1976

Depreciation, Adverse Selection and Housing Markets

Peter T. Chinloy

Follow this and additional works at: https://ir.lib.uwo.ca/economicsipsle_dp

Part of the [Economics Commons](#)

Citation of this paper:

Chinloy, Peter T.. "Depreciation, Adverse Selection and Housing Markets." Research Program. Impact of the Public Sector on Local Economies Discussion Papers, 010. London, ON: Department of Economics, University of Western Ontario (1976).

Discussion Paper 010

DEPRECIATION, ADVERSE SELECTION
AND HOUSING MARKETS

Peter T. Chinloy

RESEARCH PROGRAM:
IMPACT OF THE PUBLIC
SECTOR ON LOCAL ECONOMIES

Department of Economics Library

JUN 25 1976

University of Western Ontario

Department of Economics
The University of Western Ontario
London Ontario Canada

Discussion Paper 010

DEPRECIATION, ADVERSE SELECTION
AND HOUSING MARKETS

Peter T. Chinloy

May, 1976

DEPRECIATION, ADVERSE SELECTION
AND HOUSING MARKETS

Peter T. Chinloy
Department of Economics
University of Western Ontario
London, Ontario, Canada

Abstract

Implications of incomplete buyer and seller information on product quality are considered for the durable goods market. Hypotheses on price paths over a working life for durables of a given vintage are formulated. In particular, it is noted that traditional depreciation estimates may be biased upward. Some empirical results for single-family dwellings are used to test the hypotheses.

DEPRECIATION, ADVERSE SELECTION AND HOUSING MARKETS*

1. Introduction

Traditional depreciation estimates for housing and other durable goods have been constructed by examining price behavior over time for sales of assets of a given vintage.¹ The effect of inflation can be separated from that of economic depreciation by the inclusion of separate variables for date of sale and date of manufacture. In such a specification, geometric depreciation can be tested as a hypothesis by imposing a direct structure on the form of the estimated depreciation function.

It is our contention that these conventional approaches to depreciation will lead to estimates which are biased upward. A puzzle associated with observed estimates is that the stock of a given vintage does not disappear in a time period equal to the inverse of the depreciation rate.² Another observation is that of perverse shapes for estimated depreciation functions, with more rapid price decreases in certain age ranges than in others or functions which fail to exhibit monotone decreases in age.³ Our objective is to derive an explanation for these phenomena.

Underlying the theory is the notion of uncertainty on product quality. Goods of below average quality, or lemons, cannot be distinguished from higher quality items, and problems of adverse selection arise. Part of the observed "depreciation" arises because the proportion of lemons entering market trading is unrepresentative of the population of a given vintage.

An implication is that market data cannot be used directly to estimate depreciation functions. We indicate an empirical procedure for

disentangling economic depreciation and adverse selection effects, and provide an application to single family dwellings.

The observed upward bias in depreciation estimates in turn will influence measurements of capital stock and investment. In addition, misleading signals for larger replacement investment than is required will obtain, in comparison with predictions of a theory embodying perfect information.

2. Depreciation and Adverse Selection

Consider observations on the prices of a given house over its life history. The first time that the house is sold, the spread of the price distribution will be relatively small. This phenomenon arises because buyers, and possibly sellers, cannot distinguish individual lemons from the sample, even where the population proportion for lemons is known.

The subjective probability distribution over qualities will vary with buyer information. The distributions, moreover will have explicitly dynamic and adaptive properties in the sense that learning will take place in differential fashion between agents in the market. Typically, new houses are sold with guarantees, including repairs and maintenance.⁴ Lemon owners have recourse in the short run, but not in the long run. Screening and the identification of product quality therefore possess an explicit time dimension, whether it be year, age, experience or vintage. Although information on product quality is not immediately discernible to an owner, once the uncertainty has been resolved the owners of lemons attempt to dispose of them immediately. The effect of such actions is to increase the proportion of lemons offered among younger secondhand houses.⁵ Hence the average price will decline sharply at first, but eventually the price path with age will

become convex to the origin. There are two reasons for this development. First, the scrappage rates for lemons will be higher, and hence over time, those durables offered for sale will represent progressively higher average original quality. Second, over time other motives for asset sale will emerge, including life cycle and portfolio allocation decisions, family structure and migration and location decisions. Over time information on product quality becomes available to both potential buyers and sellers, but particularly sellers, who are owners of such items. Let the price of new houses be

$$(1) \quad p(m,0) = \lambda(m,0)p_G(m,t) + (1 - \lambda(m,0))p_L(m,t)$$

where $\lambda(m,0)$ is the initial, and true population proportion of good houses of model m , and $p_G(m,t)$ and $p_L(m,t)$ are the true and unobservable prices of good units and lemons. It follows that $p_G(m,t) \geq p(m,0) \geq p_L(m,t)$. The prices $p_G(m,t)$ and $p_L(m,t)$ are surrogates which would obtain provided that all quality differences for a given model could be distinguished.

In the next period, the average price from observed market trades is

$$(2) \quad p(m,1) = \lambda(m,1)p_G(m,t) + (1 - \lambda(m,1))p_L(m,t)$$

where $p(m,1) < p(m,0)$ for reasons discussed earlier. Some lemon owners, now apprised of the below average quality, attempt to sell their houses. Good house owners have made a bargain, and leave the market. Hence $\lambda(m,1) < \lambda(m,0)$, where $\lambda(m,1)$ is the good proportion in the sample of model m units sold at time 1 and $\lambda(m,0)$ is the good proportion in the original population.

Consider a case where the rate of depreciation, or physical deterioration and obsolescence is low. New observed depreciation rates are observed in empirical estimates for housing markets. Depreciation here is measured as a physical property.⁶ In addition, consider a case where observable quality

differences are small. For example, we can commence with new houses which are superficially homogeneous.

The potential bias now emerges from the observation of the market data, which are represented by the curved line in Figure 1. Since these data correspond to age observations of a given vintage, it is tempting to view these changes as a depreciation function. In fact there is no depreciation and the entire price decline is attributable to lemon effects.⁷

Depreciation functions are often estimated from real estate transactions for dwellings. Such depreciation estimates are likely to be biased upwards, implying an overstatement of depreciation. This bias will imply that depreciation functions will exhibit more downward slope than is actually the case. Given the predominant role of replacement type investment in fixed capital formation, such biases may have serious implications for the measurement of economic growth and productivity. If replacement is mechanistic or equal to depreciation, the level and share of replacement investment in the total will be overstated. Moreover, if replacements are made on a backward margin by retiring the oldest vintages, and there is embodied technical change, the overstated depreciation will bias upward the rate of capital services per stock unit.

Figure 1 illustrates another potential phenomenon, namely the generalized Gresham's Law process of Akerlof (1970, 1976). The observed price path is convex to the origin and suggestive of geometric or proportional depreciation, a fundamental assumption of capital theory. However, again both $p_G(m,t)$ and $p_L(m,t)$ are flat with age, so there is no depreciation. The convex shape arises because of the preponderance of lemons in the secondhand market and not because of deterioration. Ultimately, bad houses drive out good houses and we have

Figure 1

$$(3) \quad \lim_{t \rightarrow \infty} p(m,t) = p_L(m,t)$$

as our condition. We have some further predictions as a consequence. The more rapid the learning process on quality, the faster the price decline. The greater the true quality dispersion or differential between $p_G(m,t)$ and $p_L(m,t)$, the greater the price decline. In addition, a determining factor will be the population lemon proportion.

Thus far, the cases considered have been atypical, in the sense that we will generally observe some deterioration and obsolescence in housing. Such a case is illustrated in Figures 2a and 2b. Both good and bad units deteriorate over time, so

$$(4) \quad \frac{\partial p_G(m,t)}{\partial t} \leq 0, \quad \frac{\partial p_L(m,t)}{\partial t} \leq 0$$

with the case of more rapid lemon deterioration being depicted in Figure 2a. However, even if these true diminution curves occur, there is no guarantee that the market average will be monotone decreasing. Since the average depends also on the proportion of lemons offered for sale, it is by no means implausible that, for example in Figure 2a, the average can increase. The lower curve of Figure 2a represents the proportion of good units sold with age. Initially this proportion declines rapidly. After a few years of sorting, the good proportion increases, and if $p_G(m,t)$ is relatively flat, the observed selling price can rise over a period. Ultimately the dominant effects of physical deterioration will cause prices to decline, but the dotted line will represent the observed market data. In Figure 2a bad units drive out good units. In Figure 2b this process is reversed, with the proportion of good units rising asymptotically to unity as $t \rightarrow t^*$. After this time there are no lemons left and $p_G(m,t) = p_L(m,t)$.

Figure 2a

Figure 2b

There is another problem, namely that of scrappage or equivalently survival. Empirically, there will be difficulties in obtaining information on the series $p_G(m,t)$ and $p_L(m,t)$. The ideal would be to survey all owners rather than to examine only secondhand offers. We have a classic case of selectivity bias where a systematic region of the desired price distribution is not observable. Scrappage rates are presumably higher for lemons, another potential factor leading to a reduction in the proportion of lemons in the market. If "depreciation" is measured from market data there will be no provision for this differential scrappage. Here, the bias is the opposite of the earlier prediction. Suppose depreciation rates are applied to a "homogeneous" initial capital stock. These rates will therefore be applied to lemons and good units identically, regardless of the shift in the quality mix upwards from the retirement of inferior units. Failure to take differential scrappage into account will understate the average effective services per unit of capital over time, and understate the quality corrected capital stock.

These are the basic hypotheses and predictions we posit for a screening theory in the housing market. We now turn to an explicit modeling process, a discussion of the type of data which would be most appropriate for testing the model and some empirical results.

3. Price Process Modeling

In this section we formulate the precise model to be used to estimate and identify the behavior of the durable goods market with lemons.

For purposes of specification, we make two assumptions which do not appear implausible. First, we assume that the capital aggregation conditions hold within the age distribution over time for a given model. Essentially

this requires that good units and lemons have prices which exhibit fixed relative proportions. This implies

$$(5) \quad p_L(m,t) = \theta(m)p_G(m,t)$$

where $\theta(m) \in [0,1]$ may be interpreted as the lemon repair coefficient on durables of vintage m . If $\theta(m) = 1$ then all qualities are identical, so $\theta(m)$ represents the relative repair costs with respect to a good house, to convert or upgrade the condition of a lemon. The dollar costs of conversion can decline if $\partial p_G(m,t)/\partial t < 0$, but as a proportion of $p_G(m,t)$ they remain fixed. Second we assume that information on the quality of all goods of a given vintage becomes completely known at some critical age t^* , and therefore all units appearing on the market subsequent to that date can be considered as good. As a result

$$(6) \quad \lambda(m,t) = 1$$

for all $t > t^*$.

Lemons can be removed from the capital stock and the market in one of two ways. Scrappage can take place, as units are retired from the stock. Alternatively, units can be reclassified, following owner investment to correct the lemon defect. If a house has a leaking roof, the roof can be replaced. These initially unobservable features can be altered once observed, to effect the reclassification.⁸

Substituting (5) in (1) and rearranging, we obtain

$$(7) \quad \frac{\bar{p}(m,t)}{p_G(m,t)} = \bar{\lambda}(m,t) + \theta(m)(1 - \bar{\lambda}(m,t)) \leq 1$$

or the ratio of market to true good unit prices is the sum of the proportion

of good units offered plus the proportion of lemons corrected by the lemon repair coefficient. The dependent variable in (7) is also bounded non-negative. It should be stressed that for empirical purposes $p_G(m,t)$ and $p_L(m,t)$ will not be random variables, since they represent the market price for good units and lemons. However, the proportion of good units will be a random variable, upon which each buyer in the market will possess a subjective probability distribution. As a consequence, market prices $p(m,t)$ themselves will exhibit variation. The bar notation therefore refers to the means of each distribution.

Since $p(m,t) = p_G(m,t)$ for $t > t^*$, the price path of $p_G(m,t)$ can be estimated first by selecting a critical t^* , the complete lemon identification age, and estimating the path using the market data for durables of model m and age $t \in [t^*, \infty]$. By tracking the estimated path backward, for $t \in [0, t^*]$, the complete price behavior of good units can be computed. In addition, robustness tests of the paths can be performed by varying t^* and varying the information.

If the estimated $p_G(m,t)$ is downward sloping in price-age space, this can indicate deterioration conditional on the unit being good. As a result, a true depreciation rate can be recovered from these estimates. Returning to (8), the estimation of $p_G(m,t)$ implies that the left-hand side becomes known. Since the equation degenerates above t^* , our interest is in the behavior below this age.

Suppose age is measured in discrete time units. Then the system (7) contains $t^* + 1$ equations, one for each year of age. Unknown are $\lambda(m,0)$, the population mean proportion of good units, $\lambda(m,t)$, $t=1, \dots, t^*$, the mean proportion of market sales in each period which are good and $\theta(m)$, the lemon repair coefficient. However, this totals $t^* + 2$ parameters, but

identification is complete since one normalization is permitted in the construction of an index of good units. Thus by setting $\lambda(m, t_n) = 0$ for some $0 < t_n \leq t^*$, all parameters become identified. It is noted that the normalization $\lambda(m, t_n) = 0$ immediately fixes $\theta(m) = p(m, t)/p_G(m, t)$.

It should therefore be noted that no prior restriction on the shape of the $\bar{\lambda}_n(m, t) = \bar{\lambda}(m, t)/\bar{\lambda}(m, t_n)$ function is made. Consequently, market prices are permitted to take arbitrary shapes, specifically including those depicted in Figures 2a and 2b. Moreover, the actual repair coefficient, or value lemon owners ascribe to perfect information, is estimable directly as $\theta(m)$. Finally, a clear distinction should be made between $\bar{\lambda}(m, 0)$ and the subsequently normalized family $\bar{\lambda}_n(m, t)$. The former represents the population mean proportion of good units, a statistic relevant for consumer protection, quality control and capital stock estimation. The latter represent only market proportions, given that such transactions are a small portion of the capital stock.

Having indicated the procedure for estimating $p_G(m, t)$, $\theta(m)$, $\bar{\lambda}_n(m, t)$ and $\bar{\lambda}(m, 0)$ we are in a position to test the hypotheses advanced earlier. It remains to derive one further result. Thus far all our estimation has been focused on the means.

The test for adverse selection dominance, where bad units drive out good units is for monotonicity on $\lambda_n(m, t)$, or $\partial \lambda_n(m, t)/\partial t > 0$. We know from the specification that $\lim_{t \rightarrow t^*} \lambda_n(m, t) = 1$, so an acceptance of this hypothesis will reject Gresham's Law. The younger age lemon dominance follows the argument that lemons will be predominant among younger houses offered. Here the change in $\lambda_n(m, t)$, the good unit index, will be decreasing for low t . Finally, a U-shaped specification posits that the index $\lambda_n(m, t)$ will first be decreasing, then increasing.

5. Data Requirements

In order to test the various hypotheses and implications of the self-selective screening model for houses, it is desirable that certain criteria be satisfied. These rules can serve as guides in sample selection and preprocessing, and to establish immediate feasibility of a given body of data.

First, we require individual observations by vintage, so that the life history of some good or bad durable can be tracked. Since the basic theory of screening centres on information on a specific house, data on aggregates or even statistically-matched single units will not convey sufficient information.⁹ In addition, a preferable characteristic is vintage or date of manufacture.¹⁰

Second, it is preferable that the product be relatively homogeneous in observed quality, and that observed signals are not sufficient to detect lemons.¹¹ Third, a desirable attribute is a small or zero rate of physical deterioration in the durables, so that lemon effects can be more clearly distinguished from depreciation. The lemons theory is probably less applicable to producer durables for two reasons. First, industrial purchasers are more specialized and possess more information on the products they buy. Also they are less prone to caveat emptor provisions. Upon discovering lemons, resources are more likely to be available to seek legal recourse. Hence this voice option in the sense of Hirschman (1970) enforces quality control. Second, deterioration and obsolescence may be more central on producer durables. Services are consumed rapidly and technical change implies more rapid obsolescence. Hence a criterion for sample selection is one which permits lemon effects and deterioration to be distinguished.

6. Data

The data used conform to the suggested criteria, and represent transactions on similar suburban single family dwellings. The area is a suburb of London, Ontario, and the houses are in the same neighborhood, have the same floor plan, and are in the same suburban development.

For the criterion of longitudinality, or individual observations by vintage, tracking of houses in the development is conducted over the period 1967-75. Individual houses are recorded at any sale times over the period. There are two essential models in the development, a three bedroom ranch style and a four bedroom two storey style. These two types are considered as the separate models to exemplify m. At each sale point characteristics of the house are available, since the source is the card file required for listing by the city Multiple Listing Service (MLS) when sale is contemplated.

Considering product homogeneity in observable quality, since the units are identical as described, this criterion is essentially satisfied. It is possible for an individual owner to effect specific improvements such as the installation of a swimming pool or finishing of a recreation room. Controls are introduced to account for such measures. Consequently, uncontrolled subsequent price variation will tend to reflect initially unobservable price differences. The selected suburb is sufficiently small such that neighborhood effects do not have substantial influences on sub-groups within the sample.

Low physical deterioration is required since otherwise potential lemon effects will be dominated by depreciation. This criterion is relatively weak and is satisfied by most conventional consumer durables, at least in the sense that mean lives run to several years. Housing, particularly residential single-family units, exhibits little physical decay or obsolescence.¹² At

the same time, there is strong circumstantial evidence that lemon effects may be present in housing. Both the Magnuson-Moss bill in the United States and the proposed National Housing Warranty Act in Canada provide protection for purchases of new houses. The latter proposes a federally-guaranteed repair plan extending up to five years, suggesting prima facie that lemon effects exist. In Canada, the provinces of Alberta and Manitoba have both enacted legislation to provide purchasers of new houses with warranties. Of relevance is provincial legislation pending for Ontario, which would cover future developments in the jurisdiction from which our sample is drawn.

The Ontario plan would cover houses up to five years old for up to \$20,000 protection for any repairs.¹³ Any structural defect would be covered in the first year (including "repairs in basement walls, roof and roof trusses and framing defects which make the house unsafe"), and a conciliation board established to hear complaints from lemon owners. Buyers would be protected against bankruptcy or insolvency of builders. All builders would be required to participate in the plan. The pending plan suggests that lemon effects are prevalent and inducing governments to take remedial action.

Following the sample construction procedures described, and after discarding some transactions with missing or incomplete data, the number of observations is 476. This figure represents 40% of all MLS transactions in the development over the sample period.

7. Specification and Estimation

The algorithm used for estimation of the complete model is illustrated in Table 1. The test is applied to four bedroom units in our sample, constructed in 1967-69. The selection of $t^* = 5$ is made to correspond with proposed legislation.

TABLE 1. Algorithm for Estimation of Self-Selection

1. Select an age subsequent to which all traded units can be assumed good ($t^* = 5$ chosen). Test group selected is for 1967-69 built four bedroom houses.
2. Estimate for 1967-69, 1970-72, and 1973-75 sales separately and simultaneously, with separate depreciation parameters.
3. Construct the variable $p(m,t)/p_G(m,t)$ for the fitted values, corresponding to equation (7) of the text. Solve the system

$$\frac{\hat{p}(m,t)}{\hat{p}_G(m,t)} = \lambda_n(m,t) + \theta(m)(1 - \lambda_n(m,t))$$

subject to the normalization $\lambda_n(m,1) = 1$ for all makes, where $t=0$ for 1967-69 (new houses), $t=1$ for 1970-72, $t=2$ for 1973-75.

4. By the normalization

$$\theta(m) = \hat{p}(m,1)/\hat{p}_G(m,1)$$

so

$$\lambda_n(m,t) = \left[\frac{\hat{p}(m,t)}{\hat{p}_G(m,t)} - \frac{\hat{p}(m,1)}{\hat{p}_G(m,1)} \right] / \left[1 - \frac{\hat{p}(m,1)}{\hat{p}_G(m,1)} \right]$$

from which the remaining statistics also follow.

Transactions on four bedroom units during the period are divided into three time periods. A temporal transformation, as described in step 4 of Table 1, implies that all units sold when $t=2$ are assumed good. Having divided the sample, "depreciation" parameters for four bedroom units are estimated for each period. Some of these units were built as early as 1958 but none were built later than 1969. The "depreciation" function therefore includes all observed trades.

The variable to be explained is the logarithm of deflated selling prices. The data are deflated by a hedonic price index, or inflation index, constructed for all houses in the sample.¹⁴ Our "depreciation" or aging variables are specified

$$\begin{aligned}
 (8) \quad A_0 &= \text{age if house sold in 1967-69} \\
 &= 0 \text{ otherwise} \\
 A_1 &= \text{age if house sold in 1970-72} \\
 &= 0 \text{ otherwise} \\
 A_2 &= \text{age if house sold in 1973-75} \\
 &= 0 \text{ otherwise}
 \end{aligned}$$

and the list of control characteristics is listed in Table 2. The estimated equation structure is therefore

$$(9) \quad \ln p_j^* = \alpha_0 + \sum_{i=0}^2 \beta_i A_{ij} + \sum_{i=1}^n \gamma_i X_{ij} + \epsilon_j$$

where p_j^* is the corrected selling price, the elements of β and γ are parameters and ϵ an additive error for the j^{th} house. The X_{ij} variables represent the level of the i^{th} control variable in the j^{th} house. The coefficients β_i will

TABLE 2. Listing of Quality Control Variables^a

<u>Name</u>	<u>Brief Description</u>
RMS	Number of rooms in house at time of sale
OCC	Dummy variable equal to unity if owner-occupied
ARLR	Area (square feet) of living room
ARDR	" " " " dining room
ARKIT	" " " " kitchen
AR1ST	" " " " first floor
AR2ND	" " " " second floor
ARBR1	" " " " first bedroom
ARBR2	" " " " second bedroom
ARBR3	" " " " third bedroom
ARBR4	" " " " fourth bedroom
GRGE	= 1 if attached enclosed garage = 0 otherwise
DRIVE	= 1 if paved driveway = 0 otherwise
RECRM	= 1 if recreation room = 0 otherwise
POOL	= 1 if swimming pool = 0 otherwise

^aMany of these variables reflect the possibility that owners can increase living area by addition. There are also slight design choices available which permitted variation in room sizes.

represent "depreciation" in the conventional sense except that a separate coefficient is introduced for each period. Since the period 1973-75 by assumption will represent all good quality transactions, our true depreciation rate estimate is β_2 .

The results of Table 3 for the "depreciation" rates provide strong evidence of lemon effects. Houses traded in 1967-69 include the new units of our test and those four bedroom units built prior to this period. Hence observed sales will contain a quality mixture, and since we do not include any houses built after 1969 in our data base, the proportion of lemons will be the greatest of any considered selling period. By estimation of a rate for this period, we obtain a "depreciation" rate of 4.2% per annum based on 1967-69 transactions.

In 1970-72, since no new houses have been added to the sample, the average quality of observed sales will have increased, or depreciation decreased. The effects of inflation have been controlled for in the construction of p_j^* and quality change accounted for in the lower group of variables in Table 3. For the period, the "depreciation" rate falls to 1.6%, and in the period where all units are assumed good, the true rate becomes less than 0.5%, a substantial difference by comparison with the 4.2% of 1967-69. Before examining any implications of these findings, we require tests as to their statistical significance. The test of equality as applied to the "depreciation" rates yields a rejection.

We are now able to examine the hypotheses posed. The true depreciation rate from Table 3 is .49%. Since we have specified that the price of lemons is proportional to that of good units this implies that depreciation rates of each quality are equal. This may not appear intuitive, as it may be expected that lemons would depreciate more rapidly. However, lemons can be

TABLE 3. Parameter Estimates, Four Bedroom Test
(F-statistics in parentheses)^a

<u>Self-Selection Variables</u>	<u>Coefficient Estimate</u>		
A ₀	-.0421	(11.2428)	*
A ₁	-.0162	(5.0217)	*
A ₂	-.0049	(7.6201)	*
Intercept	11.2338	(670.0318)	*
<u>Control Variables</u>			
RMS	.1667	(4.1761)	*
OCC	-.0554	(.4494)	
ARLR	.1049	(1.6253)	
ARDR	.2694	(11.4267)	*
ARKIT	.1656	(4.1195)	*
AR1ST	-.0137	(.0275)	
AR2ND	.3207	(23.1933)	*
ARBR1	.1411	(2.9692)	
ARBR2	.0754	(.8345)	
ARBR3	-.1160	(1.9928)	
ARBR4	.0656	(.6307)	
GRGE	.1875	(5.3202)	*
DRIVE	.2269	(7.9257)	*
RECRM	.2397	(8.9005)	*
POOL	.0904	(1.2043)	

$R^2 = .4884$, $DF = 147$, Regression $F = 28.09$, $SSR = 12.0737$

^aThe F-statistic with 1 numerator and 150 denominator degrees of freedom has a critical value of 3.91 at the 5% level. Asterisks indicate significance at this level.

retired or repaired, and once the market has adjusted for quality differentials, there is no reason to presuppose unequal depreciation, although this is testable in principle.

8. Implications: Screening and Quality Identification

We consider a house built in 1969, assumed to be new in 1967-69, two years old in 1970-72 and five years old or quality-identified in 1973-75. First, we fit a true depreciation function by estimating only for the sample period 1973-75, where all traded units are assumed good. This yields a depreciation coefficient of .65% and an intercept of 11.3529, both significant at the 5% level.¹⁵ This intercept represents the price a buyer would be willing to pay for a house known good with certainty. From these point estimates the series on $\hat{p}_G$ can be constructed, while that on $\hat{p}$ is derived from Table 3.

Taking logarithms of (7) and substituting estimated coefficients

$$(10) \quad \ln \hat{p}(m,0) - \ln \hat{p}_G(m,0) = 11.2338 - 11.3529 \\ = -0.1191$$

$$(11) \quad \ln \hat{p}(m,1) - \ln \hat{p}_G(m,1) = -0.1191 - 0.0421(2) + 0.0065(2) \\ = -0.1903$$

and

$$(12) \quad \ln \hat{p}(m,2) - \ln \hat{p}_G(m,2) = 0$$

by restriction. So

$$(13) \quad \bar{\lambda}(m,0) + \theta(m)(1 - \bar{\lambda}(m,0)) = \exp(-0.1191)$$

$$(14) \quad \bar{\lambda}(m,1) + \theta(m)(1 - \bar{\lambda}(m,1)) = \exp(-0.1903)$$

$$(15) \quad \bar{\lambda}(m,2) + \theta(m)(1 - \bar{\lambda}(m,2)) = 1$$

becomes the system. In addition the solution set for $(\bar{\lambda}, \theta)$ must satisfy the boundedness conditions given by the right weak inequality of (7). The mean $\bar{\lambda}(m,0)$ is a population estimate while $\bar{\lambda}(m,1)$ and $\bar{\lambda}(m,2)$ are means from observed trades.

To solve, we must make one normalization on the $\bar{\lambda}$ series. We know that $\bar{\lambda}(m,2) = 1$, so the normalization is applied to $\bar{\lambda}(m,1)$. Upon this specification, the lemon repair coefficient, proportion of lemons in the population and proportion of good units become estimable. A complete grid, representing solutions of (13) - (15) is indicated in Table 4.

An extreme case is indicated when $\bar{\lambda}(m,1) = 0$ or all observed trades in 1970-72 are lemons. This implies that a lemon repair coefficient of .8267 is operative, or that a lemon will be valued at 83% of the price of a good unit. As the proportion of lemons in the sample declines, the lemon repair declines and the price of a lemon relative to good units declines. Moreover, the true population proportion of lemons also declines.

In the extreme case where $\bar{\lambda}(m,1) = 1$, or only good units are sold secondhand, the lemon repair falls to zero in our calculations. Since no lemons can be sold, as $\bar{\lambda}(m,2) = 1$, the value of holding a lemon is zero. In such cases, legal recourse may be required to compensate the 11% of original owners who now hold lemons.

The strict value of $\bar{\lambda}(m,1) = 0$ yields $\bar{\lambda}(m,0) = .3520$, which appears low. Hence it is unlikely that only lemons are traded secondhand. However, adverse selection is upheld regardless of normalization, since $\bar{\lambda}(m,0) > \bar{\lambda}(m,1)$ and $\bar{\lambda}(m,2) > \bar{\lambda}(m,1)$ everywhere. We conclude that lemons are overrepresented in the secondhand market based on Table 4.

TABLE 4. Grid Estimates of Lemon Repair Coefficients and Population Proportions Used

<u>Normalization</u>	<u>Lemon Repairs</u>	<u>Population Proportions</u>	
		<u>Good</u>	<u>Lemons</u>
$\bar{\lambda}(m,1)$	$\theta(m)$	$\bar{\lambda}(m,0)$	$1 - \bar{\lambda}(m,0)$
0.0	0.8267	0.3520	0.6480
0.2	0.7859	0.4755	0.5245
0.4	0.7112	0.6111	0.3889
0.6	0.5668	0.7408	0.2582
0.8	0.1335	0.8704	0.1296
1.0	0.0000 ^a	0.8877	0.1123

^aCoefficient set equal to zero to satisfy the boundedness constraint (7).

9. Concluding Remarks

We have indicated that theoretically there is no reason for depreciation functions to be downward sloping with age. Observed depreciation may result from the quality composition of the capital stock and acquisition of knowledge as to condition of buyers and sellers. The theory of screening unequivocally predicts that conventional depreciation estimates are biased upwards because true quality identification is not distinguished from physical deterioration. In practice, methods are required to correct for this, otherwise measures of depreciation, capital stock and productivity will be erroneous.

One possibility is to retain current procedures, on the grounds that discovery of low quality is a form of depreciation measure. Researchers using this method should not be surprised to observe perverse paths such as those in Figure 2, and to observe appreciation rather than depreciation. Moreover, by maintained hypothesis the observed trades must be representative of the population stock, an assumption which appears untenable.

A more accurate method is to estimate $\lambda(m,0)$ more precisely. We desire a depreciation rate applicable to the entire capital stock, and not only those entering the market. The degree to which $\lambda(m,t)$, $t > 0$ differs from $\lambda(m,0)$ the population proportion of good units, will determine the magnitude of depreciation bias. We have proposed methods for estimating $\lambda(m,0)$ and other statistics relevant to civil damages and consumer protection legislation such as $\theta(m)$. Criteria have been suggested for sample selection. It remains to apply these procedures to other durables such as automobiles and appliances where lemon effects are suspected of existing.

FOOTNOTES

*I am indebted to Mark Gersovitz for many detailed comments and suggestions. In addition, assistance in collecting and processing the data has been ably provided by Linda Newton and Dorothy Worth.

¹Examples are the study of pickup trucks by Hall (1971) and sedan automobiles by Malinvaud (1970).

²Griliches (1971) estimated a depreciation rate on tractors of 10%. Yet ten years later it was observed that half of the tractors of the given vintage remained in service, inconsistent with the measured rates.

³Such results have been obtained in housing markets for rentals in apartments by Gillingham (1975).

⁴It is well known that larger department stores charge higher prices for appliance makes than smaller "discounting" stores. However, risk-averse shoppers and owners of lemons are protected by more generous policies on returns and refunds in the former.

⁵A discussion of this possibility is contained in Feldstein and Rothschild (1974).

⁶At the same time, both physical deterioration and obsolescence will be affected by relative prices in consumption and production, tastes and technological change.

⁷If information were available on precisely which durables were lemons, the market would immediately discount the price, which would remain flat under our assumptions.

⁸Reclassification will depend on the cost of conversion, relative to the price of a new durable. Another factor will be the magnitude of the lemon repair coefficient $\theta(m)$.

⁹By statistically-matched data we mean the merging of groups of data sets by proportionality assumptions on characteristics not held in common, holding constant the characteristics held in common.

¹⁰A further difficulty arises as a consequence of this fact in constructing capital stock estimates. If scrapped units cannot easily be identified by vintage, aggregation may be impossible. Capital stock aggregation is often performed by year.

¹¹This idea is related to the concept of statistical discrimination, considered in Arrow (1971), Phelps (1972) and Spence (1974). Observable characteristics may be correlated positively with undesirable characteristics, and hence the former are used as screens. It is pointed out that some of this correlation may not necessarily be causal in nature.

¹²Conventional estimates of housing depreciation such as those of Grether and Mieszkowski (1974) yield rates of 7% and even then are likely to be biased upwards as we have argued.

¹³This figure is equivalent to the mean value of house sales in Ontario, after subtracting land costs, implying complete coverage.

¹⁴It is possible to distinguish the effects of inflation and depreciation in this model, because the sample includes houses built prior to 1967-69. Otherwise the effect of time (inflation) and age (depreciation) are identical and not identifiable. We assume that inflation affects all houses identically, including three bedroom houses for which the screening test is not applied.

¹⁵The re-estimation is required to generate the intercept, or initial value of good units, not available from Table 3. The point estimate of .65% differs from the .49% of Table 3 since the sample is not identical. Here we consider only 1973-75 sales, while in Table 3 all sales are estimated together.

REFERENCES

- Akerlof, G. A. (1970). "The Market for 'Lemons': Qualitative Uncertainty and the Market Mechanism," Quarterly Journal of Economics 84, 488-500.
- Akerlof, G. A. (1976). "A Theory of Information and Labor Markets," Quarterly Journal of Economics, forthcoming.
- Arrow, K. J. (1971). "Some Mathematical Models of Discrimination in the Labor Market," in A. D. Pascal, ed., Racial Discrimination in Economic Life, Lexington, Mass., D. C. Heath.
- Feldstein, M. S. and M. Rothschild (1974). "Towards an Economic Theory of Replacement Investment," Econometrica 42, 393-424.
- Gillingham, R. (1975). "Place to Place Rent Comparisons," Annals of Social and Economic Measurement 4, 153-174.
- Grether, D. M. and P. Mieszkowski (1974). "Determinants of Real Estate Values," Journal of Urban Economics 1, 127-146.
- Griliches, Z. (1971). Price Indexes and Quality Change, Cambridge, Harvard University Press.
- Gronau, R. (1974). "Wage Comparisons - A Selective Bias," Journal of Political Economy 82, 1145-1156.
- Hall, R. E. (1971). "The Measurement of Quality Change from Vintage Price Data," in Z. Griliches, ed., Price Indexes and Quality Change, Cambridge, Harvard University Press.
- Hirschman, A. (1970). Exit, Voice and Loyalty, Cambridge, Mass., Harvard University Press.

Malinvaud, E. (1970). Statistical Methods of Econometrics, Amsterdam, North-Holland.

Phelps, E. S. (1972). "The Statistical Theory of Racism and Sexism," American Economic Review 62, 659-661.

Spence, A. M. (1974). Market Signalling: Informational Transfer in Hiring and Related Screening Processes, Cambridge, Mass., Harvard University Press.

RESEARCH PROGRAM:
IMPACT OF THE PUBLIC
SECTOR ON LOCAL ECONOMIES

The Department of Economics, University of Western Ontario, has recently mounted a long-term research program on the Impact of the Public Sector on Local Economies. The program publishes Discussion Papers and Research Studies. Copies may be obtained by writing:

Mrs. Jayne Dewar	Phone: (519) 679-2693
Secretary	
Urban Research Program	
Department of Economics	
The University of Western Ontario	
London, Ontario N6A 5C2	
Canada	

The following Discussion Papers and Research Studies are currently available:

DISCUSSION PAPERS:

- 001 P. T. Chinloy, "Hedonic Prices and Age Deterioration in Urban and Suburban Housing" (September 1975).
- 002 M. W. Frankena, "Alternative Models of Rent Control" (September 1975).
- 003 J. R. Markusen and D. T. Scheffman, "Ownership Concentration and Market Power in Urban Land Markets" (October 1975).
- 004 A. J. Robson, "The Effect of Urban Structure on Ambient Pollution" (October 1975).
- 005 J. R. Markusen and D. T. Scheffman, "The Timing of Residential Land Development: A General Equilibrium Approach" (November 1975).
- 006 A. J. Robson, "Cost-Benefit Analysis and the Use of Urban Land for Transportation" (December 1975).
- 007 M. F. Goodchild and P. J. Booth, "Modelling Human Spatial Behavior in Urban Recreation Facility Site Location" (January 1976).

DISCUSSION PAPERS: (continued)

- 008 M. W. Johnson, "Consumer Location and Local Public Goods" (March 1976).
- 009 K. L. Avio and C. S. Clark, "The Supply of Property Offenses in Ontario" (April 1976).
- 010 P. T. Chinloy, "Depreciation, Adverse Selection and Housing Markets" (May 1976).

RESEARCH STUDIES:

- 01 G. W. Davies and P. L. Jackson, "A Model of the Urban Housing and Residential Land Markets" (September 1975).
- 02 G. P. Schaefer, "The Urban Area Production Function and the Urban Hierarchy: The Case of Saskatchewan" (October 1975).