# Hedonic Price-Rent Ratios for Housing: Implications for the Detection of Departures from Equilibrium

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In equilibrium the quality-adjusted price-rent ratio for housing should equal its user cost. Actual median price-rent ratios may be misleading since purchased dwellings on average tend to be of better quality than rented dwellings. Combining house sales and rents data for Sydney, Australia over the period 2001 to 2009 we construct a data set consisting of in excess of 900,000 observations. We then use an innovative hedonic approach to impute a rent for each dwelling sold and a purchase price for each dwelling rented, thus allowing us to compute price-rent ratios at the level of individual dwellings. Using these price-rent ratios, which by construction are quality adjusted, we find that the actual median price-rent ratio is systematically about 8 percent larger than its quality-adjusted counterpart. We also find that for most of our sample the quality-adjusted median price-rent ratio exceeds its equilibrium level derived from the user cost formula. The equilibrium price-rent ratio is itself highly sensitive to the assumed rate of expected capital gains. Our estimate of 21 for the equilibrium price-rent ratio is obtained using the average real capital gain during our sample of 3.4 percent per year. This is high by historical standards, thus suggesting that our equilibrium price-rent ratio may also be too high. An alternative approach is to assume that the housing market is in equilibrium and then use the user-cost formula to impute the expected capital gain. Using this approach we generate an imputed expected real capital gain of about 4.5 percent per year, which is even more implausible. This again indicates that, for at least most of our sample, the price-rent ratio in Sydney was at an unsustainable level. (**JEL.** C43, E01, E31, R31)

**Keywords:** Real estate; Housing market; Hedonic model; Price-rent ratio; User cost; Missing data

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# 1 Introduction

Housing markets seem to be particularly prone to booms and busts. Recent events have also shown how developments in the housing market can impact on the rest of the economy, as a bust in the US housing market precipitated a global financial crisis. It is particularly important therefore that policy makers and other market participants can observe departures from equilibrium in the housing market.

One way of addressing this issue is through comparisons of the price-rent ratio with the reciprocal of the user cost of housing. In equilibrium these terms should be equal. If the price-rent ratio is greater than the reciprocal of user cost, then renting should be relatively more attractive thus implying that the price-rent ratio is too high.[1] Conversely, if the price-rent ratio is lower then buying is more attractive than renting and hence the price-rent ratio is too low.

Empirical implementation of this idea, however, is hampered by the fact that actual price-rent ratios are typically calculated as the ratio of median house price to median rent. The problem with comparing medians is that there is likely to be a quality differential between the median dwelling sold and the median dwelling rented. In particular, it is likely that the median dwelling sold will in most cases be of better quality than the median dwelling rented. The equilibrium condition, by contrast, implicitly assumes that the stated price and rent apply to dwellings of equivalent quality. If in fact the median price refers to a better quality dwelling than does the median rent then a comparison of price-rent ratios with user cost will be biased in favor of finding that the price-rent ratio is above its equilibrium level.

We have two main objectives in this paper. First, we show how quality-adjusted price-rent ratios can be constructed by applying hedonic methods at the level of individual dwellings. Our hedonic approach entails imputing a rental price for each dwelling actually sold in a given year, while simultaneously imputing a sale price for each dwelling

[1] If the price-rent ratio is above its equilibrium level, this does not necessarily imply that house prices are too high. Alternatively, both house prices and rents could be too low, but rents are even further than house prices below their equilibrium level.

rented in that year. In this way we are able to obtain a matched price-rent ratio for every dwelling either sold or rented in a given year. Comparison of these two distributions of price-rent ratios (i.e., one derived from dwellings sold and the other from dwellings rented) also provides an indication of the plausibility of our underlying assumptions. Using in excess of 900,000 price and rent observations for Sydney, Australia over the period 2001-2009 we show that on average the median price-rent ratio is about 8 percent larger than its quality-adjusted counterpart. The difference is even larger (i.e., 9 percent) for the lower quartile, but lower (i.e., 3 percent) for the upper quartile of the price-rent distribution. We also show that for both dwellings sold and rented the price-rent ratio is higher for more expensive dwellings. It follows therefore that the quality-adjustment bias resulting from comparing matched percentiles of the price and rent distributions is more pronounced at the lower end of the market.

Our second objective is to use the user-cost equilibrium condition to check for departures from equilibrium in the Sydney housing market. One problem with the user cost formula is that one of its key components is the expected capital gain, which cannot be directly observed. An estimate can be obtained either by extrapolating from past trends, or implicitly by assuming that the price-rent ratio is in equilibrium. Using the first approach we find that the price-rent ratio in Sydney was above its equilibrium level for most of our sample period, although by June 2008 this gap was largely eliminated. Using the second approach, which assumes the market is in equilibrium, we find that the implied real expected capital gain of 4.5 percent per year is implausibly large, thus again indicating that for at least most of our sample the price-rent ratio is too high.

Our approach of imputing the expected capital gain from the user cost formula also allows us to explore how the expected capital gain differs at the upper and lower ends of the market. We find that the expected capital gain is about half a percentage point higher at the upper quartile than at the lower quartile (when houses are ordered from cheapest to most expensive.

# 2 Price-Rent Ratios and Equilibrium in the Housing Market

The housing market is in equilibrium when the expected annual cost of owner-occupying equals the annual cost of renting. Following Himmelberg, Mayer and Sinai (2005) the equilibrium condition can be written as follows:

$$R_t = u_t P_t, \tag{1}$$

where $R_t$ is the period $t$ rental price, $P_t$ the purchase price and $u_t$ the per dollar user cost. Abstracting from tax deductibility of mortgage interest payments by owner occupiers (which is not possible in most countries), per dollar user cost (henceforth user cost) can be calculated as follows:

$$u_t = r_t + \omega_t + \delta_t - g_{t+1} + \gamma_t, \tag{2}$$

where $r$ denotes the risk-free interest rate, $\omega$ is the property tax rate, $\delta$ the depreciation rate for housing, $g$ is the expected capital gain, and $\gamma$ is the risk premium of owning as opposed to renting. That is, an owner occupier foregoes interest on the market value of the dwelling, incurs property taxes and depreciation, benefits from any capital gains on the dwelling, and incurs risk (mainly due to the inherent uncertainty of future price movements in the housing market).[2] If $R_t > u_t P_t$, owner-occupying becomes more attractive and hence this should exert upward pressure on $P$ and downward pressure on $R$ until equilibrium is restored. The converse argument applies when $R_t < u_t P_t$. Transaction costs might slow the adjustment process but should not affect the equilibrium itself.

Rearranging (1), we obtain that in equilibrium the price-rent ratio should equal the reciprocal of user cost (i.e., $P_t/R_t = 1/u_t$). If the actual price-rent ratio exceeds our estimate of the reciprocal of user cost it follows that the housing market is not in equilibrium.

[2]Renters also incur risks, such as uncertainty over future rents and house prices. There is some debate over the sign of this risk premium.

Practical application of this approach to the housing market requires calculation of the price-rent ratio and user cost. Estimating user cost $u_t$ is not entirely straightforward. Most problematic is the fact that the expected capital gain $g$ is not directly observable. We return to this issue in section 4. Our focus for now, however, is on the estimation of the price-rent ratio $P_t/R_t$. The equilibrium condition (1) implicitly assumes that $P_t$ and $R_t$ are calculated for properties of equivalent quality. Suppose instead that the price $P_t$ refers to dwelling $A$ while the rent $R_t$ refers to dwelling $B$ and that dwelling $A$ is of superior quality to dwelling $B$. In this case, when a household is indifferent between buying and owner-occupying $A$ or renting $B$, we should expect that $R_t < P_t u_t$ and hence that $P_t/R_t > 1/u_t$.

It seems likely that publicly available price-rent ratios, which are typically calculated as the ratio of the median dwelling price to the median rent, suffer from exactly this kind of quality mismatch. The median owner-occupied dwelling is likely to be of superior quality to the median rental dwelling. By implication, observed price-rent ratios calculated from unmatched medians should be higher than matched price-rent ratios, thus introducing a systematic bias into an analysis of the housing market based on comparisons of price-rent ratios and user costs.

In the next two sections, we develop a methodology that can be used to calculate price-rent ratios at the level of individual dwellings. By construction these price-rent ratios are quality-adjusted.

# 3 An Hedonic Approach to Constructing Quality-Adjusted Price-Rent Ratios

## 3.1 The hedonic imputation method

The hedonic method dates back at least to Waugh (1928). Other early contributors include Court (1939) and Stone (1954). It was, however, only after Griliches (1961, 1971) that hedonic methods started to receive serious attention (see Schultze and Mackie

2002 and Triplett 2004). The conceptual basis of the approach was laid down by Lancaster (1966) and Rosen (1974).

An hedonic model regresses the price of a product on a vector of characteristics (whose prices are not independently observed). The hedonic equation is a reduced form equation that is determined by the interaction of supply and demand.

Hedonic methods have been widely used for constructing quality-adjusted price indexes. Three main approaches have been used in the literature. Following the terminology used in Triplett (2004) and Hill (2011), we refer to these as the time-dummy, imputation and characteristics index methods. The time-dummy method estimates an hedonic model for the whole data set that includes time dummy fixed effects. The price index for each period is then obtained directly from these time dummies. The hedonic imputation and characteristic index methods by contrast both estimate a separate hedonic model for each time period. The imputation method then imputes a price for each dwelling in each period from that period's hedonic model, after which the price index can be calculated using a standard price index formula. The characteristics index imputes the price of the same average dwelling in each period again using that period's hedonic model. The estimated price of the average dwelling, in this case, is the price index.[3]

In this paper we focus exclusively on the second approach, i.e., imputation methods. Our main reason for preferring the imputations approach is that it can be easily adapted to deal with the problem of observations in our data set that are missing some characteristics. We return to this issue later.

Imputation methods make use of standard price index formulas. In a housing context, this requires the price of each dwelling in the comparison to be available in both periods being compared. Given that dwellings typically sell only at infrequent and irregular intervals, to make this approach operational it is necessary to impute at least some of the prices. For example, suppose we are trying to measure the change in house prices from 2008 to 2009. We could consider all the dwellings that sold in 2008 and

[3]This brief description brushes over a number of subtleties of each approach.

impute prices for them in 2009. Conversely, we could consider all dwelling sold in 2009 and impute prices for them in 2008. The former is a version of a Laspeyres price index and the latter a version of a Paasche index.

An imputations method obtains these imputed prices from the hedonic model, which is estimated separately for each period using typically a semilog functional form:[4]

$$y_t = X_t\beta_t + u_t, \tag{3}$$

where $y_t$ is an $H_t \times 1$ vector with elements $y_h = \ln p_h$ (where $H_t$ denotes the number of dwellings sold in period $t$), $X_t$ is an $H_t \times C$ matrix of characteristics (some of which may be dummy variables), $\beta_t$ is a $C \times 1$ vector of characteristic shadow prices, and $u_t$ is an $H_t \times 1$ vector of random errors.

The first column in $X$ consists of ones, and hence the first element of $\beta$ is an intercept term. Examples of characteristics include the number of bedrooms, number of bathrooms, land area, and postcode or some other locational identifier. It is possible also to include functions of characteristics (such as land size squared), and interaction terms between characteristics. For example, one might want to interact bedrooms and land area, bathrooms and land area, and bedrooms and bathrooms. Focusing specifically on the last of these, the inclusion of bedroom-bathroom interaction terms could be justified by the fact that the value of an extra bathroom may depend on how many bedrooms there are.

Once the hedonic model has been estimated separately for each year, it is now possible to use it to impute prices for individual dwellings. For example, let $\hat{p}_{th}(x_{sh})$ denote the estimated price in period $t$ of a dwelling $h$ sold in period $s$. This price is imputed by substituting the characteristics of dwelling $h$ into the estimated hedonic model of period $t$ as follows:

$$\hat{p}_{th}(x_{sh}) = \exp(\sum_{c=1}^{C} \hat{\beta}_{ct} x_{csh}),$$

[4]Alternative functional forms, such as linear or Box-Cox transformations, are sometimes also considered. See Diewert (2003) and Malpezzi (2003) for a discussion of some of the advantages of advantages of semilog in an hedonic context.

where $c = 1, \ldots, C$ indexes the set of characteristics included in the hedonic model. A Laspeyres-type hedonic index can now be constructed in one of two ways:

$$\begin{aligned}
\text{L1}: \quad P_{st}^{L1} &= \sum_{h=1}^{H_s} w_{sh} \left[\hat{p}_{th}(x_{sh})/p_{sh}\right] = \sum_{h=1}^{H_s} \hat{p}_{th}(x_{sh}) \Big/ \sum_{h=1}^{H_s} p_{sh} \\
\text{L2}: \quad P_{st}^{L2} &= \sum_{h=1}^{H_s} \hat{w}_{sh} \left[\hat{p}_{th}(x_{sh})/\hat{p}_{sh}(x_{sh})\right] = \sum_{h=1}^{H_s} \hat{p}_{th}(x_{sh}) \Big/ \sum_{h=1}^{H_s} \hat{p}_{sh}(x_{sh}) \, ,
\end{aligned} \tag{4}$$

where $w_{sh}$ and $\hat{w}_{sh}$ denote actual and imputed expenditure shares calculated as follows:

$$w_{sh} = p_{sh}(x_{sh}) / \sum_{m=1}^{H_s} p_{sm}(x_{sm}), \quad \hat{w}_{sh} = \hat{p}_{sh}(x_{sh}) / \sum_{m=1}^{H_s} \hat{p}_{sm}(x_{sm}).$$

In an analogous manner corresponding Paasche-type hedonic indexes can be constructed:

$$\begin{aligned}
\text{P1}: \quad P_{st}^{P1} &= \left\{ \sum_{h=1}^{H_t} w_{th} \left[p_{th}/\hat{p}_{sh}(x_{th})\right]^{-1} \right\}^{-1} = \sum_{h=1}^{H_t} p_{th} \Big/ \sum_{h=1}^{H_t} \hat{p}_{sh}(x_{th}) \\
\text{P2}: \quad P_{st}^{P2} &= \left\{ \sum_{h=1}^{H_t} \hat{w}_{th} \left[\hat{p}_{th}(x_{th})/\hat{p}_{sh}(x_{th})\right]^{-1} \right\}^{-1} = \sum_{h=1}^{H_t} \hat{p}_{th}(x_{th}) \Big/ \sum_{h=1}^{H_t} \hat{p}_{sh}(x_{th}) \, .
\end{aligned} \tag{5}$$

In the hedonic literature L1 and P1 are referred to as single imputation price indexes, and L2 and P2 as double imputation price indexes (see Silver and Heravi 2001, Pakes 2003, de Haan 2004, and Hill and Melser 2008). Actually, in the literature it is typically not made clear whether or not the double imputation method imputes expenditure shares as well. Hence we could distinguish between two double imputation methods, one that imputes expenditure shares and one that does not.[5]

When considering which approach is best, it is useful to focus on the price relatives. A single imputation Laspeyres index uses the price relatives $\hat{p}_{th}(x_{sh})/p_{sh}$, while a double imputation index uses $\hat{p}_{th}(x_{sh})/\hat{p}_{sh}(x_{sh})$. There has been some debate in the literature

[5]We have also simplified matters here by not considering the case of repeat-sales. In any comparison, there are likely to be a small number of dwellings that sell in both periods. These repeat sales could be used as they are or double imputed. One reason for double imputing is for fear that the dwelling may have been renovated (e.g., an extra bathroom added) between sales.

on which approach is best. The discussion focuses primarily on the case of computers. Silver and Heravi (2001), Pakes (2003), de Haan (2004) and Hill and Melser (2008) all argue in favor of double imputation on the grounds that it can reduce omitted variables bias.

In a housing context, consider the case of a dwelling for which $\hat{p}_{sh}(x_{sh}) > p_{sh}$. This means either that the buyer got a bargain or that the dwelling performs poorly on its omitted variables. Assuming that the latter is correct, it follows that $\hat{p}_{th}(x_{sh})$ will overstate the true price of a house with characteristics vector $x_{sh}$ in period $t$. It follows that the price relative $\hat{p}_{th}(x_{sh})/p_{sh}$ will have an upward bias. In contrast, as long as the omitted characteristics are reasonably stable over time, the biases in $\hat{p}_{sh}(x_{sh})$ and $\hat{p}_{th}(x_{sh})$ will partially offset each other in the price relative $\hat{p}_{th}(x_{sh})/\hat{p}_{sh}(x_{sh})$, thus tending to generate a more accurate overall estimate. In a housing context, the assumption of reasonably stable omitted characteristics seems plausible. For example, a dwelling that has a bad floor plan or is located next to a busy road in 2008 will likely still have a bad floor plan or be located next to a busy road in 2009

The use of double imputation is particularly beneficial in cases such as housing where there is likely to be a serious omitted variables problem. This leads us to prefer double imputation over single imputation, even though it implies replacing some real price observations with imputations. We return to this issue later.

To ensure that both periods in each adjacent period comparison are treated symmetrically, one can take the geometric mean of L2 and P2:

$$\text{F2}: \quad P_{st}^{F2} = \sqrt{P_{st}^{L2} \times P_{st}^{L2}} = \sqrt{\frac{\sum_{h=1}^{H_s} \hat{p}_{th}(x_{sh})}{\sum_{h=1}^{H_s} \hat{p}_{sh}(x_{sh})} \times \frac{\sum_{h=1}^{H_t} \hat{p}_{th}(x_{th})}{\sum_{h=1}^{H_t} \hat{p}_{sh}(x_{th})}}. \qquad (6)$$

F2 is a Fisher-type double imputation price index.

## 3.2 Hedonic price-rent ratios for individual dwellings

Here we apply the logic of the hedonic imputation method in a new context. Our objective is to compute a matched price-rent ratio for each individual dwelling. We achieve this by first estimating separate price and rent hedonic models. A price for each dwelling can then be imputed from the hedonic price model, while a rent can be imputed from the hedonic rent model. An important feature of this approach is that the hedonic price and rent models need to be defined on the same set of characteristics.

The hedonic price equation is assumed to take the following form:

$$y_{Pt} = X_{Pt}\beta_{Pt} + u_{Pt}. \tag{7}$$

Similarly, the hedonic rent equation is as follows:

$$y_{Rt} = X_{Rt}\beta_{Rt} + u_{Rt}. \tag{8}$$

A rent for each dwelling $h$ sold in period $t$ is imputed from (8) as follows:

$$\ln \hat{r}_{th} = \sum_{c=1}^{C} \hat{\beta}_{Rch} x_{Pch}. \tag{9}$$

Similarly, a price for each dwelling $j$ rented in period $t$ is imputed from (7) as follows:

$$\ln \hat{p}_{tj} = \sum_{c=1}^{C} \hat{\beta}_{Pcj} x_{Rcj}. \tag{10}$$

We can also use the hedonic rent equation to impute a rent for a dwelling $j$ actually rented in period $t$:

$$\ln \hat{r}_{tj} = \sum_{c=1}^{C} \hat{\beta}_{Rcj} x_{Rcj}, \tag{11}$$

and the hedonic price equation to impute a price for a dwelling $h$ actually sold in period $t$:

$$\ln \hat{p}_{th} = \sum_{c=1}^{C} \hat{\beta}_{Pch} x_{Pch}. \tag{12}$$

It follows that

$$\hat{r}_{th} = \exp\left(\sum_{c=1}^{C} \hat{\beta}_{Rch} x_{Pch}\right),$$

$$\hat{p}_{tj} = \exp\left(\sum_{c=1}^{C} \hat{\beta}_{Pcj} x_{Rcj}\right),$$

$$\hat{r}_{tj} = \exp\left(\sum_{c=1}^{C} \hat{\beta}_{Rcj} x_{Rcj}\right),$$

$$\hat{p}_{tj} = \exp\left(\sum_{c=1}^{C} \hat{\beta}_{Pch} x_{Pch}\right).$$

Using this approach we can generate two alternative matched price-rent ratios for each dwelling $h$ sold in period $t$.[6] A single imputation price-rent ratio $PR(P)_h^{SI}$ divides the actual price at which dwelling $h$ sold by its imputed rent obtained from (9):

$$PR(P)_h^{SI} = \frac{p_{th}}{\hat{r}_{th}(x_{Pch})} = \frac{p_{th}}{\exp\left(\sum_{c=1}^{C} \hat{\beta}_{Rch} x_{Pch}\right)}. \tag{13}$$

A double imputation price-rent ratio $PR(P)_h^{DI}$ divides the imputed price for dwelling $h$ obtained from (12) by its imputed rent obtained from (9):

$$PR(P)_h^{DI} = \frac{\hat{p}_{th}(x_{Pch})}{\hat{r}_{th}(x_{Pch})} = \frac{\exp\left(\sum_{c=1}^{C} \hat{\beta}_{Pch} x_{Pch}\right)}{\exp\left(\sum_{c=1}^{C} \hat{\beta}_{Rch} x_{Pch}\right)}. \tag{14}$$

We can likewise generate two alternative matched price-rent ratios for each dwelling $j$ rented in period $t$. A single imputation price-rent ratio $P - R_j^{SI}$ divides the imputed price for dwelling $j$ obtained from (10) by its actual rent:

$$PR(R)_j^{SI} = \frac{\hat{p}_{tj}(x_{Pcj})}{r_{tj}} = \frac{\exp\left(\sum_{c=1}^{C} \hat{\beta}_{Pcj} x_{Rcj}\right)}{r_{tj}}.$$

A double imputation price-rent ratio $PR(R)_j^{DI}$ divides the imputed price for dwelling $j$ obtained from (10) by its imputed rent obtained from (11):

$$PR(R)_j^{DI} = \frac{\hat{p}_{tj}(x_{Rcj})}{\hat{r}_{tj}(x_{Rcj})} = \frac{\exp\left(\sum_{c=1}^{C} \hat{\beta}_{Pcj} x_{Rcj}\right)}{\exp\left(\sum_{c=1}^{C} \hat{\beta}_{Rcj} x_{Rcj}\right)}.$$

## 3.3 Median and quartile matched price-rent ratios

Our preferred median price-rent ratio is obtained from the double-imputation results. This can be calculated in one of two ways. First, let $Med[PR(P)^{DI}]$ denote the median price-rent ratio derived from the double-imputation price-rent distribution defined on the dwellings actually sold, while $Med[PR(R)^{DI}]$ denotes the corresponding median

[6]Strictly speaking, $\hat{r}$ and $\hat{p}$ are biased estimates of $r$ and $p$ since by exponentiating we are taking a nonlinear transformation of a random variable. Possible corrections have been proposed by Goldberger 1968, Kennedy 1981 and Giles 1982. From our experience, however, these corrections are typically small, and at least partially offsetting under double imputation (see below) in their impact on the price-rent ratio. Hence we ignore them here.

price-rent ratio defined on the dwellings actually rented. One way of calculating the overall median is to average these two population specific medians as follows:

$$Med[PR_{ave}^{DI}] = \sqrt{Med[PR(P)^{DI}] \times Med[PR(R)^{DI}]}.$$

An alternative approach is to first pool the price-rent distributions defined on dwellings actually sold and rented and then calculate the median.

$$Med[PR_{pool}^{DI}] = Med[PR(P)^{DI}, PR(R)^{DI}]$$

Intuitively, we prefer the former approach (i.e. averaging rather than pooling) since it gives equal weight to both data sets. Empirically the averaged and pooled medians for our data set are very similar. A similar approach can be applied to any other quantile of the price-rent distribution. We also consider the lower and upper quartiles.

# 4 Empirical Strategy and Data Sets

## 4.1 The hedonic price and rental data sets

The data set used here is for Australia's largest city, Sydney, over the period 2001 to 2009. It is assembled from three sources. Although we also have data for units, here we focus exclusively on houses.[7] The data set on actual transaction prices for individual dwellings in Sydney is obtained from Australian Property Monitors (APM). It consists of a total of 401,063 observations over the 2001 to 2009 period. The characteristics included in the data set are the transaction price, exact date of sale, land area, number of bedrooms, number of bathrooms, exact address and a postcode identifier. The rental data set is obtained by combining rental data from APM (of which we have 137,240 observations) with data from the New South Wales Department of Housing (of which

[7] We do this for two reasons. First, floor space is not one of the characteristics available in our data set. We do, however, have land area. The problem is that this is only relevant for houses. The land area data we have for units is for the strata, which is not of much use in a hedonic context. Second, houses and units are probably too different to combine in one model (for example through the inclusion of a units dummy).

we have 367,024 observations that are not also in the APM data set). In total therefore we have 504,264 rental observations. The rent recorded is that for new rental contracts. The characteristics in the APM rental data set are identical to those in the sales data set. However, the New South Wales Department of Housing data set has only the following characteristics: transaction price, exact date of sale, number of bedrooms, exact address and a postcode identifier. By matching addresses in the New South Wales Department of Housing data set with those in the APM price and rental data sets it was possible to obtain the missing land area and number of bathrooms characteristics for some observations.

Before proceeding with estimation of our hedonic models we removed some outliers. The main justification for removing outliers is due to the presence of data-entry errors, which are concentrated in the tails of the characteristic distributions. Outliers were deleted according to the follow9ing rules:

Land areas less than 100 square meters or greater than 10,000 were deleted. These thresholds corresponded to the 1.2 and 99.0 percentiles in the price data set and the 1.6 and 98.3 percentiles in the rental data set.

Prices less than $100,000 and greater than $3,000,000 (corresponding to the 0.82 and 98.7 percentiles) and rents less than $100 or greater than $2000 per week (corresponding to the 0.67 and 99.4 percentiles) were deleted.

Bedrooms greater than 6 and bathrooms greater than 6 (corresponding to the 99.67 and 99.95 percentiles in the price data and 99.96 and 99.99 in the rent data) were deleted.

One problem with our data set is that one or more of the characteristics are missing for many of the observations. The exact figures are given in Table 1. In particular, all the characteristics are available for 62.2 percent of the price data and for 38.1 percent of the rent data. For the remainder, at least one of land area, number of bedrooms and number of bathrooms is missing. We explain below how we deal with this problem.

**Insert Table 1 Here**

## 4.2 Imputing prices and rents for dwellings with missing characteristics

The problem of missing characteristics can be dealt with by estimating a number of different versions of our basic hedonic price and rent equations. This allows the price and rent for each dwelling to be imputed from an hedonic equation that is tailored to its particular mix of available characteristics. More specifically, focusing on the the case of the hedonic price equation, we estimate the following eight hedonic models (HM1,...,HM8) for each year in our data set:

(HM1): ln price = f(quarter dummy, land area, num bedrooms, num bathrooms, postcode)

(HM2): ln price = f(quarter dummy, num bedrooms, num bathrooms, postcode)

(HM3): ln price = f(quarter dummy, land area, num bathrooms, postcode)

(HM4): ln price = f(quarter dummy, land area, num bedrooms, postcode)

(HM5): ln price = f(quarter dummy, num bathrooms, postcode)

(HM6): ln price = f(quarter dummy, num bedrooms, postcode)

(HM7): ln price = f(quarter dummy, land area, postcode)

(HM8): ln price = f(quarter dummy, postcode)

Each of these eight models is estimated using all the available data that has at least these characteristics. For example, a dwelling for which land area, number of bedrooms and number of bathrooms are all available is included in all eight regressions. A dwelling that is missing the land area is included only in HM2, HM5, HM6, and HM8. A dwelling that is missing land area and number of bathrooms is included only in HM6 and HM8, etc. Also, some interaction terms between land area, number of bedrooms and number of bathrooms are included in models HM1-HM4.

The imputed price for each dwelling that is entered into (13) and (14), however, is only taken from the equation that exactly matches its list of available characteristics. This means that a dwelling for which all characteristics are available will have its price imputed from HM1. A dwelling that is missing only land area will have its price imputed from HM2. A dwelling missing land area and number of bathrooms will have its price imputed from HM6, etc.

The imputed rents are obtained in an analogous manner from eight versions of the hedonic rent equation.

## 4.3 Calculating user cost

Our user cost equation in (2) contains the following variables:[8]

$r$ – the risk-free interest rate;

$\omega$ – the land tax rate;

$\delta$ – the depreciation rate for housing;

$g$ – the expected nominal capital gain;

$\gamma$ – the risk premium of owning as opposed to renting.

We use the following values for these parameters.

$r = 5.6$ percent

This is the average 10 year interest rate over the 2001 to 2009 period (Source: Reserve Bank of Australia)

$\omega = 1.0$ percent

This is an estimate for an average land tax over the 2001-2009 period. (Source: Office of State Revenue, New South Wales, Australia)

$\delta = 2.5$ percent

This is the depreciation rate assumed by Himmelberg, Mayer and Sinai (2005)

$g = 6.4$ percent

This is the average rate of annual increase in the Australian Bureau of Statistics (ABS) Established House Price Index for Sydney over the period 2001-2009.[9] The expected

[8] Mortgage interest payments are not tax deductible for owner-occupiers in Australia.

[9] The ABS changed slightly the methodology it used to compute its Established Houses Price Index in 2005. Results based on the new methodology are only available from 2002 onwards, while results based on the old methodology are only available up to 2005. To obtain a series covering the period 1991 to 2009 we splice the two series together.

nominal capital gain $g$ can be decomposed into the sum of the expected real capital gain and expected inflation. We assume here that the expected inflation rate is 3.0 percent.[10] Hence the expected real capital gain is 3.4 percent.

$\gamma = 2.0$ percent

This is the risk premium assumed by Himmelberg, Mayer and Sinai (2005).

Inserting these values into (2) yields the result: $u = 0.047$. Taking the reciprocal, we obtain an equilibrium price-rent ratio of 21.28.

Given that the land tax ($\omega$), the depreciation rate ($\delta$), and the risk premium ($\gamma$) should all have remained more or less constant over our sample period, any variations in the equilibrium price-rent ratio should have been driven by changes in either the interest rate ($r$) or the expected capital gain ($g$). The ten-year interest rate has fluctuated between 4.1 and 6.6 percent between 2001 to 2009 period, while the annual capital gain ranged between -6.7 percent and 20.0 percent. This suggests that $g$ may have fluctuated rather more than $r$ during our sample, and hence been primarily responsible for any changes in the equilibrium price-rent ratio. However, given that $g$ is not directly observable, it is difficult to infer how $g$ may have changed over time. We return to this issue shortly.

# 5 Empirical Results

## 5.1 The estimated hedonic models

We estimate our eight versions of the price and rent hedonic models HM1-HM8 separately for each of the 9 years in our data set. The adjusted R-squared coefficients for each of our hedonic models HM1-HM8 for each year are shown in Table 2. The adjusted R-squared coefficients range between 0.71 and 0.82 for HM1, while for HM8 (where the only explanatory variables are the quarter and postcode) the adjusted R-squared coefficients range between 0.55 and 0.68.

[10] This is the average CPI inflation rate over the 2001-2009 period. Source: Reserve Bank of Australia).

**Insert Table 2 Here**

The estimated parameters and associated t-statistics for HM1 in 2009 for the price and rent data are shown in Table 3. The functional form of the hedonic model for both the price and rent data is semilog with the following explanatory variables:[11]

q2 = dummy variable for second quarter

q3 = dummy variable for third quarter

q4 = dummy variable for fourth quarter

bed2 = dummy variable for 2 bedrooms

bed3 = dummy variable for 3 bedrooms

bed4 = dummy variable for 4 or more bedrooms

bath2 = dummy variable for 2 bathrooms

bath3 = dummy variable for 3 bathrooms

bath4 = dummy variable for 4 or more bathrooms

land = land area in square meters divided by 1000

landsq = land squared

bed2land = land area in square meters divided by 1000 for houses with 2 bedrooms

bed3land = land area in square meters divided by 1000 for houses with 3 bedrooms

bed4land = land area in square meters divided by 1000 for houses with 4 bedrooms

bath2land = land area in square meters divided by 1000 for houses with 2 bathrooms

bath3land = land area in square meters divided by 1000 for houses with 3 bathrooms

bath4land = land area in square meters divided by 1000 for houses with 4 bathrooms

bed2bath2 = dummy variable for houses with 2 bedrooms and 2 bathrooms

bed3bath2 = dummy variable for houses with 3 bedrooms and 2 bathrooms

bed3bath3 = dummy variable for houses with 3 bedrooms and 3 bathrooms

PCxxxx = dummy variable for postcode PCxxxx (Note: there are 239 postcodes in our data set)

The choice of which interaction terms to include was determined largely by the data.

[11] The base quarter is the first quarter, the base number of bedrooms and bathrooms is 1, and the base postcode is PC2010.

For example, we did not interact 2 bedrooms with 3 bathrooms since such a combination is hardly observed in the data set. Most of the parameters in Table 3 are significant at the 5 percent level. One disadvantage of including interaction terms is that it makes it hard to interpret the signs of the estimated parameters. R-squared coefficients of 0.82 and 0.78 for the price and rent equations respectively indicate that our hedonic model does a reasonable job at explaining house prices.[12]

**Insert Table 3 Here**

## 5.2 Quality-adjustment bias in median and quartile price-rent ratios

Raw and quality adjusted price-rent ratios for the lower quartile, median and upper quartile (as measured from the raw price-rent ratios) for each of the 36 quarters in our data set are shown in Table 4. As expected, the raw price-rent ratios are systematically larger than their quality adjusted counterparts, thus indicating that on average owner-occupied dwellings are of higher quality than rented dwellings. The raw price-rent ratio on average is 8.9 percent larger for the lower quartile, 7.8 percent larger for the median and 2.9 percent larger for the upper quartile.[13] This implies that the smaller is the raw price-rent ratio the larger, in percentage terms, is the quality adjustment bias. Overall, though, our best estimate is that sold dwellings are on average of 7.8 percent better quality than rented dwellings.

**Insert Table 4 Here**

These results seem to be reasonably stable over the first 30 quarters. However, there is a dramatic change in the last six quarters. The magnitude of the quality-adjustment bias for the median falls in the second half of 2008, and then reverses

[12]A key for the 239 postcodes in Table 3 can be found at ≪http://auspost.com.au/products-and-services/download-postcode-data.html≫.

[13]The quality difference may in fact be larger than this, since owner-occupied dwellings may be better maintained than their rented counterparts. The state of maintenance, however, is an omitted variable in our hedonic model.

direction in 2009 before reversing back again in the last quarter. For the upper quartile the reversal of direction happens in the middle of 2008, while for the lower quartile there is no reversal even in 2009. The simplest explanation for this finding is probably a fall in the average quality of dwellings sold during the financial crisis (which admittedly did not affect Australia as much as many other OECD countries), perhaps caused by an increase in the number of distressed sales.

The relationship between price, rent and the quality-adjusted price-rent ratio is shown in Table 5. To construct Table 5, all dwellings sold in each quarter were first ordered from cheapest to most expensive by price. The lower quartile, median and upper quartile dwellings by price were then identified. Table 5 then shows the corresponding quality-adjusted price-rent ratios for each of these dwellings. The same exercise is then repeated for all dwellings rented, with the dwellings ordered from cheapest to most expensive by rent. From Table 5 it can be seen that, while the difference is not huge, the quality-adjusted price-rent ratio is systematically higher for more expensive dwellings.

**Insert Table 5 Here**

## 5.3 Actual versus equilibrium price-rent ratios

From Table 4 it can be seen that the median quality-adjusted price-rent ratio ranges between 21.2 and 34.3 over the period 2001 to 2009, while our estimated equilibrium price-rent ratio from section 4.3 is 21.3. Our results therefore suggest that the actual price-rent ratio was above its equilibrium level in every quarter in our sample except for March 2009. The price-rent ratio peaked in December 2003 at a level more than 50 percent above its equilibrium level. Thereafter it gradually fell back to its equilibrium level. One implication of quality-adjusting the median price-rent ratio, therefore, is that the extent of the perceived departure of the Sydney housing market from equilibrium is smaller than it otherwise would have been.

Allowing the expected interest rate to vary between the extreme actual 10 year interest-rates of 4.1 and 6.6 percent observed in our nine year sample period causes the equilibrium price-rent ratio to vary from 17.5 to 31.3 (with the lowest expected interest rate generating the highest equilibrium price-rent ratio). Generally, interest rates tend to fall when confidence (and hence expected capital gains) are low. Hence movements in the 10 year interest rate and expected capital gains should tend to partially offset each other in terms of their impact on the equilibrium price-rent ratio, with movements in the latter dominating. In other words, the equilibrium price-rent ratio in practice may well be procyclical with interest rates.

The modelling of expected capital gains, therefore, is crucial to the calculation of the equilibrium price-rent ratio. Using the ABS Established Houses Price Index for Sydney as a benchmark, suppose that the expected capital gain is equal to the average change in the index over the preceding two years. This calculation generates an expected capital gain that ranges between +19.1 percent in 2003 and -4.5 percent in 2006. Holding all other parameters fixed in the user cost formula (and with the interest rate again at 5.6 percent) an expected capital gain of 19.1 percent generates an infinite equilibrium price-rent ratio. This is because when the expect capital gain exceeds $r_t + \omega_t + \delta_t + \gamma_t$, which in this case equals 0.11, then the user cost becomes negative. By contrast, when the expected capital gain is -4.5 percent, the equilibrium price-rent ratio is 6.4. In other words, by varying the expected capital gain between -4.5 percent and +11.1 percent (let alone +19.1 percent) we can achieve an equilibrium price-rent ratio lying anywhere between 6.4 and infinity.

The fact that the expected capital gain cannot be directly measured and may be volatile, therefore, undermines the practical usefulness of the equilibrium price-rent ratio concept. An alternative and perhaps more illuminating approach is to assume that the housing market is in equilibrium and then derive the implied expected capital gain from the user cost equilibrium condition. This is what we now attempt to do.

## 5.4 Imputed expected capital gains assuming housing market is in equilibrium

Rearranging the user cost formula in (2) and imposing the equilibrium condition in (1) yields the following:

$$g_{t+1} = r_t + \omega_t + \delta_t + \gamma_t - \frac{R_t}{P_t}.$$

Setting $R_t/P_t$ equal to the reciprocal of the median quality-adjusted price-rent ratio and substituting the same parameter values for $r_t$, $\omega_t$, $\delta_t$ and $\gamma_t$ used previously, we generate the expected capital gain series shown in Table 6. The imputed expected capital gains in Table 6 range from 6.4 to 8.2 percent per year, with an average value of 7.4 percent. If the median price-rent ratio is not quality adjusted, the impled range broadens to 6.1 to 8.4 percent per year.

**Insert Table 6 Here**

Some insight into the speed at which expected capital gains can adjust is provided by Case and Shiller's (2006) surveys of individuals in US cities. For example, Shiller (2007) describes how the median expected capital gain in Los Angeles was 10 percent in 2003, 5 percent in 2006 and then 0 percent in 2007 (as house prices began to fall). This suggests that households may be extrapolating over relatively short time horizons when calculating expected capital gains (such as the average capital gain over the preceding two years), as witnessed by the quite rapid decline in expected capital gains in Los Angeles as boom turned to bust.

Our results perhaps indicate a greater degree of inertia in expected capital gains. House prices in Sydney fluctuated quite a bit over our sample period, with peaks in December 2003, December 2007, and December 2009 (the last date in our sample), and troughs in March 2006 and March 2009. Furthermore, prices rose strongly over the period 1992 to 2003. The average capital gain per year over this period was 9.3 percent per year, with the annual rate accelerating to a peak of 25 percent in June 2002. Assuming a slight lag in expectations, this may explain why the actual quality-adjusted price-rent ratio peaked in December 2003.

While an expected capital gain of 7.4 percent is a full percentage point higher than the actual average capital gain over our sample period of 6.4 percent, it is perhaps not surprising that extrapolating households should upgrade their expectations slightly in light of the strong performance of housing in the 9 years preceding the start of our sample.

Extrapolation, however, is not necessarily a good way of forming expectations. So while our imputed expected capital gains in Table 6 might provide plausible estimates of what households were actually thinking, this does not mean that their expectations were realistic. In particular, going forward, is it reasonable to continue assuming expected annual capital gains of 7.5 percent (or even 6.4 percent) for Sydney? The answer is possibly although probably not. Given average inflation of 3 percent, this implies real capital gains of 4.5 percent per year. By comparison, Gyourko, Mayer and Sinai (2006) find that the average annual real capital gain for the 50 cities in their sample over the period 1950 to 2000 was 1.7 percent, with the highest result of 3.5 percent being observed for San Francisco. There are in fact a number of similarities between San Francisco and Sydney, ranging from desirable coastal locations and scarcity of land to population growth. Nevertheless, it is hard to believe that Sydney can sustain a real capital gain of 4.5 percent per year.

## 5.5 Imputed expected capital gains for different market segments

It was noted earlier that the quality-adjusted price-rent ratio is higher at the upper end of the market than at the lower end. Taking the price-rent ratios of the lower quartile, median and upper quartiles of the price and rent distributions in Table 5, and inserting these into the user cost formula we can derive imputed expected capital gains for these segments of the market. The results are shown in Table 7. The average imputed expected capital gain for the lower quartile for dwellings ordered by selling price is 7.2, rising to 7.4 for the median and 7.6 for the upper quartile. The exercise is repeated in Table 7 for rented dwellings that have been ordered by rental price. To the first decimal place the results averaged across the 36 quarters are identical to those obtained from the price data set.

**Insert Table 7**

Households in Sydney therefore seem to expect slightly higher capital gains for the upper end of the market than they do for the lower end. It would be interesting to see whether the same pattern emerges for other cities.

# 6 Conclusion

Failure to quality-adjust median price-rent ratios may cause the housing market to appear to be further from its equilibrium level than it actually is. We estimate the quality-adjustment bias to be about 8 percent for Sydney. Even after quality adjusting we still find that the price-rent ratio in Sydney was above its equilibrium level from 2001 to 2007, although in 2008 and 2009 this was no longer the case. These types of comparisons, however, are inherently problematic since the equilibrium price-rent level, which is derived from the user cost formula, depends critically on the expected capital gain which is not directly observable. A more promising approach, therefore, may be to assume the housing market is in equilibrium and then derive the expected capital gain implicitly. Using this approach we find that the expected capital gain in Sydney is implausibly high. While this may not preclude the market being in equilibrium given the prevailing expectations, it suggests that these expectations are unrealistic and hence not sustainable.

# References

Case K. E., and R. J. Shiller (2006), "Home Buyer Survey Results 1988-2006," Unpublished Paper, Yale University.

Court A. T. (1939), "Hedonic Price Indexes with Automotive Examples," in *The Dy-*

*namics of Automobile Demand*. The General Motors Corporation, New York, 99-117.

de Haan J. (2004), "Direct and Indirect Time Dummy Approaches to Hedonic Price Measurement," *Journal of Economic and Social Measurement* 29(4), 427-443.

Diewert W. E. (2003), "Hedonic Regressions: A Review of Some Unresolved Issues," Mimeo.

Goldberger A. S. (1968), "The Interpretation and Estimation of Cobb-Douglas Functions." *Econometrica* 35, 464-472.

Griliches Z. (1961), "Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change," in *The Price Statistics of the Federal Government*, G. Stigler (chairman). Washington D.C.: Government Printing Office.

Griliches Z. (1971), "Introduction: Hedonic Price Indexes Revisited," in Z. Griliches (ed), *Price Indexes and Quality Change*, 3-15. Cambridge MA: Harvard University Press.

Gyourko J., C. Mayer and T. Sinai (2006), "Superstar Cities," NBER Working Paper 12355.

Hill R. J. (2011), Hedonic Price Indexes for Housing, Statistics Directorate Working Paper No. 36, OECD, Paris.
≪http://www.oecd.org/officialdocuments/displaydocumentpdf/?cote=std/doc(2011)1/REV1&doclanguage=en≫

Hill R. J. and D. Melser (2008), "Hedonic Imputation and the Price Index Problem: An Application to Housing," *Economic Inquiry* 46(4), 593-609.

Himmelberg C., C. Mayer and T. Sinai (2005), "Assessing High House Prices: Bubbles, Fundamentals and Misperceptions," *Journal of Economic Perspectives* 19(4), 67-92.

Kennedy P. E. (1981), "Estimation with Correctly Interpreted Dummy Variables in Semilogarithmic Equations." *American Economic Review* 71 (4), 801.

Lancaster K. J. (1966), A New Approach to Consumer Theory, *Journal of Political Economy* 74, 13257.

Malpezzi S. (2003), "Hedonic Pricing Models: A Selective and Applied Review," in A. OSullivan and K. Gibb (eds.) *Housing Economics: Essays in Honor of Duncan Maclennan*, 67-89. Blackwell: Malder MA.

Pakes A. (2003), "A Reconsideration of Hedonic Price Indices with an Application to PC's," *American Economic Review* 93(5), 1578-1596.

Rosen S. (1974), "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition," *Journal of Political Economy* 82(1), 34-55.

Schultze C. S., and C. Mackie (2002), At What Price? Conceptualizing and Measuring Cost-of-Living and Price Indexes, in *Panel on Conceptual, Measurement, and Other Statistical Issues in Developing Cost-of- Living Indexes.* Committee on National Statistics, Division of Behavioral and Social Sciences and Education. Washington, DC, National Academy Press.

Shiller R. J. (2007), "Understanding Recent Trends in House Prices and Home Ownership," Cowles Foundation Discussion Paper No. 1630.

Silver M. and S. Heravi (2001), "Quality Adjustment, Sample Rotation and CPI Practice: An Experiment," presented at the Sixth Meeting of the International Working Group on Price Indices, Canberra, Australia, April 2-6.

Stone R. (1954), *The Measurement of Consumer Behaviour and Expenditure in the United Kingdom, 1920 1938*, Vol.1, Studies in the National Income and Expenditure of the United Kingdom (assisted by D. R. Rowe, W. J. Corlett, R. Hurstfield, and M. Potter). Cambridge: Cambridge University Press.

Triplett J. E. (2004), *Handbook on Hedonic Indexes and Quality Adjustments in Price Indexes: Special Application to Information Technology Products*, STI Working Paper 2004/9, Directorate for Science, Technology and Industry, Organisation for Economic Co-operation and Development, Paris.

Waugh F. V. (1928), “Quality Factors Influencing Vegetable Prices,” *Journal of Farm Economics* 10, April, 185-196.

## Table 1. Percentage of Observations with these Characteristics

| **Price Data** | |
|---|---|
| Land area, num beds and num baths | 62.16 |
| Num beds and num baths | 62.95 |
| Land area and num baths | 62.16 |
| Land area and num beds | 73.72 |
| Num baths | 62.95 |
| Num beds and num baths | 74.72 |
| Land area | 98.26 |

| **Rent Data** | |
|---|---|
| Land area, num beds and num baths | 38.05 |
| Num beds and num baths | 41.12 |
| Land area and num baths | 38.05 |
| Land area and num beds | 39.80 |
| Num baths | 41.12 |
| Num beds and num baths | 91.36 |
| Land area | 39.83 |

## Table 2. Adjusted R-Squared for Our Eight Hedonic Models

**(a) Price Data**

| Year | HM1 | HM2 | HM3 | HM4 | HM5 | HM6 | HM7 | HM8 |
|---|---|---|---|---|---|---|---|---|
| 2001 | 0.77 | 0.75 | 0.77 | 0.70 | 0.75 | 0.71 | 0.74 | 0.66 |
| 2002 | 0.76 | 0.72 | 0.76 | 0.67 | 0.73 | 0.69 | 0.72 | 0.63 |
| 2003 | 0.74 | 0.71 | 0.73 | 0.64 | 0.70 | 0.67 | 0.70 | 0.60 |
| 2004 | 0.71 | 0.68 | 0.70 | 0.60 | 0.68 | 0.64 | 0.67 | 0.55 |
| 2005 | 0.76 | 0.72 | 0.75 | 0.64 | 0.74 | 0.69 | 0.72 | 0.60 |
| 2006 | 0.78 | 0.74 | 0.76 | 0.65 | 0.76 | 0.72 | 0.74 | 0.61 |
| 2007 | 0.80 | 0.77 | 0.77 | 0.68 | 0.80 | 0.77 | 0.77 | 0.68 |
| 2008 | 0.82 | 0.80 | 0.79 | 0.68 | 0.82 | 0.79 | 0.79 | 0.67 |
| 2009 | 0.82 | 0.79 | 0.79 | 0.69 | 0.81 | 0.78 | 0.78 | 0.68 |

**(b) Rent Data**

| Year | HM1 | HM2 | HM3 | HM4 | HM5 | HM6 | HM7 | HM8 |
|---|---|---|---|---|---|---|---|---|
| 2001 | 0.71 | 0.69 | 0.68 | 0.66 | 0.70 | 0.69 | 0.68 | 0.62 |
| 2002 | 0.70 | 0.69 | 0.68 | 0.66 | 0.70 | 0.67 | 0.68 | 0.61 |
| 2003 | 0.73 | 0.71 | 0.70 | 0.66 | 0.70 | 0.67 | 0.68 | 0.61 |
| 2004 | 0.72 | 0.69 | 0.70 | 0.66 | 0.72 | 0.68 | 0.70 | 0.61 |
| 2005 | 0.71 | 0.69 | 0.69 | 0.64 | 0.71 | 0.68 | 0.69 | 0.60 |
| 2006 | 0.72 | 0.70 | 0.70 | 0.65 | 0.72 | 0.69 | 0.70 | 0.60 |
| 2007 | 0.78 | 0.74 | 0.73 | 0.63 | 0.78 | 0.73 | 0.73 | 0.61 |
| 2008 | 0.79 | 0.76 | 0.74 | 0.64 | 0.79 | 0.74 | 0.73 | 0.62 |
| 2009 | 0.78 | 0.75 | 0.73 | 0.64 | 0.79 | 0.73 | 0.72 | 0.61 |

# Table 3. Estimated Hedonic Models for HM1 in 2009

## (a) Price Data

| | | | |
|---|---|---|---|
| Number of observations: | 56541 | R-Square: | 0.8171 |
| F statistic: | 970.95 | Adj R-Square: | 0.8163 |

| Variable | Parameter Estimate | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|
| Intercept | 13.38843 | 0.02640 | 507.07 | <.0001 |
| qt34 | 0.03475 | 0.00280 | 12.39 | <.0001 |
| qt35 | 0.06153 | 0.00276 | 22.32 | <.0001 |
| qt36 | 0.09978 | 0.00286 | 34.87 | <.0001 |
| bn2 | 0.14709 | 0.01490 | 9.87 | <.0001 |
| bn3 | 0.28272 | 0.01467 | 19.28 | <.0001 |
| bn4 | 0.33756 | 0.01530 | 22.06 | <.0001 |
| bt2 | 0.15393 | 0.00511 | 30.11 | <.0001 |
| bt3 | 0.32397 | 0.00650 | 49.80 | <.0001 |
| bt4 | 0.45499 | 0.01508 | 30.17 | <.0001 |
| dt2area3 | -0.03113 | 0.00772 | -4.03 | <.0001 |
| dt2area32 | -0.00049721 | 0.00039750 | -1.25 | 0.2110 |
| bn2area3 | -0.00187 | 0.00742 | -0.25 | 0.8005 |
| bn3area3 | 0.01550 | 0.00739 | 2.10 | 0.0358 |
| bn4area3 | 0.09607 | 0.00791 | 12.15 | <.0001 |
| bt2area3 | -0.01256 | 0.00225 | -5.59 | <.0001 |
| bt3area3 | -0.00413 | 0.00451 | -0.92 | 0.3599 |
| bt4area3 | 0.06522 | 0.01272 | 5.13 | <.0001 |
| bn2bt2 | -0.10483 | 0.00937 | -11.19 | <.0001 |
| bn3bt2 | -0.06085 | 0.00568 | -10.72 | <.0001 |
| bn3bt3 | -0.10722 | 0.01050 | -10.21 | <.0001 |
| pc2000 | -0.00448 | 0.06349 | -0.07 | 0.9437 |
| pc2007 | -0.08315 | 0.08430 | -0.99 | 0.3240 |
| pc2008 | -0.14949 | 0.04238 | -3.53 | 0.0004 |
| pc2009 | -0.09603 | 0.07031 | -1.37 | 0.1720 |
| pc2011 | 0.12793 | 0.05872 | 2.18 | 0.0294 |
| pc2015 | -0.21409 | 0.03104 | -6.90 | <.0001 |
| pc2016 | -0.07227 | 0.03469 | -2.08 | 0.0372 |
| pc2017 | -0.33464 | 0.04136 | -8.09 | <.0001 |
| pc2018 | -0.28274 | 0.03160 | -8.95 | <.0001 |
| pc2019 | -0.35322 | 0.03242 | -10.90 | <.0001 |
| pc2020 | -0.36746 | 0.03138 | -11.71 | <.0001 |
| pc2021 | 0.34738 | 0.02710 | 12.82 | <.0001 |
| pc2022 | 0.26761 | 0.03093 | 8.65 | <.0001 |
| pc2023 | 0.43783 | 0.04241 | 10.32 | <.0001 |
| pc2024 | 0.34716 | 0.03105 | 11.18 | <.0001 |
| pc2025 | 0.45932 | 0.03238 | 14.18 | <.0001 |
| pc2026 | 0.37299 | 0.02700 | 13.82 | <.0001 |
| pc2027 | 0.32023 | 0.05615 | 5.70 | <.0001 |
| pc2028 | 0.65951 | 0.05207 | 12.67 | <.0001 |
| pc2029 | 0.39750 | 0.03396 | 11.71 | <.0001 |
| pc2030 | 0.49178 | 0.03240 | 15.18 | <.0001 |
| pc2031 | 0.23878 | 0.02680 | 8.91 | <.0001 |
| pc2032 | 0.02981 | 0.03020 | 0.99 | 0.3237 |

| | | | | |
|---|---|---|---|---|
| pc2033 | 0.16522 | 0.03856 | 4.28 | <.0001 |
| pc2034 | 0.28282 | 0.03331 | 8.49 | <.0001 |
| pc2035 | -0.03994 | 0.02610 | -1.53 | 0.1260 |
| pc2036 | -0.11239 | 0.02826 | -3.98 | <.0001 |
| pc2037 | -0.01510 | 0.03019 | -0.50 | 0.6171 |
| pc2038 | 0.01466 | 0.02914 | 0.50 | 0.6150 |
| pc2039 | -0.02780 | 0.02899 | -0.96 | 0.3376 |
| pc2040 | -0.16984 | 0.02533 | -6.71 | <.0001 |
| pc2041 | 0.13475 | 0.02704 | 4.98 | <.0001 |
| pc2042 | -0.19371 | 0.02699 | -7.18 | <.0001 |
| pc2043 | -0.20541 | 0.03552 | -5.78 | <.0001 |
| pc2044 | -0.42684 | 0.02860 | -14.92 | <.0001 |
| pc2045 | 0.08978 | 0.03812 | 2.36 | 0.0185 |
| pc2046 | -0.03528 | 0.02641 | -1.34 | 0.1816 |
| pc2047 | 0.09475 | 0.03052 | 3.10 | 0.0019 |
| pc2048 | -0.16481 | 0.03254 | -5.07 | <.0001 |
| pc2049 | -0.25358 | 0.03063 | -8.28 | <.0001 |
| pc2050 | -0.16644 | 0.03747 | -4.44 | <.0001 |
| pc2060 | 0.11895 | 0.03331 | 3.57 | 0.0004 |
| pc2061 | 0.24614 | 0.08973 | 2.74 | 0.0061 |
| pc2062 | 0.20552 | 0.03373 | 6.09 | <.0001 |
| pc2063 | 0.32823 | 0.03323 | 9.88 | <.0001 |
| pc2064 | 0.08216 | 0.03573 | 2.30 | 0.0215 |
| pc2065 | 0.07619 | 0.02671 | 2.85 | 0.0043 |
| pc2066 | 0.06939 | 0.02550 | 2.72 | 0.0065 |
| pc2067 | 0.05837 | 0.02821 | 2.07 | 0.0385 |
| pc2068 | 0.15148 | 0.02625 | 5.77 | <.0001 |
| pc2069 | 0.17156 | 0.02670 | 6.43 | <.0001 |
| pc2070 | 0.18266 | 0.02811 | 6.50 | <.0001 |
| pc2071 | 0.09010 | 0.02839 | 3.17 | 0.0015 |
| pc2072 | 0.05549 | 0.03264 | 1.70 | 0.0891 |
| pc2073 | -0.05740 | 0.02629 | -2.18 | 0.0290 |
| pc2074 | -0.17733 | 0.02582 | -6.87 | <.0001 |
| pc2075 | -0.20357 | 0.02594 | -7.85 | <.0001 |
| pc2076 | -0.22967 | 0.02520 | -9.11 | <.0001 |
| pc2077 | -0.51480 | 0.02647 | -19.45 | <.0001 |
| pc2079 | -0.58743 | 0.03116 | -18.85 | <.0001 |
| pc2080 | -0.56488 | 0.05122 | -11.03 | <.0001 |
| pc2081 | -0.58697 | 0.03387 | -17.33 | <.0001 |
| pc2082 | -0.59509 | 0.03345 | -17.79 | <.0001 |
| pc2083 | -0.60114 | 0.04831 | -12.44 | <.0001 |
| pc2084 | -0.28825 | 0.04319 | -6.67 | <.0001 |
| pc2085 | -0.31394 | 0.02899 | -10.83 | <.0001 |
| pc2086 | -0.27982 | 0.02703 | -10.35 | <.0001 |
| pc2087 | -0.24037 | 0.02856 | -8.42 | <.0001 |
| pc2088 | 0.41280 | 0.02645 | 15.61 | <.0001 |
| pc2089 | 0.08558 | 0.03301 | 2.59 | 0.0095 |
| pc2090 | 0.16501 | 0.03102 | 5.32 | <.0001 |
| pc2092 | 0.14569 | 0.03035 | 4.80 | <.0001 |
| pc2093 | 0.10599 | 0.02608 | 4.06 | <.0001 |
| pc2094 | 0.13177 | 0.03433 | 3.84 | 0.0001 |
| pc2095 | 0.29524 | 0.03174 | 9.30 | <.0001 |
| pc2096 | 0.04022 | 0.03054 | 1.32 | 0.1878 |
| pc2097 | -0.08792 | 0.02882 | -3.05 | 0.0023 |

| | | | | |
|---|---|---|---|---|
| pc2099 | -0.16178 | 0.02589 | -6.25 | <.0001 |
| pc2100 | -0.23235 | 0.02620 | -8.87 | <.0001 |
| pc2101 | -0.20494 | 0.02763 | -7.42 | <.0001 |
| pc2102 | -0.25221 | 0.03413 | -7.39 | <.0001 |
| pc2103 | -0.16554 | 0.03048 | -5.43 | <.0001 |
| pc2104 | 0.05125 | 0.04194 | 1.22 | 0.2217 |
| pc2105 | -0.09127 | 0.04544 | -2.01 | 0.0446 |
| pc2106 | -0.09358 | 0.03046 | -3.07 | 0.0021 |
| pc2107 | -0.10056 | 0.02595 | -3.88 | 0.0001 |
| pc2108 | 0.28201 | 0.04650 | 6.06 | <.0001 |
| pc2110 | 0.21299 | 0.03109 | 6.85 | <.0001 |
| pc2111 | -0.10421 | 0.02989 | -3.49 | 0.0005 |
| pc2112 | -0.22859 | 0.02601 | -8.79 | <.0001 |
| pc2113 | -0.29254 | 0.02741 | -10.67 | <.0001 |
| pc2114 | -0.33668 | 0.02755 | -12.22 | <.0001 |
| pc2115 | -0.55004 | 0.02810 | -19.57 | <.0001 |
| pc2116 | -0.65445 | 0.03113 | -21.02 | <.0001 |
| pc2117 | -0.60021 | 0.02559 | -23.45 | <.0001 |
| pc2118 | -0.52479 | 0.02602 | -20.17 | <.0001 |
| pc2119 | -0.28063 | 0.02854 | -9.83 | <.0001 |
| pc2120 | -0.48995 | 0.02606 | -18.80 | <.0001 |
| pc2121 | -0.27324 | 0.02590 | -10.55 | <.0001 |
| pc2122 | -0.31706 | 0.02580 | -12.29 | <.0001 |
| pc2125 | -0.41431 | 0.02690 | -15.40 | <.0001 |
| pc2126 | -0.57111 | 0.02623 | -21.77 | <.0001 |
| pc2127 | -0.47377 | 0.03558 | -13.32 | <.0001 |
| pc2128 | -0.68925 | 0.04967 | -13.88 | <.0001 |
| pc2130 | -0.17703 | 0.03728 | -4.75 | <.0001 |
| pc2131 | -0.31762 | 0.02906 | -10.93 | <.0001 |
| pc2132 | -0.18618 | 0.03119 | -5.97 | <.0001 |
| pc2133 | -0.34781 | 0.02992 | -11.62 | <.0001 |
| pc2134 | -0.03444 | 0.03541 | -0.97 | 0.3308 |
| pc2135 | 0.01704 | 0.02783 | 0.61 | 0.5405 |
| pc2136 | -0.31723 | 0.03497 | -9.07 | <.0001 |
| pc2137 | -0.07837 | 0.02709 | -2.89 | 0.0038 |
| pc2138 | -0.14584 | 0.03183 | -4.58 | <.0001 |
| pc2140 | -0.40938 | 0.03770 | -10.86 | <.0001 |
| pc2141 | -0.69103 | 0.02705 | -25.55 | <.0001 |
| pc2142 | -0.86234 | 0.02731 | -31.58 | <.0001 |
| pc2143 | -0.78765 | 0.03342 | -23.57 | <.0001 |
| pc2144 | -0.83148 | 0.02669 | -31.16 | <.0001 |
| pc2145 | -0.77457 | 0.02393 | -32.36 | <.0001 |
| pc2146 | -0.83623 | 0.02726 | -30.68 | <.0001 |
| pc2147 | -0.93724 | 0.02441 | -38.40 | <.0001 |
| pc2148 | -0.99680 | 0.02382 | -41.85 | <.0001 |
| pc2150 | -0.62134 | 0.03128 | -19.86 | <.0001 |
| pc2151 | -0.62395 | 0.02677 | -23.31 | <.0001 |
| pc2152 | -0.64292 | 0.02861 | -22.47 | <.0001 |
| pc2153 | -0.62948 | 0.02394 | -26.29 | <.0001 |
| pc2154 | -0.54484 | 0.02446 | -22.28 | <.0001 |
| pc2155 | -0.69099 | 0.02421 | -28.54 | <.0001 |
| pc2156 | -0.45649 | 0.03009 | -15.17 | <.0001 |
| pc2157 | -0.47728 | 0.07291 | -6.55 | <.0001 |
| pc2158 | -0.55061 | 0.03194 | -17.24 | <.0001 |

| | | | | |
|---|---|---|---|---|
| pc2159 | -0.58258 | 0.04900 | -11.89 | <.0001 |
| pc2160 | -0.80188 | 0.02558 | -31.35 | <.0001 |
| pc2161 | -0.88723 | 0.02569 | -34.53 | <.0001 |
| pc2162 | -0.85189 | 0.02856 | -29.83 | <.0001 |
| pc2163 | -1.03620 | 0.03500 | -29.61 | <.0001 |
| pc2164 | -0.94930 | 0.02771 | -34.26 | <.0001 |
| pc2165 | -0.94473 | 0.02556 | -36.96 | <.0001 |
| pc2166 | -0.93948 | 0.02570 | -36.56 | <.0001 |
| pc2167 | -1.05289 | 0.03278 | -32.12 | <.0001 |
| pc2168 | -1.07157 | 0.02477 | -43.26 | <.0001 |
| pc2170 | -0.95114 | 0.02358 | -40.34 | <.0001 |
| pc2171 | -0.92340 | 0.02563 | -36.02 | <.0001 |
| pc2172 | -0.73211 | 0.04650 | -15.74 | <.0001 |
| pc2173 | -0.85045 | 0.02652 | -32.07 | <.0001 |
| pc2176 | -0.86789 | 0.02534 | -34.25 | <.0001 |
| pc2177 | -0.92457 | 0.03192 | -28.96 | <.0001 |
| pc2190 | -0.75631 | 0.02613 | -28.94 | <.0001 |
| pc2191 | -0.51387 | 0.03304 | -15.55 | <.0001 |
| pc2192 | -0.61363 | 0.03222 | -19.05 | <.0001 |
| pc2193 | -0.35731 | 0.03106 | -11.50 | <.0001 |
| pc2194 | -0.51820 | 0.03088 | -16.78 | <.0001 |
| pc2195 | -0.84279 | 0.02997 | -28.12 | <.0001 |
| pc2196 | -0.75812 | 0.02551 | -29.71 | <.0001 |
| pc2197 | -0.80532 | 0.03147 | -25.59 | <.0001 |
| pc2198 | -0.78585 | 0.03078 | -25.53 | <.0001 |
| pc2199 | -0.80702 | 0.02803 | -28.79 | <.0001 |
| pc2200 | -0.78442 | 0.02589 | -30.29 | <.0001 |
| pc2203 | -0.26165 | 0.03041 | -8.60 | <.0001 |
| pc2204 | -0.34930 | 0.02633 | -13.27 | <.0001 |
| pc2205 | -0.50658 | 0.03016 | -16.79 | <.0001 |
| pc2206 | -0.34819 | 0.02758 | -12.62 | <.0001 |
| pc2207 | -0.50747 | 0.02526 | -20.09 | <.0001 |
| pc2208 | -0.45132 | 0.02909 | -15.51 | <.0001 |
| pc2209 | -0.55068 | 0.02760 | -19.95 | <.0001 |
| pc2210 | -0.55781 | 0.02522 | -22.12 | <.0001 |
| pc2211 | -0.68599 | 0.02685 | -25.55 | <.0001 |
| pc2212 | -0.69692 | 0.02650 | -26.30 | <.0001 |
| pc2213 | -0.65874 | 0.02555 | -25.79 | <.0001 |
| pc2214 | -0.73486 | 0.03499 | -21.00 | <.0001 |
| pc2216 | -0.44620 | 0.02791 | -15.99 | <.0001 |
| pc2217 | -0.33260 | 0.02721 | -12.22 | <.0001 |
| pc2218 | -0.45005 | 0.03011 | -14.95 | <.0001 |
| pc2219 | -0.25472 | 0.02712 | -9.39 | <.0001 |
| pc2220 | -0.34824 | 0.02644 | -13.17 | <.0001 |
| pc2221 | -0.21522 | 0.02631 | -8.18 | <.0001 |
| pc2222 | -0.47065 | 0.03275 | -14.37 | <.0001 |
| pc2223 | -0.34542 | 0.02678 | -12.90 | <.0001 |
| pc2224 | -0.31243 | 0.02712 | -11.52 | <.0001 |
| pc2225 | -0.45349 | 0.03208 | -14.14 | <.0001 |
| pc2226 | -0.53607 | 0.02857 | -18.76 | <.0001 |
| pc2227 | -0.42215 | 0.02691 | -15.68 | <.0001 |
| pc2228 | -0.46662 | 0.02709 | -17.22 | <.0001 |
| pc2229 | -0.30813 | 0.02516 | -12.25 | <.0001 |
| pc2230 | -0.08215 | 0.02634 | -3.12 | 0.0018 |

| | | | | |
|---|---|---|---|---|
| pc2231 | -0.61066 | 0.05041 | -12.11 | <.0001 |
| pc2232 | -0.54636 | 0.02548 | -21.45 | <.0001 |
| pc2233 | -0.62967 | 0.02501 | -25.17 | <.0001 |
| pc2234 | -0.56746 | 0.02534 | -22.39 | <.0001 |
| pc2250 | -1.02465 | 0.02360 | -43.41 | <.0001 |
| pc2251 | -0.78620 | 0.02454 | -32.03 | <.0001 |
| pc2256 | -0.91403 | 0.02535 | -36.06 | <.0001 |
| pc2257 | -0.88811 | 0.02416 | -36.76 | <.0001 |
| pc2258 | -1.03811 | 0.03959 | -26.22 | <.0001 |
| pc2259 | -1.16526 | 0.02376 | -49.04 | <.0001 |
| pc2260 | -0.70280 | 0.02474 | -28.40 | <.0001 |
| pc2261 | -1.01701 | 0.02367 | -42.97 | <.0001 |
| pc2262 | -1.21401 | 0.02537 | -47.85 | <.0001 |
| pc2263 | -1.17774 | 0.02491 | -47.28 | <.0001 |
| pc2558 | -1.14012 | 0.02923 | -39.00 | <.0001 |
| pc2559 | -1.23533 | 0.07609 | -16.24 | <.0001 |
| pc2560 | -1.14351 | 0.02373 | -48.18 | <.0001 |
| pc2564 | -1.21816 | 0.02772 | -43.95 | <.0001 |
| pc2565 | -1.05567 | 0.02657 | -39.74 | <.0001 |
| pc2566 | -1.11535 | 0.02601 | -42.88 | <.0001 |
| pc2567 | -0.96617 | 0.02409 | -40.11 | <.0001 |
| pc2570 | -0.91977 | 0.02504 | -36.73 | <.0001 |
| pc2745 | -0.92094 | 0.02546 | -36.18 | <.0001 |
| pc2747 | -1.10323 | 0.02468 | -44.71 | <.0001 |
| pc2749 | -1.01984 | 0.02773 | -36.78 | <.0001 |
| pc2750 | -1.01884 | 0.02479 | -41.10 | <.0001 |
| pc2752 | -0.98648 | 0.03512 | -28.09 | <.0001 |
| pc2753 | -0.96066 | 0.02791 | -34.42 | <.0001 |
| pc2754 | -0.96884 | 0.03404 | -28.46 | <.0001 |
| pc2756 | -0.99472 | 0.02492 | -39.91 | <.0001 |
| pc2758 | -0.86068 | 0.03543 | -24.29 | <.0001 |
| pc2759 | -0.97719 | 0.02535 | -38.55 | <.0001 |
| pc2760 | -1.14606 | 0.02482 | -46.17 | <.0001 |
| pc2761 | -1.03315 | 0.02527 | -40.89 | <.0001 |
| pc2762 | -0.91748 | 0.03835 | -23.92 | <.0001 |
| pc2763 | -0.91679 | 0.02465 | -37.19 | <.0001 |
| pc2765 | -0.86858 | 0.03415 | -25.44 | <.0001 |
| pc2766 | -1.10135 | 0.02849 | -38.66 | <.0001 |
| pc2767 | -1.04650 | 0.02649 | -39.51 | <.0001 |
| pc2768 | -0.79206 | 0.02490 | -31.81 | <.0001 |
| pc2770 | -1.25731 | 0.02409 | -52.20 | <.0001 |
| pc2773 | -0.77171 | 0.03752 | -20.57 | <.0001 |
| pc2774 | -0.93229 | 0.02892 | -32.23 | <.0001 |
| pc2775 | -1.07635 | 0.05502 | -19.56 | <.0001 |
| pc2776 | -1.00556 | 0.03677 | -27.35 | <.0001 |
| pc2777 | -0.96505 | 0.02628 | -36.73 | <.0001 |
| pc2778 | -1.03535 | 0.04047 | -25.58 | <.0001 |
| pc2779 | -1.07895 | 0.03202 | -33.69 | <.0001 |
| pc2780 | -0.96762 | 0.02569 | -37.67 | <.0001 |
| pc2782 | -0.91689 | 0.02838 | -32.30 | <.0001 |
| pc2783 | -1.10028 | 0.04831 | -22.78 | <.0001 |
| pc2784 | -1.17523 | 0.04770 | -24.64 | <.0001 |
| pc2785 | -1.01995 | 0.02930 | -34.81 | <.0001 |
| pc2786 | -1.14775 | 0.04245 | -27.04 | <.0001 |

## Table 3. Estimated Hedonic Models for HM1 in 2009

### (b) Rent Data

| | | | |
|---|---|---|---|
| Number of observations: | 47109 | R-Square: | 0.7845 |
| F statistic: | 658.61 | Adj R-Square: | 0.7833 |

| Variable | Parameter Estimate | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|
| Intercept | 10.00246 | 0.01638 | 610.47 | <.0001 |
| qt34 | 0.00683 | 0.00259 | 2.64 | 0.0082 |
| qt35 | 0.01653 | 0.00255 | 6.48 | <.0001 |
| qt36 | 0.03924 | 0.00262 | 14.97 | <.0001 |
| bn2 | 0.33560 | 0.00880 | 38.15 | <.0001 |
| bn3 | 0.49111 | 0.00862 | 57.01 | <.0001 |
| bn4 | 0.56275 | 0.00938 | 60.02 | <.0001 |
| bt2 | 0.17358 | 0.00468 | 37.13 | <.0001 |
| bt3 | 0.34901 | 0.00647 | 53.95 | <.0001 |
| bt4 | 0.50457 | 0.01581 | 31.91 | <.0001 |
| dt2area3 | -0.01128 | 0.00635 | -1.78 | 0.0755 |
| dt2area32 | 0.00125 | 0.00036428 | 3.42 | 0.0006 |
| bn2area3 | 0.00223 | 0.00608 | 0.37 | 0.7143 |
| bn3area3 | -0.00150 | 0.00607 | -0.25 | 0.8044 |
| bn4area3 | 0.03223 | 0.00657 | 4.90 | <.0001 |
| bt2area3 | -0.00921 | 0.00210 | -4.38 | <.0001 |
| bt3area3 | -0.00343 | 0.00433 | -0.79 | 0.4282 |
| bt4area3 | -0.02594 | 0.01054 | -2.46 | 0.0139 |
| bn2bt2 | -0.04454 | 0.00815 | -5.47 | <.0001 |
| bn3bt2 | -0.04981 | 0.00526 | -9.48 | <.0001 |
| bn3bt3 | -0.11279 | 0.00982 | -11.49 | <.0001 |
| pc2000 | 0.07763 | 0.05936 | 1.31 | 0.1909 |
| pc2007 | -0.16563 | 0.06796 | -2.44 | 0.0148 |
| pc2008 | -0.23864 | 0.02903 | -8.22 | <.0001 |
| pc2009 | 0.10999 | 0.04176 | 2.63 | 0.0084 |
| pc2011 | -0.00961 | 0.03214 | -0.30 | 0.7650 |
| pc2015 | -0.20777 | 0.02141 | -9.70 | <.0001 |
| pc2016 | -0.11443 | 0.02316 | -4.94 | <.0001 |
| pc2017 | -0.22814 | 0.03042 | -7.50 | <.0001 |
| pc2018 | -0.24440 | 0.02706 | -9.03 | <.0001 |
| pc2019 | -0.27595 | 0.02910 | -9.48 | <.0001 |
| pc2020 | -0.30170 | 0.02719 | -11.09 | <.0001 |
| pc2021 | 0.17387 | 0.01778 | 9.78 | <.0001 |
| pc2022 | 0.09511 | 0.02059 | 4.62 | <.0001 |
| pc2023 | 0.31044 | 0.02550 | 12.18 | <.0001 |
| pc2024 | 0.22311 | 0.02374 | 9.40 | <.0001 |
| pc2025 | 0.24502 | 0.02224 | 11.01 | <.0001 |
| pc2026 | 0.17799 | 0.01948 | 9.14 | <.0001 |
| pc2027 | 0.29909 | 0.03659 | 8.17 | <.0001 |
| pc2028 | 0.22412 | 0.03238 | 6.92 | <.0001 |
| pc2029 | 0.14353 | 0.02838 | 5.06 | <.0001 |
| pc2030 | 0.27754 | 0.02278 | 12.18 | <.0001 |
| pc2031 | 0.05976 | 0.01904 | 3.14 | 0.0017 |
| pc2032 | -0.13969 | 0.02192 | -6.37 | <.0001 |

| | | | | |
|---|---|---|---|---|
| pc2033 | 0.01996 | 0.02734 | 0.73 | 0.4654 |
| pc2034 | 0.09222 | 0.02225 | 4.15 | <.0001 |
| pc2035 | -0.13093 | 0.01760 | -7.44 | <.0001 |
| pc2036 | -0.19229 | 0.01996 | -9.63 | <.0001 |
| pc2037 | -0.12504 | 0.01908 | -6.55 | <.0001 |
| pc2038 | -0.09949 | 0.01822 | -5.46 | <.0001 |
| pc2039 | -0.10547 | 0.01916 | -5.51 | <.0001 |
| pc2040 | -0.19562 | 0.01608 | -12.17 | <.0001 |
| pc2041 | -0.00181 | 0.01716 | -0.11 | 0.9159 |
| pc2042 | -0.18987 | 0.01718 | -11.05 | <.0001 |
| pc2043 | -0.19606 | 0.02170 | -9.03 | <.0001 |
| pc2044 | -0.35011 | 0.02048 | -17.10 | <.0001 |
| pc2045 | -0.27091 | 0.02790 | -9.71 | <.0001 |
| pc2046 | -0.21577 | 0.01782 | -12.11 | <.0001 |
| pc2047 | -0.14306 | 0.02109 | -6.78 | <.0001 |
| pc2048 | -0.21319 | 0.02105 | -10.13 | <.0001 |
| pc2049 | -0.21701 | 0.02062 | -10.52 | <.0001 |
| pc2050 | -0.12463 | 0.02417 | -5.16 | <.0001 |
| pc2060 | 0.03121 | 0.02166 | 1.44 | 0.1496 |
| pc2061 | 0.24587 | 0.04094 | 6.00 | <.0001 |
| pc2062 | -0.04448 | 0.02329 | -1.91 | 0.0561 |
| pc2063 | 0.10490 | 0.02279 | 4.60 | <.0001 |
| pc2064 | -0.10430 | 0.02673 | -3.90 | <.0001 |
| pc2065 | -0.07189 | 0.01774 | -4.05 | <.0001 |
| pc2066 | -0.07771 | 0.01826 | -4.26 | <.0001 |
| pc2067 | -0.07733 | 0.01911 | -4.05 | <.0001 |
| pc2068 | -0.02869 | 0.01969 | -1.46 | 0.1451 |
| pc2069 | -0.00180 | 0.02006 | -0.09 | 0.9286 |
| pc2070 | -0.06893 | 0.02112 | -3.26 | 0.0011 |
| pc2071 | -0.08931 | 0.02150 | -4.15 | <.0001 |
| pc2072 | -0.15379 | 0.02489 | -6.18 | <.0001 |
| pc2073 | -0.10692 | 0.01964 | -5.44 | <.0001 |
| pc2074 | -0.17280 | 0.01935 | -8.93 | <.0001 |
| pc2075 | -0.16600 | 0.01930 | -8.60 | <.0001 |
| pc2076 | -0.21750 | 0.01899 | -11.46 | <.0001 |
| pc2077 | -0.48010 | 0.01912 | -25.11 | <.0001 |
| pc2079 | -0.51352 | 0.03003 | -17.10 | <.0001 |
| pc2080 | -0.51268 | 0.05344 | -9.59 | <.0001 |
| pc2081 | -0.55333 | 0.03162 | -17.50 | <.0001 |
| pc2082 | -0.53922 | 0.03186 | -16.93 | <.0001 |
| pc2083 | -0.59043 | 0.03967 | -14.88 | <.0001 |
| pc2084 | -0.06622 | 0.04486 | -1.48 | 0.1400 |
| pc2085 | -0.09856 | 0.02907 | -3.39 | 0.0007 |
| pc2086 | -0.14289 | 0.02326 | -6.14 | <.0001 |
| pc2087 | -0.18350 | 0.02232 | -8.22 | <.0001 |
| pc2088 | 0.26059 | 0.01780 | 14.64 | <.0001 |
| pc2089 | -0.01991 | 0.02318 | -0.86 | 0.3904 |
| pc2090 | 0.02386 | 0.02155 | 1.11 | 0.2682 |
| pc2092 | 0.04786 | 0.02494 | 1.92 | 0.0550 |
| pc2093 | 0.00561 | 0.01887 | 0.30 | 0.7663 |
| pc2094 | 0.16254 | 0.02588 | 6.28 | <.0001 |
| pc2095 | 0.16341 | 0.02234 | 7.32 | <.0001 |
| pc2096 | 0.02524 | 0.02411 | 1.05 | 0.2951 |
| pc2097 | -0.10741 | 0.02199 | -4.88 | <.0001 |

| | | | | |
|---|---|---|---|---|
| pc2099 | -0.13698 | 0.01965 | -6.97 | <.0001 |
| pc2100 | -0.12479 | 0.02080 | -6.00 | <.0001 |
| pc2101 | -0.12255 | 0.02312 | -5.30 | <.0001 |
| pc2102 | -0.15616 | 0.03165 | -4.93 | <.0001 |
| pc2103 | -0.09440 | 0.02238 | -4.22 | <.0001 |
| pc2104 | 0.02628 | 0.03516 | 0.75 | 0.4548 |
| pc2105 | -0.33736 | 0.02808 | -12.01 | <.0001 |
| pc2106 | -0.13684 | 0.02178 | -6.28 | <.0001 |
| pc2107 | -0.14893 | 0.01939 | -7.68 | <.0001 |
| pc2108 | -0.08488 | 0.03066 | -2.77 | 0.0056 |
| pc2110 | -0.02928 | 0.02176 | -1.35 | 0.1785 |
| pc2111 | -0.22402 | 0.02072 | -10.81 | <.0001 |
| pc2112 | -0.39514 | 0.01805 | -21.89 | <.0001 |
| pc2113 | -0.39197 | 0.01967 | -19.93 | <.0001 |
| pc2114 | -0.44022 | 0.02094 | -21.03 | <.0001 |
| pc2115 | -0.55169 | 0.02208 | -24.99 | <.0001 |
| pc2116 | -0.61755 | 0.02683 | -23.02 | <.0001 |
| pc2117 | -0.54895 | 0.01888 | -29.07 | <.0001 |
| pc2118 | -0.53411 | 0.01797 | -29.72 | <.0001 |
| pc2119 | -0.31456 | 0.02207 | -14.25 | <.0001 |
| pc2120 | -0.46238 | 0.01946 | -23.76 | <.0001 |
| pc2121 | -0.39095 | 0.01859 | -21.03 | <.0001 |
| pc2122 | -0.42696 | 0.01799 | -23.73 | <.0001 |
| pc2125 | -0.44122 | 0.02142 | -20.59 | <.0001 |
| pc2126 | -0.42521 | 0.02052 | -20.72 | <.0001 |
| pc2127 | -0.38164 | 0.02455 | -15.54 | <.0001 |
| pc2128 | -0.59696 | 0.03804 | -15.69 | <.0001 |
| pc2130 | -0.30768 | 0.02838 | -10.84 | <.0001 |
| pc2131 | -0.37040 | 0.02055 | -18.03 | <.0001 |
| pc2132 | -0.36347 | 0.02329 | -15.61 | <.0001 |
| pc2133 | -0.43080 | 0.02348 | -18.35 | <.0001 |
| pc2134 | -0.31652 | 0.02493 | -12.70 | <.0001 |
| pc2135 | -0.32949 | 0.02137 | -15.42 | <.0001 |
| pc2136 | -0.41430 | 0.02871 | -14.43 | <.0001 |
| pc2137 | -0.29316 | 0.01924 | -15.23 | <.0001 |
| pc2138 | -0.36098 | 0.02383 | -15.15 | <.0001 |
| pc2140 | -0.41432 | 0.03089 | -13.41 | <.0001 |
| pc2141 | -0.56608 | 0.02015 | -28.09 | <.0001 |
| pc2142 | -0.65409 | 0.01900 | -34.43 | <.0001 |
| pc2143 | -0.65627 | 0.03001 | -21.87 | <.0001 |
| pc2144 | -0.59723 | 0.01845 | -32.38 | <.0001 |
| pc2145 | -0.64129 | 0.01569 | -40.88 | <.0001 |
| pc2146 | -0.70542 | 0.01926 | -36.62 | <.0001 |
| pc2147 | -0.73307 | 0.01725 | -42.50 | <.0001 |
| pc2148 | -0.75684 | 0.01599 | -47.33 | <.0001 |
| pc2150 | -0.57312 | 0.02044 | -28.04 | <.0001 |
| pc2151 | -0.55452 | 0.01951 | -28.42 | <.0001 |
| pc2152 | -0.67517 | 0.02164 | -31.20 | <.0001 |
| pc2153 | -0.54456 | 0.01665 | -32.70 | <.0001 |
| pc2154 | -0.47246 | 0.01711 | -27.61 | <.0001 |
| pc2155 | -0.51873 | 0.01703 | -30.46 | <.0001 |
| pc2156 | -0.38379 | 0.02883 | -13.31 | <.0001 |
| pc2157 | -0.60919 | 0.06180 | -9.86 | <.0001 |
| pc2158 | -0.44815 | 0.02843 | -15.76 | <.0001 |

| | | | | |
|---|---|---|---|---|
| pc2159 | -0.49970 | 0.04927 | -10.14 | <.0001 |
| pc2160 | -0.64691 | 0.01749 | -36.98 | <.0001 |
| pc2161 | -0.66920 | 0.01851 | -36.15 | <.0001 |
| pc2162 | -0.64817 | 0.02278 | -28.46 | <.0001 |
| pc2163 | -0.75576 | 0.03910 | -19.33 | <.0001 |
| pc2164 | -0.68540 | 0.02133 | -32.13 | <.0001 |
| pc2165 | -0.73969 | 0.01918 | -38.57 | <.0001 |
| pc2166 | -0.77975 | 0.02048 | -38.07 | <.0001 |
| pc2167 | -0.77438 | 0.02900 | -26.70 | <.0001 |
| pc2168 | -0.73237 | 0.01819 | -40.27 | <.0001 |
| pc2170 | -0.70873 | 0.01611 | -44.00 | <.0001 |
| pc2171 | -0.61751 | 0.02001 | -30.85 | <.0001 |
| pc2172 | -0.60363 | 0.05713 | -10.57 | <.0001 |
| pc2173 | -0.64444 | 0.01959 | -32.90 | <.0001 |
| pc2176 | -0.62177 | 0.01875 | -33.16 | <.0001 |
| pc2177 | -0.69916 | 0.02982 | -23.45 | <.0001 |
| pc2190 | -0.57785 | 0.02241 | -25.79 | <.0001 |
| pc2191 | -0.48137 | 0.02762 | -17.43 | <.0001 |
| pc2192 | -0.55578 | 0.02511 | -22.14 | <.0001 |
| pc2193 | -0.38911 | 0.02154 | -18.06 | <.0001 |
| pc2194 | -0.49270 | 0.02361 | -20.87 | <.0001 |
| pc2195 | -0.58614 | 0.02590 | -22.63 | <.0001 |
| pc2196 | -0.55919 | 0.01977 | -28.29 | <.0001 |
| pc2197 | -0.63395 | 0.02872 | -22.07 | <.0001 |
| pc2198 | -0.60047 | 0.02561 | -23.45 | <.0001 |
| pc2199 | -0.67601 | 0.02422 | -27.92 | <.0001 |
| pc2200 | -0.62947 | 0.01882 | -33.45 | <.0001 |
| pc2203 | -0.29920 | 0.02060 | -14.53 | <.0001 |
| pc2204 | -0.31138 | 0.01825 | -17.06 | <.0001 |
| pc2205 | -0.38649 | 0.02411 | -16.03 | <.0001 |
| pc2206 | -0.42564 | 0.02073 | -20.53 | <.0001 |
| pc2207 | -0.46146 | 0.01834 | -25.16 | <.0001 |
| pc2208 | -0.45818 | 0.02106 | -21.76 | <.0001 |
| pc2209 | -0.48262 | 0.02240 | -21.55 | <.0001 |
| pc2210 | -0.51212 | 0.01943 | -26.35 | <.0001 |
| pc2211 | -0.60321 | 0.02026 | -29.77 | <.0001 |
| pc2212 | -0.65088 | 0.02049 | -31.77 | <.0001 |
| pc2213 | -0.59618 | 0.01922 | -31.01 | <.0001 |
| pc2214 | -0.60943 | 0.04792 | -12.72 | <.0001 |
| pc2216 | -0.41707 | 0.02158 | -19.33 | <.0001 |
| pc2217 | -0.40359 | 0.02027 | -19.91 | <.0001 |
| pc2218 | -0.50183 | 0.02381 | -21.07 | <.0001 |
| pc2219 | -0.37196 | 0.02139 | -17.39 | <.0001 |
| pc2220 | -0.48289 | 0.02027 | -23.82 | <.0001 |
| pc2221 | -0.35674 | 0.02075 | -17.19 | <.0001 |
| pc2222 | -0.49995 | 0.02548 | -19.62 | <.0001 |
| pc2223 | -0.47242 | 0.02009 | -23.51 | <.0001 |
| pc2224 | -0.35025 | 0.02097 | -16.70 | <.0001 |
| pc2225 | -0.40228 | 0.02793 | -14.40 | <.0001 |
| pc2226 | -0.43990 | 0.02487 | -17.69 | <.0001 |
| pc2227 | -0.37905 | 0.02265 | -16.74 | <.0001 |
| pc2228 | -0.41625 | 0.02135 | -19.50 | <.0001 |
| pc2229 | -0.32024 | 0.01962 | -16.32 | <.0001 |
| pc2230 | -0.35649 | 0.01986 | -17.95 | <.0001 |

| | | | | |
|---|---|---|---|---|
| pc2231 | -0.45567 | 0.03857 | -11.81 | <.0001 |
| pc2232 | -0.44017 | 0.02027 | -21.72 | <.0001 |
| pc2233 | -0.48034 | 0.02399 | -20.03 | <.0001 |
| pc2234 | -0.43828 | 0.01935 | -22.65 | <.0001 |
| pc2250 | -0.82956 | 0.01596 | -51.99 | <.0001 |
| pc2251 | -0.72764 | 0.01734 | -41.96 | <.0001 |
| pc2256 | -0.80139 | 0.01817 | -44.12 | <.0001 |
| pc2257 | -0.84101 | 0.01641 | -51.25 | <.0001 |
| pc2258 | -0.86676 | 0.03705 | -23.39 | <.0001 |
| pc2259 | -0.93686 | 0.01588 | -58.99 | <.0001 |
| pc2260 | -0.68658 | 0.01644 | -41.75 | <.0001 |
| pc2261 | -0.87025 | 0.01570 | -55.44 | <.0001 |
| pc2262 | -1.00136 | 0.01704 | -58.78 | <.0001 |
| pc2263 | -0.97685 | 0.01680 | -58.14 | <.0001 |
| pc2558 | -0.83146 | 0.02190 | -37.96 | <.0001 |
| pc2559 | -0.83023 | 0.06183 | -13.43 | <.0001 |
| pc2560 | -0.84943 | 0.01564 | -54.32 | <.0001 |
| pc2564 | -0.88840 | 0.02491 | -35.67 | <.0001 |
| pc2565 | -0.83440 | 0.01926 | -43.33 | <.0001 |
| pc2566 | -0.84621 | 0.01885 | -44.90 | <.0001 |
| pc2567 | -0.72184 | 0.01651 | -43.73 | <.0001 |
| pc2570 | -0.71383 | 0.01964 | -36.35 | <.0001 |
| pc2745 | -0.76803 | 0.01910 | -40.20 | <.0001 |
| pc2747 | -0.86364 | 0.01754 | -49.24 | <.0001 |
| pc2749 | -0.78159 | 0.02237 | -34.95 | <.0001 |
| pc2750 | -0.85428 | 0.01749 | -48.83 | <.0001 |
| pc2752 | -0.76099 | 0.03761 | -20.24 | <.0001 |
| pc2753 | -0.79303 | 0.02111 | -37.57 | <.0001 |
| pc2754 | -0.79991 | 0.02533 | -31.58 | <.0001 |
| pc2756 | -0.80992 | 0.01719 | -47.11 | <.0001 |
| pc2758 | -0.92232 | 0.03970 | -23.23 | <.0001 |
| pc2759 | -0.75787 | 0.01817 | -41.71 | <.0001 |
| pc2760 | -0.86585 | 0.01717 | -50.43 | <.0001 |
| pc2761 | -0.75517 | 0.01903 | -39.69 | <.0001 |
| pc2762 | -0.76066 | 0.04312 | -17.64 | <.0001 |
| pc2763 | -0.70643 | 0.01701 | -41.52 | <.0001 |
| pc2765 | -0.75540 | 0.03395 | -22.25 | <.0001 |
| pc2766 | -0.79852 | 0.02438 | -32.76 | <.0001 |
| pc2767 | -0.77813 | 0.02078 | -37.45 | <.0001 |
| pc2768 | -0.56867 | 0.01750 | -32.49 | <.0001 |
| pc2770 | -0.91357 | 0.01653 | -55.27 | <.0001 |
| pc2773 | -0.73274 | 0.03162 | -23.18 | <.0001 |
| pc2774 | -0.76695 | 0.02907 | -26.38 | <.0001 |
| pc2775 | -0.95852 | 0.07196 | -13.32 | <.0001 |
| pc2776 | -0.80253 | 0.03189 | -25.16 | <.0001 |
| pc2777 | -0.83073 | 0.02136 | -38.89 | <.0001 |
| pc2778 | -0.77862 | 0.05044 | -15.44 | <.0001 |
| pc2779 | -0.94933 | 0.04912 | -19.33 | <.0001 |
| pc2780 | -0.88898 | 0.01744 | -50.98 | <.0001 |
| pc2782 | -0.84465 | 0.02118 | -39.88 | <.0001 |
| pc2783 | -0.94458 | 0.07195 | -13.13 | <.0001 |
| pc2784 | -0.92218 | 0.06806 | -13.55 | <.0001 |
| pc2785 | -0.97596 | 0.02209 | -44.18 | <.0001 |
| pc2786 | -1.06131 | 0.03662 | -28.98 | <.0001 |

**Table 4. Actual and Quality-Adjusted Price-Rent Ratios and Quality Bias**

| | Actual Lower Quartile | Actual Median | Actual Upper Quartile | Qual-Adj Lower Quartile | Qual-Adj Median | Qual-Adj Upper Quartile | Percent Qual Bias Lower Quartile | Percent Qual Bias Median | Percent Qual Bias Upper Quartile |
|---|---|---|---|---|---|---|---|---|---|
| Mar-01 | 20.85 | 23.01 | 25.03 | 19.67 | 21.80 | 24.64 | 5.97 | 5.57 | 1.58 |
| Jun-01 | 21.68 | 24.73 | 26.61 | 20.48 | 22.76 | 25.71 | 5.85 | 8.66 | 3.47 |
| Sep-01 | 22.35 | 25.46 | 27.88 | 21.58 | 24.00 | 27.10 | 3.53 | 6.08 | 2.88 |
| Dec-01 | 24.18 | 27.78 | 30.49 | 22.68 | 25.19 | 28.61 | 6.62 | 10.26 | 6.58 |
| Mar-02 | 25.01 | 27.96 | 28.77 | 23.49 | 26.45 | 29.56 | 6.47 | 5.69 | -2.70 |
| Jun-02 | 26.68 | 30.92 | 32.21 | 24.65 | 27.88 | 31.36 | 8.26 | 10.93 | 2.71 |
| Sep-02 | 27.52 | 30.95 | 33.56 | 25.91 | 29.28 | 32.92 | 6.20 | 5.72 | 1.95 |
| Dec-02 | 29.18 | 33.67 | 35.33 | 26.50 | 30.11 | 33.92 | 10.15 | 11.83 | 4.15 |
| Mar-03 | 29.18 | 32.30 | 33.19 | 27.24 | 30.77 | 34.25 | 7.13 | 4.98 | -3.07 |
| Jun-03 | 31.19 | 34.32 | 35.41 | 28.48 | 32.11 | 35.69 | 9.49 | 6.89 | -0.80 |
| Sep-03 | 31.94 | 35.17 | 36.41 | 29.51 | 33.31 | 37.19 | 8.23 | 5.57 | -2.09 |
| Dec-03 | 34.23 | 37.69 | 39.34 | 30.47 | 34.27 | 38.31 | 12.33 | 10.00 | 2.69 |
| Mar-04 | 32.94 | 36.76 | 37.88 | 30.35 | 33.53 | 36.67 | 8.55 | 9.62 | 3.30 |
| Jun-04 | 32.64 | 34.52 | 36.44 | 29.63 | 32.61 | 35.75 | 10.18 | 5.86 | 1.94 |
| Sep-04 | 32.60 | 35.16 | 36.92 | 29.61 | 32.69 | 35.70 | 10.12 | 7.56 | 3.41 |
| Dec-04 | 32.76 | 35.67 | 37.02 | 29.32 | 32.30 | 35.33 | 11.74 | 10.43 | 4.81 |
| Mar-05 | 31.38 | 32.43 | 33.56 | 28.37 | 30.73 | 33.85 | 10.64 | 5.55 | -0.84 |
| Jun-05 | 31.96 | 35.03 | 36.25 | 27.48 | 29.75 | 32.78 | 16.32 | 17.74 | 10.60 |
| Sep-05 | 29.92 | 32.57 | 34.25 | 26.98 | 29.33 | 32.18 | 10.88 | 11.05 | 6.42 |
| Dec-05 | 30.68 | 32.90 | 34.79 | 26.96 | 29.35 | 32.23 | 13.83 | 12.12 | 7.92 |
| Mar-06 | 29.15 | 31.16 | 33.00 | 26.11 | 28.58 | 31.52 | 11.63 | 9.03 | 4.72 |
| Jun-06 | 30.20 | 32.96 | 35.87 | 26.10 | 28.58 | 31.46 | 15.70 | 15.35 | 14.01 |
| Sep-06 | 28.58 | 30.51 | 33.03 | 25.71 | 28.17 | 31.07 | 11.15 | 8.30 | 6.31 |
| Dec-06 | 28.03 | 31.26 | 34.09 | 24.85 | 27.26 | 30.15 | 12.79 | 14.66 | 13.08 |
| Mar-07 | 25.15 | 27.53 | 29.83 | 22.83 | 25.29 | 28.64 | 10.20 | 8.87 | 4.18 |
| Jun-07 | 26.04 | 28.20 | 31.39 | 22.94 | 25.44 | 28.81 | 13.51 | 10.85 | 8.97 |
| Sep-07 | 24.86 | 27.34 | 30.00 | 22.88 | 25.51 | 28.79 | 8.64 | 7.19 | 4.18 |
| Dec-07 | 24.59 | 27.81 | 30.30 | 22.60 | 25.20 | 28.46 | 8.79 | 10.39 | 6.47 |
| Mar-08 | 23.70 | 25.27 | 28.38 | 21.54 | 23.88 | 27.31 | 10.04 | 5.82 | 3.92 |
| Jun-08 | 22.05 | 25.23 | 26.99 | 20.15 | 22.54 | 25.85 | 9.48 | 11.93 | 4.41 |
| Sep-08 | 20.85 | 22.53 | 24.79 | 19.68 | 21.96 | 25.03 | 5.92 | 2.62 | -0.94 |
| Dec-08 | 19.96 | 21.92 | 23.49 | 19.23 | 21.44 | 24.49 | 3.77 | 2.25 | -4.06 |
| Mar-09 | 19.78 | 20.00 | 20.86 | 19.22 | 21.23 | 24.08 | 2.88 | -5.80 | -13.38 |
| Jun-09 | 20.65 | 21.92 | 24.14 | 19.85 | 22.01 | 25.08 | 4.03 | -0.41 | -3.73 |
| Sep-09 | 20.55 | 21.94 | 24.51 | 20.26 | 22.57 | 25.67 | 1.46 | -2.79 | -4.49 |
| Dec-09 | 22.00 | 25.47 | 28.11 | 20.73 | 23.33 | 26.58 | 6.11 | 9.14 | 5.73 |
| Average | 26.81 | 29.45 | 31.39 | 24.56 | 27.26 | 30.46 | 8.85 | 7.76 | 2.90 |

## Table 5. Quality-Adjusted Price-Rent Ratios for Different Market Segments

**Houses are ordered from cheapest to most expensive**

| **Price Data** | | | | **Rent Data** | | | |
|---|---|---|---|---|---|---|---|
| | Lower Quartile Price-Rent Ratio | Median Price-Rent Ratio | Upper Quartile Price-Rent Ratio | | Lower Quartile Price-Rent Ratio | Median Price-Rent Ratio | Upper Quartile Price-Rent Ratio |
| Mar-01 | 21.40 | 22.01 | 23.79 | Mar-01 | 20.47 | 22.49 | 23.89 |
| Jun-01 | 21.73 | 23.73 | 25.43 | Jun-01 | 21.42 | 23.46 | 25.22 |
| Sep-01 | 22.19 | 23.96 | 26.37 | Sep-01 | 22.85 | 24.40 | 26.28 |
| Dec-01 | 23.76 | 25.34 | 27.89 | Dec-01 | 23.56 | 25.75 | 27.35 |
| Mar-02 | 26.35 | 26.72 | 29.46 | Mar-02 | 24.81 | 26.55 | 28.11 |
| Jun-02 | 27.35 | 27.98 | 30.03 | Jun-02 | 26.24 | 28.12 | 29.68 |
| Sep-02 | 27.83 | 29.02 | 32.66 | Sep-02 | 27.16 | 29.34 | 31.22 |
| Dec-02 | 29.55 | 30.46 | 32.68 | Dec-02 | 28.41 | 30.87 | 32.49 |
| Mar-03 | 29.85 | 31.90 | 32.08 | Mar-03 | 29.62 | 31.38 | 31.89 |
| Jun-03 | 30.11 | 32.26 | 34.23 | Jun-03 | 30.82 | 32.24 | 33.23 |
| Sep-03 | 30.42 | 33.90 | 36.39 | Sep-03 | 31.69 | 35.11 | 35.65 |
| Dec-03 | 31.99 | 35.58 | 36.45 | Dec-03 | 32.33 | 35.06 | 36.32 |
| Mar-04 | 32.72 | 34.07 | 37.55 | Mar-04 | 32.77 | 34.09 | 34.36 |
| Jun-04 | 32.58 | 32.11 | 33.25 | Jun-04 | 31.28 | 33.73 | 33.98 |
| Sep-04 | 31.98 | 33.99 | 33.24 | Sep-04 | 31.96 | 33.26 | 33.87 |
| Dec-04 | 31.51 | 29.76 | 33.10 | Dec-04 | 31.83 | 33.19 | 32.37 |
| Mar-05 | 30.69 | 29.85 | 32.92 | Mar-05 | 30.15 | 31.21 | 32.10 |
| Jun-05 | 29.78 | 29.92 | 31.42 | Jun-05 | 29.01 | 30.68 | 30.35 |
| Sep-05 | 29.03 | 29.66 | 30.91 | Sep-05 | 28.79 | 29.12 | 30.57 |
| Dec-05 | 29.78 | 28.80 | 31.08 | Dec-05 | 28.99 | 30.51 | 30.81 |
| Mar-06 | 27.57 | 28.68 | 30.38 | Mar-06 | 27.18 | 29.28 | 30.65 |
| Jun-06 | 27.40 | 29.79 | 27.30 | Jun-06 | 27.51 | 29.09 | 29.06 |
| Sep-06 | 27.27 | 29.46 | 30.79 | Sep-06 | 26.90 | 28.50 | 29.69 |
| Dec-06 | 26.21 | 27.89 | 29.58 | Dec-06 | 25.41 | 26.85 | 28.65 |
| Mar-07 | 23.52 | 27.15 | 28.45 | Mar-07 | 24.04 | 25.80 | 28.51 |
| Jun-07 | 23.12 | 26.34 | 28.12 | Jun-07 | 23.97 | 26.03 | 27.78 |
| Sep-07 | 24.28 | 26.09 | 29.04 | Sep-07 | 23.99 | 26.17 | 28.86 |
| Dec-07 | 24.42 | 26.15 | 27.69 | Dec-07 | 23.67 | 25.38 | 28.14 |
| Mar-08 | 21.59 | 26.18 | 26.40 | Mar-08 | 22.56 | 24.31 | 27.08 |
| Jun-08 | 21.23 | 24.46 | 25.63 | Jun-08 | 21.09 | 22.57 | 24.55 |
| Sep-08 | 20.65 | 21.42 | 23.21 | Sep-08 | 20.75 | 22.53 | 24.59 |
| Dec-08 | 19.83 | 20.57 | 24.24 | Dec-08 | 20.30 | 22.01 | 24.15 |
| Mar-09 | 19.72 | 19.71 | 22.64 | Mar-09 | 20.14 | 22.18 | 23.81 |
| Jun-09 | 20.38 | 21.85 | 24.68 | Jun-09 | 21.31 | 22.73 | 24.86 |
| Sep-09 | 21.97 | 23.11 | 24.76 | Sep-09 | 21.18 | 22.98 | 25.59 |
| Dec-09 | 21.62 | 22.70 | 25.34 | Dec-09 | 21.21 | 23.71 | 26.04 |
| Average | 26.15 | 27.57 | 29.42 | Average | 25.98 | 27.80 | 29.22 |

**Table 6. Imputed Expected Capital Gains Derived from User Cost Formula**

| | Price Data | Rent Data |
|---|---|---|
| Mar-01 | 6.51 | 6.75 |
| Jun-01 | 6.71 | 7.06 |
| Sep-01 | 6.93 | 7.17 |
| Dec-01 | 7.13 | 7.50 |
| Mar-02 | 7.32 | 7.52 |
| Jun-02 | 7.51 | 7.87 |
| Sep-02 | 7.68 | 7.87 |
| Dec-02 | 7.78 | 8.13 |
| Mar-03 | 7.85 | 8.00 |
| Jun-03 | 7.99 | 8.19 |
| Sep-03 | 8.10 | 8.26 |
| Dec-03 | 8.18 | 8.45 |
| Mar-04 | 8.12 | 8.38 |
| Jun-04 | 8.03 | 8.20 |
| Sep-04 | 8.04 | 8.26 |
| Dec-04 | 8.00 | 8.30 |
| Mar-05 | 7.85 | 8.02 |
| Jun-05 | 7.74 | 8.25 |
| Sep-05 | 7.69 | 8.03 |
| Dec-05 | 7.69 | 8.06 |
| Mar-06 | 7.60 | 7.89 |
| Jun-06 | 7.60 | 8.07 |
| Sep-06 | 7.55 | 7.82 |
| Dec-06 | 7.43 | 7.90 |
| Mar-07 | 7.15 | 7.47 |
| Jun-07 | 7.17 | 7.55 |
| Sep-07 | 7.18 | 7.44 |
| Dec-07 | 7.13 | 7.50 |
| Mar-08 | 6.91 | 7.14 |
| Jun-08 | 6.66 | 7.14 |
| Sep-08 | 6.55 | 6.66 |
| Dec-08 | 6.44 | 6.54 |
| Mar-09 | 6.39 | 6.10 |
| Jun-09 | 6.56 | 6.54 |
| Sep-09 | 6.67 | 6.54 |
| Dec-09 | 6.81 | 7.17 |
| | | |
| Average | 7.35 | 7.60 |

## Table 7. Imputed Expected Capital Gain for Different Segments of the Market Derived from User Cost Formula

**Houses are ordered from cheapest to most expensive**

| **Price Data** | | | | **Rent Data** | | | |
|---|---|---|---|---|---|---|---|
| | Percentage Expected Cap Gain Lower Quartile | Percentage Expected Cap Gain Median | Percentage Expected Cap Gain Upper Quartile | | Percentage Expected Cap Gain Lower Quartile | Percentage Expected Cap Gain Median | Percentage Expected Cap Gain Upper Quartile |
| Mar-01 | 6.43 | 6.56 | 6.90 | Mar-01 | 6.22 | 6.65 | 6.91 |
| Jun-01 | 6.50 | 6.89 | 7.17 | Jun-01 | 6.43 | 6.84 | 7.13 |
| Sep-01 | 6.59 | 6.93 | 7.31 | Sep-01 | 6.72 | 7.00 | 7.30 |
| Dec-01 | 6.89 | 7.15 | 7.52 | Dec-01 | 6.85 | 7.22 | 7.44 |
| Mar-02 | 7.30 | 7.36 | 7.71 | Mar-02 | 7.07 | 7.33 | 7.54 |
| Jun-02 | 7.44 | 7.53 | 7.77 | Jun-02 | 7.29 | 7.54 | 7.73 |
| Sep-02 | 7.51 | 7.65 | 8.04 | Sep-02 | 7.42 | 7.69 | 7.90 |
| Dec-02 | 7.72 | 7.82 | 8.04 | Dec-02 | 7.58 | 7.86 | 8.02 |
| Mar-03 | 7.75 | 7.96 | 7.98 | Mar-03 | 7.72 | 7.91 | 7.96 |
| Jun-03 | 7.78 | 8.00 | 8.18 | Jun-03 | 7.86 | 8.00 | 8.09 |
| Sep-03 | 7.81 | 8.15 | 8.35 | Sep-03 | 7.94 | 8.25 | 8.30 |
| Dec-03 | 7.97 | 8.29 | 8.36 | Dec-03 | 8.01 | 8.25 | 8.35 |
| Mar-04 | 8.04 | 8.17 | 8.44 | Mar-04 | 8.05 | 8.17 | 8.19 |
| Jun-04 | 8.03 | 7.99 | 8.09 | Jun-04 | 7.90 | 8.14 | 8.16 |
| Sep-04 | 7.97 | 8.16 | 8.09 | Sep-04 | 7.97 | 8.09 | 8.15 |
| Dec-04 | 7.93 | 7.74 | 8.08 | Dec-04 | 7.96 | 8.09 | 8.01 |
| Mar-05 | 7.84 | 7.75 | 8.06 | Mar-05 | 7.78 | 7.90 | 7.98 |
| Jun-05 | 7.74 | 7.76 | 7.92 | Jun-05 | 7.65 | 7.84 | 7.81 |
| Sep-05 | 7.66 | 7.73 | 7.86 | Sep-05 | 7.63 | 7.67 | 7.83 |
| Dec-05 | 7.74 | 7.63 | 7.88 | Dec-05 | 7.65 | 7.82 | 7.85 |
| Mar-06 | 7.47 | 7.61 | 7.81 | Mar-06 | 7.42 | 7.69 | 7.84 |
| Jun-06 | 7.45 | 7.74 | 7.44 | Jun-06 | 7.46 | 7.66 | 7.66 |
| Sep-06 | 7.43 | 7.71 | 7.85 | Sep-06 | 7.38 | 7.59 | 7.73 |
| Dec-06 | 7.28 | 7.51 | 7.72 | Dec-06 | 7.16 | 7.38 | 7.61 |
| Mar-07 | 6.85 | 7.42 | 7.59 | Mar-07 | 6.94 | 7.22 | 7.59 |
| Jun-07 | 6.78 | 7.30 | 7.54 | Jun-07 | 6.93 | 7.26 | 7.50 |
| Sep-07 | 6.98 | 7.27 | 7.66 | Sep-07 | 6.93 | 7.28 | 7.63 |
| Dec-07 | 7.00 | 7.28 | 7.49 | Dec-07 | 6.88 | 7.16 | 7.55 |
| Mar-08 | 6.47 | 7.28 | 7.31 | Mar-08 | 6.67 | 6.99 | 7.41 |
| Jun-08 | 6.39 | 7.01 | 7.20 | Jun-08 | 6.36 | 6.67 | 7.03 |
| Sep-08 | 6.26 | 6.43 | 6.79 | Sep-08 | 6.28 | 6.66 | 7.03 |
| Dec-08 | 6.06 | 6.24 | 6.97 | Dec-08 | 6.17 | 6.56 | 6.96 |
| Mar-09 | 6.03 | 6.03 | 6.68 | Mar-09 | 6.13 | 6.59 | 6.90 |
| Jun-09 | 6.19 | 6.52 | 7.05 | Jun-09 | 6.41 | 6.70 | 7.08 |
| Sep-09 | 6.55 | 6.77 | 7.06 | Sep-09 | 6.38 | 6.75 | 7.19 |
| Dec-09 | 6.48 | 6.69 | 7.15 | Dec-09 | 6.39 | 6.88 | 7.26 |
| Average | 7.18 | 7.39 | 7.64 | Average | 7.16 | 7.42 | 7.63 |