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Water, Heritage and the Arts

ENERGY EFFICIENCY RATING AND HOUSE PRICE IN THE ACT

National Framework
for Energy Efficiency

ENERGY EFFICIENCY RATING AND HOUSE PRICE IN THE ACT

Modelling the relationship of energy efficiency attributes to house price: the case of detached houses sold in the Australian Capital Territory in 2005 and 2006.

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OVERVIEW

In 2007, the Department of the Environment, Water, Heritage and the Arts (DEWHA) commissioned the Australian Bureau of Statistics (ABS) to produce a statistical report modelling the relationship between the energy efficiency rating (EER) of houses and house prices in the Australian Capital Territory (ACT).

This statistical report and the Department's overview of it is the first study of its kind in Australia.

It shows that the ACT housing market, which in 1999 became the first jurisdiction in Australia to introduce mandatory energy disclosure for all houses on the market, places a higher value on energy efficiency and suggests that 'location, location, EER' has replaced the traditional real estate mantra of 'location, location, location' in the ACT.

The study looked at whether a relationship exists between the EER of a house and sale price using data from 2005 and 2006 and found that a statistically significant relationship does exist. This means, if a house has a higher EER than another house, but in all other respects the houses are the same, the house with the higher EER will command a higher price.

In Europe, energy efficiency disclosure (providing information about a house's energy efficiency) is high on the energy and climate change agenda. Mandatory energy efficiency disclosure is also being considered in a number of other countries, including Australia.

This study will be of value to all governments considering disclosure as a way to improve energy efficiency in existing houses. It will also be of interest to consumers, the real estate sector and the building and housing industries.

The Australian Government's commitment

In 2004 the Australian Government committed to the concept of mandatory energy efficiency disclosure. This commitment was supported by all Australian State and Territory jurisdictions through the Ministerial Council on Energy and is part of the National Framework for Energy Efficiency (NFEE).

On behalf of all jurisdictions, the DEWHA (which includes programs of the former Australian Greenhouse Office) was asked to develop a nationally consistent framework that would allow the mandatory disclosure of energy performance on sale or lease of buildings.

The intention of the 2007 ABS study commissioned by DEWHA was to look at whether a relationship exists between the EER of a house and the house price. The intention was not to determine the actual value of the EER.

ENERGY EFFICIENCY RATING IN THE ACT

Since 1999 in the ACT, sellers of residential properties have had to provide information about their property's Energy Efficiency Rating (EER) to potential buyers. This is known as mandatory energy efficiency disclosure.

When a property is put on the market in the ACT, the EER must be provided to consumers in all advertising material and the full certificate supplied when the sale is transacted. This certificate also sets out a menu of possible energy performance improvements specific to the building.

What is EER?

The EER used in the ACT is confined to a rating of the thermal performance of the building shell. It is designed to provide accurate and standardised information about building energy efficiency (excluding the hot water and lighting system, other fixed or movable appliances and occupant requirements for temperature control). Efficient thermal performance means that a house achieves a comfortable temperature for the occupants for the time they are in the house with minimal energy input from fossil fuel or other unsustainable or polluting sources.

How is EER measured?

An accredited and professionally trained ACT House Energy Rating Scheme assessor measures a house's energy efficiency using a thermal software package (known as *FirstRate*). The assessment takes into account features such as building fabric, window design, orientation, air leakage and cross ventilation.

The Star Rating

A star rating is given as part of the EER assessment of a building, it provides a simplified indication of how efficient the building is, ranging from 0 to 10 stars (initially the range was to 6 stars) in 0.5 star increments. This is similar to energy labelling of appliances, such as refrigerators. A 0 star rating is very poor and means the building shell does practically nothing to reduce the discomfort of hot or cold weather. A 5 star rating indicates good, but not outstanding, thermal performance. People living in a 10 star home are unlikely to need any artificial cooling or heating.

HOW WE ALL BENEFIT

The results of the ABS study show that the property market values energy efficiency and can benefit from the disclosure of EER on existing homes.

Property owners

Knowledge that a good EER could bring a higher sale price creates an incentive to property owners to invest in improving the energy efficiency of their home. This can be particularly appealing as the cost involved in making an energy improvement may be significantly less than the increased capital value of the property resulting from the improvement.

For example, the study found (in Model 1) that if the energy performance of a house improves by 1 star level, on average, its market value will increase by about 3 per cent (2.5 in 2005 and 3.8 in 2006). Therefore, if a property owner installs R4 ceiling insulation at an approximate cost of AUD$1,200 they will, on average, improve the energy performance of a poorly insulated home by at least 1 star. This means that a detached house sold in 2005 for AUD$365,000 could fetch an additional AUD$8,979 with only a 1 star improvement in energy rating.

Consumers

For the consumer, disclosure of EER assists with purchaser knowledge, particularly as buying a house with a better EER means reduced operational energy costs as well as greater thermal comfort, physical health, and the satisfaction associated with doing something positive for the environment.

Real estate industry

For the real estate industry, EER disclosure creates a more efficient market – because all players have information about a property's energy efficiency, they can better determine the value of the property.

For example, if a person buying a house knows from the disclosed EER that a building is more energy efficient than other houses, they may be willing to pay more for the property because the additional cost will be offset by expected savings in lower energy bills. Or they may choose to pay less for homes with a low rating, at the same time recognising that the ongoing energy costs to stay comfortable will be greater.

Building industry

EER disclosure benefits the building industry and encourages new residential buildings to be created above the minimum energy performance requirements. Since 2006 the Building Code of Australia has required a minimum 5 star rating for all new houses and all houses built in the ACT between 1996 and 2006 were required to achieve a minimum 4 star energy standard.

THE STUDY

Climate in the ACT

The cool temperate climate of the ACT is one of extremes. With its major city, Canberra, elevated at 580 metres above sea level in the Great Dividing Range, winter night-time conditions can reach minus 10°C while summer day-time temperatures can exceed 35°C.

The main climate characteristics that impact energy efficient design are:

- low humidity
- high diurnal (shift from day-time to night-time) temperature range
- four distinct seasons
- summer and winter conditions that regularly exceed human comfort range
- cold to very cold winters
- hot dry summers; and
- variable spring and autumn conditions.

Housing sample in the ACT

The ACT housing market is small but robust servicing just over 330,000 people. Many of these live in Canberra, Australia's national capital. Canberra was settled from 1912 but grew rapidly during the 1960s and 1970s.

The ACT market is made up of a relatively homogeneous stock of detached housing in suburban neighbourhoods. Over 87 per cent of existing homes sold in 2005 and 2006 were detached houses, mostly with 3 or 4 bedrooms. The average house size in the study sample was around 141 m^2 on a block of 836 m^2 located in a suburban setting averaging 11 km from the central business district.

Before minimum energy performance standards were introduced, homes in the ACT were typically built to a standard lower than 2 stars. The average performance of homes in the study was just below 1.7 stars, with examples ranging from 0 to 6 stars.

Unique data set

Mandatory disclosure has created a large data set of building energy performance and sales information unusual for a modern city. This represents a unique opportunity to establish whether a relationship exists between a house's energy efficiency and it's sale price.

To build the data set, the ACT Planning and Land Management Agency (ACTPLA) was commissioned to examine all house data files that matched house sales records in the calendar years 2005 and 2006.

Relevant house characteristics necessary for the analysis were then collated. These characteristics included (among many others):

- house size
- block size
- window area
- floor and wall material
- the number of storeys
- the potential for cross ventilation; and
- the presence of shading schemes.

Sales information held by ACT Government was also collated for the same houses, including:

- settlement date
- transfer date; and
- transfer price.

The data was cleaned and checked, and unexplained data removed. The ACTPLA and EER records were then linked using the suburb, block and section information.

The impact of house price inflation was removed from the house price data using the ABS house price index for the ACT. This was done to produce a better 'cross-sectional' dataset. This means that, after deflation, housing characteristics are assumed to be the reason for variation in house prices.

Over 5,000 homes sold in the ACT in 2005 and 2006 were included in the study. The final dataset was made up of 2,385 house records for 2005 and 2,719 for 2006.

The years 2005 and 2006 were used as they represent the latest possible complete dataset for a mature market. To reduce the likelihood of influences from the start-up of building regulation minimum energy performance, the study did not include houses built after 1995 as these houses were required to achieve a minimum 4 or 5 star rating.

Method of analysis

Hedonic analysis was used to establish the association between energy performance and price. Hedonic analysis is an economic valuation technique that works out the implicit price of housing variables, by decomposing the item being researched (in this case, house price) into its constituent variables (for example, house features or house location). The value of each variable is then estimated.

Variables

Five main categories of variables were considered:

1. Structural variables-which covered the design and construction features
2. Distance variables-which described the relative location to shops, schools, hospitals, and the central business district
3. Neighbourhood variables-which covered key social and economic conditions surrounding the home
4. Locational variables-which can explain elements of suburb prestige
5. Energy efficiency variables

The study was careful to allow major variables (such as location, size and construction of house, and value of land) to be treated in a consistent way to that of the energy efficiency variables.

Modelling house price

In statistics, modelling is the analysis of data objects and their relationships to other data objects. The prices of detached houses sold in the ACT in 2005 and 2006 were modelled in relation to land, distance, neighbourhood, socio-economic and EER data using five hedonic models.

Models 1 to 3 addressed the hypotheses of the study. Models 4 and 5 validated the use of EER in Models 1 to 3.

Model 1 (basic model) included EER as an explanatory variable.

Model 2, an extension of Model 1, accounted for the non-thermal attributes of EER. EER was included as an explanatory variable as well as some individual energy efficiency-related variables suspected of having non-thermal effects.

Model 3, also an extension of the Model 1, accounted for thermal attributes separately. In addition to those included in Model 2, some energy efficiency-related variables accepted to have thermal effects were included. This model modifies the EER variable to rule out the possibility of any random error contained in the EER of the basic model. Such random error also accounts for any omitted (but important) factors that may be related to the EER.

Model 4, modified Model 1 and treated the EER as a fitted variable.

Model 5, modified Model 1 and treated the EER as a derived principal component score.

Results

There is a statistically significant relationship between house price and EER

Model 1 showed that there was a statistically significant relationship between the house price and the following house characteristics:

- floor area
- block area
- distance to CBD
- socio-economic advantage
- window area
- percentage of 5 bedroom homes in local area
- whether the house had previously been a government rental property; and
- the energy efficiency rating (EER).

EER was found to be positively associated with house price. The association on average for 2005 was 1.23 percent for each 0.5 EER star and 1.91 percent in 2006, holding all other variables constant.

When the basic model was extended in Model 3 to include some individual energy efficiency variables, it was implied that the EER coefficient was sensitive to any addition of separate energy efficiency related variables.

Some factors underlying EER add value to a house for reasons other than energy efficiency

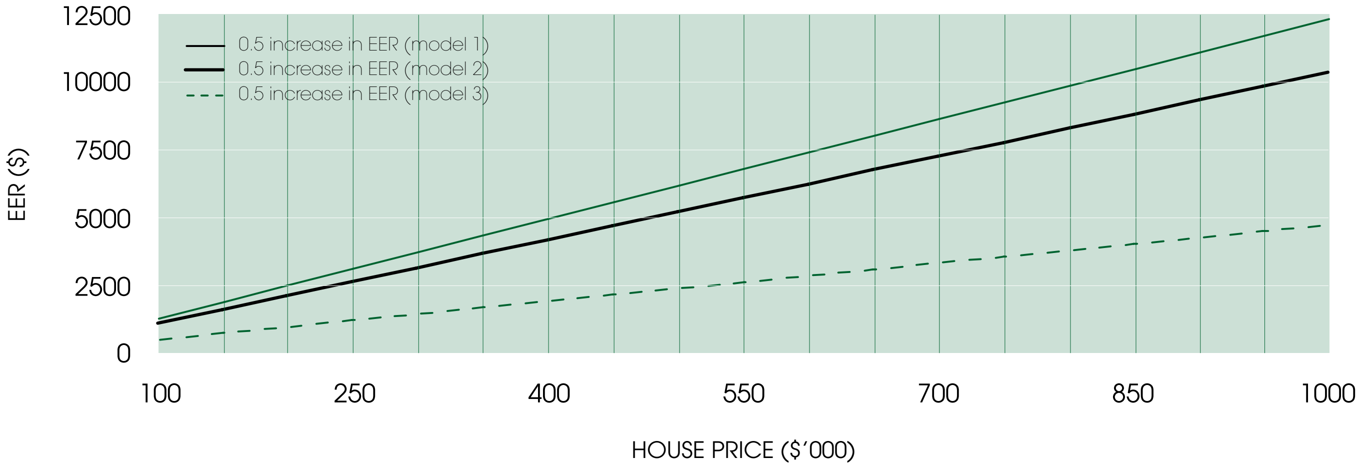
Model 2 found there are some factors underlying EER that add value to a house for reasons other than energy efficiency. For example, double-glazed windows are a visible energy efficiency feature (unlike wall insulation which cannot be seen) as well as a good barrier for noise, so would add value to the house.

Ceiling and wall vents, common in houses built in the 1970s and early 80s, reduce the thermal performance of a building and were found to have a negative relationship with house price. This is possibly due to trends and fashions in the housing market. Other EER non-thermal attributes (such as a brick wall, timber flooring, largest window facing north) were found not to be significant.

The implicit price range of EER can be determined, but not the value being placed on EER disclosure itself.

Figure 3 below shows the estimated implicit price range of EER using the 2005 data. For example, holding all other house characteristics constant, for a detached house sold in ACT in 2005 with a price value of $365,000 (that is, the median price), increasing the EER star by 0.5 would be associated with an additional $4,489 in its price.

Figure 3. Graphical illustration of the implicit price range of EER, 2005



Although this study modelled the relationship between house price and the EER, (and not EER disclosure itself), Figure 3 may roughly suggest that the degree of association of EER disclosure on house price in 2005 would lie somewhere between the x-axis and the lighter bold line (the maximum range). This effect depends, however, on how much the consumers have been exposed to EER features, what they already know about EER measurement, and the value they put on them. For example, consumers who know little about EER may add a value of between 0.5 and 1 percent of the house price if the EER is disclosed to them when buying a house. In contrast, for a consumer with a comprehensive knowledge of strategies to improve the thermal performance of a home (e.g. an architect), EER disclosure may not be significantly associated with increased house price, as any value associated with EER may have already been added to the house price.

CONCLUSION

As with all hedonic models, it is impossible to collect a dataset that contains every possible influence in the sale price. EER makes up only a small part of the total value of a house – block and house size, and location, have a greater influence on house price than energy efficiency. It is also impossible to calculate ***exactly*** how much energy efficiency is worth as the EER has both thermal and non-thermal effects on house price.

The sample used in this study, however, is large and of high quality, making it unique in Australia and probably in the world.

The study concluded there is a significant relationship between the house price and EER. This finding was based on modelling through hedonic regression the various factors that influence house price. A powerful hedonic price model (R^2>0.8), with a highly significant coefficient for EER, is evidence that the market values energy performance.

Acknowledgements

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Further information

You can access the original Australian Bureau of Statistics report in its entirety at www.nathers.gov.au/about/research or contact the Department of the Environment, Water, Heritage and the Arts on 02 6274 1111.

FULL STATISTICAL REPORT

MODELLING THE RELATIONSHIP OF ENERGY EFFICIENCY ATTRIBUTES TO HOUSE PRICE: THE CASE OF DETACHED HOUSES SOLD IN THE AUSTRALIAN CAPITAL TERRITORY IN 2005 AND 2006

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PREFACE

The study modelled the relationship between house price and the energy efficiency attributes of houses sold in the ACT in 2005 and 2006 using data from administrative sources.

Two sets of regression models were estimated: (1) models which test for any statistically significant link between house prices and Energy Efficiency Rating (EER), and (2) models which validated the use of the EER in the hedonic regressions undertaken.

The results indicated a statistically significant relationship between the EER and house price. However, caution should be taken when using or interpreting the results, as there are recognised limitations in the data and the models that were used.

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Disclaimer

Views expressed in this report are those of the principal investigator (author) and do not necessarily represent those of the Australian Bureau of Statistics. Where quoted or used, they should be attributed clearly to the author. For more information, contact franklin.soriano@abs.gov.au.

Confidentiality

Data have been provided for this study by official sources on the understanding that they are not to be released outside of the ABS, DEWHA or their contracted parties.

1. BACKGROUND

This study examines the relationship between energy efficiency rating and house price, a relationship that has never before been modelled using Australian data. The energy efficiency attributes of a house are considered by many as a selling point (e.g. north-facing living spaces), but how they are associated with house price was previously unknown. This paper sheds information on this using hedonic regression and data on Class 1a buildings[1] sold in the Australian Capital Territory (ACT) in 2005 and 2006.

Governments in many countries have recently examined the policy option of mandating the disclosure of energy or environmental performance of buildings to facilitate a more efficient real estate market where all players could recognise the inherent performance characteristics, and be better able to determine value. In Europe, the Energy Performance of Buildings Directive (EPBD) has moved mandatory energy efficiency disclosure to the forefront of the energy and climate change policy agenda (see European EPBD Directive Implementation Advisory Group (DIAG) 2003).

Securing Australia's Energy Future, the Energy White Paper released by the Australian Government in 2004, committed to ensuring that all commercial and residential building owners disclose the building's energy performance prior to sale or lease. This concept has been supported by all Australian State and Territory jurisdictions through the Ministerial Council on Energy, and is part of the National Framework for Energy Efficiency (NFEE) (Commonwealth of Australia 2004).

The former Australian Greenhouse Office (AGO)[2], on behalf of all jurisdictions, was asked to develop a nationally consistent framework that would allow the mandatory disclosure of energy performance on sale or lease of buildings.

In 2005, the AGO and the ACT Government conducted a study to examine the impact of mandatory energy efficiency disclosure (MEPD) requirements for Class 1 buildings in the ACT.

The Productivity Commission in its inquiry entitled, *The private cost effectiveness of improving energy efficiency* (Productivity Commission 2005) had recommended independent evaluations of the influence of the MEPD on the house purchasing decisions of consumers.

The DEWHA-ACT study aimed to produce a quantitative analysis that measures the impact of MEPD requirements for Class 1 buildings with respect to improving the market's ability to value thermal performance (i.e. statistically identifying the impact of the value of energy efficiency rating (EER) on house prices in the ACT). In addition, DEWHA wanted to identify major factors other than EER that may have contributed to any change in house prices, energy and greenhouse performance of residential buildings in the ACT.

In late 2005, DEWHA asked the Australian Bureau of Statistics (ABS) through the ABS Statistical Consulting Unit (ABS SCU) to provide a critique of the DEWHA-ACT study. The ABS made recommendations for methodological improvements and the use of alternative sources of data (ABS 2006). This formed the first stage of the technical assistance requested by DEWHA.

DEWHA subsequently requested ABS assistance to: (a) compile data; and (b) analyse the relationship between EER and house prices in the ACT. DEWHA commissioned the ACT Planning and Land Authority (ACTPLA) to extract the necessary EER and house sales information with the technical guidance of the ABS.

As previously mentioned, the aim of AGO and ACT Government was to examine the effects of the mandatory reporting of EER on house prices. The original intention was thus to examine the relationship of the *disclosure* itself, not of the actual value of the EER, with house prices. Studying the effect of mandatory reporting of EER on house price requires a randomly selected sample of sold houses, where both EER reporting and EER non-reporting houses are included. These data are not available. The study was therefore refocused to look at the association of the EER value or score itself, with house prices.

This paper reports on the modelling and analysis conducted by the ABS, and is divided into six sections. Section 2 provides a brief description of the EER. A critical review of data quality, sources and limitations is presented in Section 3. The research hypotheses, hedonic models and methods utilised in determining the statistical relationship between the EER and house prices are discussed in Section 4. Section 5 reports the findings. Section 6 concludes. Appendices are also attached to this report.

1 The Building Code of Australia (Volume 2) defines a Class 1a building as single dwellings which is either a detached house, or one of a group of two or more attached dwellings, each being a building, separated by a fire-resistant wall, including a row house, terrace house, townhouse or villa unit, which is not located above or below another dwelling or another class of building other than a private garage (ABCB 2007).

2 The functions of the Australian Greenhouse Office were split in 2007, between the Department of Climate Change and the Department of the Environment, Water, Heritage and the Arts.

2. UNDERSTANDING THE ENERGY EFFICIENCY RATING

2.1 Defining and calculating the EER

The house energy rating measures the energy efficiency of a house by allocating a point score for various design features (such as building fabric, window design, orientation and other features) and provides an overall rating on a scale from 0 to 10 stars, with half star increments. The rating scheme was originally developed from computer modelling of heat flows in building shells, and relates only to the thermal performance of the building shell. The higher the number of stars, the more energy efficient the dwelling is. A higher star rating would mean that the dwelling consumes less energy for heating and cooling, resulting in lower greenhouse gas emissions, and providing greater comfort.

The house energy rating is independent of the size and type of housing. This means that large and small houses, attached and detached dwellings, all have the potential to achieve a high energy efficiency rating.

The EER is calculated by an accredited and professionally trained ACT House Energy Rating Scheme (ACTHERS) assessor using a house energy rating computer software program called *FirstRate.* The program generates point scores based on design information and features, such as the floors, external walls, ceilings, windows, skylights, air leakage, orientation, zoning, glazing, thermal mass, cross ventilation, etc. For example, insulated ceilings and walls as well as double-glazed windows increase the point score. Windows without curtains or drapes, and unsealed cracks and gaps around doors and vents reduce the point score. The total point score determines the EER value of the house[3].

Once an EER statement has been issued by the assessor, anyone selling or leasing a house is required to disclose the EER value in all sales advertising of the house. A copy of the EER Statement has to be provided to the purchaser and is included in the contract for sale[4].

More information about the ACTHERS can be found in ACTPLA (2003).

2.2 Other features captured or not captured in an EER

When modelling the relationship between the EER and house price, it is important to recognise that the EER may have an association with house price for reasons other than the thermal effect. Efficient thermal effect means that a house achieves a comfortable temperature for the occupants at the time that they are in the house with minimal input of energy from fossil fuel sources or other sources that are either not sustainable or polluting. In addition, thermal effect is closely associated with thermal mass, a term used to describe the ability of house building materials to store heat.

2.2.1 Non-thermal features embodied in an EER

An EER encapsulates the energy efficiency attributes of a house, but these attributes also reflect characteristics that may influence the house price (or the buying decision) for reasons other than their effect on energy demand. For example, while brick walls, timber flooring, and attic ceilings may influence the energy efficiency of the house, they also have some ‘aesthetic’ appeal that adds value to the house for reasons other than the thermal effects.

2.2.2 Thermal features not captured in an EER

In addition, there may be thermal features which are not captured in the EER score. There are some features of the house which have a thermal or energy efficiency impact but which are not taken into account in the FirstRate assessment. For example, the presence of an efficient and flexible heating system and energy efficient hot water system (e.g. solar) installed in the house, as well as the lighting system and appliances (e.g. built-in oven or dishwasher), are not covered. Landscaping sympathetic to the microclimate of the house was another element that may further add to the energy efficiency of a home (ACTPLA 2003 p. 6). Many consumers would think of these as having energy efficiency effects as well.

3 In *FirstRate* EER assessment, utility rooms such as bathrooms, laundries, powder rooms and toilets as well as garages are not considered because they are assumed to be not centrally heated or cooled, and their construction has little impact on the energy use of the house. For more information about the *FirstRate* software, see SEAV (2004). More details about the EER calculation can be found in HEAT (2007), NFEE (2005), and NatHERS (2007).

4 Since 1995 it has been a Government requirement that all designs for newly constructed houses in ACT achieve an EER of at least four stars.

3. DATA

3.1 Data sources

The modelling to be described in Section 4 made use of data on house price, EER, other house characteristics, and geographic and socio-economic characteristics of the neighbourhood where the house is located. Data were sourced from ACTPLA administrative forms as well as from the 2001 Census of Population and Housing conducted by the ABS.

3.1.1 ACT Planning and Land Agency (ACTPLA) Land Information Centre (LIC) Transfer Data

The electronic dataset obtained from the LIC included individual records of all Class 1 buildings (i.e. detached house) sold in the ACT in 2005 and 2006. Each record contained the following information:

- block-key (unique ID)
- suburb and postcode
- street number and name
- block and section
- commencement date of original construction
- contract date (i.e. exchange date)
- settlement date
- transfer date
- transfer price (i.e. purchase price); and
- block area.

Appendix A gives an account of the steps undertaken to ensure that the above dataset was useful for the modelling activities in this study.

3.1.2 ACTPLA EER Data

The EER Statements of the dwellings sold or leased in 2005 and 2006 are kept by ACTPLA. (Most of these were stored as paper files prior to 2005, while the more recent EER statements were scanned and electronically stored in portable document format, PDF).

From the EER statements, in addition to the overall EER star rating and score, the following specific information was available:

- assessment date
- gross and net conditioned floor areas[5]
- largest window's direction and area
- total area of the windows
- presence or absence of double-glazed windows
- floor, ceiling and wall (material and insulation R value)
- presence of eaves, shading, chimney, fans, vents, utility and external doors, and skylights
- whether the dwelling was one-storey or not
- cross-flow ventilation; and
- whether the house was a former government housing facility or not.

5 Conditioned floor area is the area of the house assumed to be heated or cooled for EER purposes.

3.1.3 ABS Distance Data

Earlier studies suggest that the distance of the house to certain points may have an influence on house price, and therefore this was accounted for in the model. The ABS distance data included the distance (in kilometres) from the mid-point of each street where the house is located, to the central business district (CBD), the nearest shops, the nearest primary, secondary and tertiary educational institution, and the nearest hospital and emergency service provider.

3.1.4 ABS 2001 Socio-Economic Indexes for Areas (SEIFA)

The neighbourhood's socio-economic characteristics are represented in the model by the ABS SEIFA, the latest of which was calculated based on the 2001 Census of Population and Housing. In particular, the Index of Relative Socio-Economic Advantage/Disadvantage was used. Further information about this index can be found in the ABS Cat No. 2309 (ABS 2001).

3.1.5 ABS 2001 Census Neighbourhood Data

Other housing neighbourhood attributes at collection district (CD)[6] level were obtained from the 2001 ABS Census. These included the following:

- percentage of dwellings with 2, 3, 4, 5 or more bedrooms
- percentage of dwellings that were privately-owned, occupied, rented or in the process of being leased or purchased; and
- percentage of dwellings that were house, townhouse or unit types.

3.2 Compiling the data

After the necessary data cleaning and quality checks, removal of outliers and influential observations, and the linking of the ACTPLA and EER records using the suburb, block and section information, a dataset consisting of 2,385 and 2,719 house records for 2005 and 2006, respectively, became available for merging with ABS data. The ABS distance data were merged with the above linked dataset via street name and number. The ABS SEIFA and Census neighbourhood data were linked to the merged dataset via CD information, where CD was available, and by postcode if CD was not available.

Further details regarding the data cleaning and compiling processes that were undertaken in this study are found in Appendix A. An important consideration that was made is the exclusion in the dataset of houses younger than 10 years. Newly-built houses constructed after the implementation of the ACT House Energy Rating Scheme (ACTHERS) in July 1995 were excluded from the dataset. These new houses were required to achieve a minimum four-star rating. Their exclusion ensured that the focus of the study was on the housing stock that existed prior to the introduction of minimum energy standards, and that for modelling purposes, there was sufficient variation in the variable for the regressions to work.

6 The census Collection District (CD) is the smallest geographic area defined in the Australian Standard Geographical Classification (AGSC). It has been designed for use in the Census of Population and Housing as the smallest unit for collection, processing and output of data. For the 2001 Census there is an average of about 225 dwellings in each CD (ABS 2001 p.183).

4. MODELLING THE RELATIONSHIP OF EER TO HOUSE PRICE

4.1 Research hypotheses

The study aimed to test the following hypotheses:

- that EER has a statistically significant association with the price of detached houses in the ACT in 2005 and 2006; and
- that the variation in house prices explained by EER is small relative to other explanatory variables.

In addition to testing the above hypotheses, the study also aimed to determine the possible implicit price range of EER. Whilst it is possible to establish this implicit price range, an 'exact' value cannot be determined, due to data constraints. A theoretical model that illustrates the concept of implicit price determination in hedonic regression is found in Dinan and Miranowski (1989 p. 53).

4.2 Model specification

In this study, hedonic regression was employed to determine the degree of association of EER on the house price, holding all other house characteristics constant. Essentially, **hedonic regression** regresses price against a host of explanatory variables, where it decomposes the item being researched (house price) into its constituent characteristics (e.g. house features or characteristics), and obtains estimates of the value of each characteristic.

Many studies on house price modelling in Australia have involved the use of hedonic techniques. For example, the recent work of the Reserve Bank of Australia (RBA) found hedonic regression to be useful in measuring pure house price changes after controlling for both compositional and quality change (see Hansen 2006). Melser and Hill (2006) made use of hedonics to examine the effects of quality adjustments in accounting for house price changes across regions in Sydney. In 2004, the ABS experimented with and tested the efficacy of hedonic methods to account for the impact of housing attributes on the house price index (HPI) (Chen et al. 2004).

4.2.1 The choice of functional form

The initial step in hedonic regression is to specify a hedonic model whose explanatory variables capture much of the variation in house prices. While it is relatively easy to generate a list of house characteristics, the question is what functional form should these variables take? Unfortunately, there is no a prior theoretical reason for assuming any particular functional form. This is because a hedonic equation is a reduced form reflecting both supply and demand influences. While theory may provide information about the form of the underlying supply and demand equations, the resulting functional form for the hedonics equation depends on unknown parameters (elasticities) and can only be determined empirically. By experience, plotting the house price against individual house characteristics is the most powerful way of examining the functional form of the variables in the hedonic model.

Several studies on house prices and energy- or efficiency-related variables have shown that the non-linear functional form performs well in explaining the variation of house prices. Grether and Mieszkowski (1973) and Halvorsen and Pollakowski (1981) made use of a semi-log model while Longstreth, Coveney and Bowers (1984) preferred a polynomial functional form. Dinan and Miranowski (1986) used a Box-Cox model. Some studies used linear functional forms (e.g. Ridker and Henning (1967), Horowitz and Haeri (1990), Johnson and Kaserman (1983) and Nevin and Watson (1998)), but most of these were found to suffer from several problems such as heteroscedasticity, bias in the hedonic implicit price estimates and simultaneous relationships in the data. Diewert (2001) argued that linear hedonic models are difficult to justify on theoretical grounds and hence should be avoided if possible. The advantages and disadvantages of using log-log, semi-log, translog, non-parametric and other generalised functional forms were discussed in Diewert's paper.

Dinan and Miranowski (1986) argued for the use of a general functional form that is as flexible as possible so that the data ultimately determine the model specification. Flexible functional forms allow analysis of second-order effects. For example, the implicit price of EER is allowed to vary over different values of EER or different values of other explanatory variables. In addition, by choosing a functional form that best fits the data, the overall error variance is reduced, reducing the standard errors of the estimates. Dinan and Miranowski used the Box-Cox modelling procedure. However, estimating a Box-Cox model presents a lot of problems in practice (e.g. availability of software to perform the estimation; estimation of the transformation parameters; dealing with zero characteristics if present). In addition, flexible functional forms have not been used in the hedonic literature to a greater extent due to problems with multicollinearity.

For this study, a semi-log functional form is employed, although one explanatory variable has undergone logarithmic transformation. Some researchers have found that semi-log functional forms are sufficient in addressing the problems of multicollinearity and heteroscedasticity. This is also the functional form used in the ABS and RBA hedonic studies (see Hansen 2006 and Chen et al. 2004).

4.2.2 The dependent variable: the item being researched

To produce a better 'cross-sectional' dataset, house price inflation was removed from the house prices data. This means that the house prices were first deflated by the ABS house price index to produce a dependent variable in which the variation is only caused by non-inflationary effects. Thus the variation in house prices, after deflation, is assumed to be a function of housing characteristics only. A logarithmic transformation was then applied to the deflated house prices due to its distribution and to improve the ease of interpretation of the results.

To further verify if logarithmic transformation was adequate for the hedonic model, a Box-Cox transformation of the dependent variable was performed using maximum likelihood estimation (MLE). The estimated transformation parameter revealed that the log of the deflated house price was the preferred functional form for the dependent variable.

4.2.3 The explanatory variables: the constituent characteristics

A listing of the explanatory variables and their descriptive statistics are provided in Appendix B.

As in previous hedonic studies, the most difficult part of the process is obtaining a suitably comprehensive dataset of house characteristics. Ideally, all major house price determining characteristics should be represented in the dataset, but often such data are not available, as is the case in this study.

In this study, the explanatory variables were divided into five categories, namely:

1. Structural variables

Structural variables point to the 'qualities' or structural features of the house. They consist mainly of the age, block area and gross floor area of the house. Since the information on the number of main rooms, bedrooms and bathrooms was not available, the gross floor area was then divided to form two variables: conditioned floor area and laundry and bathroom area. In addition, window area and window space were also considered as additional structural variables. All of the above variables were used in the model as continuous variables.

Whether a house was privately owned or part of the existing public housing stock at the time of sale may also be considered as another feature of the house that may influence a consumer's valuation. This was also added to the model in a form of a dummy variable.

2. Distance variables

Distance variables included the distance from the mid-point of the street where the house is located, to the following: the central business district (CBD), the nearest shops, the nearest school and tertiary institutions (primary secondary, college and university), the nearest hospital, and emergency service providers. All of these were continuous variables.

3. Neighbourhood variables

Neighbourhood attributes refer to the general social and economic conditions in the surrounding environment of the house.

This study made use of the ABS SEIFA Index of Relative Socio-Economic Advantage/Disadvantage as an indicator of the socio-economic condition of the area where the house is located[7]. ABS HPI studies (ABS 2005 and Chen et al. 2004) have shown that SEIFA can explain most of the variation in house prices across areas, followed by location and structural

7 A higher score on the Index of Relative Socio-Economic Advantage/Disadvantage indicates that an area has attributes such as a relatively high proportion of people with high incomes or a skilled workforce. It also means an area has a low proportion of people with low incomes and relatively few unskilled people in the workforce. Conversely, a low score on the index indicates that an area has a higher proportion of individuals with low incomes and more employees in unskilled occupations; and a low proportion of people with high incomes or in skilled occupations. For more information about the SEIFA and to guide the interpretation of its estimated coefficients in this study, see ABS (2004).

characteristics. The SEIFA index used in this study was based on the 2001 Census, and therefore it was necessary to assume that the socio-economic status of the CDs in ACT in 2005 and 2006 were similar to those in 2001. (The 2006 SEIFA will be available in 2008).

The study also made use of other variables which supplemented the structural characteristics of houses. These included the housing neighbourhood attributes at CD level (e.g. proportion of two, three, four, five or more bedroom houses in CD, proportion of privately owned, rented or leased dwellings in CD) and these were obtained from the 2001 Census.

4. Locational variable

Although distance and neighbourhood variables can be thought of as locational attributes, in this study, the locational variable refers only to the house address postcode. The RBA study (Hansen 2006) revealed that postcode can be the most important characteristic explaining the variation of prices in Sydney, Brisbane and Melbourne, in the absence of structural, locational and neighbourhood attributes. While postcode is not a house characteristic per se, it can be considered as a proxy for a range of unaccounted characteristics associated with house location. However, because postcode might have some degree of collinearity with both neighbourhood and distance variables, caution was exercised when it was included in the final model.

Nineteen postcode dummies were created for the modelling.

5. Energy efficiency variables

The EER star rating (i.e. values ranging from 0 to 6 with an increment of 0.5) is the energy efficiency variable for the model. This variable was used as a continuous variable in the basic model and the model extensions, as described in section 4.3.

As discussed in Section 2.2, the EER also has attributes that may influence the house price for reasons other than its effect on energy efficiency or demand. Dummy variables were created for these factors and were included in the supplementary models, in addition to the EER score itself. Likewise, a few pure thermal variables, such as the R values[8] for wall, ceiling and floor insulation, were also used in some of the models tested.

4.2.4 Non-linear variables

Transformations were applied to structural, distance, neighbourhood and locational variables that depicted non-linear relationships with log deflated house price based on scatter plots. Logarithmic transformations were applied to block area, conditioned floor area and all the distance variables, however diagnostics showed that only block area required such transformation. We found that squaring the house age and its distance to CBD was necessary for the hedonic model.

4.2.5 Other variables

Interaction effects among all explanatory variables were considered in the modelling process, however no one interaction was found to be significant. Adding a time-dummy variable to represent the quarterly house price variation was also found to be not significant and unnecessary in this cross-sectional analysis. A Box-Cox transformation was not implemented for all explanatory variables due to processing constraints.

8 All insulation materials are rated for their performance in restricting heat transfer. This is expressed as the R value, which is the measure of the material's resistance to heat transfer (alternatively known as thermal resistance or resistivity) (SEAV 2004).

4.3 The hedonic models

Five hedonic models were estimated in this study and are listed in the table below:

Table 1. Summary of the models estimated

Category	Model number	Model name	Short description
Models that addressed the hypotheses of the study	1	Basic model	EER is included as an explanatory variable
	2	Basic model extension- accounting for the non-thermal attributes of EER	EER is included as an explanatory variable, and in addition, some individual energy efficiency-related variables that are suspected of having non-thermal effects, are included among the explanatory variables
	3	Basic model extension- accounting for the thermal attributes separately	As Model 2, and in addition, some individual energy efficiency-related variables that are accepted to have thermal effects are included among the explanatory variables
Models that validated the use of EER star rating in the above models	4	Basic model modification- the EER as a fitted variable	EER is a model-fitted explanatory variable
	5	Basic model modification- the EER as a derived principal component score	EER is a derived principal component explanatory variable

4.3.1 Model 1 – the basic model

The basic house price model was formulated as:

$$\ln P_i = \alpha_0 + \sum_{j=1}^{J} \beta_j S_{ji} + \sum_{k=1}^{K} \delta_k D_{ki} + \sum_{m=1}^{M} \phi_m N_{mi} + \sum_{p=1}^{P} \theta_p L_{pi} + \sum_{q=1}^{Q} \gamma_q W_{qi}^2 + \pi EER_i + \varepsilon_i \qquad (1)$$

where, InP_i is the natural logarithm of the deflated house price (i=1,2,....n;n is the total number of observations), S_{ji} is the j^{th} structural variable, D_{ki} is the k^{th} distance variable, N_{mi} is the M_{th} neigbourhood variable, L_{pi} is the p^{th} locational variable, W^2_{qi} is the q^{th} distance or structural variable squared, EER_1 is the energy efficiency rating and e^i is the error term. α_0 is the model intercept while $\beta_j, \delta_k, \phi_m, \theta_p, \gamma_q$ and π are the parameter coefficients which will be estimated. The estimate for the parameter π will be used to establish the implicit price range of energy efficiency rating.

In the Model 1 above, we assumed that the housing characteristics contained in the structural, distance, neighbourhood and locational variables do not significantly contribute much to the EER, otherwise π will be unidentified. Moreover, we assumed that Model 1 satisfies the standard regression assumptions (see Greene 2008[*sic*] p.44).

4.3.2 Model 2 – Basic model extension that accounts for the non-thermal attributes of EER

Section 2.2 asserted that there were thermal factors which added value to the price of a house for reasons other than their contribution to energy efficiency (for example, a timber floor may have an aesthetic effect, which consumers value in addition to thermal efficiency). These factors may also be considered as additional house characteristics and if not included in the model, may lead to unidentified and biased estimate for π. This implies that the estimate for π in Model 1 may not be the pure magnitude of association of the energy efficiency rating with house price.

The first extension to the basic model is thus given by:

$$\ln P_i = \alpha_0 + \sum_{j=1}^{J} \beta_j S_{ji} + \sum_{k=1}^{K} \delta_k D_{ki} + \sum_{m=1}^{M} \phi_m N_{mi} + \sum_{p=1}^{P} \theta_p L_{pi} + \sum_{q=1}^{Q} \gamma_q W_{qi}^2 + \pi EER_i + \sum_{r=1}^{R} \varphi_r EER_{ri}^{non-thermal} + \varepsilon_i \qquad (2)$$

The extension is in the form of the last vector of explanatory variables, the $EER_{ri}^{non-thermal}$ which are the r^{th} EER non-thermal factors which add value to the house price for reasons other than energy efficiency. These are in a form of dummy variables, for example, the presence or absence of brick wall, the presence or absence of timber flooring, presence or absence of chimney, and the like. In Model 2, because of the inclusion of the vector $EER_{ri}^{non-thermal}$, π may now depict the much purer association of EER with house price.

4.3.3 Model 3 – Basic model extension that accounts for the thermal attributes separately

The study aimed to test what might happen to π if the EER pure thermal factors ($EER_{ri}^{thermal}$) were added to the basic model separately. Can EER still establish a statistically significant relationship with house price despite the presence of pure thermal factors that only add value to house via their contribution to energy efficiency? The third model below was formulated to answer this question.

$$\ln P_i = \alpha_0 + \sum_{j=1}^{J} \beta_j S_{ji} + \sum_{k=1}^{K} \delta_k D_{ki} + \sum_{m=1}^{M} \phi_m N_{mi} + \sum_{p=1}^{P} \theta_p L_{pi} + \sum_{q=1}^{Q} \gamma_q W_{qi}^2 + \pi EER_i + \sum_{r=1}^{R} \varphi_r EER_{ri}^{non-thermal} + \sum_{u=1}^{U} \varphi_u EER_{ui}^{thermal} + \varepsilon_i \qquad (3)$$

4.3.4 Model 4 – Basic model modification that treats the EER as a fitted variable

This model modifies the EER variable to rule out the possibility of any random error contained in the EER star rating of the basic model. Such random error also accounts for any omitted (but important) factors that may be related to the EER star rating. Instead of using the actual EER star rating, the EER was derived as a fitted number using a regression model. The EER star rating was regressed onto all available EER thermal factors and was predicted using only those factors that were found statistically significant to EER star rating. If the estimate of π^* in the model is found to be statistically significant then this would imply that the EER star rating fits for the basic model above. It is given by,

$$\ln P_i = \alpha_0 + \sum_{j=1}^{J} \beta_j S_{ji} + \sum_{k=1}^{K} \delta_k D_{ki} + \sum_{m=1}^{M} \phi_m N_{mi} + \sum_{p=1}^{P} \theta_p L_{pi} + \sum_{q=1}^{Q} \gamma_q W_{qi}^2 + \pi^* E\hat{E}R_i^* + \varepsilon_i \qquad (4)$$

where

$$E\hat{E}R_i^* = \hat{\alpha}_0^* + \sum_{j=1}^{J} \hat{\beta}_j^* X_{ji}$$

$E\hat{E}E_i^*$ is the predicted EER score rating for each i^{th} house ($i=1,2,\dots n; n$ is the total number of observations), $\hat{\alpha}_0^*$ is the estimated EER equation intercept and $\hat{\beta}_j^*$ is the estimated j^{th} coefficient for the j^{th} significant EER thermal factor, X_{ji}.

4.3.5 Model 5 – Basic model modification that treats the EER as a derived principal component score

For Model 5, an EER variable was created using principal component analysis (PCA). PCA was employed to reduce a large number of related, or correlated, EER thermal variables into a smaller set of transformed variables, called ‘components’. The said components capture much of the information, or variation, contained in the EER thermal variables. The derived principal component score, based on the first principal component, was used for each house observation given by Z_i. The principal component score was substituted in place of the EER variable in Model 1. The model is given by

$$\ln P_i = \alpha_0 + \sum_{j=1}^{J} \beta_j S_{ji} + \sum_{k=1}^{K} \delta_k D_{ki} + \sum_{m=1}^{M} \phi_m N_{mi} + \sum_{p=1}^{P} \theta_p L_{pi} + \sum_{q=1}^{Q} \gamma_q W_{qi}^2 + \tau Z_i + \varepsilon_i \qquad (5)$$

If the estimate of t in the above model is found to be statistically significant then it would further verify that there is no systematic bias in the EER star rating data and that the variable is consistently fit for using in the basic model.

4.3.6 Interpreting the EER parameter estimate

The results of the statistical analysis could indicate that the EER may or may not have a statistically significant relationship with house prices. If a statistically significant relationship is not established, this does not necessarily imply that energy efficiency is not capitalised by the market into house prices, as some research studies have found evidence to the contrary (see Kain and Quigley (1970), Grether and Mieszkowski (1973), Halvorsen and Pollakowski (1981), Longstreth, Coveney and Bowers (1984) and Dinan and Miranowski (1986)). The quality of the data may also have an impact on any estimated relationship. As the EER is essentially a summary of potentially many energy efficiency features (as discussed in Section 2) as well as the weights that *FirstRate* applies to the features in the rating process, it may or may not reflect the prices that consumers are willing to pay for a house with high EER.

On the other hand, if a statistically significant relationship is found, then readers should be careful of the interpretation of the coefficient estimate for o as it may not truly reflect the 'exposure' of EER in its own right. EER was shown to have characteristics that have both thermal and non-thermal effects.

The reader is also cautioned that the value of the EER coefficient may be affected by other features of the house which were not considered in the model, due to their unavailability, and these features may have had an interaction with the EER variable in relation to house price. Moreover, extra care must be taken when interpreting the coefficient, as it is based on modelling a dataset consisting only of houses older than nine years, for two selected years (2005 or 2006) and for a specified city only (Canberra) which may have a price-market environment very different to other cities.

4.4 Estimation and Diagnostics

Correlation analyses among the explanatory variables were run initially to rule out any collinearity problems. Because there was a large number of potential independent variables, a stepwise selection method was employed using backward elimination. This removed the independent variables that were least significant (i.e. those with a $p - value > 0.10$).

To cross check, automatic model selection was utilised using the adjusted R-squared, Mallows' Cp and Howking's criterion in the determination of the possible basic models.

Initially, a simple least square estimation procedure was used to estimate the parameters of the models. The goodness-of-fit of each of the estimated models was examined by looking at the estimated adjusted R-squared, which was found to be reasonably high for this cross-sectional analysis. The analysis of variance table was also examined for the overall significance of the model. Each of the coefficient estimates was then scrutinised, the sign was examined (to determine the direction of association) and statistical significance was checked. The chosen model was further subjected to a regression specification test (RESET) to test whether the model was misspecified (i.e. whether it omitted important variables, included irrelevant ones or chosen a wrong functional form). Restricted least square regressions were also implemented to test whether a group of explanatory variables (e.g. postcodes, EER non-thermal factors, EER thermal factors) was relevant in the models. Multicollinearity was also checked.

The standard assumptions behind the multiple regression modelling were examined for possible violation. The plots of the residuals versus the predicted values as well as the plot of the residuals versus the independent variables were checked. Increasing patterns from left to right were evident from the plots of residuals, suggesting the presence of heteroscedastic variance. The Breusch-Pagan tests (both the original Lagrange multiplier(LM) test and the more robust LM test) were run and indicated that heteroscedasticity was indeed a problem. With a large number of observations at hand and the presence of heteroscedastic variance, the Feasible Generalised Least Squares (FGLS) was the most efficient approach used in the final hedonic estimation.

5. RESULTS

5.1 Explanatory notes

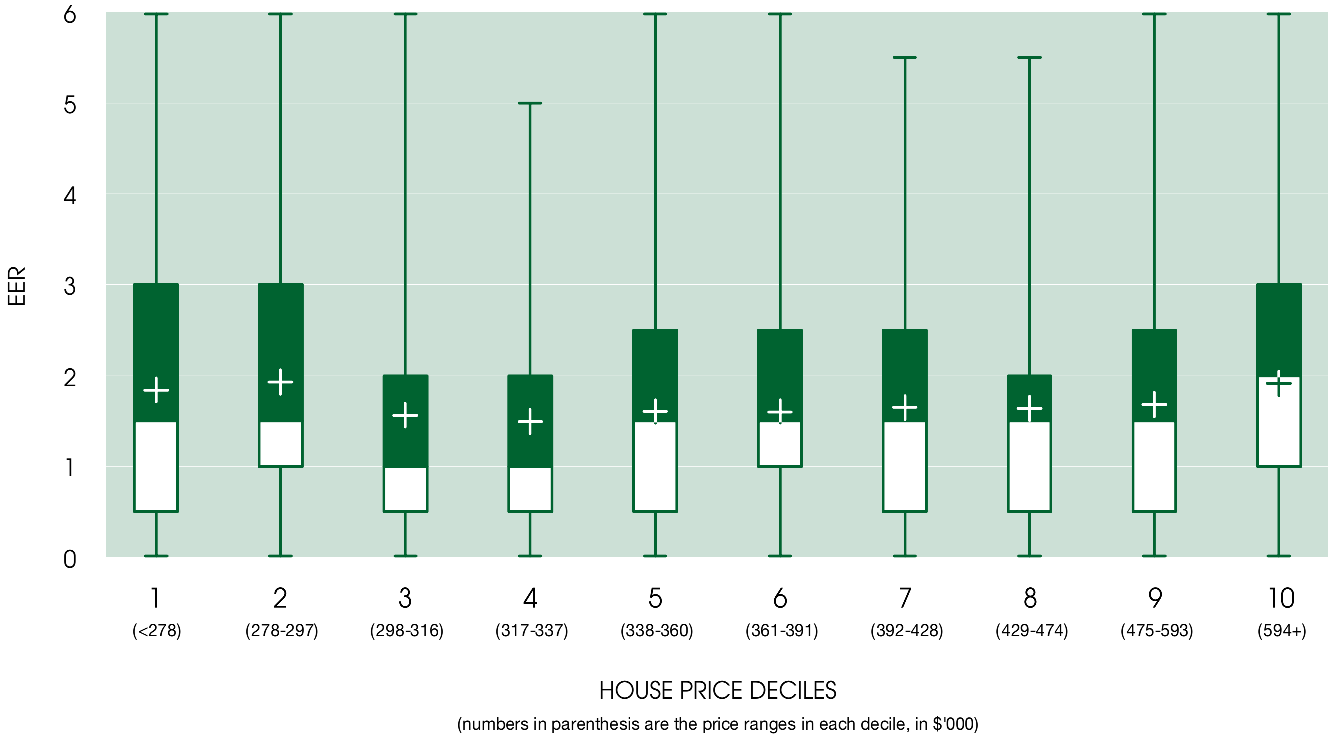
In interpreting or using the results presented in this section, the following explanatory and cautionary remarks are important:

- The datasets used contained incomplete information on house characteristics (e.g. number of bedrooms, bathrooms, toilets, covered garages and carports) and locational variables (e.g. views from the house), therefore not all factors that were major determinants of house prices in ACT can be included in the model.
- The data covered only two years (2005 and 2006) of housing information for detached houses sold in ACT. The degree of association of EER with house price may be different had there been more years considered, or had there been more cities or classes of buildings included in the dataset.
- As we have excluded recently built houses (i.e. those built after the inception of ACTHERS in 1995), the study results cannot be generalised easily to new detached houses. The study only looked at the relationship between EER and the price of houses older than nine years.
- Because the data were scoped in such a way that only houses with EER information were included, it was not possible to model the effect on price of the EER 'disclosure' itself. There are no data available for houses without an EER in the dataset.
- The study can only determine the implicit price range for the EER (p.26) and similarly, it can only state that the degree of association of EER star rating with house price falls in the range of 0 to 1.03 percent. For any given property, we cannot precisely determine either the implicit price of EER or its disclosure.
- The age variable used in the analysis (i.e. age based on the house's commencement date) was not able to distinguish old houses that were totally knocked down and rebuilt. However, according to the ACTPLA, there was only a very minimal number of cases of these in the ACT in the years covered by this study.
- Renovations are likely to impact on house price. Some renovations may already be reflected in the data (e.g. the inclusion of a sun room would be reflected in the conditioned floor area; additional bathroom would be reflected in the size of the utility area, and renovations of wall, ceiling and floor materials, as well as additional insulation). However, there may be other renovations that are not reflected in the data (e.g. quality changes in the kitchen).

5.2 EER distribution

Figure 1 (next page) shows the variability in the EER by house price deciles for the 2005 data. The EER's of 0 to 6 were found in most of the decile groups, but the majority of the EER star ratings were found within the range of 0.5 to 3, with the mean and median for all of the groups falling between 1 and 2. Overall, the sample mean was found to be 1.69 for the 2005 sample.

Figure 1. Distribution of EER data by house price deciles, 2005



5.3 Regression results

This section presents the *Feasible Generalised Least Squares* estimates of the five models specified in Section 4. The analysis focused on the first three models presented in Table 1 using the 2005 data.

5.3.1 Basic model and its extensions (Models 1, 2 and 3)

Table 2 shows the parameter estimates for the structural, distance, locational, neighbourhood and energy efficiency attributes that were found to be statistically significant at α=0.05 level of significance. The figures in the parentheses are their corresponding t–$value$. The detailed results are provided in Appendix C.

Table 2. Model estimates using the 2005 data

House characteristics	Model 1	Model 2	Model 3
Log deflated house price (dependent variable)			
EER (star rating)	0.0123	0.0103	0.0047
	(4.87)	(4.05)	(1.53)
Double glazed windows	-	0.0451	0.0424
		(3.71)	(3.48)
Wall/ceiling vents	-	-0.0156	-0.0167
		(-2.24)	(-2.41)
Utility door	-	0.0155	0.0168
		(2.72)	(2.95)
Wall insulation	-	-	0.0133
			(2.68)
Ceiling insulation	-	-	0.0050
			(1.91)
Conditioned floor area	0.0030	0.0030	0.0029
	(38.72)	(37.99)	(37.80)
Block area (in log form)	0.1992	0.1981	0.1974
	(15.09)	(15.06)	(15.02)
Age (of the house)	-0.0126	-0.0126	-0.0120
	(-6.74)	(-6.74)	(-6.38)
Age-squared	0.0002	0.0002	0.0002
	(6.75)	(6.80)	(6.57)
CBD (distance to CBD)	-0.0517	-0.0515	-0.0515
	(-6.77)	(-6.76)	(-6.78)
CBD-squared	0.0014	0.0013	0.0013
	(4.21)	(4.17)	(4.14)
SEIFA (Advantage/Disadvantage index)	0.0007	0.0007	0.0007
	(6.58)	(6.52)	(6.57)
Window space	0.0032	0.0028	0.0025
	(6.55)	(5.70)	(5.03)
% of 5 bedroom houses in CD	0.0060	0.0062	0.0063
	(6.18)	(6.41)	(6.50)
Former public housing (dummy)	-0.0742	-0.0770	-0.0784
	(-2.79)	(-2.91)	(-2.97)
% of privately owned dwellings in CD	-0.0010	-0.0011	-0.0011
	(-1.83)	(-1.88)	(1.89)
Intercept (constant term)	10.8186	10.8446	10.8331
	(75.13)	(75.57)	(75.56)
Postcodes*			
F Value	**373.56**	**343.23**	**325.15**
Adjusted r-squared	**0.82**	**0.83**	**0.83**
No. of observations	**2385**	**2385**	**2385**

Note: '-' means variable was not included in the model

*Complete parameter estimates for the postcode dummies are shown in Appendix C.1-3

There is a statistically significant relationship between house price and the following house characteristics: floor area, block area, age, distance to CBD, SEIFA, window space, % of 5 bedroom houses in the CD, and whether or not the house was a part of the public housing stock prior to sale.

As expected (using Model 1), the signs of the coefficient estimates made sense and were consistent with the results in Chen et al. (2004). The following relationships were found:

- The size of the block was positively and strongly associated with price, but as the block area became much larger, the marginal increase in the house price became smaller (This relationship was also the same for conditioned floor area)
- An increase in the neighbourhood's socio-economic status, as proxied by the SEIFA, was positively associated with house price
- The age of the house and house price were negatively related, that is, house price declined as it aged (holding everything else constant)
- There was also a negative association between the house price and the house distance to CBD
- There was a positive relationship between house price and wider windows; and
- The property of being part of the public housing stock prior to sale was negatively associated with house price.

The estimated coefficients for the postcode dummies were consistent with expectations. The findings revealed that, assuming all other house characteristics held constant, a house located in any of the following inner city postcodes: 2603, 2600 and 2604 would have a higher price than a house located in postcodes 2614, 2615 and 2617. The former group of postcodes include the Red Hill, Forrest, Griffith, Yarralumla, Deakin, Kingston and Narrabundah suburbs known to have houses being sold at high prices in ACT because of their location.

There is a statistically significant relationship between house price and EER

Results from Model 1 showed that EER was positively associated with house price. The statistical relationship was found to be strongly significant at $\alpha=0.01$ level of significance ($t\text{–}value=4.87$). The significant association indicated that on average, house price for detached houses sold in ACT in 2005 changed by approximately 1.23 percent per one unit (equivalent of 0.5 EER star rating) change in the EER, holding all other variables constant.

It could be noted that because the EER star rating was used as a continuous variable in the basic model, the basic assumption was that across the range (0 to 10) of EER star rating, an increment of 0.5 amounts to a constant 1.2 percent increase in house price. This may not be true in the real market situation as a jump from 1.0 to 1.5 may not have the same degree of association, in terms of effect on consumers' buying decisions, as a jump from 4.5 to 5.

To verify the latter argument, the basic model was re-estimated, but this time the EER star rating was treated as a categorical variable rather than a continuous variable[9]. The results of this are shown in Appendix D. Readers are cautioned that this extra modelling was not meant to invalidate the use of EER star rating as a continuous variable. The estimated coefficients indicated that houses in higher EER categories have a price premium over houses in lower EER categories, holding everything else constant. For example, a house belonging to the EER 1 category attracted a 1.6% premium (i.e. the house price is 1.6% higher) over the reference category (i.e. EER 0 category). This premium rises as the EER category goes up, but the marginal addition to the premium declines.

When the basic model was extended to include some individual energy efficiency variables (i.e. Model 3), the degree of association of the EER star rating with house price remained statistically significant, but has slightly decreased, and was only marginally significant at $\alpha=0.10$ level of significance. This implies that the EER coefficient was sensitive to any addition of separate energy efficiency-related variables.

The magnitude of the estimated EER coefficient was found to be higher when the model was estimated using 2006 data (see Appendix B6). The EER coefficients in both Models 1 and 3 were also found significant. In addition, the EER coefficient was found to be stable even with the addition of some energy efficiency-related variables that are also thought of as having non thermal effects.

9 Using the EER point scores, five EER categories were created, each corresponding to one-star increments with the exception of the 5- and 6-star ratings which were combined into one due to the small number of observations belonging to these ratings. The 0 star rating was treated as the base reference category. Moreover, the estimation used pooled 2005 and 2006 data.

There are factors underlying EER that add value to a house for reasons other than energy efficiency

Results from Model 2 suggest that there are EER factors which have non-thermal associations with price, as well as having thermal associations. The EER factors that were found to be statistically significant were the presence of double glazed windows, utility doors and wall and ceiling vents. Double glazed windows are a visible energy efficiency feature (unlike wall insulation) and a good barrier for noise, hence would add value to a house. Wall and ceiling vents are commonly present on houses built in late 1970's and early 1980's, so the negative association of these variables with house price might be due to trends and fashions in the housing market.

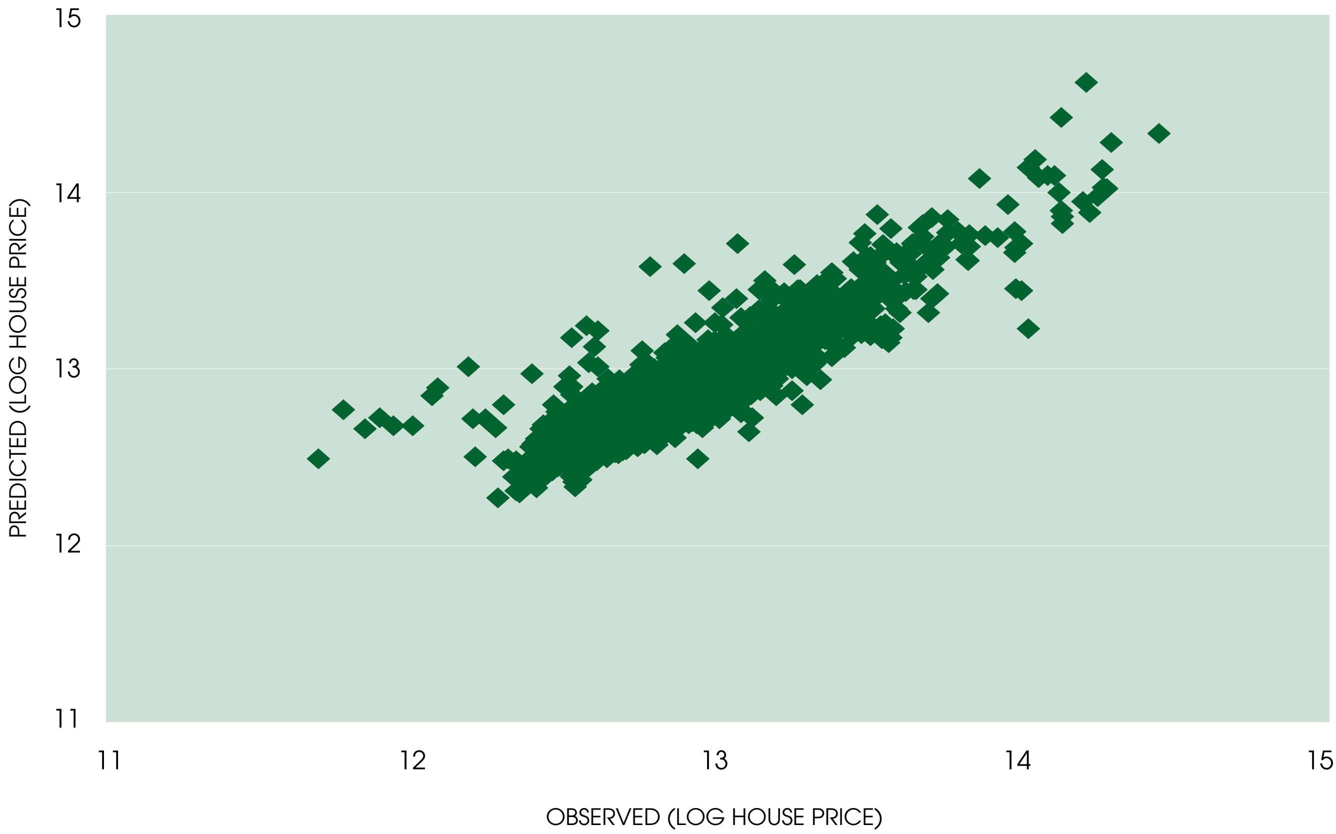
Although we have added the three additional factors of double-glazed windows, wall and ceiling vents, and utility doors into the model, the relationship between house price and EER remained significant. In addition, it can be observed that there were minimal changes to the magnitude of the coefficients of other house characteristics.

Other EER non-thermal attributes (e.g. presence of brick wall, presence of timber flooring, largest window facing north, and the like) have also been considered in the actual modelling but were found to be not significant.

The variation in house prices is adequately explained by the explanatory variables in the model.

Figure 2 below shows the robustness of the estimated model. For Model 1, the adjusted R-squared is found to be 0.82, indicating that the model gives a very good approximation of the relationship between house price and the explanatory variables. This value is relatively higher than the adjusted R-squared found in the Chen et al. (2004), Hill and Melser (2006) and Hansen (2006).

Figure 2. Predicted vs. observed house price, 2005 (Model 1)



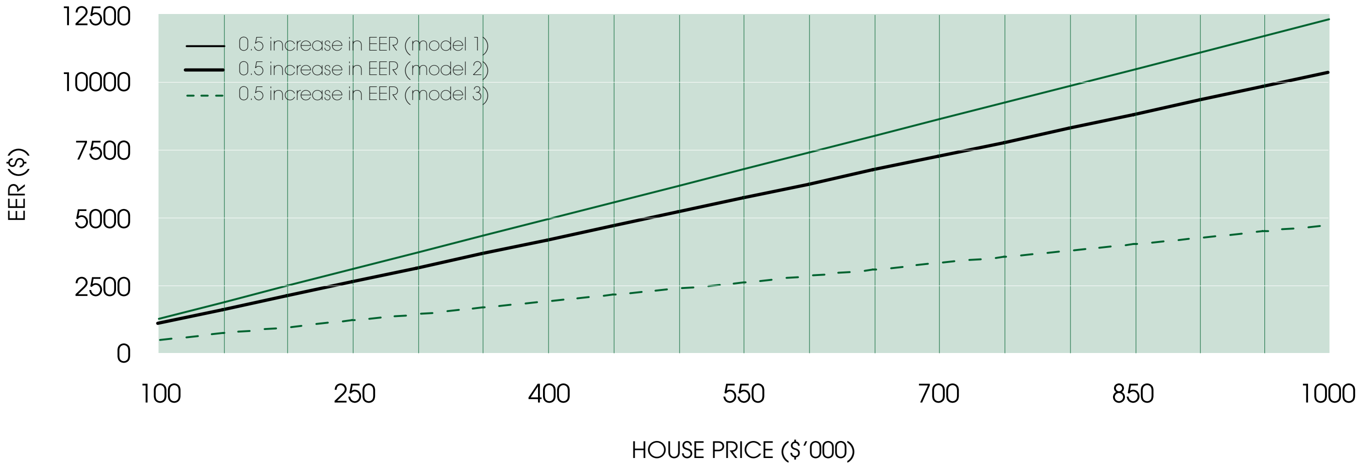
In this study, the structural, distance, locational and neighbourhood variables demonstrated that they had a good explanatory power in explaining the log of house price in the ACT. Structural variables explained around 67 percent of the log of price variation, while neighbourhood and distance variables explained around 12 percent on top of structural variables. The postcode dummies explained 3 percent of the log of price variation when added to the model.

Although EER was found to be a statistically significant characteristic in explaining log of prices in the regression, it was found to have very low explanatory power of only 0.4 percent.

The implicit price range of EER can be determined...

Figure 3 below graphically illustrates the estimated implicit price range of EER using the 2005 data. The illustration uses the estimated coefficients of the EER variable provided in Table 2. The estimated coefficient in Model 1 quantifies the upper bounds of the implicit price range of EER and is given by the upper dark line in Figure 3. For example, holding all other house characteristics constant, for a detached house sold in ACT in 2005 with a price value of $365,000 (i.e median price), increasing the EER star rating by 0.5 would be associated with an additional $4,489 in its price.

Figure 3. Graphical illustration of the implicit price range of EER, 2005



When the basic model is extended to include significant energy efficiency non-thermal variables (i.e. Model 2), the implicit price range of the EER star rating that is shown in Figure 3 by the lighter bold line is reduced by around 0.2 percent of the house price. This line is likely to illustrate the maximum association of thermal efficiency variables with house price. As we include the significant EER thermal variables, the relationship between EER and house price becomes less significant, which is expected. This purer relationship is exhibited by the broken line. Extreme care should be taken when using or interpreting the above illustration because, as shown in Appendix D, the relationship between EER and house price could be nonlinear.

...but not the EER disclosure itself

This study modelled the relationship between house price and the EER's, and not EER disclosure itself. However, if inferences are to be cautiously made about house price and EER disclosure, Figure 3 may roughly suggest that the degree of association of EER disclosure on house price in 2005 would lie somewhere between the x-axis and the lighter bold line, the latter being the maximum range. However, this effect is conditional on how much the consumers have been exposed to EER features, what they already know about EER measurement, and the value they put on them. For example, consumers who know little about EER may add a value of between 0.5 and 1 percent of the house price if the EER is disclosed to them when buying a house. In contrast, for a consumer with a comprehensive knowledge of EER (e.g. a builder), EER disclosure may not be significantly associated with increased house price as any value associated with EER may have been added already to the house price.

5.3.2 Results using 2006 data (Models 1, 2 and 3)

Table 3 provides the results for Models 1, 2 and 3 respectively, using the 2006 data. The results were very similar to those from the 2005 estimations:

- The signs of the statistically significant variables were consistent with those from the 2005 data
- The magnitudes of the coefficient estimates were reasonable including those of the postcode dummies
- The house characteristics that were found to have a significant statistical relationship with house price in 2005 are also found to have the same degree of statistical relationship in 2006, with the addition of four house characteristics namely: bathroom and laundry area; proportion of 3 bedroom houses in CD; proportion of privately not owned/rented dwellings in CD; and distance to secondary school; and
- The adjusted R-squared statistics were found to be 0.83 in all models and were very similar to those in the 2005 estimations.

The results above indicate the robustness of the three models.

5.3.3 Results for Models 4 and 5

Examining the results for 2005 (see Appendix C.4-5), the coefficient estimate for the predicted EER star rating variable in Model 4 was found to be statistically significant at $\alpha=0.01$ level of significance. This indicates that random error was not contained in the EER star rating and endogeneity in the EER star rating was not a problem[10].

Model 5, on the other hand, returned a coefficient estimate for the principal component variable which was similar to the EER coefficient estimate coming from Model 1. They were expected to be different, as there were fewer individual house energy efficiency-related factors used in the principal component analysis than in the actual calculation of the EER star rating by assessors. The estimate from Model 5 was found to be statistically significant, indicating that EER did not contain any systematic bias or measurement error. The same results were found using the 2006 data.

Table 3. Model estimates using the 2006 data

House characteristics	Model 1	Model 2	Model 3
Log deflated house price (dependent variable)			
EER (star rating)	0.0191	0.0191	0.0173
	(7.61)	(7.48)	(5.55)
Largest window facing north	-	-0.0113	-0.0113
		(-2.16)	(-2.16)
Chimney	-	0.0188	0.0191
		(1.93)	(1.97)
Double glazed windows	-	0.0156	0.0152
		(1.13)	(1.10)
Wall/ceiling vents	-	-0.0007	-0.00002
		(-0.04)	(-0.001)
Utility door	-	0.0088	0.0092
		(1.03)	(1.07)
Wall insulation	-	-	0.0066
			(1.38)
Ceiling insulation	-	-	-0.0011
			(-0.48)
Conditioned floor area	0.0025	0.0025	0.0025
	(24.31)	(24.31)	(24.36)
Block area (in log form)	0.1796	0.1785	0.1765
	(14.49)	(14.42)	(14.24)
CBD (distance to CBD)	-0.0590	-0.0583	-0.0574
	(-8.21)	(-8.11)	(-8.00)
CBD-squared	0.0017	0.0017	0.0017
	(5.71)	(5.67)	(5.57)
Bathroom and laundry area	0.0066	0.0065	0.0064
	(7.28)	(7.26)	(7.14)
SEIFA (Advantage/Disadvantage index)	0.0007	0.0007	0.0007
	(6.20)	(6.27)	(6.20)

10 Endogeneity refers to a difficulty in modelling when a given explanatory variable is highly correlated with unobservable factors relegated to the error term in the model.

Table 3. continued

House characteristics	Model 1	Model 2	Model 3
Former public housing (dummy)	-0.1104	-0.1094	-0.1182
	(-5.62)	(-5.58)	(-5.96)
Window space	0.0028	0.0028	0.0027
	(5.94)	(5.85)	(5.64)
Age (age of the house)	-0.0088	-0.0088	-0.0079
	(-4.69)	(-4.73)	(-4.08)
Age-squared	0.0001	0.0001	0.0001
	(4.21)	(4.23)	(3.57)
% of 3 bedroom houses in CD	-0.0011	-0.0011	-0.0011
	(-3.19)	(-3.03)	(-3.26)
% of privately owned dwellings in CD	-0.0017	-0.0017	-0.0016
	(-3.04)	(-3.05)	(-2.80)
% of 5 bedroom houses in CD	0.0035	0.0035	0.0031
	(3.14)	(3.12)	(2.79)
% of privately not owned/rented dwellings in CD	0.0026	0.0025	0.0030
	(2.17)	(2.15)	(2.54)
Distance to secondary school	0.0113	0.0117	0.0124
	(2.18)	(2.24)	(2.37)
Intercept (constant term)	10.9922	10.9867	10.9856
	(68.05)	(68.07)	(68.01)
Postcodes*			
F value	**385.71**	**337.41**	**321.03**
Adjusted r-squared	**0.83**	**0.83**	**0.83**
No. of observations	**2719**	**2719**	**2719**

Note: '-' means variable was not included in the model

*Complete parameter estimates for the postcode dummies are shown in Appendix C.6-8

6. CONCLUDING REMARKS

This study has found a statistically significant relationship between the EER and house price for detached dwellings in the ACT. This finding was based on modelling, through hedonic regression, various factors that influence house price. A useful dataset from administrative sources was constructed for the analysis.

Econometric methods using the available dataset produced robust results of the association between house price and EER. However, extreme care should be taken when using and interpreting the coefficient estimate of EER, as EER is shown to have characteristics that have both thermal and non-thermal effects on house prices. In addition, the results from this study must be used with care due to the recognised limitations outlined in section 5. For example, there were major determinants of house price that were not available in the dataset. The study was also restricted to just two years of data.

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APPENDICES

A. DATA CLEANING AND COMPILATION

This appendix explains the data cleaning process that was undertaken to render the ACT Planning and Land Authority administrative datasets useful for modelling purposes and for linking to other datasets.

A.1 Cleaning the ACTPLA Land Information Centre transfer data

To prepare the data for modelling and to ensure that only in-scope dwellings were included, the following ‘data cleaning’ processes were undertaken:

- Records for dwellings which were not detached houses (i.e. apartments or units) were removed
- Records with all three vital dates (contract, settlement and transfer) missing were dropped
- New houses whose commencement date was after the inception of the ACT House Energy Rating Scheme (i.e. July 1995) were excluded
- Houses from NSW rural areas that are close to ACT boundaries (e.g. Tharwa and Hall) were sampled out
- Houses whose prices were considered outliers (extremely high or unreasonably low) were removed from the data, likewise, houses with outlier block areas (more than 10,000 square meters) were removed
- If a suburb or street name was misspelled and inconsistent with the block and section, the information was manually corrected; and
- Duplicate records (i.e. same settlement dates and purchase price) were removed.

The above cleaning produced a dataset with 3,876 observations for 2005 and 4,079 observations for 2006.

A.2 Cleaning ACTPLA EER data

The cleaned transfers data described in Appendix A.1 formed the frame for the extraction of EER Statements, either in pdf or paper print form, by the ACTPLA. The EER information were manually extracted and encoded following the data specification given in ABS (2006).

The encoded EER information were checked for misspelt entries, improper formats, inconsistent ratings following the EER score, invalid entries, coding errors and missing entries. Records with missing and questionable entries were reviewed by the ACTPLA.

As per the client’s instruction, newly-built houses constructed after the inception of the ACT House Energy Rating Scheme (ACTHERS) in 1995 were excluded from the dataset (e.g. houses from Harrison and inner Gungahlin). These new houses were mandated to have star ratings of 4.5 or above. Their exclusion meant that most of the EER’s in the dataset would fall between the range 0.5 to 3, because older houses are generally less energy efficient. The exclusion of new houses whose EER’s were constantly in the range of 4.5 and above ensured that, for modelling purposes, there was sufficient variation in the dependent variable for the regressions to work.

B. VARIABLES AND SUMMARY STATISTICS

B.1 Variable description and summary statistics, 2005

Variable	Mean	Std Dev	Minimum	Maximum
House price				
Purchase price (original price, in $)	411,898	169,151	120,000	1,925,000
Deflated purchase price	408,875	167,592	119,760	1,890,962
Log of deflated price	12.9	0.3	11.7	14.4
Structural				
Age (age of the house, in year)	28	11	9	74
Block area (m^2)	836	239	179	2762
Block area (in log form)	6.68	0.29	5.18	7.92
Former public housing (dummy)	0.01	0.10	0	1
Gross floor area (m^2)	142	50	40	568
Conditioned floor area (m^2)	128	45	38	517
Bathroom and laundry area (m^2)	14	7.2	0	206
Area of largest window (m^2)	14.5	7.4	1.0	171.0
Total area of all windows (m^2)	32.2	13.4	9.0	257.0
Window space (m^2)	25.2	6.0	10.0	104.0
Postcode (House sold belongs to postcode)				
2600	0.0239	0.15	0	1
2602	0.0797	0.27	0	1
2603	0.0201	0.14	0	1
2604	0.0193	0.14	0	1
2605	0.0335	0.18	0	1
2606	0.0189	0.14	0	1
2607	0.0419	0.20	0	1
2611	0.0822	0.27	0	1
2612	0.0176	0.13	0	1
2614	0.0503	0.22	0	1
2615	0.1304	0.34	0	1
2617	0.0704	0.26	0	1
2902	0.0608	0.24	0	1
2903	0.0335	0.18	0	1
2904	0.0608	0.24	0	1
2905	0.1103	0.31	0	1
2906	0.0604	0.24	0	1
2913	0.0759	0.26	0	1
2914	0.0101	0.10	0	1
Distance				
Distance to nearest CBD (in km)	11.1	4.6	0.9	21.9
Distance to nearest college (in km)	6.9	3.8	0.2	14.5
Distance to nearest hospital (in km)	4.1	2.0	0.2	9.1
Distance to nearest primary school (in km)	0.6	0.3	0.03	2.0

Table B.1 continued

Variable	Mean	Std Dev	Minimum	Maximum
Distance to nearest secondary school (in km)	1.2	0.6	0.05	3.2
Distance to nearest university (in km)	5.3	3.2	0.09	14.3
Distance to nearest shop (in km)	1.7	0.9	0.05	5.3
Distance to nearest emergency services (in km)	2.7	1.8	0.13	9.0
SEIFA				
Index of relative socio-economic Advantage/Disadvantage (Adv/Dis)	1120	54	944	1293
Neighbourhood				
% Dwellings that are houses in CD	87.2	15.3	8.1	100.0
% Dwellings that are townhouses in CD	9.2	12.6	0.0001	73.3
% Dwellings that are units in CD	3.5	7.7	0.0001	87.6
% of privately owned dwellings in CD	73.8	8.8	30.9	94.7
% of privately being purchased, rent free, others dwellings in CD	8.1	3.0	0.0001	26.5
% of privately rented dwellings in CD	18.1	7.8	0.8772	56.5
% of 2 bedroom houses in CD	8.4	5.7	0.0001	42.3
% of 3 bedroom houses in CD	52.0	15.7	8.5	95.4
% of 4 bedroom houses in CD	33.4	13.9	4.5	71.6
% of 5 bedroom houses in CD	6.2	4.6	0.0001	36.8
EER attributes				
EER star rating	1.6889	1.32	0	6
Floor insulation R value	0.1504	0.36	0	4
Wall insulation R value	0.4696	0.77	0	4
Ceiling insulation R value	2.7273	1.14	0	6.5
Largest window facing east	0.1451	0.35	0	1
Largest window facing north	0.4675	0.50	0	1
Largest window facing south	0.2541	0.44	0	1
Largest window facing west	0.1333	0.34	0	1
Presence of double glazed windows	0.0566	0.23	0	1
Concrete flooring	0.3434	0.47	0	1
Timber flooring	0.6566	0.47	0	1
Brick wall	0.9715	0.17	0	1
Attic ceiling	0.9618	0.19	0	1
Cross flow ventilation is good	0.6092	0.49	0	1
Presence of eaves	0.9975	0.05	0	1
Presence of window shading	0.4327	0.50	0	1
House have two-storey	0.1086	0.31	0	1
Entry open to living area	0.6826	0.47	0	1
Presence of chimney	0.0784	0.27	0	1
Presence of wall and ceiling vents	0.2289	0.42	0	1

Table B.1 continued

Variable	Mean	Std Dev	Minimum	Maximum
Presence of fans	0.4470	0.50	0	1
Presence of skylights	0.0235	0.15	0	1
Presence of utility door	0.5468	0.50	0	1
Presence of exit door	0.7866	0.41	0	1
Estimated				
Principal component score	0.0000	1.79	-3.7378	24.9469
Predicted EER star rating	1.6889	1.02	-1.6304	4.6769

B.2 Variable description and summary statistics, 2006

Variable	Mean	Std Dev	Minimum	Maximum
House price				
Purchase price (original price, in $)	438,179	189,091	100,000	2,500,000
Deflated purchase price	404,879	174,151	90,909	2,272,727
Log of deflated price	12.8	0.3	11.4	14.6
Structural				
Age (age of the house, in year)	29	11	10	71
Block area (m^2)	836	229	183	2,809
Block area (in log form)	6.69	0.29	5.21	7.94
Former public housing (dummy)	0.02	0.14	0	1
Gross floor area (m^2)	140	48	52	613
Conditioned floor area (m^2)	126	45	45	573
Bathroom and laundry area (m^2)	13.2	4.5	0	75.1
Area of largest window (m^2)	14.1	5.6	2.0	54.0
Total area of all windows (m^2)	31.6	12.8	7.0	135.0
Window space (m^2)	25.2	5.7	8.0	65.0
Postcode (House sold belongs to postcode)				
2600	0.0184	0.13	0	1
2602	0.0872	0.28	0	1
2603	0.0224	0.15	0	1
2604	0.0162	0.13	0	1
2605	0.0364	0.19	0	1
2606	0.0173	0.13	0	1
2607	0.0382	0.19	0	1
2611	0.0857	0.28	0	1
2612	0.0217	0.15	0	1
2614	0.0522	0.22	0	1
2615	0.1405	0.35	0	1
2617	0.0655	0.25	0	1
2902	0.0588	0.23	0	1
2903	0.0375	0.19	0	1
2904	0.0489	0.22	0	1
2905	0.1173	0.32	0	1

Table B.2 continued

Variable	Mean	Std Dev	Minimum	Maximum
2906	0.0592	0.24	0	1
2913	0.0673	0.25	0	1
2914	0.0085	0.09	0	1
Distance				
Distance to nearest CBD (in km)	11.0	4.7	0.9	21.9
Distance to nearest college (in km)	6.8	3.9	0.2	14.4
Distance to nearest hospital (in km)	4.1	2.0	0.2	9.1
Distance to nearest primary school (in km)	0.6	0.3	0.02	2.1
Distance to nearest secondary school (in km)	1.2	0.6	0.04	3.2
Distance to nearest university (in km)	5.3	3.3	0.09	14.3
Distance to nearest shop (in km)	1.6	0.9	0.05	8.3
Distance to nearest emergency services (in km)	2.6	1.8	0.13	9.0
SEIFA				
Index of relative socio-economic advantage/ disadvantage (Adv/Dis)	1121	55	944	1294
Neighbourhood				
% Dwellings that are houses in CD	87.2	15.6	8.1	100.0
% Dwellings that are townhouses in CD	9.0	12.7	0.0001	67.4
% Dwellings that are units in CD	3.8	8.3	0.0001	89.5
% of privately owned dwellings in CD	74.0	8.7	36.7	94.7
% of privately being-purchased, rent free, others dwellings in CD	8.1	3.2	0.0001	43.5
% of privately rented dwellings in CD	17.9	7.7	0.9	56.5
% of 2 bedroom houses in CD	8.4	5.7	0.0001	42.3
% of 3 bedroom houses in CD	52.0	15.8	8.5	95.4
% of 4 bedroom houses in CD	33.3	13.9	4.1	72.8
% of 5 bedroom houses in CD	6.2	4.6	0.0001	41.2
EER attributes				
EER star rating	1.6764	1.2642	0	6
Floor insulation R value	0.1122	0.3029	0	5
Wall insulation R value	0.4452	0.7647	0	4
Ceiling insulation R value	2.8828	1.1018	0	7
Largest window facing east	0.1629	0.3694	0	1
Largest window facing north	0.4332	0.4956	0	1
Largest window facing south	0.2644	0.4411	0	1
Largest window facing west	0.1379	0.3449	0	1
Presence of double glazed windows	0.0368	0.1883	0	1
Concrete flooring	0.3152	0.4647	0	1
Timber flooring	0.6848	0.4647	0	1
Brick wall	0.0335	0.1799	0	1
Attic ceiling	0.9735	0.1606	0	1
Cross flow ventilation is good	0.9250	0.2635	0	1

Table B.2 continued

Variable	Mean	Std Dev	Minimum	Maximum
Presence of eaves	0.9989	0.0332	0	1
Presence of window shading	0.3350	0.4721	0	1
House have two-story	0.1159	0.3201	0	1
Entry open to living area	0.6907	0.4623	0	1
Presence of chimney	0.0820	0.2744	0	1
Presence of wall and ceiling vents	0.0331	0.1789	0	1
Presence of fans	0.2243	0.4172	0	1
Presence of skylights	0.0055	0.0741	0	1
Presence of utility door	0.1313	0.3378	0	1
Presence of exit door	0.5767	0.4942	0	1
Estimated				
Principal Component Score	0.0012	1.9504	-3.8877	16.2105
Predicted EER star rating	1.6744	1.0024	-0.3941	6.3744

C. MODEL ESTIMATES

C.1 Parameter estimates of Model 1 using the 2005 data

Variable	Parameter estimate	Standard error	t statistic for Ho:parameter=0	Prob
Intercept (constant term)	10.8186	0.1440	75.13	<.0001
EER (star rating)	0.0123	0.0025	4.87	<.0001
Conditioned floor area	0.0030	0.0001	38.72	<.0001
Window space	0.0032	0.0005	6.55	<.0001
Block area (in log form)	0.1992	0.0132	15.09	<.0001
Age (age of the house)	-0.0126	0.0019	-6.74	<.0001
CBD (distance to CBD)	-0.0517	0.0076	-6.77	<.0001
SEIFA (Adv/Dis)	0.0007	0.0001	6.58	<.0001
% of privately owned dwellings in CD	-0.0010	0.0006	-1.83	0.0678
% of 5 bedroom houses in CD	0.0060	0.0010	6.18	<.0001
Former public housing (dummy)	-0.0742	0.0266	-2.79	0.0052
Age-squared	0.0002	0.0000	6.75	<.0001
CBD-squared	0.0014	0.0003	4.21	<.0001
Postcode dummies (Base reference: 2615)				
2600	0.3485	0.0320	10.88	<.0001
2602	0.0615	0.0283	2.18	0.0297
2603	0.4145	0.0309	13.41	<.0001
2604	0.2343	0.0273	8.57	<.0001
2605	0.1712	0.0224	7.64	<.0001
2606	0.1443	0.0230	6.28	<.0001
2607	0.1630	0.0170	9.60	<.0001
2611	0.0862	0.0131	6.56	<.0001
2612	0.1460	0.0415	3.52	0.0004
2614	-0.0187	0.0177	-1.06	0.2909
2617	-0.0385	0.0160	-2.40	0.0164
2902	0.0560	0.0144	3.90	<.0001
2903	0.0717	0.0176	4.08	<.0001
2904	0.0712	0.0163	4.37	<.0001
2905	0.0292	0.0211	1.39	0.1655
2906	0.0403	0.0383	1.05	0.2936
2913	0.0010	0.0180	0.06	0.9557
2914	-0.0159	0.0313	-0.51	0.6107
Adjusted r-squared	**0.8242**			

C.2 Parameter estimates of Model 2 using the 2005 data

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
Intercept (constant term)	10.8446	0.1435	75.57	<.0001
EER (star rating)	0.0103	0.0026	4.05	<.0001
Conditioned floor area	0.0030	0.0001	37.99	<.0001
Window space	0.0028	0.0005	5.70	<.0001
Block area (in log form)	0.1982	0.0132	15.06	<.0001
Age (age of the house)	-0.0126	0.0019	-6.74	<.0001
CBD (distance to CBD)	-0.0515	0.0076	-6.76	<.0001
SEIFA (Adv/Dis)	0.0007	0.0001	6.52	<.0001
% of privately owned dwellings in CD	-0.0011	0.0006	-1.88	0.0598
% of 5 bedroom houses in CD	0.0062	0.0010	6.41	<.0001
Former public housing (dummy)	-0.0770	0.0265	-2.91	0.0036
Age-squared	0.0002	0.0000	6.80	<.0001
CBD-squared	0.0013	0.0003	4.17	<.0001
Postcode dummies (Base reference: 2615)				
2600	0.3467	0.0319	10.87	<.0001
2602	0.0581	0.0282	2.06	0.0394
2603	0.4084	0.0308	13.25	<.0001
2604	0.2346	0.0272	8.62	<.0001
2605	0.1701	0.0223	7.61	<.0001
2606	0.1425	0.0229	6.23	<.0001
2607	0.1630	0.0169	9.63	<.0001
2611	0.0854	0.0131	6.53	<.0001
2612	0.1402	0.0413	3.40	0.0007
2614	-0.0191	0.0176	-1.08	0.2800
2617	-0.0380	0.0160	-2.38	0.0176
2902	0.0569	0.0143	3.97	<.0001
2903	0.0715	0.0175	4.08	<.0001
2904	0.0744	0.0163	4.57	<.0001
2905	0.0332	0.0210	1.58	0.1143
2906	0.0460	0.0382	1.20	0.2287
2913	0.0027	0.0180	0.15	0.8807
2914	-0.0141	0.0311	-0.45	0.6506
Double-glazed windows	0.0451	0.0122	3.71	0.0002
Wall and ceiling vents	-0.0156	0.0070	-2.24	0.0255
Utility door	0.0155	0.0057	2.72	0.0066
Adjusted r-squared	**0.8257**			

C.3 Parameter estimates of Model 3 using the 2005 data

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
Intercept (constant term)	10.8331	0.1434	75.56	<.0001
EER (star rating)	0.0047	0.0031	1.53	0.1253
Conditioned floor area	0.0029	0.0001	37.80	<.0001
Window space	0.0025	0.0005	5.03	<.0001
Block area (in log form)	0.1974	0.0131	15.02	<.0001
Age (age of the house)	-0.0120	0.0019	-6.38	<.0001
CBD (distance to CBD)	-0.0515	0.0076	-6.78	<.0001
SEIFA (Adv/Dis)	0.0007	0.0001	6.57	<.0001
% of privately owned dwellings in CD	-0.0011	0.0006	-1.89	0.0588
% of 5 bedroom houses in CD	0.0063	0.0010	6.50	<.0001
Former public housing (dummy)	-0.0784	0.0264	-2.97	0.003
Age-squared	0.0002	0.0000	6.57	<.0001
CBD-squared	0.0013	0.0003	4.14	<.0001
Postcode dummies (Base reference: 2615)				
2600	0.3425	0.0319	10.75	<.0001
2602	0.0570	0.0281	2.03	0.0428
2603	0.4077	0.0308	13.25	<.0001
2604	0.2323	0.0272	8.54	<.0001
2605	0.1685	0.0223	7.55	<.0001
2606	0.1391	0.0229	6.08	<.0001
2607	0.1615	0.0169	9.56	<.0001
2611	0.0832	0.0131	6.37	<.0001
2612	0.1398	0.0412	3.39	0.0007
2614	-0.0207	0.0176	-1.18	0.2394
2617	-0.0400	0.0160	-2.50	0.0124
2902	0.0575	0.0143	4.01	<.0001
2903	0.0722	0.0175	4.12	<.0001
2904	0.0747	0.0163	4.59	<.0001
2905	0.0355	0.0210	1.69	0.0915
2906	0.0494	0.0382	1.30	0.1953
2913	0.0021	0.0180	0.12	0.9068
2914	-0.0177	0.0311	-0.57	0.5706
Double-glazed windows	0.0424	0.0122	3.48	0.0005
Wall and ceiling vents	-0.0167	0.0070	-2.41	0.0162
Utility door	0.0168	0.0057	2.95	0.0032
Wall insulation	0.0133	0.0050	2.68	0.0075
Ceiling insulation	0.0050	0.0026	1.91	0.0563
Adjusted r-squared	**0.8264**			

C.4 Parameter estimates of Model 4 using the 2005 data

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
Intercept (constant term)	10.7849	0.1441	74.82	<.0001
EER (predicted star rating)	0.0215	0.0038	5.73	<.0001
Conditioned floor area	0.0029	0.0001	37.19	<.0001
Window space	0.0035	0.0005	7.04	<.0001
Block area (in log form)	0.1971	0.0131	15.02	<.0001
Age (age of the house)	-0.0115	0.0019	-6.03	<.0001
CBD (distance to CBD)	-0.0523	0.0076	-6.86	<.0001
SEIFA (Adv/Dis)	0.0007	0.0001	6.73	<.0001
% of privately owned dwellings in CD	-0.0010	0.0006	-1.80	0.0724
% of 5 bedroom houses in CD	0.0061	0.0010	6.30	<.0001
Former public housing (dummy)	-0.0789	0.0264	-2.99	0.0029
Age-squared	0.0002	0.0000	6.31	<.0001
CBD-squared	0.0014	0.0003	4.27	<.0001
Postcode dummies (Base reference: 2615)				
2600	0.3432	0.0320	10.72	<.0001
2602	0.0599	0.0282	2.12	0.0338
2603	0.4139	0.0308	13.42	<.0001
2604	0.2314	0.0273	8.48	<.0001
2605	0.1701	0.0224	7.61	<.0001
2606	0.1408	0.0229	6.14	<.0001
2607	0.1615	0.0170	9.52	<.0001
2611	0.0837	0.0131	6.39	<.0001
2612	0.1439	0.0414	3.48	0.0005
2614	-0.0223	0.0177	-1.26	0.2066
2617	-0.0409	0.0160	-2.55	0.0108
2902	0.0570	0.0143	3.98	<.0001
2903	0.0710	0.0175	4.05	<.0001
2904	0.0702	0.0163	4.32	<.0001
2905	0.0279	0.0210	1.33	0.1840
2906	0.0403	0.0382	1.05	0.2918
2913	-0.0007	0.0180	-0.04	0.9680
2914	-0.0191	0.0312	-0.61	0.5397
Adjusted r-squared	**0.8249**			

C.5 Parameter estimates of Model 5 using the 2005 data

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
Intercept (constant term)	11.0074	0.1467	75.05	<.0001
EER (principal component score)	0.0188	0.0050	3.78	0.0002
Conditioned floor area	0.0023	0.0002	11.02	<.0001
Window space	0.0008	0.0007	1.20	0.2292
Block area (in log form)	0.1968	0.0132	14.90	<.0001

Table C.5 continued

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
Age (age of the house)	-0.0144	0.0018	-7.85	<.0001
CBD (distance to CBD)	-0.0499	0.0076	-6.53	<.0001
SEIFA (Adv/Dis)	0.0007	0.0001	6.64	<.0001
% of privately owned dwellings in CD	-0.0009	0.0006	-1.62	0.1060
% of 5 bedroom houses in CD	0.0058	0.0010	5.90	<.0001
Former public housing (dummy)	-0.0863	0.0265	-3.26	0.0011
Age-squared	0.0002	0.0000	7.63	<.0001
CBD-squared	0.0013	0.0003	3.88	0.0001
Postcode dummies (Base reference: 2615)				
2600	0.3513	0.0321	10.95	<.0001
2602	0.0625	0.0283	2.21	0.0274
2603	0.4085	0.0311	13.15	<.0001
2604	0.2311	0.0274	8.43	<.0001
2605	0.1767	0.0224	7.88	<.0001
2606	0.1463	0.0230	6.36	<.0001
2607	0.1662	0.0170	9.77	<.0001
2611	0.0837	0.0132	6.36	<.0001
2612	0.1510	0.0415	3.64	0.0003
2614	-0.0201	0.0177	-1.13	0.2584
2617	-0.0392	0.0161	-2.44	0.0149
2902	0.0579	0.0144	4.02	<.0001
2903	0.0710	0.0176	4.03	<.0001
2904	0.0727	0.0163	4.45	<.0001
2905	0.0342	0.0211	1.62	0.1053
2906	0.0535	0.0384	1.39	0.1634
2913	0.0004	0.0181	0.02	0.9816
2914	-0.0136	0.0313	-0.44	0.6634
Adjusted r-squared	**0.8235**			

C.6 Parameter estimates of Model 1 using the 2006 data

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
Intercept (constant term)	10.9922	0.1615	68.05	<.0001
EER (star rating)	0.0191	0.0025	7.61	<.0001
Conditioned floor area	0.0025	0.0001	24.31	<.0001
Bathroom and laundry area	0.0066	0.0009	7.28	<.0001
Window space	0.0028	0.0005	5.94	<.0001
Block area (in log form)	0.1796	0.0124	14.49	<.0001
Age (age of the house)	-0.0088	0.0019	-4.69	<.0001
CBD (distance to CBD)	-0.0590	0.0072	-8.21	<.0001
Distance to secondary school	0.0113	0.0052	2.18	0.0296
SEIFA (Adv/Dis)	0.0007	0.0001	6.20	<.0001

Table C.6 continued

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
% of privately owned dwellings in CD	-0.0017	0.0006	-3.04	0.0024
% of privately not owned/rented dwellings in CD	0.0026	0.0012	2.17	0.0298
% of 3 bedroom houses in CD	-0.0011	0.0003	-3.19	0.0014
% of 5 bedroom houses in CD	0.0035	0.0011	3.14	0.0017
Former public housing (dummy)	-0.1104	0.0196	-5.62	<.0001
Age-squared	0.0001	0.0000	4.21	<.0001
CBD-squared	0.0017	0.0003	5.71	<.0001
Postcode dummies (Base reference: 2615)				
2600	0.4462	0.0331	13.47	<.0001
2602	0.0607	0.0273	2.22	0.0262
2603	0.4588	0.0294	15.63	<.0001
2604	0.2441	0.0267	9.16	<.0001
2605	0.1878	0.0213	8.81	<.0001
2606	0.1139	0.0236	4.82	<.0001
2607	0.1887	0.0164	11.51	<.0001
2611	0.1207	0.0126	9.58	<.0001
2612	0.1368	0.0390	3.51	0.0005
2614	0.0232	0.0169	1.37	0.1715
2617	-0.0282	0.0163	-1.73	0.0834
2902	0.0557	0.0133	4.18	<.0001
2903	0.0989	0.0167	5.93	<.0001
2904	0.0730	0.0165	4.43	<.0001
2905	0.0492	0.0210	2.34	0.0194
2906	0.0551	0.0374	1.47	0.1405
2913	0.0072	0.0180	0.40	0.6906
2914	0.0037	0.0317	0.12	0.9065
Adjusted r-squared	**0.8280**			

C.7 Parameter estimates of Model 2 using the 2006 data

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
Intercept (constant term)	10.9867	0.1614	68.07	<.0001
EER (star rating)	0.0191	0.0026	7.48	<.0001
Conditioned floor area	0.0025	0.0001	24.31	<.0001
Bathroom and laundry area	0.0065	0.0009	7.26	<.0001
Window space	0.0028	0.0005	5.85	<.0001
Block area (in log form)	0.1785	0.0124	14.42	<.0001
Age (age of the house)	-0.0088	0.0019	-4.73	<.0001
CBD (distance to CBD)	-0.0583	0.0072	-8.11	<.0001
Distance to secondary school	0.0117	0.0052	2.24	0.0251
SEIFA (Adv/Dis)	0.0007	0.0001	6.27	<.0001
% of privately owned dwellings in CD	-0.0017	0.0006	-3.05	0.0023

Table C.7 continued

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
% of privately not owned/rented dwellings in CD	0.0025	0.0012	2.15	0.0313
% of 3 bedroom houses in CD	-0.0011	0.0003	-3.03	0.0024
% of 5 bedroom houses in CD	0.0035	0.0011	3.12	0.0018
Former public housing (dummy)	-0.1094	0.0196	-5.58	<.0001
Age-squared	0.0001	0.0000	4.23	<.0001
CBD-squared	0.0017	0.0003	5.67	<.0001
Postcode dummies (Base reference: 2615)				
2600	0.4449	0.0332	13.42	<.0001
2602	0.0628	0.0273	2.30	0.0215
2603	0.4587	0.0294	15.59	<.0001
2604	0.2452	0.0266	9.20	<.0001
2605	0.1902	0.0213	8.91	<.0001
2606	0.1136	0.0236	4.82	<.0001
2607	0.1884	0.0164	11.49	<.0001
2611	0.1214	0.0126	9.64	<.0001
2612	0.1405	0.0390	3.60	0.0003
2614	0.0245	0.0170	1.45	0.1484
2617	-0.0264	0.0163	-1.62	0.1045
2902	0.0548	0.0134	4.08	<.0001
2903	0.0975	0.0167	5.84	<.0001
2904	0.0707	0.0166	4.26	<.0001
2905	0.0478	0.0211	2.27	0.0236
2906	0.0540	0.0375	1.44	0.1496
2913	0.0083	0.0180	0.46	0.6431
2914	0.0039	0.0317	0.12	0.9027
Largest window facing north	-0.0113	0.0052	-2.16	0.0312
Chimney	0.0188	0.0097	1.93	0.0537
Double-glazed windows	0.0156	0.0138	1.13	0.2588
Wall and ceiling vents	-0.0007	0.0161	-0.04	0.9668
Utility door	0.0088	0.0086	1.03	0.3051
Adjusted r-squared	**0.8284**			

C.8 Parameter estimates of Model 3 using the 2006 data

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
Intercept (constant term)	10.9856	0.1615	68.01	<.0001
EER (star rating)	0.0173	0.0031	5.55	<.0001
Conditioned floor area	0.0025	0.0001	24.17	<.0001
Bathroom and laundry area	0.0065	0.0009	7.17	<.0001
Window space	0.0027	0.0005	5.59	<.0001
Block area (in log form)	0.1793	0.0124	14.47	<.0001

Table C.8 continued

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
Age (age of the house)	-0.0087	0.0019	-4.62	<.0001
CBD (distance to CBD)	-0.0580	0.0072	-8.05	<.0001
Distance to secondary school	0.0115	0.0052	2.21	0.0272
SEIFA (Adv/Dis)	0.0007	0.0001	6.26	<.0001
% of privately owned dwellings in CD	-0.0017	0.0006	-3.06	0.0022
% of privately not owned/rented dwellings in CD	0.0025	0.0012	2.13	0.0329
% of 3 bedroom houses in CD	-0.0010	0.0003	-3.01	0.0027
% of 5 bedroom houses in CD	0.0035	0.0011	3.17	0.0015
Former public housing (dummy)	-0.1087	0.0196	-5.54	<.0001
Age-squared	0.0001	0.0000	4.16	<.0001
CBD-squared	0.0017	0.0003	5.60	<.0001
Postcode dummies (Base reference: 2615)				
2600	0.4450	0.0332	13.42	<.0001
2602	0.0623	0.0273	2.28	0.0225
2603	0.4578	0.0294	15.55	<.0001
2604	0.2435	0.0267	9.13	<.0001
2605	0.1898	0.0213	8.89	<.0001
2606	0.1123	0.0236	4.75	<.0001
2607	0.1882	0.0164	11.47	<.0001
2611	0.1208	0.0126	9.58	<.0001
2612	0.1402	0.0390	3.60	0.0003
2614	0.0239	0.0170	1.41	0.1594
2617	-0.0263	0.0163	-1.62	0.1058
2902	0.0549	0.0134	4.09	<.0001
2903	0.0987	0.0167	5.90	<.0001
2904	0.0709	0.0166	4.28	<.0001
2905	0.0486	0.0211	2.31	0.0212
2906	0.0554	0.0375	1.48	0.1396
2913	0.0064	0.0180	0.35	0.7238
2914	0.0029	0.0317	0.09	0.9263
Largest window facing north	-0.0113	0.0052	-2.16	0.0309
Chimney	0.0192	0.0097	1.97	0.0486
Double-glazed windows	0.0152	0.0138	1.10	0.2715
Wall and ceiling vents	-0.00003	0.0161	-0.00	0.9986
Utility door	0.0092	0.0086	1.07	0.2861
Wall insulation	0.0066	0.0048	1.38	0.1680
Ceiling insulation	-0.0012	0.0025	-0.48	0.6348
Adjusted r-squared	**0.8284**			

C.9 Parameter estimates of Model 4 using the 2006 data

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
Intercept (constant term)	10.9675	0.1629	67.31	<.0001
EER (predicted star rating)	0.0218	0.0036	6.14	<.0001
Conditioned floor area	0.0025	0.0001	24.33	<.0001
Bathroom and laundry area	0.0059	0.0009	6.48	<.0001
Window space	0.0029	0.0005	6.02	<.0001
Block area (in log form)	0.1796	0.0124	14.43	<.0001
Age (age of the house)	-0.0089	0.0019	-4.69	<.0001
CBD (distance to CBD)	-0.0594	0.0072	-8.23	<.0001
Distance to secondary school	0.0110	0.0052	2.11	0.0352
SEIFA (Adv/Dis)	0.0007	0.0001	6.38	<.0001
% of privately owned dwellings in CD	-0.0017	0.0006	-2.99	0.0028
% of privately not owned/rented dwellings in CD	0.0025	0.0012	2.12	0.0338
% of 3 bedroom houses in CD	-0.0011	0.0003	-3.21	0.0013
% of 5 bedroom houses in CD	0.0036	0.0011	3.22	0.0013
Former public housing (dummy)	-0.1131	0.0197	-5.74	<.0001
Age-squared	0.0001	0.0000	4.32	<.0001
CBD-squared	0.0018	0.0003	5.77	<.0001
Postcode dummies (Base reference: 2615)				
2600	0.4492	0.0332	13.51	<.0001
2602	0.0609	0.0274	2.22	0.0264
2603	0.4585	0.0295	15.56	<.0001
2604	0.2438	0.0268	9.11	<.0001
2605	0.1890	0.0214	8.84	<.0001
2606	0.1143	0.0237	4.83	<.0001
2607	0.1880	0.0165	11.42	<.0001
2611	0.1188	0.0127	9.37	<.0001
2612	0.1390	0.0391	3.55	0.0004
2614	0.0212	0.0170	1.24	0.2134
2617	-0.0267	0.0163	-1.64	0.1014
2902	0.0552	0.0134	4.12	<.0001
2903	0.1007	0.0167	6.02	<.0001
2904	0.0721	0.0165	4.36	<.0001
2905	0.0457	0.0211	2.16	0.0307
2906	0.0533	0.0375	1.42	0.1560
2913	0.0095	0.0180	0.53	0.5993
2914	0.0137	0.0318	0.43	0.6670
Adjusted r-squared	**0.8267**			

C.10 Parameter estimates of Model 5 using the 2006 data

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
Intercept (constant term)	11.2296	0.1650	68.07	<.0001
EER (principal component score)	0.0227	0.0053	4.28	<.0001
Conditioned floor area	0.0017	0.0002	7.50	<.0001
Bathroom and laundry area	0.0055	0.0009	6.00	<.0001
Window space	-0.0004	0.0008	-0.54	0.5878
Block area (in log form)	0.1806	0.0125	14.40	<.0001
Age (age of the house)	-0.0113	0.0019	-6.09	<.0001
CBD (distance to CBD)	-0.0575	0.0073	-7.93	<.0001
Distance to secondary school	0.0124	0.0052	2.36	0.0184
SEIFA (Adv/Dis)	0.0007	0.0001	6.15	<.0001
% of privately owned dwellings in CD	-0.0016	0.0006	-2.88	0.0040
% of privately not owned/rented dwellings in CD	0.0026	0.0012	2.17	0.0301
% of 3 bedroom houses in CD	-0.0011	0.0003	-3.15	0.0017
% of 5 bedroom houses in CD	0.0034	0.0011	3.03	0.0025
Former public housing (dummy)	-0.1169	0.0197	-5.92	<.0001
Age-squared	0.0001	0.0000	5.40	<.0001
CBD-squared	0.0017	0.0003	5.49	<.0001
Postcode dummies (Base reference: 2615)				
2600	0.4553	0.0333	13.66	<.0001
2602	0.0659	0.0275	2.40	0.0165
2603	0.4636	0.0296	15.68	<.0001
2604	0.2479	0.0268	9.23	<.0001
2605	0.1943	0.0214	9.06	<.0001
2606	0.1154	0.0238	4.85	<.0001
2607	0.1908	0.0165	11.56	<.0001
2611	0.1241	0.0127	9.79	<.0001
2612	0.1459	0.0392	3.72	0.0002
2614	0.0226	0.0171	1.32	0.1862
2617	-0.0248	0.0164	-1.52	0.1296
2902	0.0568	0.0134	4.22	<.0001
2903	0.0991	0.0168	5.90	<.0001
2904	0.0744	0.0166	4.48	<.0001
2905	0.0520	0.0212	2.46	0.0140
2906	0.0634	0.0377	1.68	0.0925
2913	0.0181	0.0180	1.01	0.3145
2914	0.0217	0.0319	0.68	0.4962
Adjusted r-squared	**0.8254**			

D. MODEL WHERE EER WAS TREATED AS A CATEGORICAL VARIABLE

D.1 Parameter estimates of Model 1 using pooled 2005-2006 data

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
Log of deflated house price (dependent variable)				
EER categories (Base reference: EER Star Rating 0 - EER point score lower than -70):				
EER Star Rating 1 (EER point score between -70 and -46 inclusive)	0.0156	0.0050	3.12	0.0018
EER Star Rating 2 (EER point score between -45 and -26 inclusive)	0.0298	0.0059	5.05	<.0001
EER Star Rating 3 (EER point score between -25 and -11 inclusive)	0.0590	0.0075	7.88	<.0001
EER Star Rating 4 (EER point score between -10 and 4 inclusive)	0.0628	0.0086	7.35	<.0001
EER Star 5 and 6 (EER point score above 4)	0.0614	0.0151	4.05	<.0001
Conditioned floor area	0.0028	0.0001	45.60	<.0001
Block area (in log form)	0.1880	0.0091	20.60	<.0001
CBD (distance to CBD)	-0.0559	0.0053	-10.64	<.0001
CBD-squared	0.0017	0.0002	7.36	<.0001
Window space	0.0032	0.0003	9.29	<.0001
SEIFA (advantage/disadvantage)	0.0007	0.0001	8.63	<.0001
Age (age of the house)	-0.0102	0.0013	-7.72	<.0001
Age-squared	0.0001	0.00002	7.36	<.0001
Former public housing (dummy)	-0.0964	0.0157	-6.14	<.0001
% of 5 bedroom houses in CD	0.0040	0.0008	4.80	<.0001
Bathroom and laundry area	0.0018	0.0004	4.36	<.0001
% of 3 bedroom houses in CD	-0.0009	0.0003	-3.47	0.0005
% of privately owned dwellings in CD	-0.0014	0.0004	-3.36	0.0008
% of privately not owned/rented dwellings in CD	0.0017	0.0009	1.91	0.0564
Postcode dummies (Base reference: 2615)				
2600	0.3967	0.0232	17.10	<.0001
2602	0.0660	0.0197	3.35	0.0008
2603	0.4468	0.0216	20.66	<.0001
2604	0.2435	0.0192	12.70	<.0001
2605	0.1877	0.0156	12.02	<.0001
2606	0.1404	0.0168	8.37	<.0001
2607	0.1798	0.0119	15.09	<.0001
2611	0.1076	0.0091	11.77	<.0001
2612	0.1497	0.0285	5.26	<.0001
2614	0.0085	0.0124	0.68	0.4938
2617	-0.0266	0.0115	-2.31	0.0211
2902	0.0533	0.0098	5.43	<.0001

Table D.1 continued

Variable	Parameter estimate	Standard error	t-statistic for Ho:parameter=0	Prob
2903	0.0781	0.0119	6.59	<.0001
2904	0.0658	0.0116	5.66	<.0001
2905	0.0254	0.0148	1.73	0.0845
2906	0.0210	0.0271	0.77	0.4401
2913	0.0039	0.0128	0.30	0.7604
2914	-0.0034	0.0225	-0.15	0.8806
Dummy for 2006	-0.0023	0.0038	-0.61	0.5415
Intercept (constant term)	10.9441	0.1156	94.67	<.0001
F value	**632.16**			
Adjusted R-squared	**0.8246**			
Number of observations	**5104**			