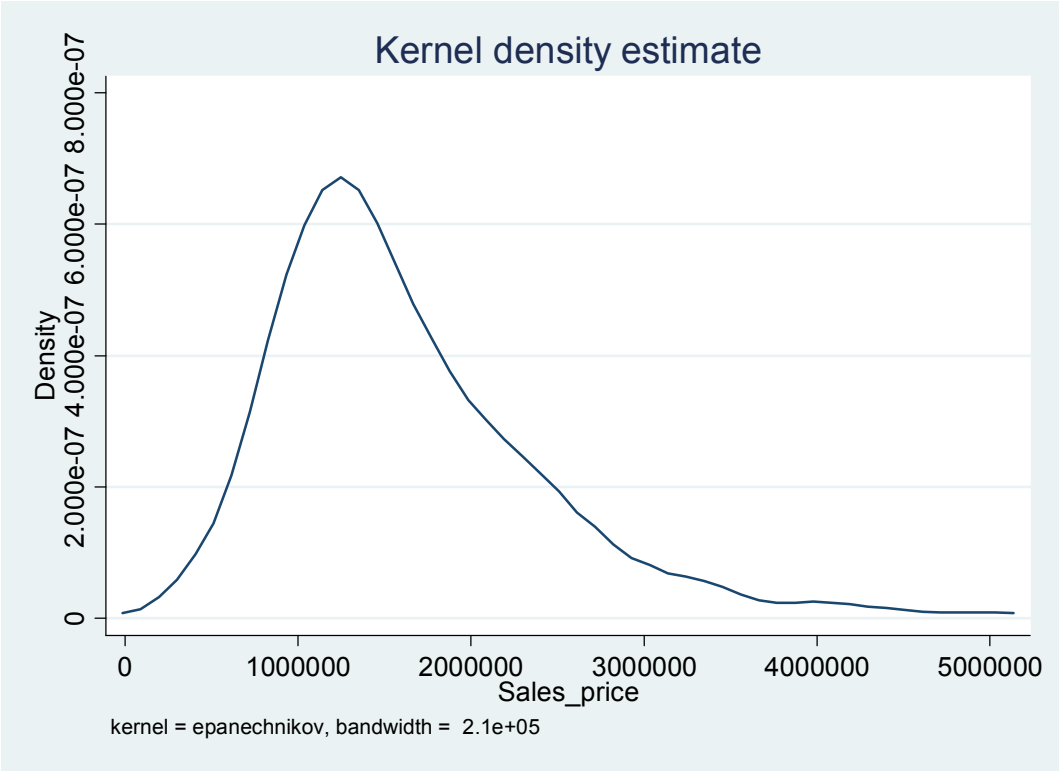

Figure 5.3: Sales price kernel density estimate

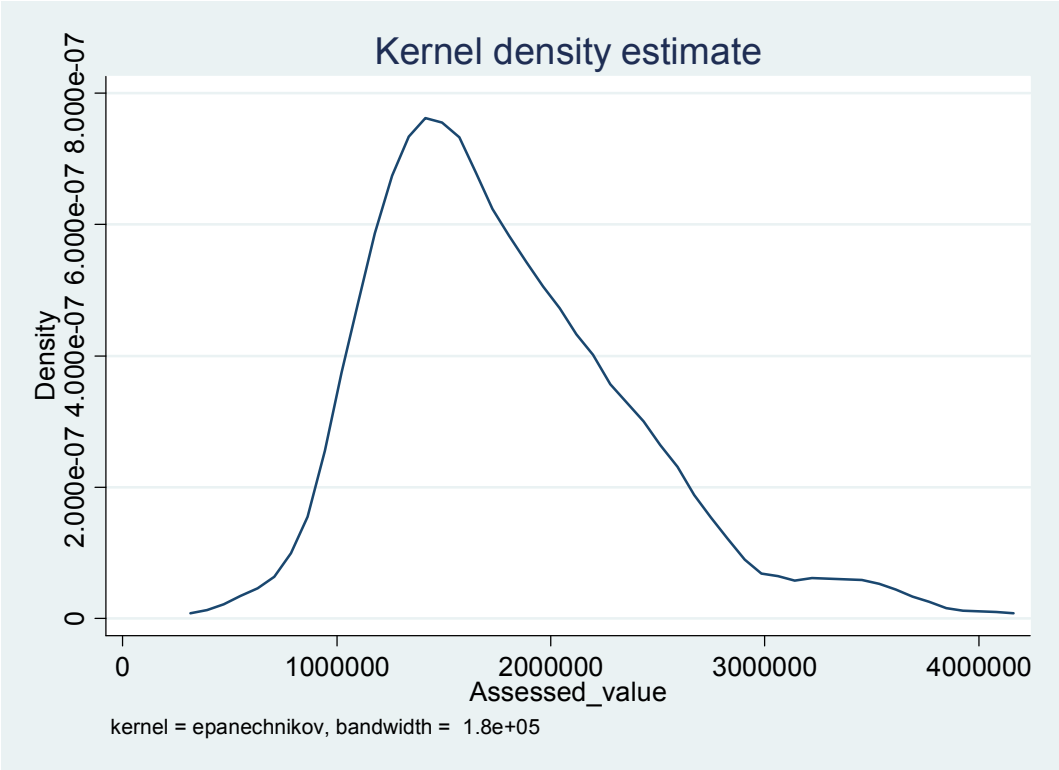

Figure 5.4: Assessed value kernel density estimate

The distributions were tested for differences by conducting a *z*-test. The *z*-statistic of 2.06 was greater than the critical value of 1.96. The null hypothesis of equal distributions was, thus, rejected. [58]

A paired *t*-test was also conducted in order to determine whether or not a significant difference between the mean values was present. The *t*-statistic of 2.1 was greater than the critical value of 1.96. This led to the rejection of the null hypothesis of no significant difference between the two mean values.

Although there is evidence of divergence between actual sales prices and assessed values, hedonic price models based on assessed values and actual sales values can still result in similar coefficient estimates of location-specific amenities (Cotteleer & van Kooten, 2012). Therefore, in order to compare Models 2 and 3, the actual sales prices and assessed values were paired and a SUR model was estimated. Table 5.8 presents the results of the SUR.[59]

[58] The relevant *z*-statistic is calculated as follows:

$$z = (\bar{x}_1 - \bar{x}_2)/\sqrt{\sigma_{x1}{}^2 + \sigma_{x2}{}^2} \quad \text{.....(5.8)}$$

where: $\bar{x}_1$ = mean value of sample one
$\bar{x}_2$ = mean value of sample two
$\sigma_{x_1}{}^2$ = standard deviation of sample one divided by the square root of the number of data points
$\sigma x_2{}^2$ = standard deviation of sample two divided by the square root of the number of data points (Comparing Distributions: *z*-test, 2013).

[59] In the estimation of the SUR model, *m* = 1 represented the equation with sales prices as the dependent variable and *m* = 2 represented the equation with assessed values as the dependent variable (see Equation 5.4).

Table 5.8: Estimation results for the Seemingly Unrelated Regression (SUR)

	Dependent variable	
Variable	**Sales_price**	**Assessed_value**
Constant	-740535.3 (278355)[d]	-87872.14 (201522)[d]
Structural characteristics		
Erf_size	580.57[a] (75.76)[d]	535.96[a] (55)[d]
Age	876.43 (2067.4)[d]	1839.15 (1497)[d]
Stories	278600.5[b] (118212)[d]	236269.1[a] (85582)[d]
Bath	61209.5 (47838)[d]	70848.12 (34633)[d]
Bed	-315 (60340)[d]	-23524.19 (43684)[d]
Swim	364337.9[a] (116401)[d]	84038.74 (84271)[d]
Aircon	6010.76 (97060)[d]	131321.2[c] (70268)[d]
Garage	41360.15 (41360)[d]	54500.07 (84198)[d]
Elec_fence	279153.4[a] (279153)[d]	227486.3[a] (72751)[d]
Neighbourhood characteristics		
Dist_Wal	198[b] (84)[d]	178.82[a] (61)[d]
Dist_school	25.59 (75)[d]	-61.48 (54)[d]
R-squared	0.48	0.54

Notes: [a] Significant at the 1 percent level
[b] Significant at the 5 percent level
[c] Significant at the 10 percent level
[d] Standard errors in parentheses

A visual inspection of the coefficient estimates in the SUR model indicates that all the coefficients had similar signs in the actual sales price and assessed value equations, except for distance to the nearest school. Overall, the model explained variation in actual sales price and assessed value fairly well, with R-squared values of 0.48 and 0.54, respectively.[60] Based on the results of the SUR model, the hypothesis that all 11 coefficients included in the model (excluding the constant) are equal was rejected with near certainty. More specifically, the Wald statistic was 119. This was greater than the Chi-squared critical value of 19.68 (with 11 degrees of freedom). In addition to testing the full model, the parameter of interest (distance to the Walmer Township) was also tested. In this case, the Wald statistic was 4.57, which was greater than the Chi-squared critical value of 3.84 (with 1 degree of freedom). The null hypothesis of equal coefficient estimates was, thus, rejected - the estimated coefficients were not similar enough to assume they were the same in both equations.

[60]A stepwise regression for both models revealed that the following independent variables drove the better fit of the assessed value model: number of bathrooms and the presence of an air conditioner.

These results are similar to the results obtained in the Cotteleer and van Kooten (2012) study. In the Cotteleer and van Kooten (2012) study the non-market estimates were too dissimilar to assume that they were equal in both equations.

Since sales prices reflect true market conditions more accurately than assessed values, economic intuition suggests that actual market prices are preferred to assessed values (Freeman, 2003; Cotteleer & van Kooten, 2012). For this reason, Model 3 is the preferred model. Since Model 3 is the preferred specification (compared to Models 1 and 2), a reduced version of it was also estimated for all three functional forms.

5.6 THE COMPLETE HEDONIC PRICE MODEL (MODEL 3) VERSUS THE REDUCED MODEL

The reduced version of Model 3 included only the variables that were significant at the 10 percent level or less. Table 5.8 presents the results of the reduced model.

Table 5.9: Regression results: Model 3 (reduced model) (n = 170)

	Model		
Variable	**Linear**	**Semi-log**	**Double-log**
Constant	-637227 (229462)[d]	12.8 (0.13)[c]	9.19 (0.68)[c]
Structural Characteristics			
Erf_size	612.6[a] (81.7)[d]	0.00033[a] (0.00004)[c]	0.34[a] (0.06)[c]
Stories	315564.1[b] (131615.2)[d]	0.21[a] (0.07)[c]	0.22[a] (0.073)[c]
Swim	379897.9[a] (81253.7)[d]	0.32[a] (0.07)[c]	0.38[a] (0.072)[c]
Elec_fence	288136.1[b] (116086.5)[d]	0.15[b] (0.06)[c]	0.17[b] (0.07)[c]
Neighbourhood characteristics			
Dist_Walmer	234.59[a] (61.3)[d]	0.00015[a] (0.000045)[c]	0.25[a] (0.07)[c]
R-squared	0.47	0.47	0.41
Adjusted R-squared		0.45	0.39
F-statistic	22.88	28.77	22.89

Notes: [a] Significant at the 1 percent level
[b] Significant at the 5 percent level
[c] Standard errors in parentheses
[d] Robust standard errors in parentheses

The results of the reduced model are consistent with the results of the complete model with regard to coefficient significance. More specifically, all of the variables used to generate the reduced model (Erf_size, Stories, Swim, Elec_fence and Dist_wal) displayed statistically significant coefficients in the reduced model. These variables also had the same signs in the reduced model. The coefficient estimates were, however, slightly larger in the reduced

model, with the variable of interest (Dist_wal) displaying a coefficient estimate of 198 in the complete model and 234 in the reduced model (linear model).

Using the nested *F*-test[61], the complete (linear, semi-log and double-log) and reduced models were compared for goodness of fit. The *F*-test statistics for the linear, semi-log and double-log models were 0.39, 0.77 and 1.46, respectively. These values were all smaller than the critical value of 1.84 (at the 90 percent confidence level), and for this reason the null hypothesis (all the coefficients of variables excluded in the reduced model equal zero) could not be rejected. In all three cases, it was deduced that the reduced model was preferable to the complete model.

5.7 A COMPARISON OF ALL THE MODELS ESTIMATED

Table 5.10 presents a comparison of the key estimation results of each model specification, including the reduced version of Model 3.

[61] The test statistic used for this purpose is defined as follows:

$$F = \frac{(R^2complete - R^2reduced)*(n - k - 1)}{(1 - R^2complete)*(k-g)} \quad \text{.....(5.9)}$$

where: n = number of observations
k = number of variables included in the complete model
g = number of variables included in the reduced model

Table 5.10: A comparison of the basic hedonic price models

	Adjusted R-squared	P-value of key variable (distance to Walmer Township)	Implicit price of key variable (distance to Walmer Township)
MODEL 1			
Linear	0.46[a]	0.100	103.50
Semi-log	0.36[a]	0.033	127.88
Double-log	0.37	0.016	97.88
MODEL 2			
Linear	0.54[a]	0.001	178.82
Semi-log	0.48	0.008	155.00
Double-log	0.37	0.008	135.61
MODEL 3 (Complete)[b]			
Linear	0.48[a]	0.001	198.00
Semi-log	0.45	0.016	211.43
Double-log	0.40	0.010	180.81
MODEL 3 (Reduced)			
Linear	0.47[a]	0.000	234.59
Semi-log	0.45	0.001	243.96
Double-log	0.39	0.001	226.01

Notes: [a] In these models heteroskedasticity was identified. For this reason, only the R-squared value is reported.
[b] It was shown in Section 5.6 that the reduced version of Model 3 is preferable to the complete version. The complete version of Model 3 is included in Table 5.9 simply for interest sake.

Although there appears to be very little variation in terms of robustness across the four models, the reduced version of Model 3 produced the most consistent implicit prices (R234.59, R243.96 and R226.01 for the linear, semi-log and double-log models, respectively). In addition to this, the key independent variable (distance to the Walmer Township) displayed the highest degree of statistical significance in this model. These findings, coupled with the results of the nested F-test presented in Section 5.6, suggest that the reduced version of Model 3 is the preferred basic hedonic price model.[62]

[62] The following three hedonic price equations were estimated:

P = -637 227 + 621.6erf_size + 315564.1stories +379897swim + 288136.1elec_fence + 234.59dist_wal……(5.10)

lnP = 12.8 + 0.00033erf_size + 0.21stories + 0.32swim + 0.15elec_fence + 0.00015dist_wal……(5.11)

lnP = 9.19 + 0.34lnerf_size + 0.22stories + 0.38swim + 0.17elec_fence + 0.25lndist_wal……(5.12)

Equations 5.10, 5.11 and 5.12 represent the linear, semi-log and double-log models, respectively. The purpose of these equations is twofold: firstly, the coefficient on the distance to the Walmer Township can be used to calculate the welfare effects of a change in distance to the Walmer Township, and secondly, they can be used for predictive purposes.

5.8 CONCLUSION

Chapter Five explored a number of different specifications of the hedonic price equation. The first specification employed a sales price as the dependent variable and an assessed value as a proxy for independent variables. The second specification made use of actual housing characteristics as explanatory variables and used an assessed value as the dependent variable. The third specification also employed house characteristics as independent variables but used a sales price as the dependent variable. All specifications were modelled with the standard linear, semi-log and double-log models. The third specification was deemed to be the most appropriate and as a result a reduced version of it was also estimated. The results of an *F*-test revealed that the reduced version of the third specification is preferred.

The model specifications employed in this chapter neglected two important and emerging aspects, namely the selection of appropriate functional forms based on Box-Cox transformations and the effect of neighbouring properties on house value (i.e. the inclusion of a spatial autoregressive term in the hedonic price equation).

The next chapter (Chapter Six) addresses these emerging issues by extending the reduced version of Model 3 estimated in this chapter. The results generated in Chapter Six are used in order to present a policy discussion on social housing and municipal property rates.

CHAPTER SIX: EXTENDING THE BASIC HEDONIC PRICE MODEL AND APPLYING ITS RESULTS TO A POLICY DISCUSSION

6.1 INTRODUCTION

The hedonic price models estimated in Chapter Five have shown that structural and neighbourhood (locational) characteristics play an important role in house price determination. These models, however, neglected two specification issues which have come to dominate hedonic price theory in recent times, namely the influence of neighbouring property prices (i.e. the inclusion of a spatial autoregressive term in the hedonic price model) and functional form selection (i.e. employing Box-Cox transformations to determine the functional form which fits the data best). These two issues are addressed in this chapter by means of the development and estimation of an extended hedonic price model.

In addition, a validity test of the extended hedonic price model is conducted via the estimation of a random utility model. Finally, a policy discussion on social housing developments and municipal property rates estimation is presented, which draws on the results of the extended hedonic price model.

6.2 ESTIMATION OF THE EXTENDED HEDONIC PRICE MODEL

6.2.1 EXTENSIONS

6.2.1.1 THE AUTOREGRESSIVE TERM

The autoregressive term for inclusion as an additional covariate in the reduced hedonic price model (see Section 3.2.3.9) was formally defined in Chapter Three (Equation 3.59) and is a weighted average of the value of houses sold within a 4.8 kilometre radius of each house in the data set (Can & Megbolugbe, 1997). The number of neighbouring houses selected for each observation in the sample was three. Thus, in addition to the data collected for the 170 sample houses, sales price and distance data for a further 510 houses were collected. Table 6.1 provides the descriptive statistics for the additional 510 houses sold.

Table 6.1: Descriptive statistics of the houses used to populate the autoregressive term (n = 510)

Variable	Unit of measurement	Min	Max	Mean	Standard deviation
Sales price	Rands	193 600	4 336 000	1 531 219	756 468
Distance to subject property	Metres	8	4 800	1080	920

As is evident from Table 6.1, the highest price of a house used to populate the autoregressive term is R4 336 000 and the lowest house price is R193 600. The average house is priced at R1 532 219, with a standard deviation of R756 468. The closest neighbouring house to a subject property is located 8 metres away and the furthest neighbouring house is situated 4.8 km's away. On average, houses that sold within 6 months of a subject property are situated 1 080 metres away, with a standard deviation of 920 metres. Table 6.2 provides the descriptive statistics for the autoregressive term (i.e. $\sum jW_{ij}P_{j,t-m}$ in Equation 3.59).

Table 6.2: Descriptive Statistics of the autoregressive term (n = 170)

Variable	Unit of measurement	Min	Max	Mean	Standard deviation
Autoregressive_term	Rands	511 995	4 572 982	1 597 708	674 505

As can be seen from Table 6.2, the average weighted value of houses sold, situated within a 4.8 kilometre radius of a subject house, is R1 597 708, with a standard deviation of R674 505. The minimum weighted value is R511 995 and the maximum weighted value is R4 572 982.

6.2.1.2 BOX-COX TRANSFORMATIONS

Four Box-Cox functional form transformations were implemented: one in which only the lefthand side of the hedonic price function is transformed (lhBC), one in which only the righthand side is transformed (rhBC), one in which both sides are transformed by employing the same parameter (rBC), and one in which both sides are transformed but by employing different parameters (uBC).

6.2.2 ESTIMATION RESULTS

The estimation results of the reduced spatial hedonic price model inclusive of a spatial autoregressive term and employing three conventional functional forms and four Box-Cox transformed functional forms are presented in Table 6.3.

Table 6.3: Estimation results of the extended hedonic price model

Variable	Model						
	Linear	Semi-log	Double-log	lhBC model	rhBC model	rBC model	uBC model
Constant	-850912.6 (239532.7)[e]	12.7 (0.15)[d]	8.14 (1.22)[d]	99.91	-214272.7	-5.521	111.84
Structural Characteristics							
Erf_size	623.14[a] (83.4)[e]	0.00033[a] (0.00004)[d]	0.348[a] (0.058)[d]	0.016[a] (58.051)[f]	109.24[a] (65.696)[f]	7.84[a] (48.215)[f]	0.013[a] (57.537)[f]
Stories	304642.1[b] (135506.6)[e]	0.2055[a] (0.07)[d]	0.213[a] (0.074)[d]	9.53[a] (8.907)[f]	284338.1[a] (7.535)[f]	66.82[a] (8.182)[f]	9.545[a] (8.914)[f]
Swim	359880.5[a] (82903.25)[e]	0.316[a] (0.07)[d]	0.369[a] (0.073)[d]	13.599[a] (17.622)[f]	355489[a] (9.941)[f]	81.004[a] (18.162)[f]	13.74[a] (17.497)[f]
Elec_fence	277279.2[b] (112864.5)[e]	0.141[a] (0.062)[d]	0.167[b] (0.065)[d]	7.19[b] (6.51)[f]	273190.7[a] (7.491)[f]	46.18[a] (7.903)[f]	7.26[b] (6.454)[f]
Neighbourhood Characteristics							
Dist_wal	234.72[a] (61.62)[e]	0.00015[a] (0.0000448)[d]	0.248[a] (0.074)[d]	0.00699[a] (11.594)[f]	41.018[a] (9.673)[f]	3.756[a] (12.652)[f]	0.005498[a] (11.398)[f]
Autoregressive_term	0.1418[c] (0.083)[e]	0.000000067 (0.00000004)[d]	0.074 (0.071)[d]	0.000003[c] (3.33)[f]	0.00524[b] (5.17)[f]	0.105 (2.622)[f]	0.00000207[c] (3.337)[f]
R-squared	0.48	0.47	0.42				
Adjusted R-squared		0.46	0.39				
F-statistic	18.82	24.61	19.26				
Transformation Parameters							
λ				0.2713[a] (0.1011)[f]	---	0.394[a] (0.096)[f]	0.272[a] (0.101)[f]
θ				---	1.23[a] (0.323)[f]	0.394[a] (0.096)[f]	1.03[a] (0.296)[f]
Log likelihood				-2467.04	-2489.3	-2471.7	-2467.03

Notes: [a]Significant at the 1-percent level
[b] Significant at the 5-percent level
[C] Significant at the 10-percent level
[d] Standard errors in parentheses
[e]Robust standard errors in parentheses
[f] Chi–square values in parentheses[63]

[63] The Box-Cox produced probability values for the coefficients on the basis of chi–square tests (as the use of ordinary least squares estimates of variance may produce inaccurate measures of significance when used with Box-Cox transformations) (Williams, 2008).

The results from all the hedonic regressions generally conform to *a priori* expectations (Table 6.3). More specifically, the number of stories, the size of the erf, the presence of a swimming pool and the presence of an electric fence all have statistically significant, positive effects on property values in the sample. A very encouraging result is the statistically significant positive relationship that exists in all seven models between house prices and distance from the Walmer Township. The significance of this coefficient allows for the calculation of implicit prices and provides evidence that house prices in the suburb of Walmer are, in part, negatively affected by proximity to the township.

6.2.3 FUNCTIONAL FORM SELECTION

Box–Cox transformations can also be used as tests for functional form selection (see Section 3.2.3.7, Chapter Three). The results of these tests are presented in Table 6.4.

Table 6.4: Hypothesis tests for Box–Cox transformations

Transformation	λ	θ	**Ho Equation**	**Chi² statistic for rejecting Ho when X =**			**Standard functional forms rejected**
				1	**0**	**-1**	
lhBC	0.27123		λ=X	45.10	7.61	198.83	Semi-log and linear
rhBC		1.23	θ=X	0.58	28.91	60.76	Semi-log and reciprocal
rBC	0.394	0.394	θ=λ=X	35.78	16.82	203.91	Linear and log-log
uBC	0.272	1.03	θ=λ=X	45.11	26.15	213.24	Linear and log-log

As tests for functional form selection, the Box-Cox regressions eliminated the standard linear, double-log and semi-log forms. As previously mentioned, the Box–Cox regressions can be used as functional forms themselves and based on the results shown in Table 6.4, the Box–Cox regressions appear to fit the data best. The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were used to select the appropriate Box-Cox model. Table 6.5 presents the AIC and BIC values of the four Box-Cox transformations.

Table 6.5: AIC and BIC values

Model	**AIC**	**BIC**
lhBC	4936	4939
rhBC	4980	4983
rBC	4945	4948
uBC	4938	4944

According to Table 6.5, the lhBC had the lowest values for the AIC and the BIC, suggesting it is the most appropriate model. However, because it is preferable to transform both sides of the hedonic price equation (see Williams, 2008), the uBC transformation was selected for use in this study, as it had lower AIC and BIC values compared to the rBC. The hedonic price function used in this study can, thus, be represented by the following equation:

$$\frac{y^{\lambda}-1}{\lambda} = \alpha + \sum_{z=1}^{k} \beta z \frac{Xz^{\theta}-1}{\theta} + \sum_{s=1}^{j} \gamma_{s} D_{s} + \epsilon \text{ for } \lambda \text{ and } \theta \neq 0 \quad \text{.....(6.1)}$$

6.2.4 IMPLICIT PRICE CALCULATION

The implicit price of distance to the Walmer Township can be calculated by taking the partial derivative of the price, *Y,* in respect of distance, *X,* from Equation 6.1:

$$\frac{\partial Y}{\partial X} = \beta z X z^{\theta-1} Y^{1-\lambda} \quad \text{.....(6.2)}$$

Applying Equation 6.2, the mean implicit price calculated in this study was R234.49.[64] In other words, distance away from the Walmer Township is valued at R234.49 per metre.[65] Using Equation 6.1 and holding all other variables constant reveals a predicted house price of R1 198 816 for a house situated 500m (i.e. the lower distance limit in the sample) away from the township. This same house would increase in value by approximately 49 percent (or R588 514) when located 3200m away from the township.

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[64] Substituting for all the variables in Equation 6.2 produced $\frac{\partial Y}{\partial X} = 0.005498(1799)^{1.03-1}(1626395)^{1-0.272}$ = R234.49.

[65] The price-distance relationship was tested for linearity by adding a quadratic distance term to the simple linear model (see Table 6.3). The estimated quadratic hedonic price function is as follows:

P = -1290603 + 614erf_size + 304960stories +364378swim + 281938elec_fence + 0.13autoregressive_term + 833dist_wal - 0.17dist_wal^2 .....(6.3)

Equation 6.3 implies that the incremental addition to house price diminishes by R0.34 per additional metre in distance (Coulson, 2008). However, the coefficient of the quadratic term was insignificant (P = 0.138). Therefore, it cannot be concluded that the price distance relationship is non-linear. For interests' sake, the implicit price of distance to the Walmer Township was estimated by taking the partial derivative of dist_wal with respect to P:

∂P/∂dist_wal = 833 – 0.34dist_wal.....(6.4)
= R221.34

Equation6.4 implies that distance to the Walmer Township is valued at R221.34 per metre, which is very similar to the result obtained by applying Equation 6.2.

6.2.5 CONVENTIONAL HEDONIC PRICE MODELS VERSUS BOX-COX TRANSFORMED MODELS – A COMPARISON

Table 6.6 presents a comparison of the implicit prices estimated using conventional hedonic price models (linear, semi-log and double-log models) and those estimated using Box-Cox transformed models.

Table 6.6: Implicit prices

Functional form	Coefficient: β	Implicit price*
Linear ($\lambda = \theta = 1$)	234.72	R234.72
Semi-log ($\lambda = 0, \theta = 1$)	0.00015	R238.75
Double-log ($\lambda = \theta = 1$)	0.248	R224.38
lhBC ($\lambda = 0.271, \theta = 1$)	0.00699	R234.81
rhBC ($\lambda = 1, \theta = 1.2302$)	41.018	R230.34
rBC ($\lambda = 0.394, \theta = 0.394$)	3.756	R233.11
uBC ($\lambda = 0.272, \theta = 1.033$)	0.005498	R234.49

Note: *Implicit price = $\beta X^{\theta-1} Y^{1-\lambda}$ where X = 1799 and Y = 1 626 395

As is evident from Table 6.6, the implicit prices derived from the coefficients estimated in the seven hedonic price models are all very similar. The mean implicit price is R232.94, with a standard deviation of 4.52, implying minimal variation around the mean. Moreover, all of the implicit prices presented in Table 6.6 were derived from statistically significant coefficients which displayed consistently positive signs. These results are similar to those obtained by Haab and McConnell (2002)[66] who investigated the use of four different functional forms – linear, semi-log, rBC and uBC, and found that the variable of interest (i.e. mean fecal coliform concentration) displayed very similar implicit prices across the different specifications (Haab & McConnell, 2002). This is in stark contrast to a study by Anderson, Shyr and Fu (2010), which modelled the hedonic price equation using a total of six different functional forms (log-linear, semi-log, lBC, rBC, uBC and a Box-Cox model with four transformations employing four different parameter estimates) (Anderson *et al*., 2010). The results of this study revealed inconsistent coefficient estimates of the key variable (i.e. distance to a high speed rail station) - they were statistically significant in only three (log-linear, rBC and uBC) of all the estimated models and in one of the models (the semi-log one) the coefficient of the key variable displayed the wrong sign (Anderson *et al*., 2010).

[66] The data set used for the Haab and McConnell (2002) study was sourced from the Leggett and Bockstael (2000) data set (Haab & McConnell, 2002).

6.3 A VALIDITY TEST OF THE EXTENDED HEDONIC PRICE MODEL – THE APPLICATION OF A RANDOM UTILTY MODEL

This section applies the random utility model to the Walmer data set in order to assess the validity of hedonic price model regression results.

6.3.1 THE DATA

6.3.1.1 THE SAMPLING METHODOLOGY

Due to the relatively large number of house sales that occurred over the study period (1326) and the unavailability of house specific data, McFadden's (1974) sampling technique was used to reduce the number of alternatives used in the model estimation. More specifically, in addition to the chosen house, two rejected houses were also selected. The two rejected houses were selected on the basis of temporal proximity to the chosen house. In other words, two rejected houses that were sold within a six month period prior to the chosen house were selected. It was not possible to consider a narrower window (less than 6 months), since there was a lack of sales data. This selection was clustered random by area (Walmer neighbourhood), which is similar to the approach adopted by Palmquist and Israngkura (1999).

In the end, the sample consisted of 154[67] chosen dwellings and 308 rejected dwellings (154*2). Although the number of alternatives in the narrow choice set (3 dwellings) used in this study may appear small, Parsons and Kealy (1992) have shown that a three alternatives choice set is acceptable for randomly drawn opportunity sets in random utility model applications. Moreover, Chattopadhyay (2000) applied a two alternatives choice set at the dwelling level in a nested logit estimation, and Earnhart (2002) used three alternatives in a multinomial logit analysis.

6.3.1.2 DESCRIPTIVE STATISTICS OF SAMPLED HOUSES

Table 6.7 presents the descriptive statistics of the chosen and rejected houses that were selected by applying McFadden's (1974) sampling rule.

[67] The data set used for the discrete choice model (154) was slightly smaller than the data set used for the extended hedonic price model (170), due to the fact that a sufficient choice set could not be constructed for 16 of the accepted houses (house specific data was not available).

Table 6.7: Average characteristics of sampled dwellings (standard deviations in parentheses)

Characteristic	Dwelling type	
	Chosen dwellings	Rejected dwellings
Structural characteristics		
Sales_price	1 598 624 (732 592)	1 664 592 (767 043)
Erf_size	1737 (611)	1787 (632)
Swim	0.79 (0.4)	0.74 (0.44)
Elec_fence	0.27 (0.45)	0.26 (0.44)
Stories	1.19 (0.39)	1.17 (0.37)
Neighbourhood characteristics		
Dist_wal	1913 (613)	1809 (587)
Dist_school	2223 (1228)	2316 (2319)

The average chosen house is located on a 1737m² erf, has 1.19 stories and sells for R1 598 624. On average, households tended to select dwellings with a swimming pool and an electric fence and also tended to select houses that were further away from the township and closer to the nearest school. The average household also tended to select a dwelling with more than one story and generally opted for the cheaper house in the choice set. Interestingly, the average household generally selected dwellings with a smaller erf size. This does not conform to *a priori* expectations and a possible reason for this is the fact that the price, swimming pool, electric fence, distance to the nearest school and distance to the Walmer Township were seen as more important than erf size when selecting the dwelling.

6.3.2 ESTIMATION RESULTS

6.3.2.1 DIAGNOSTIC TESTS FOR MULTICOLLINEARITY IN THE RANDOM UTILITY MODEL DATA SET

A hedonic price model was employed to assess the degree of multicollinearity present in the extended data set. The data for this purpose included data for dwellings chosen (the original data set of 154) and rejected dwellings (an additional 308 houses). Variance inflation factors for the independent variables were calculated and are presented in Table 6.8.

Table 6.8: Variance inflation factors

Variable	VIF
Erf_size	1.09
Dist_school	1.09
Swim	1.06
Elec_fence	1.05
Dist_wal	1.03
Stories	1.01

The results in Table 6.8 show that multicollinearity is not a problem (the calculated VIFs were all less than 5). In addition to the VIF test, three correlation matrices were also estimated, one on the accepted dwelling data, one on the rejected dwelling data, and one on the entire data set. The results of these estimations are presented in Tables 6.9, 6.10 and 6.11, respectively.

Table 6.9: Correlation matrix for rejected dwellings

	Erf	Dist_school	Dist_wal	Swim	Elec_fence	Stories
Erf	1					
Dist_school	-0.2088	1				
Dist_wal	0.1687	-0.1256	1			
Swim	0.1538	-0.0569	0.0016	1		
Elec_fence	0.0062	-0.0930	-0.0085	0.1558	1	
Stories	0.0535	-0.0217	0.0335	0.0280	0.0712	1

Table 6.10: Correlation matrix for chosen dwellings

	Erf	Dist_school	Dist_wal	Swim	Elec_fence	Stories
Erf	1					
Dist_school	-0.3526	1				
Dist_wal	0.0238	-0.1760	1			
Swim	0.1498	-0.2519	0.0499	1		
Elec_fence	0.0078	-0.2241	0.0864	0.2058	1	
Stories	0.1482	-0.1929	0.0757	0.1239	0.0780	1

Table 6.11: Correlation matrix for chosen and rejected dwellings

	Erf	Dist_school	Dist_wal	Swim	Elec_fence	Stories
Erf	1					
Dist_school	-0.2301	1				
Dist_wal	0.1165	-0.1325	1			
Swim	0.1498	-0.0939	0.0221	1		
Elec_fence	0.0063	-0.1167	0.0250	0.1719	1	
Stories	0.0721	-0.0572	0.0506	0.0608	0.0738	1

As is evident from Tables 6.9, 6.10 and 6.11, the correlation matrices' results confirm the finding of the VIF test (i.e. no strong correlations exist between any of the independent variables in the extended data set).

6.3.2.2 THE CONDITIONAL LOGIT RESULTS

LIMDEP Nlogit Version 4.0 was used to estimate the conditional logit model. Table 6.12 presents the estimation results.

Table 6.12: Coefficient estimates for dwelling choice (standard errors in parentheses)

Variable	Coefficient
Price	-0.0000004[b] (0.000000233)
Erf_size	-0.000012 (0.0002)
Stories	0.23 (0.284)
Swim	0.43 (0.258)
Elec_fence	0.031 (0.230)
Dist_wal	0.00049[a] (0.0002)
Distance to nearest school	-0.000055 (0.000077)
Log likelihood	-163.56

Notes: [a] Significant at the 5-percent level
[b] Significant at the 10-percent level

The signs all conform to *a priori* expectations, with the exception of erf size. The probability of selecting a specific house increases if the house has a swimming pool, an electric fence, the lower the price, the further away from the township and the closer the house is to the nearest school. The negative erf size coefficient implies that the probability of choosing a house decreases if the house is situated on a larger erf. This anomalous result could be explained by the fact that the *ceteris paribus* condition of maximum likelihood estimation may change the sign of a covariate's coefficient from its expected effect if it were considered in isolation (Earnhart, 2002).

In respect of the significance of the coefficients, the price coefficient is significant at the 10 percent level and the distance to the Walmer Township coefficient is significant at the 5 percent level. This is very encouraging, since the price coefficient is very important for marginal value estimation and also allows for an estimation of willingness to pay (WTP) for a non – marginal change. None of the other coefficients are statistically significant. This result is not unusual. In a study by Palmquist and Israngkura (1999), most of the coefficients of the housing characteristics (even ones they deemed important) were statistically insignificant when single market data were used.

6.4 A COMPARISON OF THE HEDONIC PRICE MODEL AND THE RANDOM UTILITY MODEL

In this section, the hedonic price model and the random utility model is compared based on their estimation results and implicit price estimates for the variable of interest. Table 6.13 compares the estimated coefficients of the variables present in both of the models in terms of their levels of statistical significance and signs.

Table 6.13: Coefficient estimates of the variables present in the hedonic price model and the random utility model

Variable	Model	
	Random utility model coefficient	**Hedonic price model (uBC) coefficient**
Erf_size	-0.000012 (0.0002)	0.013[a] (57.537)
Stories	0.23 (0.284)	9.545[a] (8.914)
Swim	0.43 (0.258)	13.74[a] (17.497)
Elec_fence	0.031 (0.230)	7.26[b] (6.454)
Dist_wal	0.00049[b] (0.0002)	0.005498[a] (11.398)

Notes: [a] Significant at the 1-percent level
[b] Significant at the 5-percent level
[c] Standard errors in parentheses
[d] Chi-squared values in parentheses

The coefficients in both models display the same signs, with the exception of erf size in the discrete choice model. In terms of coefficient significance, only one coefficient (distance to the Walmer Township) is significant in the discrete choice model, whereas all the coefficients in the hedonic price model are statistically significant at the 5-percent level, or better.

Table 6.14 compares the implicit prices (for the distance to the Walmer Township variable) generated from the hedonic price model with those obtained from the discrete choice model. Also included for comparative purposes in Table 6.14 are the results of two other studies, namely the Palmquist and Israngkura (1999) study and the Cropper *et al*. (1993) study.

Table 6.14: Implicit prices and willingness to pay for a marginal/non-marginal change for the key housing attribute

Study	Attribute	Implicit price/WTP/Average error	Model	
			Random utility model	Hedonic price model
This study	Distance to the Walmer Township	Implicit price	R1 225	R234.49
		WTP for a non-marginal change	R441 000[a]	R84 416[a]
Palmquist and Israngkura (1999)	Air pollution	WTP for a non-marginal change	$3 129.58[b]	$577.42[b]
Cropper *et al*. (1993)	Air pollution	Average error between the predicted and actual attribute bids (marginal change)	27.2%[c]	29%[c]
		Average error between the predicted and actual attribute bids (non-marginal change)	4.2%[c]	35%[c]

Notes: [a] An estimate for a 20 percent increase in distance from the Walmer Township (for the average house in the sample).
[b] An estimate for a 20 percent reduction in air pollution - the Palmquist and Israngkura (1999) study did not report marginal implicit prices.
[c] Average error between the predicted and actual attribute bids – the Cropper *et al*. (1993) study compared the performance of the two models by comparing the average error. Implicit prices were not reported.

The hedonic price model estimated in this study produced a more conservative implicit price estimate compared to the one produced by the random utility model. The random utility model produced a high implicit price that is not plausible. This result may be due to the fact that the true choice set is unknown, which may result in inaccurate implicit price estimates (see Palmquist and Israngkura, 1999). Like the Palmquist and Israngkura (1999) study, the WTP for a non-marginal change was far higher in the random utility model than in the hedonic price model. These results, however, are in stark contrast to those from the Cropper *et al*. (1993) study. In this study, the random utility model and the hedonic price model performed equally well when estimating marginal values, but the random utility model, in the case of estimating non-marginal changes, yielded better results than the hedonic price model in terms of percentage error (Cropper *et al*., 1993).

6.5 POLICY DISCUSSION

6.5.1 SOCIAL HOUSING

Given the estimation results of the extended hedonic price model presented in Section 6.2, the question arises - what meaningful policy conclusions can be drawn regarding the effect of existing social housing developments on surrounding property values? Although it has been established that the Walmer Township has a significant negative effect on surrounding property values of R234.49 per metre, a more comprehensive welfare measure could

provide more concrete policy answers and recommendations. To this end, a household's (with a mean vector of attributes) WTP for a finite change in the distance to the Walmer Township characteristic was calculated. This distance is based on the results of a base hedonic regression, which used a single dummy variable to indicate the subject property's location relative to the township. Table 6.15 presents the results of this regression.

Table 6.15: Impact zones

Impact zone	Estimated coefficient	t – value
0 – 999	-418884.7	-2.08*
0 – 1 499	-470670.2	-3.83*
0 – 1 999	-231085	-1.94*
0 – 2 499	-42991.62	-0.25

Note: * Significant at the 10-percent level

The impact area (i.e. the area where proximity to the Walmer Township has a statistically significant, negative effect on Walmer house prices) was estimated as a 1 999m radius around the Walmer Township (starting from the outer limit of the township). At a mean distance away from the Walmer Township of 1 799m for the average house in Walmer, the finite change was estimated to be 200m (i.e. 1 999m – 1 799m).

The first-order approximation (i.e. finite change*implicit price) of the average household's WTP to move 200m further away from the Walmer Township, using the implicit price of R234.49 per metre, equals R46 898. As an alternative to the first approximation, the WTP value was also estimated, as per Haab and McConnell (2002), by calculating the discrete change associated with a 200m increase in distance from the Walmer Township. The basic expression for the discrete change is given by:

$$WTP = h(z^*) - h(z) \qquad (6.5)$$

where: z^* = the new vector of parameters (i.e. an increase in distance of 200 metres away from the Walmer Township)

z = the original vector (Haab & McConnell, 2002).

The welfare effects are calculated at the mean house price (Haab & McConnell, 2002). In Equation 6.5, $h(z)$ is specified as the mean house price and $h(z^*) = (P^{\lambda} + \lambda(z^*(\theta) - z(\theta))\beta)^{1/\lambda}$. The discrete change estimate for the uBC[68] is presented in Table 6.16.

[68] The first order approximations and discrete change calculations for the other models estimated in Section 6.2 are not reported here since the Box-Cox functional form test rejected the linear, semi-log and double-log models and the information criteria (AIC and BIC values) generated, rejected the rhBC, lhBC and rBC.

Table 6.16: A discrete change welfare measure

Model	Coefficient: β	Box-Cox parameters	*P*	*z**	*z*	Discrete Change
uBC	0.005498	λ = 0.272 θ = 1.033	1 626 395	1999	1799	38 033

It is interesting to note that the first-order approximation using the marginal value is quite close to the estimate of the discrete change - the average household in Walmer is willing to pay between R38 033 and R46 898 to be located outside of the impact zone (i.e. to be situated 200 metres further away from the Walmer Township).

This WTP figure can be interpreted as the capital loss (in the form of house value reduction) due to being located within a 1999m radius of the Walmer Township. Since it is impossible for the average homeowner to costlessly move the necessary 200 metres in order to avoid the capital loss, the once-off WTP amount of between R38 033 and R46 898 can be interpreted as a willingness to accept (WTA) measure instead (i.e. the amount the average homeowner is willing to accept in lieu of the capital loss they are suffering as a result of being located within a 1999m radius of the Walmer Township).

This result may have important policy implications regarding existing social housing developments. If affected residents have assurance from the government that they will be compensated for any property value reductions, they may be more inclined to accept social housing projects, such as the Walmer Township one. The question arises: how should affected parties be compensated? A useful and easily administered mechanism that can be used as a vehicle for compensation is the municipal property rate. Affected parties could receive annual or monthly rebates on their property rate payments as compensation.

The once-off willingness to accept amount can easily be converted into an annual one. If it is assumed that the WTA amount is the capitalised current value of the capital loss, then the annual rental value or stream can be estimated by multiplying the capitalised value by the appropriate discount rate.[69] The best estimate of the latter is the average interest rate paid on a home loan in South Africa (i.e. the prime rate of interest of 8.5 percent per annum).

Taking into account the capitalised current values estimated (i.e. the first approximation value of R46 898 and the discrete change value of R38 033), the rental value per annum is between R3 232.81 and R3 986.33. This translates into monthly rebates of between

[69] More formally,
$R = P \cdot r$……(6.6)
(See footnote 23, page 57).

R269.40 and R332.19 that could provide the compensation necessary to mitigate the capital loss associated with the presence of the Walmer Township.

The discussion so far has focused attention on possible ways of ameliorating the negative impacts of existing social housing developments. What can be done differently with the establishment of new social housing developments in order to mitigate possible negative impacts? Answering this question requires an understanding of why social housing may have a negative effect. Unfortunately, the hedonic price model alone cannot shed light on this. However, the international literature reveals that the characteristics of the social housing facility, management and clients are generally responsible for the effect a social housing project has on the surrounding neighbourhood (Dear, 1992; Hogan, 1996; Santiago *et al*., 2001; Nguyen, 2005). Careful consideration by policy makers of these three components of social housing may provide the necessary panacea for the potential negative effects associated with social housing. In this spirit, five broad recommendations for policy makers guiding the design and implementation of future social housing projects are offered.

First, social housing projects should ideally be located where existing dwellings are present and these dwellings should be renovated (Santiago *et al*., 2001). Where possible, every effort should be made by social housing developers to acquire and rehabilitate existing properties for social housing purposes as positive externalities have been associated with this approach (Santiago *et al*., 2001).

Second, tenants should be monitored (Santiago *et al*., 2001). Once a social housing project is established and operational, social housing managers need to ensure that tenants adhere to the conditions as stipulated in the lease, which include meeting financial and behavioural obligations. In addition, residents of adjacent non-subsidised housing need assurance that management of social housing projects will evict tenants found to be in breach of lease agreements (Koebel *et al*., 2004).

Third, social housing dwellings should be designed and maintained appropriately (Santiago *et al*., 2001; Koebel *et al*., 2004). Ideally, social housing projects should be designed to blend in with the host neighbourhood, a design method known as the invisibility approach (Koebel *et al*., 2004). New and well-designed social housing projects have been known to result in positive externalities in surrounding neighbourhoods (Dear, 1992). The appropriate maintenance of social housing projects is of equal importance. Ideally, social housing projects should be “maintained at a level superior to the general upkeep of the surrounding

neighbourhood, to confound public stereotypes and make the unit less likely to be identified as subsidised" (Santiago *et al*., 2001).

Fourth, the composition of the host neighbourhood plays a role in determining the effect of a social housing project. It is also important to assess the compatibility of the social housing project with the surrounding area (Nguyen, 2005). Areas where there are large discrepancies in property values between existing homes and future social housing units are not ideal sites. Establishing social housing projects in areas where price differences are large increases the likelihood that negative price effects will be felt (Lee *et al*., 1999; Nguyen, 2005).

Fifth, the image of social housing needs to be improved (Dear, 1992; Santiago *et al*., 2001; Koebel *et al*., 2004). If the aforementioned pragmatic recommendations are to be of any success, the concept of "social housing" needs to be destigmatised. To this end, constructive and ongoing relationships between neighbourhood groups, municipal ward representatives and local social housing authorities need to be developed and fostered (Dear, 1992; Santiago *et al*., 2001). A concerted effort should be made by local authorities to embark on campaigns to educate the public on the potential benefits that social housing may have for low-income households (Santiago *et al*., 2001). Public participation processes where affected residents are able to voice their concerns should also be given priority.

6.5.2 PROPERTY RATES

Two policy questions in respect of municipal property assessments are dealt with in this section: one, are assessed values[70] accurate proxies for actual market prices (actual sales prices), and two, is the hedonic price model developed in this study more effective than the official assessor's model in terms of predictive capability (or, put differently, should a multi-attribute hedonic price model be used instead of the official assessor's model to value properties for property rates purposes). These two questions are answered simultaneously by comparing three sets of prices, namely actual market prices, assessed values, and house prices as predicted by the hedonic price model developed in this chapter (see Section 6.2). The comparisons are carried out over the same period[71] and are described in two ways: first, graphically, and second, according to the distribution for the percentage difference among

[70] The 2007/2008 municipal valuations are used in this study.
[71] For the purposes of this comparison, the 2007/2008 assessed values were adjusted to 2009 constant rands, using the ABSA house price index.

the respective values. For completeness' sake, both an in-sample and an out-of-sample[72] predictive capability comparison is carried out.

6.5.2.1 AN IN-SAMPLE COMPARISON OF MARKET PRICES, MUNICIPAL ASSESSED VALUES AND PREDICTED VALUES OBTAINED FROM THE HEDONIC PRICE EQUATION

In order to execute the in-sample comparison, municipal assessed values of all the 170 houses in the sample were used, as well as the predicted values estimated from the hedonic price regression (Equation 6.1). Figure 6.1 graphically presents the in-sample comparison of the respective prices. The market price for each house in the sample has been arranged in ascending order.

[72] A total of 25 houses from the suburb of Walmer were randomly selected. These houses were not part of the original data set of 170 houses. Additional house specific data were collected for the additional 25 houses. This data included information on all the variables required to populate Equation 6.1, namely, the number of stories, the presence of a swimming pool, the presence of an electric fence, the erf size and the distance from the Walmer Township. In addition to the structural and neighbourhood variables, an autoregressive term was estimated.

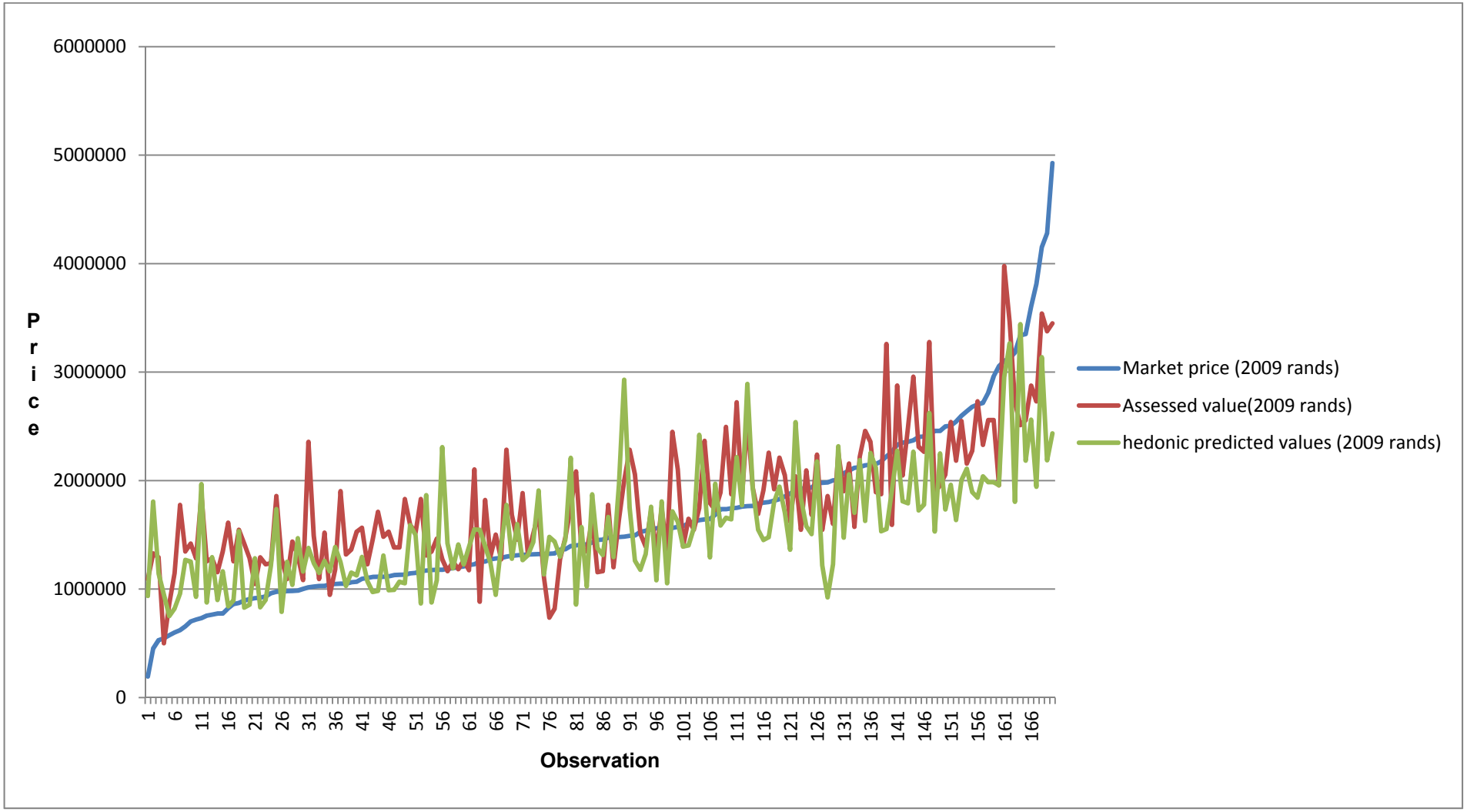

Figure 6.1: Market prices, assessed values and hedonic predicted values (in-sample)

From Figure 6.1, it is clear that discrepancies exist among the market prices, the assessed values, and the hedonic price predictions. In order to compare the relative size of these discrepancies, percentage differences were calculated. Tables 6.17 and 6.18 present the distribution for the percentage difference between the market price and the assessed value, and the market price and the hedonic predicted value, respectively.

Table 6.17: Distribution of the percentage difference between actual market prices and the municipal assessed values (in-sample)

	Value (%)
Mean difference	13.89
Percentile	
Smallest value	-57.0
1%	-47.4
5%	-28.3
10%	-22.2
25%	-6.7
50%	10.2
75%	33.5
90%	51.6
95%	64.8
99%	98.6
Largest value	139.8

Table 6.17 shows that there is a 13.89 percent difference, on average, between market prices and municipal assessments (on average, the assessed values are 13.89 percent higher). The median value of 10.2 percent is less than the mean, meaning the distribution is skewed right.[73] One quarter of houses in the sample appear to be overvalued by more than 33.5 percent and a number of houses are overvalued by more than 100 percent (Table 6.17).

[73] The distribution is asymmetrical with the tail of the distribution on the right side.

Table 6.18: Distribution of the percentage difference between actual market prices and the predicted values from the hedonic price regression (in-sample)

	Value (%)
Mean difference	1.2
Percentile	
Smallest value	-72.9
1%	-67.7
5%	-46.4
10%	-35.8
25%	-21.2
50%	-1.1
75%	16.8
90%	39.7
95%	56.1
99%	120.0
Largest value	131.5

Table 6.18 shows that discrepancies also exist between the market prices and the values predicted by the hedonic price model, but the differences appear to be smaller than those displayed in Table 6.17. More specifically, a mean difference of 1.2 percent exists between market prices and the predicted hedonic price values (the latter are, on average, 1.2 percent greater). The median value of -1.1 percent is less than the mean, implying a skewness to the right. Approximately half of the houses in the sample are undervalued by 1.1 percent and one quarter of the houses are overvalued by more than 16.8 percent (compared to 33.5 percent from the municipal assessments). A number of homes are also overvalued by more than 100 percent according to the hedonic price model (Table 6.18).

The results from the in-sample comparisons show that the hedonic price model, developed as part of this study, provides more accurate predictions of property prices compared to the municipal assessment model.

6.5.2.2 AN OUT-OF-SAMPLE COMPARISON OF MARKET PRICES, MUNICIPAL ASSESSED VALUES AND PREDICTED VALUES OBTAINED FROM THE HEDONIC PRICE REGRESSION

In order to assess the validity of the above analysis, out-of-sample comparisons were also made. Figure 6.2 graphically presents the out-of-sample comparison of the respective prices.

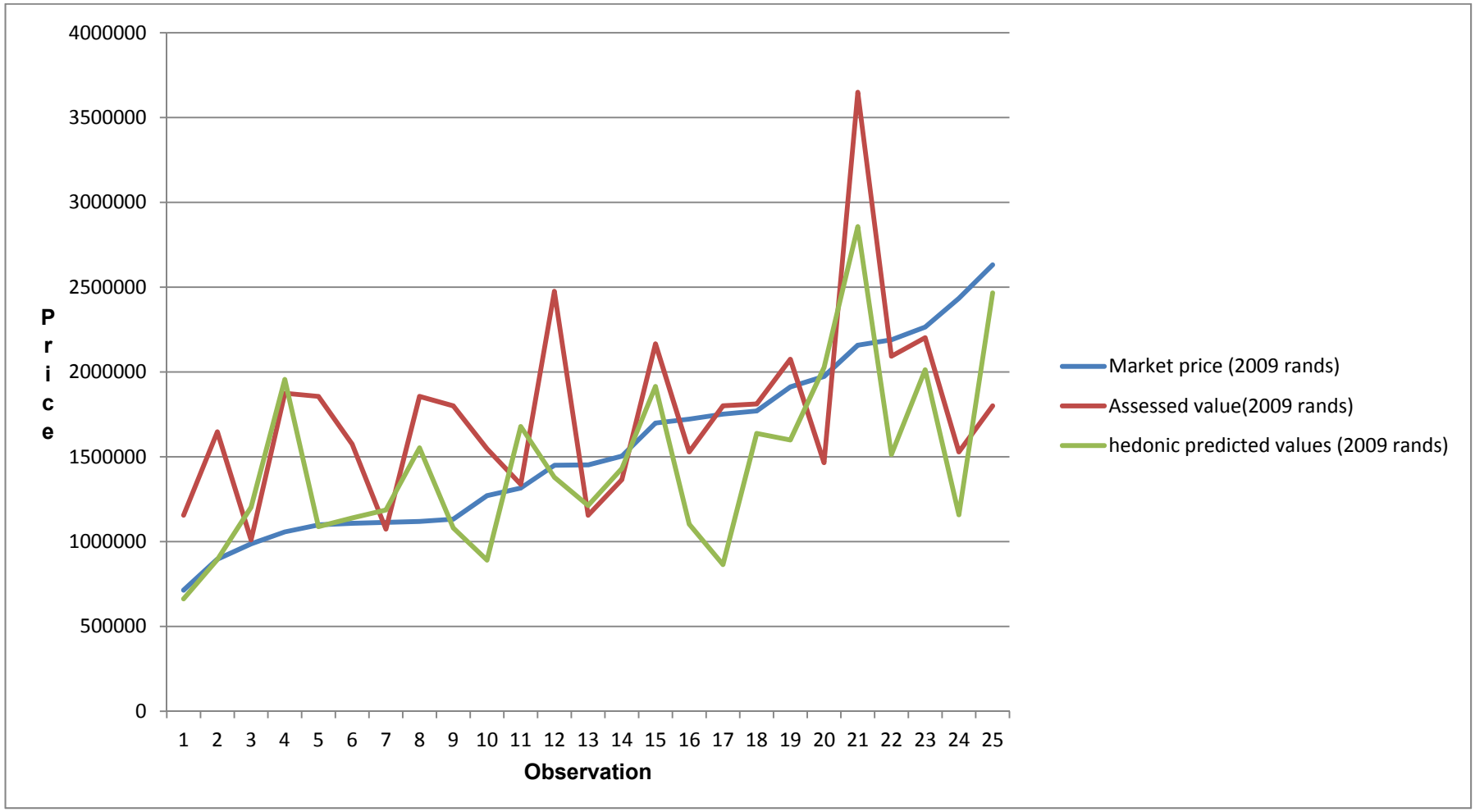

Figure 6.2: Market prices, assessed values and hedonic predicted values (out-of-sample)

Not unlike Figure 6.1, Figure 6.2 also shows that clear discrepancies exist among the market prices, the assessed values, and the hedonic price predictions. In order to compare the relative size of these discrepancies, percentage differences were once again calculated. Tables 6.19 and 6.20 present the distribution for the percentage difference between the market price and the assessed value, and the market price and the hedonic predicted value, respectively.

Table 6.19: Distribution of the percentage difference between actual market prices and the municipal assessed values (out-of-sample)

	Value (%)
Mean difference	13.6
Percentile	
Smallest value	-45.7
1%	-45.7
5%	-37.5
10%	-29.6
25%	-4.5
50%	2.74
75%	47.3
90%	52.2
95%	55.8
99%	59.0
Largest value	59.0

On average, the municipal assessed values are 13.6 percent higher than the market prices (Table 6.19). The median value of 2.74 percent is less than the mean, which means that the distribution is skewed to the right. Approximately one quarter of the houses appear to be overvalued by at least 47.3 percent. No houses in the sample are overvalued by more than 100 percent, although a few houses are overvalued by 59 percent (Table 6.19).

Table 6.20: Distribution of the percentage difference between actual market prices and the predicted values from the hedonic price regression (out-of-sample)

	Value (%)
Mean difference	-6.1
Percentile	
Smallest value	-71.0
1%	-71.0
5%	-67.8
10%	-43.8
25%	-17.8
50%	-5.0
75%	6.4
90%	27.9
95%	32.5
99%	59.7
Largest value	59.7

The mean difference between market prices and the hedonic price model's predicted values (-6.1 percent) is less than the mean difference calculated for the municipal assessed values (13.6 percent) (Table 6.19). In fact, the hedonic price model's predictions are, on average, 6.1 percent smaller than the actual market values. Only one tenth of the houses are overvalued by more than 27.9 percent (compared to 52.2 percent for the municipal assessments).

Not unlike the in-sample comparisons, the results of the out-of-sample comparisons reveal the predicted property values (generated using Equation 6.1) are more consistent with actual market prices compared to the municipal assessed values. This may be due to the fact that the hedonic price approach incorporates property-specific, non-market attributes which are known to affect market values whereas the municipal assessment model[74] does not (Cotteleer & van Kooten, 2012).

6.6 CONCLUSION

The results of the extended hedonic price model and the discrete choice model were presented in this chapter. Both models found that the Walmer Township exerts a statistically significant, negative effect on adjacent properties in the Walmer neighbourhood. The preferred specification of the hedonic price model found that a monthly compensation amount (in the form of a property tax rebate) of between R269.40 and R332.19 could be sufficient to mitigate the capital loss associated with the presence of the Walmer Township.

Chapter Six also assessed the accuracy of the Nelson Mandela Bay Municipality's 2007/2008 property valuations carried out for rates purposes. It is clear from both the in-sample and out-of-sample comparisons performed in this chapter that attribute-based hedonic price models offer an attractive and pragmatic alternative to the currently employed market-based assessor models.

The next chapter (Chapter Seven) provides conclusions, recommendations and directions for future research.

[74] A more thorough critical assessment of the municipal assessment model is not possible since the assessment is outsourced to a privately-owned contractor who is under no obligation to release the details of its operation.

CHAPTER SEVEN: CONCLUSION, RECOMMENDATIONS AND DIRECTIONS FOR FUTURE RESEARCH

7.1 CONCLUSION

Social housing and property valuations for municipal rates purposes are two important policy issues that currently tend to dominate the South African housing sector landscape. Social housing is deemed an essential aspect of poverty alleviation in South Africa as it has the ability to address social and spatial dysfunctionalities present within the current housing system (Social Housing Policy for South Africa, 2005). This thesis set out to explore whether the presence of social housing projects leads to reductions in nearby residential property values. The results of this study confirm this hypothesis and reveal that the presence of the Walmer Township (a proxy for a social housing development) in Nelson Mandela Bay exerts a statistically significant, negative effect on adjacent residential property prices (those of houses in the Walmer neighbourhood). The negative effect follows the expected diminishing pattern the larger the distance from the housing development.

Two distinct economic models were employed to test the hypothesis, namely the hedonic price model and a discrete choice model. The latter was employed as a validity test of the hedonic price model's results. The hedonic price model, which is based on Lancastrian utility, allows the researcher to isolate the indirect effect of social housing on residential property values by investigating the behaviour of economic agents in the housing market (Lyons & Loveridge, 1993). The hedonic price model shows how property prices vary with a set of housing characteristics. These characteristics include, among others, proximity to social housing projects. In this study, twelve characteristics were hypothesised to influence house prices in the Walmer neighbourhood. Using regression analysis, six were found to be statistically significant (one of which was proximity to the Walmer Township). In addition to estimating the parameters of the hedonic price function, regression analysis allowed for the control of the other five characteristics, effectively singling out the effect of proximity to the Walmer Township. The hedonic price model revealed that residents of the Walmer neighbourhood would be willing to pay an amount of between R38 033 and R46 898 to be located 200 metres further away from the housing development.

Are the techniques applied and findings of this thesis robust? A review of the international literature (Chapter Four) revealed a range of weaknesses, especially the way in which the hedonic price method was applied. The hedonic price model applied in this thesis overcomes most of the major limitations of previous work on this topic, namely the failure to implement flexible functional forms (Box-Cox transformations), the failure to address the

spatial nature of property values, and the omission of a validity check on the hedonic results. These improvements, combined with a solid basis in Lancastrian utility theory, a firmly entrenched statistical method, a sufficient number of statistically significant structural variables and a plausible hypothesis concerning social housing and property values lends support for the findings of this thesis. However, a deficiency of the hedonic price model, as applied in this study, is that it is not able to provide answers as to why the Walmer Township has a negative effect on adjacent property values.

The results of this thesis with regard to social housing are subject to three important qualifications. First, the Walmer Township is not a recognised social housing development but merely a proxy for one. Second, a relatively small data set was used in this study and only one social housing development was considered. Third, the sample period for this study covers the period 1995 to 2009. Market prices for this period were adjusted to constant 2009 rands using the Port Elizabeth and Uitenhage index. Unfortunately, it was not possible to obtain an index for the Walmer area, which makes it possible that an imperfect correlation exists between the Walmer property trend and the local (Port Elizabeth and Uitenhage) trend used in this study.

The hedonic price model developed and estimated in this study was also used to examine the accuracy of the Nelson Mandela Metropolitan Municipality's 2007/2008 property valuation roll. The examination was confined to municipal assessments for a single neighbourhood, namely the Walmer neighbourhood. The Rates Act clearly stipulates that property rates should be based on the market value of residential property. This study reveals differences between the 2007/2008 municipal valuations and the comparable market prices (based on actual sales data). On average, the 2007/2008 municipal valuations were 13.89 percent higher than the prices revealed by the market for the in-sample comparison and 13.6 percent higher for the out-of-sample comparison. The predicted property prices obtained from the hedonic price equation appeared to be more in line with actual market prices, with a discrepancy of 1.2 percent (in-sample) and -6.1 percent (out-of-sample).

This finding, with respect to the accuracy of the municipal valuations, is subject to two qualifications. Firstly, only sales transactions for the Walmer neighbourhood were considered. Secondly, a fairly small data set was used.

7.2 RECOMMENDATIONS

Mitigation of the negative impact of existing social housing developments could be achieved by providing compensation to affected neighbouring residents in the form of monthly

property rates rebates. In the case of the Walmer neighbourhood, a monthly rebate on property rates of between R269.40 and R332.19 is suggested for affected residents. Assurance from government that social housing need not result in capital losses for home owners could improve the image of social housing and assist in gaining community acceptance.

With regard to the design and management of new social housing projects, a number of possible actions can be taken to alleviate the NIMBY syndrome: the renovation of existing dwellings, the monitoring of tenants, appropriate design and maintenance of dwellings, assessing the composition of the host neighbourhood and improving the image of social housing.

Concerning municipal valuations for property rates purposes, it is recommended that policy makers consider the option of adopting an attribute-based hedonic price model for the purposes of municipal property valuations, as opposed to the current market-based assessor model.

7.3 DIRECTIONS FOR FUTURE RESEARCH

It is strongly recommended that further research be undertaken in other areas in South Africa to assess the effect of social housing on adjacent property prices and to check whether the results remain consistent across different locations. Future studies should ideally incorporate an existing social housing development, as opposed to a proxy for one. In addition to this, future studies should consider the use of larger data sets as this could lead to more accurate parameter estimates and welfare measures.

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