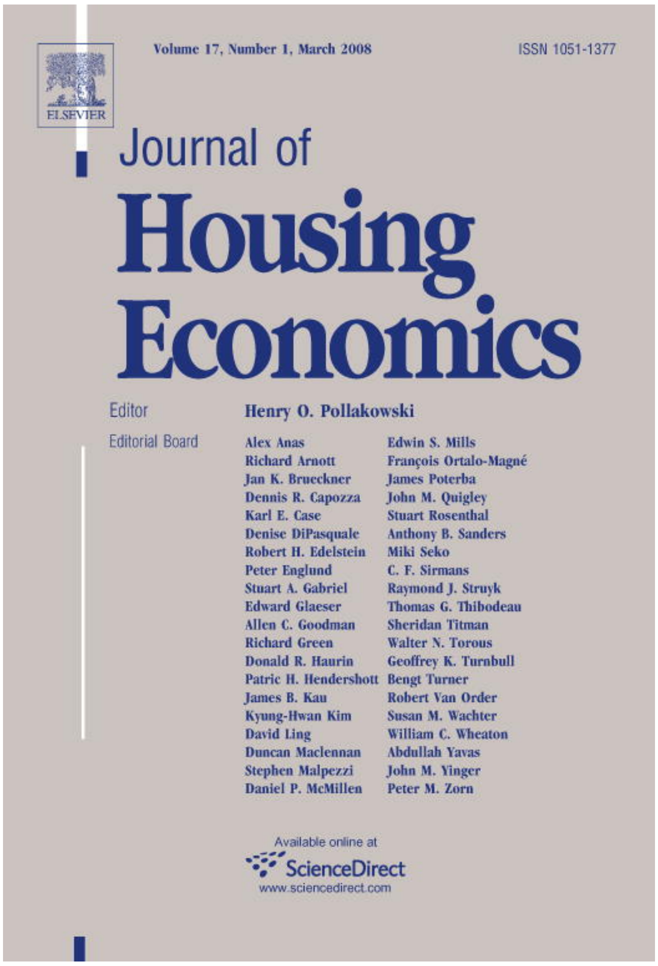
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# House price depreciation rates and level of maintenance

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**Abstract**

My objective in this paper is to estimate different depreciation rates of house prices depending on the level of maintenance of the property and the location of the property. I do this by supplementing transaction price data with owner information about level of maintenance. The result indicates that the level of maintenance has a substantial impact on the price level. Since maintenance offsets some of the physical deterioration of the property, the depreciation rate will be lowered by maintenance, ceteris paribus. To be able to estimate maintenance effects on depreciation rates, I isolated the interaction effect between the level of maintenance and the age of the property to allow for the fact that maintenance has an impact on the effective age of the property. In this study, I separate maintenance into indoor and outdoor maintenance levels (or absence of maintenance).

My results show that the depreciation rates are significantly different for a maintained property and for a property that is not maintained. The price difference between a 40-year-old property (built in 1960) and maintained both indoors and outdoors and a property of the same age that is not maintained is about 13% (−10% compared to −23% in total age effect). The absence of outdoor maintenance has more impact on price depreciation rates.


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## 1. Introduction

Analysis of depreciation rates and level of maintenance is important, among other thing, since housing depreciation may bias the estimation of the consumer price index, real estate price indices, appraisals, and tax assessments. Increased knowledge of economic depreciation is also important for assessing public policies see e.g., Malpezzi et al. (1987) and Smith (2004).

Why does a property depreciate over time? Depreciation can be caused by three different reasons, namely, physical deterioration, functional and external obsolescence. Functional obsolescence is due to technological changes and layout designs. External obsolescence may result from changes in the neighborhood, such as changes in traffic volume. Both of these are difficult for the owner to have any impact on. On the other hand, the owner of the property can reduce physical deterioration by maintaining the property. Therefore, depreciation of the value of a property is to be expected as the property gets older and older, but good maintenance may decrease the depreciation rate. However, it is not possible to reduce the depreciation rate to zero as functional and external obsolescence is always present. Clapp and Giaccotto (1998) define depreciation as "the decline in value with respect to age because of increased maintenance costs and decreased usefulness." However, there is also a vintage effect, that is, a price appreciation over time due to design and preferences, which may offset the negative effect of age over time. Thus, it is important not to mix the concepts of age depreciation effects and vintage effects. The vintage effect is defined as housing and neighborhood characteristics correlated with a certain construction year. Asabere and och Huffman (1991) investigated the vintage effect by analyzing the price difference between properties inside a historically interesting area and properties outside the area. They concluded that there is such a difference and they estimated it to be around 25% of the value.

My main objective here is to estimate different house price depreciation rates depending on the level of maintenance of the house. My contributions presented in this study compared to earlier studies are: first, I measure the effect of both indoor and outdoor physical deterioration; second, I divide physical deterioration into the need for upgrading the kitchen and the laundry room, changing the electrical system and the drainage systems. Third, I analyze whether depreciation rates differ across different sub-markets within a housing market; and finally, I use spatial econometrics to take care of potential spatial autocorrelation.

The disposition of the paper is as follows: Section 2 includes a brief literature review and Section 3 presents the theory and methodology used in the study. Sections 4 and 5 present the data and the econometric analysis. Section 6 summarizes and concludes the paper.

## 2. A brief literature review and our contribution

The use of the age of a property as a proxy for its depreciation is usual in traditional hedonic pricing models including non-housing models such as analysis of VCR (e.g., Silver, 2000) and wine (e.g., Angula et al., 2000; Malpezzi et al. (1987) present an extensive review of the housing literature on depreciation and housing prices. Their main objective was to estimate the rates of depreciation and how it varies across housing markets. The conclusion they drew from their literature review is that estimated depreciation rates vary substantially between studies. The wide range of depreciation rates seems to be a consequence of different choices of method, housing markets, and time periods. In their econometric analysis, they tried to control for the first and last difference. What they do find when they are studying different housing markets is that on average values decrease with age at a declining rate and in some housing markets depreciation rates deviate substantially from the average. The average depreciation rate for housing ranges from 0.9% in year 1 to 0.28% in year 20. In this literature review I will concentrate on some important articles published after Malpezzi et al. (1987).

Shilling et al. (1991) investigate the relationship between depreciation rates and tenure status. They theoretically argue and empirically show that the economic depreciation rate is lower in properties with owner-occupants than in rental housing. The difference is in the range of 0.5% per year.

Rubin (1993) takes another position when it comes to the interpretation of the estimates of negative age effect. He argues that the negative age affect is not a consequence of depreciation, but instead is an indication of age premiums for newer houses; that is, there exists a taste for newer housing. By controlling for differences in quality, he interprets the negative age coefficient as an age premium. However, housing price depreciation does not owe only to physical deterioration, but also to functional obsolescence and external obsolescence, which he does not account for. Of course, a pure taste for newer houses might exist, but further tests need to be made. There also exists a pure taste for old houses with some charm; see Asabere and och Huffman (1991) and Smith (2004). Rubin also separated the age coefficient into owner-occupied and renter-occupied. He concluded that it is not clear that depreciation rate is higher for renter-occupied houses than for owner-occupied houses.

Goodman and Thibodeau (1995) theoretically and empirically verified that housing depreciation is non-linear and "dwelling age-induced heteroskedasticity is prevalent in hedonic house price equations." They conclude that it is important that the age effect be included as a second-order effect in the housing price equation. The age-related heteroskedasticity is induced by the fact that housing is a durable good subject to renovation, which will increase the probability of wrongly predicting the price as age increases. The reason for this is that the variance of the price will increase with the age of the property as the condition of the house (renovated, maintained or run down) is likely to vary more. That is, if information on renovation were available, age-related heteroskedasticity would not be a problem. As I do have information about renovation and level of maintenance, I can test whether age-related heteroskedasticity is a major problem.

Knight and Sirmans (1996) present a very interesting article in which they analyze the effects of maintenance on the depreciation rate for housing and house price indexes. In many respects, my paper is very much inspired by and similar to theirs and the earlier paper by Chinloy (1980). They test three different specifications of the housing price model. The first model includes both age and an interaction variable between age and level of maintenance, the second model includes only age and the third model includes neither age nor maintenance level. The maintenance level comes from broker information about the object. In their sample, only 2.2% of the houses were considered poorly maintained. However, the average age of the properties was fairly low (18 years). Applying the models on 775 observations over a 9-year period, they obtained results that indicate that the information on maintenance has an important impact on individual depreciation rates. However, they do not find any significant effect of maintenance on the hedonic price index.

Their estimated depreciation rate is high (1.9% per year) and a property with a level of maintenance below average will depreciate 0.9% faster per year.

My extension of their model presented here is that I separate the level of maintenance into indoor and outdoor levels of maintenance, which makes it possible estimate the relative importance of these maintenance aspects. Then, I use data from a number of neighborhoods within a housing market and not just a single neighborhood. This means that I can test the hypothesis that depreciation rates differ from location to location. Lastly, I estimate a non-linear relationship between the price of the property and its age I test whether a spatial error model takes care of spatial autocorrelation more accurately than the models that include sub-markets dummies.

Clapp and Giaccotto (1998) developed a model in which they separated the age effect into two separate components: first, what they call a pure cross-sectional depreciation component and second a demand-side component that changes over time. As I am not using cross-sectional time-series data, I cannot test their hypothesis about a demand side component.

Knight et al. (2000) investigated the impact of repair expenditures on the transaction price of a property. Studying sale contracts, they summarize their study as the follows: "We find evidence that a home's transaction price represents the value of a normally maintained home even when the home has been substantially under-maintained prior to being marketed. As a result, concern over omitting extraordinary maintenance as a variable in transaction-based hedonic equations appears misplaced." My results from this study contradict their results, as I found that the effects of under-maintained properties are highly capitalized into the property price. Knight et al. (2000) argued that buyers of under-maintained properties either require the seller to do the necessary repairs to the property or that they be paid an allowance by the seller as part of the purchase agreement. In either case the transaction price will represent the price for a well-maintained house even if the house is under-maintained, that is, repair expenditures would not be capitalized into the property price. This is not a controversial hypothesis. However, to make the overall conclusion that under-maintained properties do not have maintenance expenditures capitalized into their price, they have to make some unrealistic assumptions. As they do not have information about buyers purchasing under-maintained properties and in the purchasing process getting a reduction in the selling price, they have to implicitly assume that this group of buyers is small in the sample. That is, the assumption that all properties sold without a repair clause in the sale contract are well-maintained seems to be unrealistic. They also implicitly assume that any repair costs included in the selling contract are correct, which of course may not be the case.

In a recent article, Smith (2004) concluded that "the intramarket location and the year in which the property sold have significant impacts on the observed rate of economic depreciation." Furthermore, he argued that the land value should be eliminated from the sale price, as land does not usually depreciate over time. However, as it is difficult to establish accurate land values, I have not used this method. Further, as I do not have pooled cross-section and time-series data, I cannot test the empirical result that the depreciation rate varies over time. However, I have tested whether the depreciation rate varies across location. Since I include an interaction variable between location and age, I can test the hypothesis that depreciation varies in space. The Smith (2004) result indicates that the rate of depreciation ranges from 0.5% to as much as 7% less than the mean for the housing market—a substantial variation dependent on location. In a recent article, Harding et al.

(2006) used a repeated sales model framework to relate house price depreciation and maintenance. Their results indicate that on average houses depreciate 2.5% per year. However, net maintenance depreciation is only 2% per year. That is, used measures for house price appreciation overestimate capital gains.

## 3. Theoretical model and methodology

I use the commonly used hedonic price method in this paper. This is not the only possible method, but it has some advantages compared to, e.g., the stock-adjustment method (see Malpezzi et al., 1987). I use the data collected to construct a cross-sectional hedonic regression model of house prices in the municipality of Stockholm, Sweden, in 2000. Hedonic price models have long been used to estimate implicit prices of housing attributes that comprise a composite good. Basically, a hedonic equation is a regression of, e.g., house values against attributes that determine these values and the regression coefficients can be interpreted as estimates of the implicit prices of these attributes, that is, the willingness to pay. The method has a long tradition. The first hedonic model dates back to Haas (1922), but it was Court (1939) who first used the expression 'hedonic,' and it was Rosen (1974) who developed the theoretical foundation of the model. A large number of studies have estimated implicit prices for housing and neighborhood attributes, but the models may also be used for the purpose of constructing house price indices as the method isolates constant quality price appreciation.

The hedonic price equation can be expressed in the following general form (see for example Knight and Sirmans, 1996):

$$\ln(Y) = X\beta + A\alpha + A^2\alpha_{\text{sq}} + AM\alpha_M + \varepsilon \qquad (1)$$

where $Y$ is an $1 \times n$ vector of observations of the dependent variable (here in log form), $\beta$ is a $k \times 1$ vector of parameters (regression coefficients) associated with exogenous explanatory variables, $X$, which are in the form of an $n \times k$ matrix. The variable $A$ measures the age of the property and the parameter $\alpha$ measures the effect of age. The stochastic term $\varepsilon$ is assumed to have a constant variance and normal distribution. It is implicitly assumed that all relevant attributes are included in the matrix $X$, that is, no problem variables have been omitted. The matrix $X$ can be decomposed into structural housing attributes and neighborhood attributes. The latter is included to control for the fact that property age is correlated with location. Furthermore, the age effect can be decomposed into physical deterioration, and functional and external obsolescence. I specify the age-effect in the model in this study, first, as a second-order polynomial ($A^2$) and, second, as an interaction term with the level of maintenance ($M$) to allow houses in different conditions to have different depreciation rates. The second-order term is included to control for non-linear relationship between age and property value as well as to control for possible difference in construction quality. Changing construction quality over time can cause a bias in the estimates of depreciation rates. The hypothesis I test is that when the level of maintenance is higher the depreciation rate will be lower, ceteris paribus.

If we regard age as a commodity, as Rubin (1993) did, the interaction variable investigates whether the implicit price of age varies with the level of maintenance. That is, the implicit price is here equal to (see Wilhelmsson, 2000):

$$\frac{\partial Y}{\partial A} = \alpha Y + \alpha_{sq} 2AY + \alpha_M MY \tag{2}$$

where $\alpha_M$ is equal to the parameter for the interaction variable between maintenance and age.

Spatial econometrics explicitly accounts for the influence of space in housing price models. If the spatial dimension is not included in the building of the housing price model, estimated parameters may be biased, ineffective and inconsistent. A general spatial lag model incorporates a spatial structure, the weight matrix $W$, into both the dependent variable and the error term (Anselin, 1988). That is, the spatial weight matrix produces a weighted average of the neighboring observations. The weight matrix defines how much a nearby observation in space should influence the averaging procedure.

$$\begin{aligned} Y &= \rho WY + X\beta + u \\ u &= \lambda Wu + \varepsilon \end{aligned} \tag{3}$$

The parameter $\rho$ is the coefficient of the spatially lagged dependent variable and measures the spatial dependency between $i$ and $j$. The parameter $\lambda$ is the coefficient in a spatial autoregressive structure for the disturbance. The weight matrix is of course of special interest in spatial models. First, it is exogenous, that is, it is based on prior knowledge of the spatial structure. Second, it may be based in actual (inverse) distance between observations or border conjunction. Third, it is an $n \times n$ matrix that may be symmetric or asymmetric with a diagonal of zeros (it is typically row standardized which makes it asymmetric). I use the inverse squared distance here.

The first step in the analysis is to estimate a hedonic regression model of house prices using housing structural characteristics and neighborhood attributes with the ordinary least squares method. In the second step I will use Moran's $I$ to test for the presence of spatial autocorrelation. If spatial autocorrelation is present, I will use spatial econometrics.

## 4. Descriptive analysis

The empirical analysis in this paper is based on cross-sectional data that originally included all 968 transactions for single-family houses in 2000 in the municipality of Stockholm, Sweden. In addition to the transaction data, such as price, size, quality and the exact spatial location ($x$ and $y$ coordinates), the data set is supplemented with data on housing structural attributes that was collected by a postal survey. The postal survey was conducted in 2003 to all households that bought a single-family house in Stockholm 2000 and that still own it in 2003. A number of questions about the household, the buying process and structural attributes were put to the household. The response rate was around 65%, which can be considered as good. Hence, the total number of observations included in the sample is now 640. In Table 1 below, the description of the attributes and transaction price is presented.

On average, a house in Stockholm was sold for SEK 2.6 million. The deviation from the mean is relatively high. The mean size of living area was 118 square meters, the standard deviation was about 43 square meters and the average number of rooms was about 5. The average age is about 55 years old, that is, the houses were built in around the end of Second World War. Approximately 5% of the houses had a view

Table 1
Descriptive statistics

| Variable | Description | Unit | Average | Standard deviation |
|---|---|---|---|---|
| Price | Transaction price | SEK | 2545026 | 1215467 |
| Living area | Living area size | Square meters | 118 | 43 |
| Other area | Other indoor area size | Square meters | 58 | 33 |
| Lot size | Outdoor area size | Square meters | 724 | 266 |
| Rooms* | Number of rooms | Number | 5.03 | 1.3 |
| Quality | Quality of the house | Index | 27.6 | 5.9 |
| Sea view* | Presence of sea view | Binary | 0.05 | |
| Age | Age of the house | Year | 51 | 18 |
| Distance | Distance to CBD from the house | Meters from CBD | 8754 | 2694 |
| Sauna* | Presence of sauna | Binary | 0.35 | |
| Heating* | Presence of electrical heating | Binary | 0.20 | |
| Cabel-tv* | Presence of cable-tv | Binary | 0.30 | |
| Garage* | Presence of garage | Binary | 0.62 | |
| Fireplace* | Presence of fireplace | Binary | 0.63 | |
| Inside maintenance (IM)* | Need for indoor repairs | Binary | 0.79 | |
| Electricity | Concerning electricity | Binary | 0.56 | |
| Kitchen | Of the kitchen | Binary | 0.68 | |
| Laundry | Of the laundry | Binary | 0.63 | |
| Outside maintenance (OM)* | Need for outdoor repairs | Binary | 0.50 | |
| Drainage | Concerning drainage | Binary | 0.38 | |
| Road traffic* | Close to road | Binary | 0.28 | |
| Number of observations | | | 640 | |

Note: *indicate information from the postal survey.

of the sea. More than half of the households indicate that the property is in need of maintenance, especially indoor maintenance. Road traffic affects 28% of the households. The heating variable indicates the proportion of the properties where the heating distribution system is electricity. Around one fifth of the properties have an electric heating distribution system (see Table 1).

As the information from the postal survey is only in terms of binary variables, the economic interpretation can be difficult to make. Need of repairs indoors could mean very different things for the different houses, for example, painting the walls, upgrading the kitchen or rewiring all the entire house. That is, the initial costs of each repair may be very different as may be the future housing service that it provides. To get a more detailed picture of the needs, questions about the kind of repairs needed were asked, such as the need to rebuild the kitchen or to upgrade the electrical system.[1]

As Goodman and Thibodeau (1995) indicate, the range between well-maintained properties and under-maintained properties are more likely to be larger in the older age groups

[1] A more appropriate variable to use would be a variable indicating whether the owner carried out repairs. However, due to data limitation the variable indicating whether the house needed maintenance at purchase could be seen as a proxy for a variable indicating whether the owner actual carried out repairs.

Table 2
Properties in need of maintenance or renovation (percentage)

| Age group | Outdoor | Indoor | Electricity | Laundry | Drainage | Kitchen |
|---|---|---|---|---|---|---|
| 0–10 | 16 | 37 | 0 | 21 | 0 | 21 |
| 11–20 | 36 | 52 | 20 | 48 | 8 | 72 |
| 21–30 | 39 | 78 | 28 | 64 | 19 | 67 |
| 31–40 | 38 | 79 | 43 | 57 | 36 | 64 |
| 41–50 | 41 | 83 | 53 | 55 | 41 | 64 |
| 51–60 | 63 | 86 | 72 | 70 | 52 | 73 |
| 61–70 | 53 | 84 | 63 | 61 | 39 | 73 |
| 71–80 | 61 | 80 | 67 | 73 | 48 | 71 |
| All | 50 | 79 | 56 | 63 | 38 | 68 |

of houses. In Table 2 below are the relative proportions indicating that property are under-maintained or in a need of a renovation shown. As expected, the relative maintenance proportion increases with the age of the property.

Property age is highly correlated with the location. In fact, cities are more likely to grow from the city centre and as a consequence, the oldest properties in a housing market can be found closer to CBD (central business district). The box-plot in Fig. 1 below shows the relationship between property age and location (measured as distance from city) in the city of Stockholm, Sweden.

As this relationship can be observed, it makes interpretation difficult and it is therefore important to control for location effects in the estimation of depreciation rates. In the econometric analysis below, the distance to CBD variable and sub-market dummies will control for location within the housing market.

## 5. Econometric analysis

There are a number of attributes in the estimation of the hedonic price equation that are meant to explain the price variation. The first four attributes measure living area, other

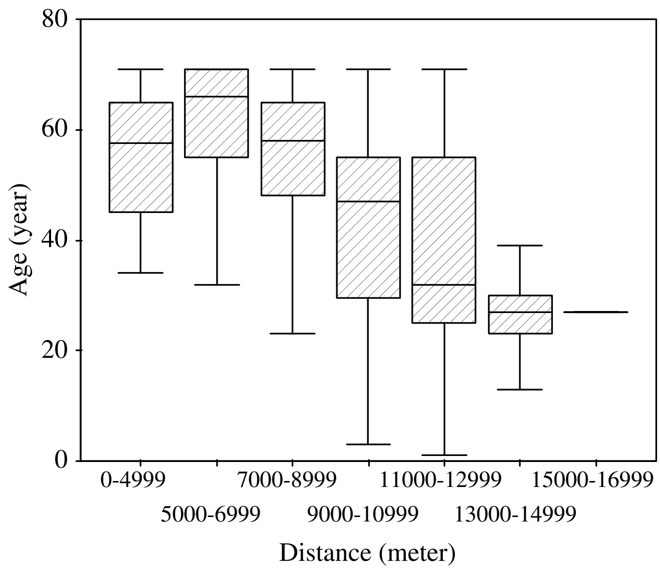


Fig. 1. Property age and distance from CBD.

indoor area and outdoor lot size (variable name Lot) in square meters, and number of rooms. The fifth attribute in the model is a measure of indoor quality. This attribute, used for assessment tax purposes, is constructed from data provided by the owner of the property. To some extent it includes the attributes that were asked for in the survey. This means that the estimated parameter may not be statistically different from zero owing to multicollinearity. The sixth attribute is a binary variable that indicates whether the property has a sea view or not. The seventh and eighth variables in the model are age, measured as the difference between building year and transaction year, and age squared. The ninth and tenth attributes are the distance in meters from the house to the CBD and an interaction variable between distance and south of the CBD. Attributes 11–15 are all binary variables indicating whether or not the house has the attribute (*Sauna*, *Cable TV*, *Garage*, *Heating*, and *Fireplace*). Attributes 16 and 17 are the month and whether the house is close to a road. Attributes eighteen and nineteen indicate, respectively, whether the house is in need of indoor and outdoor maintenance or not (IM and OM). Furthermore, the hedonic model includes 55 binary variables for sub-areas. The sub-areas are defined as the administrative parish.

The main objective in this paper is to analyze the price depreciation rates and how they differ depending on the need for maintenance. Therefore, the attribute age variable is combined with the maintenance variables to create two new variables, AIM and AOM (as in Knight and Sirmans, 1996). The testable hypothesis is that when the level of maintenance is higher the depreciation rate will be lower, ceteris paribus.

Models 1 and 2 are models excluding and including survey data, respectively, but without the sub-area dummies. Models 3 and 4 only add the sub-area dummies. There are a number of differences in the results between the models. First, the introduction of the survey data including maintenance variables increases the goodness-of-fit substantially, from 60% to 67%. Second, the inclusion of the sub-areas adds explanatory power. Thirdly, the models without sub-area dummies are affected by spatial autocorrelation, but the sub-area dummies pick up all the spatial dependency. Finally, the use of sub-area dummies takes all the exploratory power from the distance to CBD variables, not surprisingly. In the first two models, the distance variables are highly significant and of expected sign and magnitude, but in models 3 and 4 they are not statistically significant. The same is true, to some extent, for the variable closeness to road traffic.

The introduction of interaction variables between age and the maintenance variables in model 5 does not increase the determination coefficient. However, the parameters are highly statistically significant. Models 6 and 7 use spatial econometrics to estimate the parameters compared to the ordinary least squares of the first five models. The exploratory power decreases, but the parameters are of the same magnitude and are, as before, statistically significant.

In Fig. 2 below, the willingness to pay has been estimated for some of the attributes using the results from model 5. As in many investigations, sea view is one of the attributes with high willingness to pay (around 30% of the property value). We can also notice that the willingness to pay for a heating system not based on electricity is fairly high (almost 10%). There are a number of reasons for this including cost of heating, comfort, flexibility, and heating efficiency.

Property age is included in the model as two separate variables, untransformed and squared, to permit test whether there is a vintage effect or not (as proposed by Goodman and Thibodeau, 1995). As can be seen, both parameters are statistically different from zero and both have the expected sign, that is, a positive possible vintage effect can be noticed

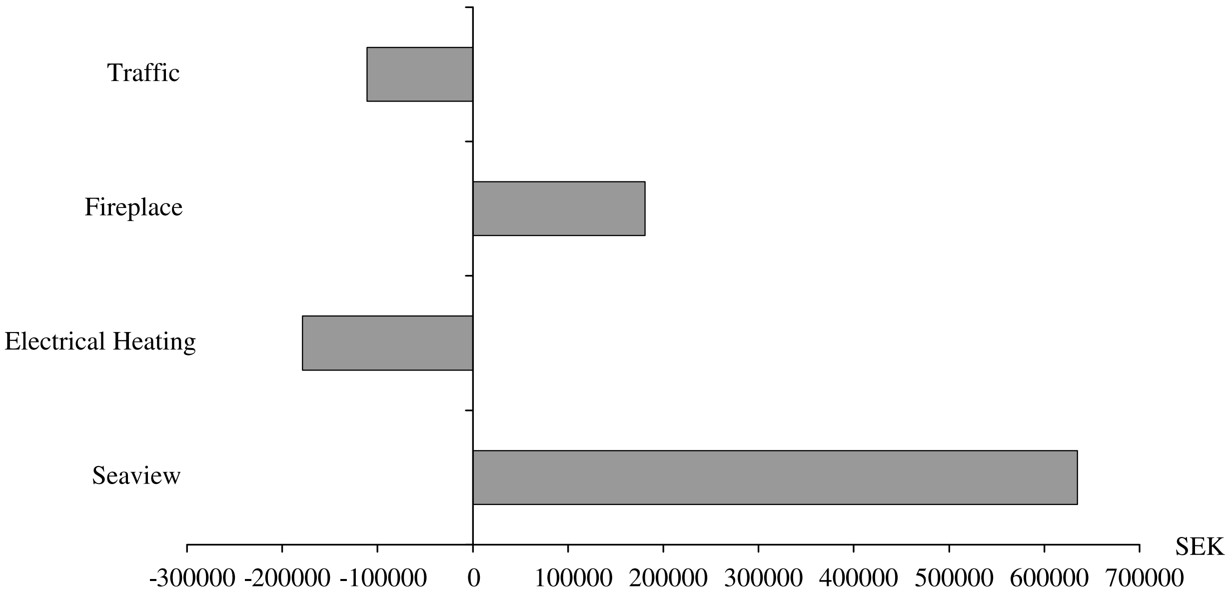


Fig. 2. WTP for different attributes (model 5). Note: all WTP are evaluated at average quantity of the housing attributes (see e.g., Wilhelmsson, 2000). For a logarithmic functional form, the coefficient concerning a dummy variable is not interpreted as the percentage impact on price of a change in the dummy variable from zero to one status. The correct expression for this percentage impact is $e^{\beta}-1$ (Halvorsen and Palmquist, 1980).

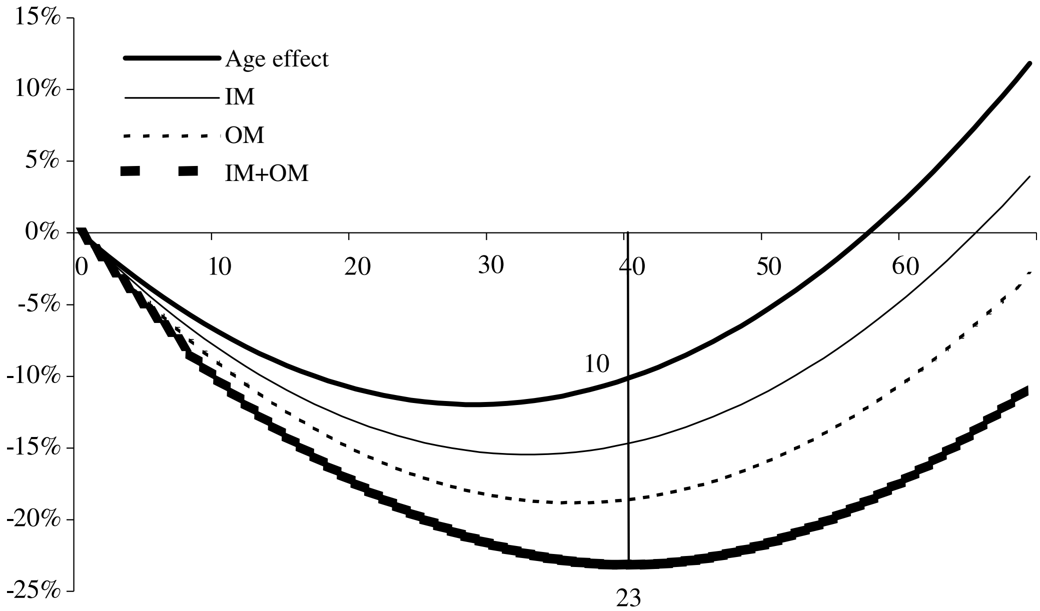


Fig. 3. Depreciation effect (model 7).

for houses older than 60 or 70 years.[2] In Fig. 3 shows the depreciation rates for properties that have been maintained and not maintained, respectively. All the differences are statis-

[2] Of course, the "vintage effect" is a consequence of the nonlinearity in the effect of age on house price. Using a squared term indicate depreciation increasing at a decreasing rate, but at some point the squared takes over and houses appear to appreciate with age. By using dummy variables for various age ranges (10 years as in Table 2), we more or less get the same results and pattern. However, we seem to overestimate the possible "vintage effect" when we are using age and age squared instead of a dummy structure for age (9% instead of 20).

tically different from each other. As can be observed, there is a huge effect on depreciation rates depending on if the property is maintained or not.

If we interpret this literally, we can say that a property that is well-maintained over the years can be expected to have a price around 10% lower than a new property. On the other hand, if the property is in a need of both indoor and outdoor repairs, the expected price is around 23% lower than for a new property (Table 3).

The estimated depreciation rate is 0.77% per year for a well-maintained property and 1.10% for a property that is not renovated indoors or outdoors year 1. The estimates for the annual depreciation rates in year 20 are 0.34% and 0.67%, respectively. By way of comparison, Kain and Quigley (1970) estimated a constant depreciation rate of 0.7%, in Chinloy (1980) the net depreciation rate ranges from 0.69% to 0.91%, Malpezzi et al., 1987 to 0.9%, Gatzlaff and Haurin (1998) to 0.3, and Knight et al. (2000) to 0.3% per year.

As pointed out in a number of articles, location and property age are highly correlated. As a result, the overall results presented above are only valid for the whole housing market if there is no correlation between depreciation rates and location. We have tested this hypothesis by estimating separate depreciation rates for the sub-markets (including the interaction variable age and level of maintenance), but found no correlation between location within the housing market and depreciation rates (in contrast with, e.g., Smith, 2004).

In Table 4 below, the renovation needs have been separated into upgrading the kitchen and laundry, upgrading the drainage system and upgrading the electrical system. All the variables are interacted with age.

The parameters for under-maintenance outdoors are still statistically different from zero even if the binary variables are included. It is especially the need of upgrading the kitchen and drainage system that has an additional impact on the price. If the separate upgrading variables are included in the model the depreciation rates for a well-maintained property decrease slightly year 1 from 0.78% to 0.75% per year. However, the depreciation rate for under-maintained properties increases from 1.12% to 1.21% per year (year 1).[3] The appreciation rates that can be noted for the oldest properties could be an indication of a vintage effect. It seems that very old properties have a premium attached to the price, because of charm, exclusivity and quality of construction.

## 6. Conclusion

Measuring economic depreciation in housing is an important task. Over the years a number of articles about depreciation have been published. Researchers' understanding of how housing values depreciate is quite good. The objective of my investigation here is to deepen our understanding. My main contribution in this paper is that I relate depreciation rates to the level of maintenance, which has a clear impact on the property value and the depreciation rate. The results show that the depreciation rates are significantly lower for a maintained property than for a property that is not maintained (see Table 5). Thus, the owner can delay physical deterioration by maintaining the property. I estimate the depreciation rate to be 0.77% per year for a well-maintained property and 1.10% for a property that is not renovated indoors or outdoors year 1. I estimate that

[3] The first year depreciation rate is estimated by using the coefficients in Table 4 (Model A and C), that is, $1.12 = -0.807 + 0.012 - 0.144 - 0.181$ and $1.21 = -0.773 + 0.012 - 0.046 - 0.109 + 0.023 - 0.1 - 0.079 - 0.142$.

Table 3
Regression results

| | | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 | Model 7 |
|---|---|---|---|---|---|---|---|---|
| | Constant | 14.04 | 14.26 | 14.30 | 14.13 | 14.09 | 10.88 | 10.84 |
| | | (118.93) | (126.65) | (28.96) | (30.88) | (30.86) | (19.28) | (19.19) |
| 1 | Living area | 0.00576 | 0.00511 | 0.00428 | 0.00388 | 0.00382 | 0.004508 | 0.004458 |
| | | (18.67) | (14.51) | (11.74) | (10.16) | (10.04) | (12.87) | (12.76) |
| 2 | Other area | 0.00117 | 0.00057 | 0.00095 | 0.00041 | 0.00046 | 0.000479 | 0.000506 |
| | | (3.29) | (1.67) | (2.73) | (1.22) | (1.37) | (1.47) | (1.55) |
| 3 | Lot | −0.00002 | −0.00004 | 0.00009 | 0.00007 | 0.00007 | −0.000033 | −0.000030 |
| | | (−0.54) | (−1.06) | (1.80) | (1.52) | (1.57) | (−0.75) | (−0.70) |
| 4 | Rooms | | 0.01719 | | 0.02242 | 0.02163 | 0.015596 | 0.015509 |
| | | | (1.65) | | (2.23) | (2.16) | (1.56) | (1.55) |
| 5 | Quality | 0.00773 | 0.00384 | 0.00749 | 0.00316 | 0.00341 | 0.003683 | 0.003848 |
| | | (3.72) | (1.88) | (3.81) | (1.62) | (1.76) | (1.86) | (1.95) |
| 6 | Sea view | | 0.29371 | | 0.24119 | 0.24937 | 0.27128 | 0.282358 |
| | | | (6.51) | | (5.31) | (5.49) | (6.11) | (6.36) |
| 7 | Age | −0.01178 | −0.01031 | −0.00951 | −0.00714 | −0.00800 | −0.0076 | −0.008360 |
| | | (−3.72) | (−3.41) | (−2.91) | (−2.30) | (−2.59) | (−3.28) | (−3.61) |
| 8 | Age square | 0.00018 | 0.00016 | 0.00011 | 0.00009 | 0.00011 | 0.00012 | 0.000146 |
| | | (5.02) | (4.70) | (3.04) | (2.47) | (3.28) | (5.20) | (6.42) |
| 9 | Dist | −0.00004 | −0.00004 | −0.00004 | −0.00003 | −0.00002 | −0.000030 | −0.000030 |
| | | (−6.40) | (−7.15) | (−1.42) | (−0.86) | (−0.84) | (−6.15) | (−6.14) |
| 10 | Dist-south | −0.00002 | −0.00002 | −0.00003 | −0.00008 | −0.00008 | −0.000013 | −0.000013 |
| | | (−5.65) | (−5.71) | (−0.54) | (−1.44) | (−1.48) | (−4.05) | (−4.07) |
| 11 | Sauna | | 0.00583 | | 0.01164 | 0.00900 | 0.003981 | 0.001831 |
| | | | (0.25) | | (0.53) | (0.41) | (0.18) | (0.08) |
| 12 | Cabel-tv | | 0.01568 | | 0.02616 | 0.02403 | 0.027076 | 0.024250 |
| | | | (0.70) | | (1.17) | (1.08) | (1.25) | (1.12) |
| 13 | Garage | | −0.02445 | | −0.02419 | −0.02407 | −0.021235 | −0.020343 |
| | | | (−1.16) | | (−1.19) | (−1.19) | (−1.04) | (−1.00) |
| 14 | Heating | | −0.07039 | | −0.06815 | −0.07024 | −0.072398 | −0.074936 |
| | | | (−2.54) | | (−2.57) | (−2.66) | (−2.70) | (−2.80) |
| 15 | Fireplace | | 0.09453 | | 0.07140 | 0.07111 | 0.081361 | 0.081030 |
| | | | (4.29) | | (3.30) | (3.29) | (3.84) | (3.84) |
| 16 | Month | 0.01916 | 0.01681 | 0.02130 | 0.01904 | 0.01895 | 0.017617 | 0.017639 |
| | | (6.15) | (5.86) | (7.14) | (6.87) | (6.84) | (6.36) | (6.39) |
| 17 | Traffic | | −0.06347 | | −0.04442 | −0.04365 | −0.049167 | −0.047728 |
| | | | (−2.88) | | (−1.96) | (−1.93) | (−2.30) | (2.23) |
| 18 | IM | | −0.05429 | | −0.07818 | | −0.062234 | |
| | | | (−2.08) | | (−3.15) | | (2.46) | |
| 19 | OM | | −0.10713 | | −0.09442 | | −0.110671 | |
| | | | (−5.23) | | (−4.78) | | (−5.58) | |
| 20 | AIM | | | | | −0.00144 | | −0.001142 |
| | | | | | | (−3.03) | | (−2.36) |
| 21 | AOM | | | | | −0.00181 | | −0.002128 |
| | | | | | | (−5.04) | | (−5.92) |
| | $\rho$ | | | | | | 0.2231 | 0.228708 |
| | | | | | | | (6.95) | (6.12) |
| | Adjusted $R^2$ | 0.604 | 0.669 | 0.675 | 0.724 | 0.725 | 0.689 | 0.691 |
| | Moran's $I$ | 4.16 | 2.94 | .07 | −.21 | −0.15 | — | — |

Note: coefficients for sub-area variables are not included in this table. Dependent variable: ln(price).

Table 4
Regression results

| | Model A | | Model B | | Model C | |
|---|---|---|---|---|---|---|
| | Coefficient | *t*-value | Coefficient | *t*-value | Coefficient | *t*-value |
| Constant | 14.09008 | 30.84 | 14.14639 | 31.17 | 14.09930 | 31.11 |
| Living area | 0.00383 | 10.04 | 0.00403 | 10.52 | 0.00400 | 10.55 |
| Other area | 0.00048 | 1.40 | 0.00040 | 1.19 | 0.00045 | 1.33 |
| Lot | 0.00007 | 1.54 | 0.00005 | 1.06 | 0.00005 | 1.04 |
| Quality | 0.00339 | 1.75 | 0.00327 | 1.67 | 0.00246 | 1.26 |
| Age | −0.00807 | −2.61 | −0.00813 | −2.64 | −0.00773 | −2.51 |
| Age square | 0.00012 | 3.30 | 0.00011 | 3.28 | 0.00012 | 3.50 |
| Dist | −0.00002 | −0.84 | −0.00003 | −0.95 | −0.00002 | −0.77 |
| Dist-south | −0.00008 | −1.47 | −0.00007 | −1.38 | −0.00009 | −1.74 |
| Month | 0.01905 | 6.86 | 0.01914 | 6.89 | 0.01883 | 6.83 |
| Rooms | 0.02161 | 2.15 | 0.01811 | 1.80 | 0.01817 | 1.81 |
| Seaview | 0.24861 | 5.47 | 0.22133 | 4.88 | 0.24030 | 5.33 |
| Sauna | 0.00860 | 0.39 | 0.00220 | 0.10 | 0.00681 | 0.31 |
| Cabel-tv | 0.02408 | 1.08 | 0.01807 | 0.80 | 0.01370 | 0.61 |
| Garage | −0.02357 | −1.16 | −0.02704 | −1.34 | −0.02195 | −1.09 |
| Heating | −0.07024 | −2.66 | −0.07842 | −2.97 | −0.07511 | −2.86 |
| Fireplace | 0.07072 | 3.27 | 0.07862 | 3.64 | 0.07403 | 3.45 |
| Traffic | −0.04448 | −1.96 | −0.06281 | −2.76 | −0.05321 | −2.34 |
| AIM | −0.00144 | −3.03 | | | −0.00046 | −1.17 |
| AOM | −0.00181 | −5.02 | | | −0.00109 | −2.42 |
| AElectricity | | | −0.00065 | −1.66 | 0.00023 | 0.58 |
| AKitchen | | | −0.00139 | −3.14 | −0.00100 | −2.67 |
| ALaundry | | | 0.00017 | 0.42 | −0.00079 | −1.56 |
| ADrainage | | | −0.00137 | −3.74 | −0.00142 | −3.84 |
| Adjusted $R^2$ | 0.725 | | 0.725 | | 0.733 | |

Note: coefficients for sub-area variables are not shown in the table. Dependent variable: ln(price).

Table 5
Depreciation rates

| | Model A | | Model B | | Model C | |
|---|---|---|---|---|---|---|
| | Well-maintained (%) | Under-maintained (%) | Well-maintained (%) | Under-maintained (%) | Well-maintained (%) | Under-maintained (%) |
| Year 1 | −0.78 | −1.11 | −0.79 | −1.11 | −0.75 | −1.20 |
| Year 10 | −0.58 | −0.90 | −0.58 | −0.91 | −0.53 | −0.98 |
| Year 20 | −0.34 | −0.67 | −0.35 | −0.68 | −0.29 | −0.74 |
| Year 40 | 0.12 | −0.21 | 0.11 | −0.22 | 0.20 | −0.25 |
| Year 60 | 0.58 | 0.26 | 0.56 | 0.24 | 0.69 | 0.24 |

the annual depreciation rates for year 20 are 0.42% and 0.84%, respectively. However, I do not find that depreciation rates vary in space within the same housing market.

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