SECTION 5

PROPERTY VALUE REGRESSION STUDY

5.1 THEORETICAL FRAMEWORK

Numerous studies have attempted to link property values to environmental amenity levels, among them studies by Paul (1971) on aircraft noises; Oates (1969) on public expenditures; Spore (1972), Harrison and Rubinfeld (1978), Ridker and Henning (1967), Anderson and Crocker (1971), Lave (1972), Wieand (1973) and Brookshire (1979) on air quality; and Bahl, Coelen and Warford (1974) on water supply projects. In all of these studies the question was to test whether the value of public investment projects or the public goods in question were capitalized into the price of the property that included the amenity.

The form of the relationship estimated for property value (PV) generally has been:

$$PV=f(a,h,s,t,l)$$

where:
- a denotes environmental amenities
- h denotes house characteristics (such as size, number of bathrooms)
- s denotes social amenities (schools, fire protection)
- t denotes tax levels
- l denotes other locational characteristics (such as distance to jobs)

The basis for this type of model has been a hedonic price model based on the work of Rosen. The consumer chooses a location and house according to the composite characteristics z = (a,h,s,t,l):

$$\max_{x,z} \; U(x,z)$$

$$\text{s.t. } z=(a,h,s,t,l)$$

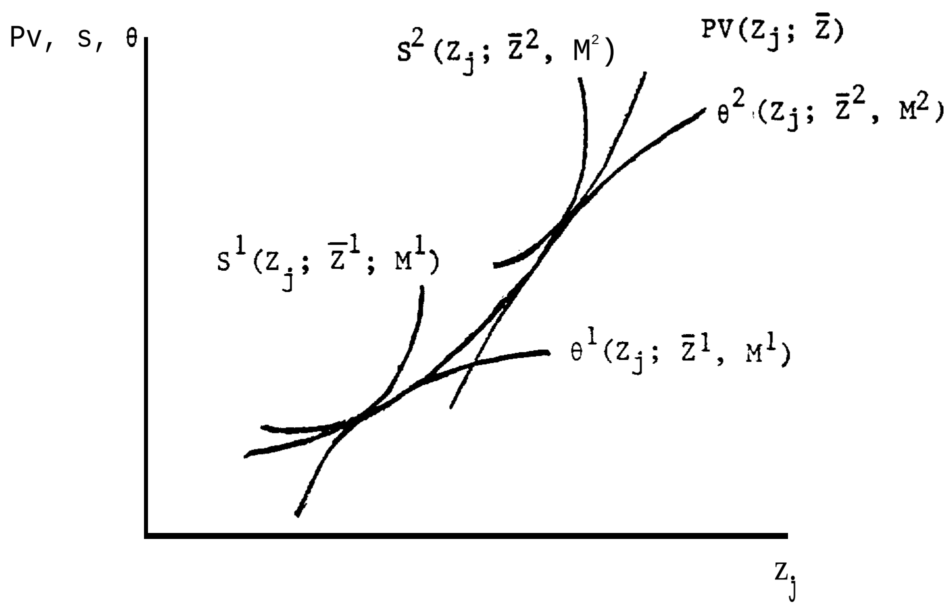
$$p_x x + (1+t)PV(z) \leq M$$

where x and p_x denote private goods and the price of private goods and PV(z) is the hedonic value function. (See Harrison and Rubinfeld, 1978 and Diamond, 1975 for such a model.)

As discussed by Rosen and illustrated in Figure 13, PV(z) is actually the locus of equilibrium points between the bid curves of buyers $\Theta(z_j;\bar{z}, M)$ and offer curves of sellers $S(z_j;\bar{z}, M)$ for characteristic z_j given other

Figure 13

HEDONIC MODEL



Pv - locus of equilibrium points

Z_j - house characteristic j

$\bar{Z}$ – vector of other house characteristics for household i

M^i – income for household i

θ^i – bid curve i

S^i – offer curve i

characteristics $\bar{Z}$ and income M. At an equilibrium between buyers and sellers, the slopes of the bid curves and the slopes of the offer curves are equal. Market data on sales prices thus simultaneously give observations about the slopes of bid curves and offer curves. The observed equilibrium points are affected by incomes, tastes, and other characteristics of buyers and sellers.

First order conditions derived from this model give a system of simultaneous equations of the form:

$$\frac{1}{\lambda}\frac{\partial U}{\partial z_i} = (1+t)\frac{\partial PV}{\partial z_i}$$

where Z_i denotes the ith characteristic, and λ is the marginal utility of income. Due to the similarity of these conditions to the conditions for the usual types of market goods, the hedonic (marginal) price may be associated with a demand curve. Thus the integral of the hedonic price function may be used to derive benefit estimates for nonmarginal changes in house characteristics similar to evaluation of benefits for ordinary market goods (Maler, 1974).

5.2 CRITICISMS OF THE HEDONIC APPROACH

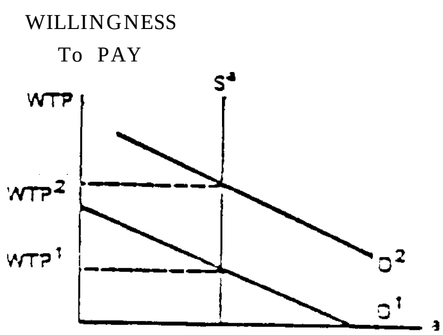
There have been a variety of criticisms of the property value approach. Maler (1974) discusses two problems. One is the proper specification of the property value relationship itself. Another is the validity of the use of this property value relationship to express willingness to pay for air quality improvements. A third issue, raised by Freeman (1978), is that property values cannot reflect values for effects not perceived by individuals. Freeman (1978) also criticized the exclusion of supply factors from most studies. That is, in addition to amenities, the availability of housing sites will certainly influence property values. As Freeman (1978) pointed out, the explanation of absolute levels of property values also requires a theory of capitalization; expectations about the future influence the capitalization of air quality changes (Maler, 1974).

Another criticism has to do with the partial equilibrium nature of hedonic studies. As Freeman (1978) points out, the change in property values at a given location caused by an air quality improvement depends on what happens in surrounding regions; the property value equation gives the "ceteris paribus" average effect and may not predict what happens to property value when air quality changes are actually made.

The correspondence of marginal changes in property values to willingness to pay depends on certain additional assumptions (Maler, 1974). First and foremost is the requirement for homogeneity of preference orderings among households. If homogeneity does not hold, then marginal changes-in property values due to air quality or other changes will not correspond to willingness to pay. This problem is illustrated in Figure 14 below. In this figure, for varying amenity levels (a) with all other

Figure 14

POTENTIAL DIFFERENCES IN
WILLINGNESS TO PAY



characteristics constant (lot size, public service, taxes, etc.), demander 1 has willingness to pay D^1_a while demander 2 has willingness to pay D^2. With fixed supply S^a, the highest bidder obtains the house; hence the observed marginal evaluation is WTP^2. Thus, only demander 2's willingness to pay (a higher value) is included in benefit estimation. As Maler points out, it is difficult to know whether this type of misspecification of willingness to pay leads to over- or under-specification of total benefits. If demander 1 could find another house to buy consistent with his willingness to pay, then observed property value effects could be even higher!

5.3 PAST HEDONIC PRICING STUDIES

5.3.1 Air Pollution Studies

Tables 19 and 20 show a comparison of some notable air pollution-property values studies. (Although some of these studies were discussed by Freeman (1978), additional ones have been added.) The studies are compared with respect to data aggregation, specification of the model, and pollution measures.

Studies shown in Table 19 had varying conclusions about the significance of the pollution coefficient in explaining property values. The early work of Ridker and Henning (1967) and Anderson and Crocker (1971) showed that a statistically significant (negative) relationship exists between air pollution and property values. However, using essentially the same data as Ridker and Henning, Wieand (1973) could find no statistically significant relationship between various pollution measures and the dependent variable (monthly housing expenditures per acre). This conclusion was in accord with the results of Smith and Deyak (1975) and Skov (1976). Later studies by Harrison and MacDonald (1974), Harrison and Rubinfield (1978), B. Smith (1978) and Brookshire and Schulze (1979) all found that air pollution negatively affects property values. The potential reasons for these varying conclusions may be accounted for by a variety of reasons discussed below.

5.3.2 San Francisco Property Value Studies

Various property value studies have been completed in the San Francisco area and are summarized in Tables 21 and 22.

Using individual transactions data, Stonstelie and Portney (1978) examined the effects of public service quality, distance to employment centers, air pollution and other factors on annualized market value for a large sample of single family dwellings in San Mateo County. The results indicated that all household variables (rooms, pool, age, etc.) were significant with the anticipated sign. Measures of public services (crime rate, fire department rating, street maintenance and educational quality) were also significant with the anticipated sign. The distance to employment coefficient had a negative sign but was not significant. The air pollution measure (number of days with high hour oxidant reading exceeding 10 pphm) had a negative impact on the annualized market value of

Table 19

General Model Comparisons

	Ridker-Henning	Anderson-Crocker	Wieand	Harrison-MacDonald	Smith-Deyak	Skov	Harrison-Rubinfeld	Nelson	Smith	Brookshire-Schulze
Areas Studied	St. Louis	St. Louis, Kansas City, Washington D.C.	St. Louis	Los Angeles, Boston	85 cities	Los Angeles	Boston	Washington	Chicago	Los Angeles
Aggregation	Cen. Tract	Cen. Tract	Cen. Tract	Cen. Tract	SMSA	Cen. Tract	Cen. Tract	Cen. Tract	Household	Household
Functional Form	Linear	Log-Linear	Linear	Linear, Semi-Log	Log-Linear	Linear	Non-Linear	Log-Linear	Linear	Linear, Non-Linear
Supply-Demand Variables	S/D	Demand	Demand		S/D	S/D	Demand	Demand	Demand	Demand
Dependent Variable	Median Prop. Value (1960)	Median Prop. Value, Median Rent (1960)	Monthly Housing Exp. Per Acre (1960)	Median Prop. Value (1970)	Median Prop. Value, Median Rent (1970)	Median Prop. Value (1970)	Median Prop. Value (1970)	Median Prop. Value (1970)	Site Value Premium	Sale Price
Pollution Variable	Ann. Geom. Sulfation (1963)	Ann. Arith. Sulfation Ann. Arith. TSP (1963)	Ann. Arith. Sulfation Ann. Arith TSP (1963-4)	HC, NOX, Oxidant Index (HC-NOX) (NA)	Ann. Geom. TSP (1969)	Ozone Index Based On Days Exceeding 15 pphm (1969)	Ann. NO$_x$, Ann. [illegible] (NA)	Avg. Quar. Oxidant Month. Geom. TSP (1967-8)	Ann. TSP (NA)	Ann. NO$_2$*, Ann. Arith. TSP (1975)
Source	Interpolated From Monitor Station	Interpolated From Monitor Station	Interpolated From Monitor Station	Calculated From Model	Monitoring Station	Interpolated From Monitor Station	Calculated From Model	Not Specified	Calculated From Model Station	Interpolated From Monitor Station
Significance	YES	YES	NO	YES	NO	NO	YES	YES	YES	YES

Table 20

Comparison of Independent Variables
Pollution Studies

Independent Variables	Ridker-Henning	Anderson-Crocker	Wieand	Harrison-MacDonald	Smith-Deyak	Skov	Harrison-Rubinfeld	Nelson	Smith	Brookshire-Schulze
House Variables										
Sales Date										+S
Age (Old)			+S	-S		-S	+	+S		-S
High Quality Housing[a]			+S							
Low Quality Housing		+			S					
Value of Improvements										
Number of Rooms	+S	+S		+S	S	+S	+S	+S		
Living Area										+S
Bathrooms										+S
Lacking Toilet										
Public Water and Sewer									+S	
Pool										+S
Fireplace										+S
Air Conditioning								+S		
Lot Size								+S		
Housing Density	+S									
Persons Per Room	-S				S	-				
Nuisance Near Property										
Location (cul-de-sac)										
Location (Alley)										
Similarity Between House and Neighborhood									+S	

Table 20 (continued)

Comparison of Independent Variables
Pollution Studies

	Ridker-Henning	Anderson-Crocker	Wieand	Harrison-MacDonald	Smith-Deyak	Skov	Harrison-Rubinfeld	Nelson	Smith	Brookshire-Schulze
Neighborhood Characteristics										
% Non-White	+S	+S	+	-S	S		+s	-S	-	
% White			-S							+
% Lower Status[b]	+S					-S	-S			
% Below Poverty Level				-S						
Median Income	+S	+S	+S		S	+S				
Population Density					S					-S
% Commercial-Industrial At*rage										
City Characteristics										
Expenditures on Services[c]					+s	-		+		+s
Property Tax	-s		-S		-s		-s	-S	-S	-
Crime Sate							-s	-	-S	-S
Pupil-Teacher Ratio							-s			
School Quality[d]	+								+s	+S
% Non-Retail Business Acerage							+			
Zoning[e]							+			
Fire Rating[f]										
Fire Stations (per sq. mile)										

Table 20 (continued)

Comparison of Independent Variables
Pollution Studies

	Ridker-Henning	Anderson-Crocker	Wieand	Harrison-MacDonald	Smith-Deyak	Skov	Harrison-Rubinfeld	Nelson	Smith	Brookshire-Schulze
Other Environmental										
Employment (did	+S	-S	-S			+,-	-S	-S	-S	-S
Beach (dist)						-S				-S
Transportation (dist)									-S	
Transportation (dummy)[h]	+S						+S			
Recreation (dummy)										
shopping (dummy)			+							
Carbon Monoxide[i]				+S						
Air Pollution	-S	-S	-	-S	-	+	-S	-S	-S	-S
Noise Pollution										
Terrain, View								+S		
Proximity to River							+S			
Amenity Index[j]						+				
supply Variables										
Vacant Land										
% Units Recently Constructed	+S									
Vacancy Rate						+				

+/- = sign of coefficient

S = significant

Table 21

General Model Comparisons
Bay Area Studies

	Dygert-Sanders (1971)	Stonstelie-Portney (1977)	Pollakowski (1973)	Vincent-Reinhard (1974)
Areas Studied	San Mateo	San Mateo	San Francisco Bay Area	San Jose, San Mateo
Aggregation Level	Census Tract	Individual Transaction	Individual Transaction	Individual Transaction
Functional Form	Linear, Log-Log	Box-Cox	Linear	Log-Log, Box-Cox
Supply-Demand Treatment	Supply-Demand Variables	Demand Variables Only	Demand Variables Only	Demand Variables only
Dependent Variable				
Measure	Median Property Value, Median Land Value Per Sq. Ft.	Annualized Market Value	Annualized Market Value (owner-occupied units) Annual Rental	Annualized Market Value
Year	1960	1970	1965	1978
Pollution Variable				
Measure	None	Number of Days per year with at least 10 pphm High hr. oxidant	None	Air Quality Index
Year		1970		
Source		Monitoring Station		
Significance		Yes		Yes

..Table 22

Comparison of Independent Variables
Bay Area Studies

Independent Variables	Dygert-Sanders	Stonstelie-Purtney	Pollakowski	Vincent-Reinhard
House Variables				
Sales Date				
Age (Old)	+	-S	-S	-S
High Quality Housing[a]	+S	+S		
Low Quality Housing				
Value of Improvements				
Number of Rooms	+		+S	+S
Living Area		+S		+S
Bathrooms		+S		+S
Lacking Toilet				
Public Water and Sever				
Pool		+S		+S
Fireplace				
Air Conditioning				
Lot Size		+S	+S	+S
Housing Density	+S		-S	
Persons Per Room				
Nuisance Near Property				
Location (Cul-de-sac)		+S		
Location (Alley)				
Similarity Between House and Neighborhood				

Table 22 (continued)

Comparison of Independent Variables
Bay Area Studies

	Dygert-Sanders	Stonstelie-Purtney	Pollakowski	Vincent-Reinhard
Neighborhood Characteristics				
% Non-White				
% White				
% Lower Status[b]				
% Below Poverty Level				
Median Income				
Population Density	-S			
% Commercial-Industrial Acerage	+			
City Characteristics				
Expenditures on Services[c]		-S	+	
Property Tax				
Crime Rate		-S	+	-S
Pupil-Teacher Ratio				
School Quality[d]	-S	+S	+S	+S
Z Non-Retail Business Acerage				
Zoning[e]				
Fire Rating[f]		-S		
Fire Stations (per sq. mile)				

Table 22 (continued)

Comparison of Independent Variables
Bay Area Studies

	Dygert-Sanders	Stonstelie-Purtney	Pollakowski	Vincent-Reinhard
Other Environmental				
Employment (access.)			+S	
Employment (dist)[g]	-S			+S
Beach (dist)				
Transportation (dist)	-S			
Transportation (dummy)[h]				
Recreation (dummy)			+S	
Shopping (dummy)				
Carbon Monoxide[i]				
Air Pollution		-S		-S
Noise Pollution	-S			
Terrain, View	+		+S	
Proximity to River				
Amenity Index[j]				
Supply Variables				
Vacant Land	+			
% Units Recently Constructed				
Vacancy Rate				

+/- = sign of coefficient

S = significant

Table 22 (concluded)

FOOTNOTES

a. Dummy variable measures of the quality of construction

b. Percentage of population lacking high school education and/or classified as laborers

c. Measures have included expenditures on recreation, street and highways, public protection and general city expenditures

d. Measure of performance on tests by students or expenditures per pupil on education

e. Proportion of city's residential land zoned for lots greater than 25,000 square feet

f. Rating of quality of fire protection (low rating indicates better protection)

g. A measured distance to employment centers weighted by employment if there is more than one center

h. Shopping, recreation and transportation dummy variable indicating presence or absence of these services in a neighborhood

i. Carbon monoxide was included in one study as a measure of accessibility to transportation arteries, not as an air pollution measure

j. Dummy variable indicator of positive or negative factors within a tract a house. An additional day per year exceeding 10 pphm (ozone) decreased annual rents by $115.

Other Bay Area property value studies included in Table 21 [Pollakowski (1977), Dygert and Sanders (1971) and Vincent and Reinhart (1979)] did not use ameasure of air pollution in the housing price equation. These studies were included to indicate variables other than pollution which are important to specify a housing price equation in the San Francisco Bay Area.

Dygert and Sanders (1971) performed a cross sectional study of San Mateo County in the proximity of the San Francisco airport. The independent variables include measures of neighborhood quality, accessibility to employment and transportation, vacant land, site characteristics, and an aircraft noise measure (composite noise rating). The results indicate that in 12 of 20 models, aircraft noise negatively affected property values. The vacant land measure was positive (but not significant) while the employment/transportation distance variables were negative and significant.

Pollakowski tested whether public services are valued by households. A two-stage least squares regression model was used with cross sectional data. The study used individual housing data (obtained from a survey completed by the Bay Area Transportation Commission); explanatory variables included public service variables, an employment accessibility index, and other socioeconomic variables. As a dependent variable, the study derived a measure of imputed annual gross rental value. The study examined the relationship between gross rental value and independent variables for a number of subsamples (single family residences, white collar vs. non white collar, rental units, etc.). The results indicate a strong positive relationship between property values and certain measures of public services (educational expenditures) but not with other measures (crime rate and park and recreation expenditures). The tax variable used in the study was not significant. Individual housing characteristics such as the number of rooms, lot size, age of house and amenities were shown to be strongly related to the annualized market value.

Vincent and Reinhard estimated the extent of property tax capitalization in San Jose and San Mateo. The study of San Mateo used essentially the same data as Stonstel ie-Portney. For the San Jose area, the researchers looked at a sample of 130 houses in 13 different school districts within the city of San Jose. The dependent variable was a measure of annualized market value. This variable was regressed on numerous physical attributes of the residence, the crime rate, distance to employment, school quality and a school revenue measure. All the household level variables, the crime rate and the measure of school quality were significant with the anticipated sign. The distance to employment was positive but not significant.

5.4 ISSUES IN HEDONIC MODELLING

Here we discuss potential reasons why previous studies may have had varying conclusions about effects of pollution (and other variables) on property values. In section 5.6, we study the effects of alternative assumptions on model results.

5,4.1 Aggregation and Sampling

The first issue is the level of aggregation of the data. Data used in earlier studies were at the census tract, rather than individual household level. Census tract average median values were used as observations; pollution and property values may have been from disparate years. More recent studies have been at the individual household level. For example in Los Angeles, Skov (1976) did not find ozone to be significant using data at the tract level; in contrast, Brookshire et. al. (1979) found TSP to be significant.

Use of individual household data presents another issue, that of proper sampling procedures. When a housing market area is quite large, there may be too many observations of individual sales to use all of them in a regression model. In this case it is necessary to sample from the universe of sales. Brookshire et. al. (1979) used a matched pairs design consisting of sales from 14 census tracts in the Los Angeles area; all sales in these tracts were used. However, unless sampling from the universe of sales is done according to statistical principles, it may not be possible to extrapolate properly to the universe. For example, in a stratified sampling plan, sampling could be according to the number of sales and variance of property values in each stratum.

Another issue of aggregation has to do with pooling data from geographic-socioeconomic areas which are different. Strazheim (1974) discussed the effect of combining unlike market areas and showed that such aggregation can cause differences in coefficient results. Thus, the proper identification of market areas which should be analyzed separately is" an issue.

5.4.2 Specification of the Hedonic Regression Model

Tables 20 and 22 show independent variables used in past hedonic models.

Differences in results may be caused by the specification of the model in terms of the independent variables used. Basically, variables used in past studies represent house, neighborhood, city and other environmental characteristics. Some studies have used supply as well as demand variables. Past studies vary as to the number and type of variables used.

It should be noted that there are usually multicollinearity problems in the data set which may cause difficulties in the analysis. Some studies have attempted to correct for such problems by using principal components (Smith, 1975) and ridge regression (Soskin, 1978).

There are also differences among studies in the dependent variable used. Some studies have used sales price or tract average sales price while others have converted sales price data into an annualized value (including depreciation, maintenance, and taxes).

Other differences are due to the functional form used for estimation. Earlier studies were linear in pollution yielding a constant marginal value per unit of pollution regardless of other house characteristics. More recently it has been suggested that nonlinear functional forms are more appropriate. Monotone transformations of independent variables (e.g., logs) should not cause changes in whether or not a coefficient is significant; such a transformation would merely change the magnitude of the benefit estimate obtained from the hedonic regression. Most recently, the Box-Cox transformation has been used to test for nonlinearity; the log-log form is an approximation of this form.

5.4.3 Pollution Measures

The measurement of pollution may also cause differences in results. Different areas have different pollutant problems. A possible problem is that the "right" pollution measure (that which is most correlated with behavior) may not be used in a regression. Actions are influenced by psychological factors which may not be well correlated with a physical measure of pollution. For example, Flachsbart (1979) showed that perceptions of smoggy days in Los Angeles were linked more to a measure of ability to see distant objects at the horizon than to a physical measure of pollution (e.g., TSP).

Errors in measuring pollution may also cause problems. For example, a single value for pollution may be used to represent air quality over a wide area or there may be uncertainty as to the actual air quality in areas where isopleths are close together. The date of pollution data compared to date of property value data may also be important; air quality in some years may not represent actions taken in other years.

5.5 REPLICATION OF THE LOS ANGELES STUDY

One of the main objectives of this study is to use the same methods as a previous study (Brookshire et. al. 1979) to obtain a hedonic relationship in a different area. This section reports results of this effort.

5.5.1 Variables Used in the Replication

As in the Los Angeles study, we used data for all households in the selected tracts. A regression analysis for these households was carried out using the same or similar variables as used by Brookshire et. al. Table 23 shows the Brookshire et. al. analysis with a logarithmic form of the dependent variable. Table 24 defines variables used in our study. Some differences in variables used in our replication of their study are as follows:

1. We had the quarter in which the sale occurred rather than an

Table 23

Los Angeles Study

Estimated Econometric Equations*

Dependent Variable - Log (Home Sale Price in $1,000)

Independent Variable	NO_2 Equation	TSP Equation
Sale Date	.018439 (10.108)	.018924 (10.427)
Age	-.0027044 (-3.5185)	-.0031401 (-4.1178)
Living Area	.00019976 (14.024)	.0001?688 (13.896)
Bathrooms	.14777 {9. 2661)	.25285 (9. 6443)
Pool	.089959 (4.2096)	.092764 (4.389)
Fireplaces	.10355 (7. 8325)	.09922$ 3.5833)
Distance to Beach	-.014037 (-9.1443)	-.013132 (-9.1824)
Distance to Employment	-.26979 (-11.663)	-.23201 (-9.1314)
Crime	-2.2798 (-2.3574)	-1.5245 (-1.5444)
school Quality	.00099327 (2.02S6)	.0010087 (2.0792)
Ethnic Composition	.0081532 (1. 2523)	.027307 (4.5564)
Population Density	-.000067145 (-7.8422)	-.000061627 (-7.2705)
Log (Tax)	-.030991 (-1.8253)	-.046438 (-2. 7565)
Public Safety Expenditures	.00032792 (5.1487)	.00028288 (4.8582)
$(TSP)^2$		-.000015702 (-4.1798)
$(NO_2)^2$	-.0010374 (-2.6935)	
Constant	4.2297 (6.2304)	2.3602 (3.8836)
R^2	.877	.878
Sum of Squared Residuals	"22.62	22.29
Degrees of Freedom	703	703

Table 24

Definition of Regression Variables[a]

Variable Name	Defination	Units	Source
PROPVAL	Sales price of owner occupied single family residence	$100	MDC, 1978
HSEAGE	Age of home	Years	MDC, 1978
LOTSIZE	Size of lot	Acres	MDC, 1978
QTR (1-4)	Quarter of year in which sale occurred		MDC, 1978
MEDOCCT	Median occupants per house (neighborhood quality indicator)	Persons per house	Census, 1970
HDENS	Persons per acre		Census, 1970
LIVAREA	Living area	Square feet	MDC, 1978
COND (Lo, Med, Hi.)	House condition indicator	0-1	MDC, 1978
FP	Fireplace	Number	MDC, 1978
POOLS	Swimming pool	0 -1	MDC, 1979
BATH	Bathrooms (housing quality indicator)	Number	HOC, 1978
PARKING	Availability of on site parking	0-1	MDC, 1979
VIEW	Presence of a view	0-1	MDC, 1978
ELEV1	Low elevation indicator (nearness to Bay)	0 - 1; 1 - below 15 feet	MDC, 1979
SLOPE	Average tract slope		Compiled by ABAG
MEDSCHT	Median years of schooling, tract level (neighborhood quality indicator)	Years	Census, 1970
PCTPOV	Percent of persons in tract below	Percent x 100	Census, 1970
NEWHSPT	Percent of houses in tract built between 1960 - 1970	Percent x 100	Census, 1970
NONRES	Percent of land in nonresidential use (business, commercial, industrial)	Percent	Calculated from ABAG data
DEVEL	Percent of land availabe for development	Percent	Calculated from ABAG data
NODEV	Percent of land precluded from development	Percent	Calculated from ABAG data

Table 24 (continued)

DIST	Expected distance to 20 employment centers	Hundredths of miles	Calculated from MTC data
CRIMERA	Number of occurrences of 7 major crimes per capita (socio-economic indicator for city)	Crimes/person	CA Dept. of Justice 1977
TAX	Representative composit rate, city, county, school, and other types	$/$100 of assessed value	1977-1978 County Assessors
VAC	City vacancy rate	Percent x 100	U.S. Postal Service 1978
SCORES	Sum of 6th and 12th grades reading and math CA achievement test scores	Number	CA Dept. of Education
MKT	Incicator of Bay side	0 - 1; 1 = West Bay	
URBAN	Indicator of city type	0=Suburban, 1=Urban	
TEMP	Mean daily maximum July temperature	Degrees	U.S. Weather Bureau
OZEX	Days exceeding .08 pphm (old Federal standard)	Days; avg. of 1977-1978 reading	BAAPCD
OZMAX	Average of daily maximum values (July - September)	pphm; avg. of 1977-1978 reading	BAAPCD
OZONE	OZEX times OZMAX	pphm times days	Calculated
TSPMN	Annual Geometric Mean	Avg. 1977-1978 $\mu m/m^3$	BAAPCD
PS12	Avg. PSI value times the percent of days which are not rated as "good" days	PSI times fraction of days (avg. 1977-78)	Calculated
AVENO$_2$	Avg. of hourly concentration	ppm; avg. 1977-78	BAAPCD

actual sales date available to us.

2. Rather than distance to the beach, we used other variables (Elevl and View) as environmental amenities. Distance to the beach is not relevant in the Bay Area. Closeness to the Bay is a disamenity represented by "Elevl". "View" is an amenity associated with higher elevations; view seems to be more relevant to the Bay Area in explaining property values than distance to the beach.

3. School quality is measured by the sum of four scores rather than an average of two. Thus, the expected coefficient should be smaller than that in the Los Angeles study, all other things equal.

4. The ethnic variable is measured as the percent white, rather than black, population. (This should only affect the sign of the coefficient but not the magnitude; the constant term will be different however.)

5. Public safety expenditures were not used because of the high correlation with the tax rate.

6. Because of many employment centersin the Bay area, our distance to work measure is an expected distance measure.

7. Rather than only city tax, our tax variable is based on the total tax bill that would have to be paid by a household living in a given city; it includes school taxes and special district taxes as well as city and county taxes.

These differences were due to the difference in study areas and availability of data. The same pollution measures (NO_2 and TSP) as in the Los Angeles study were used; in addition we tested several alternative measures of pollution (ozone and PSI) which we thought were more relevant to our area.

5.5.2 Comparison of Results

The results of the replication are shown in Table 25. The "quarter of sales" variable is significant and shows that the highest value is obtained in the third quarter of the year. House age is not significant except in one case out of the six; a possible explanation is that in the Bay Area, age of the house is less important than condition. The "fireplace" and "living area" coefficients are of similar magnitudes to those in the Los Angeles study although they are bigger in our study. The "bathroom" coefficient is less significant and smaller in our study than in the Los Angeles study. "Elevl" and "View" have the expected signs. The significance of the "ethnic" variable is varying as in the Los Angeles study. The population density coefficient is of opposite sign but of similar significance; San Francisco, with the highest density, is the highest property value area in our sample. The tax variable also has the opposite sign in our study; San Francisco also has the highest tax rates in

Table 25

Rep Lication Regression
Household Level
. . . Varying Pollution
Dependent Variable Log(Property Value in S1OO)

Independent Variable	Pollution variable NO2	TSP	OZEX	OZMAX	OZONE	PSI2
Intercept	3.99550 (24.3646)	4.03309 (23.9501)	3.72714 (22.4330)	3.5 772S (22.1844)	3.67273 (21.7759)	3.78639 (22.9983)
Log (Tax)	Q. 0751A (7.5185)	0.05913 (6.0353)	0.05879 (5.9670)	0.06005 (6.2127)	0.06018 (6.1158)	0.0s951 (6.0067)
Hseage	-0.00015 (-0.5238)	4.00041 (-1.3206)	-o. 00024 (-o. 7740)	-0.00075 (-2.4626)	-0.00025 (-0.8061)	-0.00019 (-0.6415)
Qtr 1	-0.02920 (-i. 7460)	-0.01659 (-1.4269)	-0.01749 (-1.4969)	-0.01436 (-i.2516)	-0.01718 (-i.4715)	-0.01826 (-1.5630)
Qtr 2	0.02914 (2.5470)	0.03150 (2.7394)	0.02976 (2.5772)	0.03384 (2.9824)	0.02961 (2.5632)	0.02944 (2.5474)
Qtr 3	0.05590 (4.9909)	0.06036 (5.3658)	0.05912 (5.2295)	0.06152 (5.54.40)	0.05933 (5.2520)	0.05833 (5.1589)
Bath	0.01719 (1.9343)	O. 02S60 (2.8758)	0.02411 (2.6917)	0.02543 (2.8988)	0.026.42 (2.7296)	0.02289 (2.544a)
Livarea	0.00041 (33.3678)	o. 00042 (34. 1856)	0.00042 (33.9015)	0.00063 (35.1714)	0.00042 (33.9550)	0.00042 (33.8320)
FP	0.17805 (19.9457)	0.16186 (17.9674)	O. 167S3 (18.5849)	0.15332 (17. 1894)	0.16759 (1 S.6939)	O. 16971 (18.7409)
Pools	0.09507 (5.3541)	0.10035 (6.1256)	0.09265 (5.6525)	0.10142 (6.2941)	0.09228 (5.6424)	0.09155 (5.5838)
Elev 1	-0.41671 (-7.9497)	-0.39891 (-7.5862)	-o. 40033 (-7.5764)	-O. 42505 (-8. 1831)	-0.39871 (-7.5506)	-0.39951 (-7.5484)
View	0.13555 (9.2139)	0.11700 (7.7347)	0.13046 (8.6915)	0.10607 (7.1456)	0.12941 (8.6473)	0.13448 (9.0200)
Dist	-0.00010 (-5.5308)	-0.000075 (-4.0125)	-0.000073 (-3.5614)	-0.003039 (-2.0835)	-0.000071 (-3.5408)	-0.000089 (-4.7128)
Ethnic	-0.00308 (-2. 4126)	0.00049 (0.4242)	0.00126 (1.0234)	0.00579 (4.5810)	0.00155 (1.2549)	0.00064 ("0.5002)
Hdens	0.00163 (4.1065)	0.00223 (6.8533)	0.00237 (7.2769)	0.00169 (4.5166)	0.00234 (7.1920)	0.00238 (7.2830)
Crimra	-3.74399 (-5.5182)	-2.58998 (-4. 0024)	-1.85452 (-2.8349)	-3.69639 (-1.0781)	-1,69693 (-2.5752)	-2.06851 (-3.1234)
Scores	0.03448 (26.3711)	0.02954 (22.6859)	0.03119 (24.5972)	0.027$4 (21.1613)	0.03142 (25.0668)	0.03154 (23.7043)

Table 25
(cent'd)

Independent Variable	NO2	TS?	OZEX	OZMAX	OZONE	PS12
NO_2^2	0.0089S (7.1749)					
TSP^2		-0.000025 (-5.3818)				
$OZEX^2$			-0.000022 (-1.8215)			
$OZMAX^2$				-0.00506 (-10.0979)		
NE					-0.00000067 (-2.5839)	
$PSI2^2$						-0.00000039 (4.0314)
R^2	.7773	. 77s5	.7733	.7814	.7736	.7730
SSE	107.49	108.39	109. 45	105.5192	109.3069	109.5824
DF	2648	2668	2648	2648	2668	2648

the area. The “scores” measure in our study is much more significant; our factor analysis indicates that school scores are much more related to socioeconomic conditions in the area than to city service measures. Thus, perhaps not surprisingly (since San Francisco and Los Angeles are different types of market areas), the sign and significance of coefficients in our study are different from those in Los Angeles, even apart from the pollution coefficient.

The coefficient of the TSP pollution measure is quite similar in magnitude and significance to that in the Los Angeles study. However, the nitrogen oxide coefficient is positive and significant; it should be noted that nitrogen oxide standards are rarely exceeded in our area and thus this measure is not an appropriate pollution measure for our area. Of the ozone pollution measures tested, the OZMAX variable was the most significant in the replication model at the household level; it is more significant and yields a higher R-squared than does the TSP variable. The PSI variable was not significant in this model.

The R-squared in our model is lower than that in the Los Angeles study for this model. The probable reason in addition to differences in the areas, is that we had much more variation in our data set due to a much larger sample size.

5.6 MODEL MODIFICATIONS

In addition to the independent variables used in the replication model above, we included others which have been used in previous studies. Figure 15 shows the variables in our modified model and their type (demand and supply, etc.). For housing characteristics, we added dummy variable measures of housing condition and availability of on-site parking (important particularly in San Francisco). Lot size was also added.

For additional neighborhood variables, we used the tract level factor analysis as a guide. The factor analysis produced three neighborhood factors: “life cycle”, “socioeconomic status”, and “land use”. The factor analysis grouped neighborhood variables into these factors according to the correlations among variables. To minimize problems of multicollinearity while retaining maximum information, we selected representative variables for each factor. From the “life cycle” factor, we chose median occupants per house. From the “socioeconomic status” factor, two variables were used (percent of occupants below poverty level and median years of schooling); these two were not very highly correlated and represent different socioeconomic aspects. From “land use”, we used the percent of land available for development, the percent of land excluded from development, and the percent of land devoted to nonresidential uses; land available for development is considered to be a supply, rather than demand, variable.

For city variables, we again used the factor analysis as a guide for variable selection. Crime rate and school scores are city variables which reflect socioeconomic conditions. The tax rate was shown to be a positive indicator of city service quality (it is negatively correlated with the fire rating which shows a higher quality the lower the rating value)[9]. In

Figure 15

CLASSIFICATION OF REGRESSION VARIABLES

	DEMAND							SUPPLY	
	House	Neighborhood			City		Other		
		Life	SES	Land	SES	Service		Avail	Mkt. Area
HSGAGE	X								
LOTSIZE	X								
QTR 1	X								
QTR2	X								
QTR 3	X								
LIVAREA	X								
CONDLO	X								
CONDMED	X								
PARKING	X								
FP	X								
BATH	X								
POOLS	X								
POLLUTION							X		
MEDOCCT		X							
POTPOV			X						
MEDSCHT			X						
NEWHSPT								X	
VAC								X	
DEVEL								X	
NONRES				X					
NODEV				X					
DIST							X		
VIEW							X		
ELEV 1							X		
SLOPE							X		
CRIMRA					X				
TAX						X			
SCORES					X				
MKT 1									X
URBAN									X
TEMP							X		

addition to pollution, elevation, slope, and other environmental measures were added to those in the replication study. Slope measures a negative aspect of high elevation while view is a positive aspect; it is well known that lots with a greater slope entail higher building cost as well as problems of sliding. We also tested a measure of summer temperature; temperature was added because higher summer temperatures are known to be a disamenity. The PCTVIS measure of visual quality was also tested as an additional pollution measure.

Because environmental measures were potentially correlated, we performed a factor analysis on these environmental variables. The factor analysis showed that the factor containing PCTVIS is independent of the factor containing the ozone variable. Factor analysis with the PS12 variable puts PCTVIS in the same factor with PSI2.[10] Ozone and temperature occurred in the same factor; however the PSI measure and temperature occurred in different factors indicating that these variables could be used together in the regression. However, areas with the greatest amount of land precluded from development were also shown to be areas with higher temperature indicating potential correlation problems between TEMP and NODEV.

In addition to the demand variables discussed above, we added several supply variables; following past property value studies, we used vacancy rate, an indicator of new building activity, and availability of developable land. We tested existence of separate market areas using the dummy variables for bayside and urban/suburban city type.

We chose the functional form of our regression equation in order to obtain demand curves with the correct slope; i.e., the marginal utility of additional units should decrease for “goods” (such as living area) and the absolute value of the marginal utility should increase for the "bads" (such as pollution). Therefore, to obtain such slopes, we used a logarithmic form for hypothesized “goods” and squared terms for hypothesized "bads". We did not transform supply side variables.

Table 26a, b shows household level results using the additional variables discussed above and OZONE and PS12 pollution measures. Note that the R-squared is considerably higher with the inclusion of these variables. It should be noted that, with the exception of the land use variable DEVEL, all variables added to the replication have significant coefficients.

There are some differences in coefficients between the replication and modified models. House age is significant in the modified model. The living area coefficient is much larger. The fireplace coefficient is much smaller. These changes may all be attributed to the addition of the condition variables. View is less significant.

Changes also occurred for variables at the neighborhood and city level. Low elevation became positive since the slope variable now indicates the negative disamenity (closeness to flat, marshy areas). Distance to work has a much smaller coefficient than in the replication because of the use of dummies to denote market and urban areas. The

Table 26a

HOUSEHOLD PROPERTY VALUE MODEL
PS12

MODEL:	MDC2	SSE	S6.02S762	F RATIO	585.46
		DFE	2489	PROB>F	0.0001
DEP VAR:	LPROPVAL	MSE	0.022S09	R-SQUARE	0.8759

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	-3.487453	0.488201	-7.143s	0.0001
SHSEAGE	1	-.0000432969	.00000474399	-9.1267	0.0001
LLOTSIZE	1	0.046948	0.004651409	10.0932	0.0001
QTR1	1	-0.016568	0.008906153	-1 .8599	0.0630
QTR2	1	0.033315	0.008797697	3.7867	0.0002
QTR3	1	0.047652	0.008592418	5.5458	0.0001
SMEDOCCT	1	-0.00510433	0.001671355	-3.0540	0.0023
LLIVAREA	1	0.591619	0.016633	35.5686	0.0001
CONDLO	1	-0.178369	0.022374	-7.9721	0.0001
CONDMED	1	-0.062735	0.011828	-6.3040	0.0001
FP	1	0.051247	0.007523018	6.8120	0.0001
POOLS	1	0.090860	0.012369	7.3459	0.0001
BATH	1	0.033862	0.006990155	4,8443	0.0001
PARKING	1	0,062910	0.014515	4.3340	0,0001
VIEW	1	0.014481	0.011679	1,2399	0.2151
ELEV1	1	0,049112	0.018585	2,6426	0.0083
SSLOPE	1	-0.000233326	.00004593474	-5.0795	0.0001
MKT1	1	0.249690	0.018405	13.5664	0.0001
LMEDSCHT	1	0.571160	0.086143	6,6303	0.0001
SPCTPOV	1	-0.00146641	.00007S22068	-19.4948	0.0001
NEWMSPT	1	-0.00243059	0.0002612033	-9.3054	0.0001
SNONRES	1	-0.880163	0.256000	-3.4381	0.0006
DEVEL	1	0.030531	0.047347	0.6448	0.5191
LNODEV	1	0.016421	0.00386560S	4.2480	0.0001
SDIST	1	-2.01978E-08	8.29200E-09	-2.4358	0.0149
SCRIMRA	1	-27.41S604	1.955502	-14.4190	0.0001
LTAX	1	0.539696	0,06697s	8.0582	0,0001
VAC	1	-0.049623	0.006829093	-7.2664	0.0001
LSCORES	1	0.625981	0.105043	'5.$9593".	0.0001
OZONE	1	-.0000022786	3.57943E-07	-6.3657	0.0001
URBAN	1	0.172527	0.022128	7.7968	0.0001

"S" in front of a variable name dentoes the variable is squared

"L" in front of a variable name denotes the log of the variable

Pollution variables are squared.

Table 26b

HOUSEHOLD PROPERTY VALUE MODEL
PS12

MODEL: MDC7		SSE	56.880741	F RATIO	556.62
		DFE	2488	PROB>F	0.0001
DEP VAR: LPROPVAL		MSE	0.022862	R-SQUARE	0.8740

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	-3.602410	0.577825	-6.2344	0.0001
SHSEAGE	1	-.0000401207	.00000483232	-$.3026	0.0001
LLOTSIZE	1	0.045747	0.004684892	9.7648	0.0001
QTR1	1	-0.017238	0.008977033	-1.9203	0.0549
QTR2	1	0.034473	0.008871061	3.8860	0.0001
QTR3	1	0.046589	0.008661034	5.3791	0.0001
SMEDOCCT	1	-0.00333013	0.001949683	-1 .7080	0.0878
LLIVAREA	1	0.601284	0.016795	35.8018	0.0001
CONDLO	1	-0.179985	0.022553	-7.9807	0.0001
CONDMED	1	-0.065164	0.011927	-5.4634	0.0001
FP	1	0.046283	0.007561068	6.1212	0.0001
POOLS	1	0.091438	0.012S33	7.2957	0.0001
BATH	1	0.031806	0.007081813	4.4912	0.0001
PARKING	1	0.062604	0.014647	4.2742	0.0001
VIEW	1	0.021274	0.011857	1.7943	0.0729
ELEV1	1	0.064628	0.019364	3.3376	0.0009
SSLOPE	1	-0.000105014	.00004551239	-2.3074	0.0211
MKT1	1	0.129969	0.024447	5.3163	0.0001
LMEDSCHT	1	0.361662	0.102803	3.5180	0.0004
SPCTPOV	1	-0.00150786	.00008440475	-17.8646	0.0001
NEWHSPT	1	-0.00254755	0.0002713785	-9.3874	0.0001
SNONRES	1	-0.646780	0.265280	-2.4381	0.0148
DEVEL	1	-0.043666	0.053796	-0.8$17	0.4170
LNODEV	1	0.0097S5018	0.003792091	2.5804	0,0099
s01S1	1	-4.58326E-08	9.21817E-09	-4.9720	0.0001
SCR IMRA	1	-23.159614	2.717S36	-8.5223	0.0001
LTAX	1	0.139000	0.070539	1.9705	0.0489
VAC	1	-0.059090	0.013033	-4.5338	0.0001
LSCORES	1	0.902670	0.142431	6.3376	0.0001
PS12	1	0.0000391052	.00002550403	1.5333	0.1253
URBAN	1	0.233047	0.025958	8.9778	0.0001
STEMP	1	-7.48655E-07	.00000880494	-0.0850	0.9322

"S" in front of a variable name denotes the variable is squared

"L" in front of a variable name denotes the log of the variable

Pollution variables are squared.

magnitude of the coefficient for crime rate is larger and more significant because of market and urban dummies as well. School score has a larger coefficient. The ozone coefficient is larger and more significant in the modified model. However the PS12 coefficient is positive for the household model .

We also estimated a model at the tract level using all tracts ("master" tracts). Table 26 c, d shows the modified model at the tract level; at the tract level both OZONE and PS12 were significantly negative,

5.6.2 Experiments with Pollution Measures, Aggregation and Market Stratification

In addition to experiments regarding independent variables and measures of pollution, we also examined the effect of alternative data aggregation methods. In addition to our household level sample, we had two data sets at the tract level: the "master tracts" representing the complete Bay Area and the "pool" tracts containing information for tracts with the least error in measurement of pollution and socioeconomic information. (Since the "pool" tracts are a nonrandom sample of the master tracts, estimates extrapolated from the pool tracts to all tracts may be biased.)

We also examined differentiation by market area. The suburban area spans all air pollution types; however, the suburban area does not constitute a closed market area. The West Bay includes all air quality types; it is mostly a closed market area according to the work trip flows information (more than 90 percent of work trips are within the area). As an alternative to studying the whole Bay Area, a researcher studying effects of air pollution might have decided to carry out a study using only suburban tracts (to hold constant effects of city type) or might have decided to limit the study to the West Bay. Market areas are designated as "all", "suburb", and "west" to indicate respectively, no market area differentiation, limitation to suburban areas, and limitation to West Bay. Appendix tables A14-A20 show results for these models.

Table 27 compares the coefficients of the pollution measures by aggregation and market area. Table 28 shows the corresponding $\bar{R}^2$ values. Note that the OZONE measure is significant at least at the 95% level for eight of the nine models and has a similar magnitude across all the models. For all but the household level, the PS12 coefficient is of consistent magnitude and significance. In view of significance of PS12 for the pool and master levels, the insignificance of PSI2 result at the household level may be due to a sampling problem.

The set of pollution measures is most consistently significant for the "pool" sample; this is the data set with the most exact measurement of pollution and generally the most variation in the pollution measures (according to the standard deviations). For the "pool" tracts (all and suburban) all pollution coefficients except TSPMN are significant at the 99% level. For the "master" tracts ("all" and "suburban" tracts) the level of significance is at least 95% except for TSPMN.

TABLE 26c

TRACT PROPERTY VALUE MODEL[a]
OZONE

MODEL: MDC2		SSE	15.075054	F RATIO	235.51
		DFE	791	PROB>F	0.0001
DEP VAR: LPROPVAL		MSE	0.019058	R-SQUARE	0.8993
LOG OF PROPERTY VALUE					

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	-3.139160	0.781115	-4.0188	0.0001
SHSEAGE	1	-.0000180502	0.000008145	-2.2161	0.0270
LLOTSIZE	1	0.002029127	0.013419	0.1512	0.8798
QTR1	1	-0.172688	0.053232	-3.2441	0.0012
QTR2	1	-0.00423630	0.048995	-0.0865	0.9311
QTR3	1	0.075693	0.046918	1.6133	0.1071
SMEDOCCT	1	-0.0056562	0.001632262	-3.4665	0.0006
LLIVAREA	1	0.748752	0.055346	13.5285	0.0001
CONDLO	1	-0.841204	0.111016	-7.5773	0.0001
CONDMED	1	-0.221679	0.061241	-3.6198	0.0003
FP	1	0.110994	0.025407	4.3687	0.0001
POOLS	1	0.151670	0.060291	2.5160	0.0121
BATH	1	0.071191	0.027746	2.5659	0.0105
PARKING	1	0.031947	0.037829	0.8445	0.3986
VIEW	1	0.209974	0.034020	6.5236	0.0001
ELEV1	1	0.017806	0.016724	1.0647	0.2873
SSLOPE	1	-0.000104788	0.0000433634	-2.4165	0.0159
MKT1	1	0.217576	0.017106	12.7177	0.0001
LMEDSCHT	1	0.592465	0.077293	7.6662	0.0001
SPCTPOV	1	-0.000262321	.00003530275	-7.4306	0.0001
NEWHSPT	1	-0.00181129	0.0002777179	-6.5221	0.0001
SNONRES	1	-0.061198	0.098049	-0.6242	0.5327
DEVEL	1	-0.117279	0.040426	-2.9010	0.0038
LNODEV	1	0.018140	0.003847587	4.7147	0.0001
SDIST	1	-2.95949E-09	7.45758E-09	-0.3960	0.6916
SCRIMRA	1	-6.596401	1.924257	-3.6280	0.0006
LTAX	1	0.099034	0.058686	1.6875	0.0919
VAC	1	-0.058213	0.011021	-5.2818	0.0001
LSCORES	1	0.496393	0.125173	3.9657	0.0001
OZONE	1	-.0000010099	3.68567E-07	-2.7400	0.0063
URBAN	1	-0.015952	0.025697	-0.6208	0.5349

[a] all "master" tracts were used in this analysis

TABLE 26d

TRACT PROPERTY VALUE MODEL[a]
PS12

MODEL: MOC7		SSE	14.956006	F RATIO	229.64
		DFE	790	PROB>F	0.0001
DEP VAR: LPROPVAL		MSE	0.018932	R-SQUARE	0.9001
LOG OF PROPERTY VALUE					

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T RATIO	PROB>|T|
INTERCEPT	1	-2.499037	0.800547	-3.1217	0.0019
SHSEAGE	1	-.0000188788	.00000515854	-2.3140	0.0209
LLOTSIZE	1	0.010207	0.013892	0.7346	0.4627
QTR1	1	-0.168182	0.053058	-3.1699	0.0016
QTR2	1	0.004730655	0.049002	0.0965	0.9231
QTR3	1	0.07S872	0.046777	1.6220	0.1052
SMEDOCCT	1	-0.005540S6	0.001632"?3	-3.3930	0.0007
LLIVAREA	1	0.740795	0.055251	13.4078	0.0001
CONDLO	1	-0.821267	0.111012	-7.3960	0.0001
CONDMED	1	-0.220723	0.06099'?	-3.6185	0.0003
FP	1	O.1O9l76	0.025341	4.3083	0.0001
POOLS	1	0.153745	0.060264	2.5512	0.0109
BATH	1	0.074388	0.027682	2.6872	0.0074
PARKING	1	0.027035	0,037724	0.7166	0.4738
VIEW	1	0,276732	0,034474	8.0272	0.0001
ELEV1	1	0.011133	0.016881	0.6595	0.5099
SSLOPE	1	-0.00011727!	.00004340407	-2.7018	0.0070
MKT1	1	0.225049	0,018623	12.08s2	0.0001
LMEDSCHT	1	0.611378	0.076682	7.9729	0.0001
SPCTPOV	1	-0.000257801	.00003516736	-7.3307	0.0001
NEWHSPT	1	-0.00177341	0.0002773329	-6.3945	0.0001
SHONRES	1	-0,042204	0.098060	-0.4304	0.6670
DEVEL	t	-0.115651	0.040206	-2.8764	0.004!
LNODEV	1	0.017699	0.003844735	4.6033	0.0001
SDIST	1	-3.95856E-09	7.47977E-09	-0,5292	0.5968
SCRIMRA	1	-7.593816	1.940251	-3,9136	0.0001
LTAX	1	0,094921	0.059680	1.5905	0.1121
VAC	1	-0.053308	0.0)2030	-4.4314	0.0001
LSCORES	1	0.397174	0.134539	2,9521	0.0032
PSI2	1	-.000057500a	.00001979548	-2.9047	0.0038
URBAN	1	-0.028001	0.026954	-1.0388	0.2992
STEMP	1	-.000008S723	.00000753523	-1.1376	0.2556

[a] all "master" tracts were used in this analysis

I'able 2 7

COMPARISON OF POL1.OTION COEFFICIENTS BY MODEL

	HOUSEHOLD			POOL			MASTER		
	All	Suburb	West	All	Suburb	West	All	Suburb	West
OZONE	-.0000023 (-6. 36)[a]	-.000002 b (-6.81)	-.0000032 (-3. 41)	-.00000 I 5 (-3. 39)	-.000001 1 (-3.00)	-.0000010 (-1.74)	-.0000010 (-2.74)	-.000001 (-3. 33)	$-4.3x10^{-7}$ (-.99)
OZMAX	-.002149 (-.32)	-.014016 (-1.62)	.066381 (1.53)	-.0030002 (-3.26)	-.0026638 (-3.28)	-.002077 (-1.43)	-.0010554 (-1.74)	-.002170 (-5.16)	-.001566 (-1.89)
OZEX	.000945 (.81)	-.000952 (-.82)	.002832 (.58)	-.0000812 (-'1.62)	-.0000651 (-3.45)	-.0000489 (-1.64)	-.0000435 (-2.74)	-.000043 (-3.95)	-.000021 (-1.39)
TSPMN	.000034 (.499)	.000039 (5.41)	-.0000036 (-.11)	-.0000127 (-1.15)	-.0000101 (-1.03)	-.0000281 (-1.82)	.0000031 (.42)	-.000012 (-2.17)	-.000012 (-1.33)
PS12	.000039 (1.53)	.000010 (3.51)	-.000341 (-1.12)	-.0000174 (-2.89)	-.0000712 (-2.97)	-.0000545 (-1.56)	-.0000575 (-2.90)	-.000049 (-3.65)	-.000037 (-1.62)

a T- Ratio

Table 28

COMPARISON OF R^2 BY MODEL	HOUSEHOLD			POOL			MASTER		
	All	Suburb	West	All	Suburb	West	All	Suburb	West
OZONE	.8759	.8854	.8412	.9499	.9714	.9517	.8993	.9437	.8972
OZMAX	.8739	.8829	.8461	.9-498	.9717	.9514	.8987	.9452	.%9?6
OZEX	.8739	.8828	.8459	.9502	.9717	.9516	.8993	.9442	.891.4
TSPMN	.8751	.8645	.8458	.9480	.9702	.9518	.0984	.9431	.8974
PSI2	.8740	.8835	.8469	.9580	.9724	.9521	.9001	.9456	. 89s1

For the West Bay (household, pool, and master), the OZONE measure is significant at the 99% level for the household sample and at the 95% level for the pool sample but not significant at the master level. PS12 is significant at the 95% level in the household, pool, and master levels.

Thus, the conclusion which may be drawn from this experiment is that the level, of aggregation and geographic stratification of a market area will indeed affect the indicated significance of the pollution measure.

The consistency of the OZONE results across all models gives validity to the use of OZONE in explaining variation in property values. However there is a caveat to this result; due to collinearity problems we are not able to separate temperature effects from OZONE effects in explaining property value variation.

Other independent variables may also be compared across models. Table 29 shows a comparison of selected variables from alternative models using OZONE as the pollution measure. By comparison, the stability of the pollution measures across models shown in Table 27 is notable! "Living area" is the most stable variable. Lot size, slope, view, nonresidential land use, vacancy rate, and distance to work all vary in significance across the models. The lotsize and slope variables are most significant for the household level regressions. "View" is most significant for the master tract model. Nonresidential land use is significantly negative (the expected sign) only in the household level regressions. Distance to work is negative and significant only in the household level regression over all markets. On the supply side, an increased vacancy rate has the expected effect of reducing property values in all cases.

The household level study using all market areas is most consistent with expectations regarding signs of coefficients. In general, the aggregation of data to the tract level seems to reduce the significance of specific house characteristics as variation is reduced through aggregation.

5.6.3 Conclusions from Experiments

Our studies indicate that the OZONE measure of pollution does have a statistically significant effect on property values in the San Francisco Bay Area for the aggregation levels and market specifications we examined. The magnitude of the coefficient is consistent across models. The PS12 measure, which combines ozone, TSP, and CO measures according to equal severity of health effects, was also significant in all but the household level equations.

Our experiments with aggregation and market stratification show that such modelling decisions can indeed affect conclusions about significance and sign of pollution and other variables hypothesized to affect property values. The implication of our experiments is that researchers who obtained insignificant pollution coefficients might have obtained different results using different procedures (pollution measures, aggregation procedures, sampling procedures, and reduction in measurement error). We

Table 29

Comparison of Selected Coefficients By Model
OZONE Pollutant

	HOUSEHOLD All	HOUSEHOLD Suburb	HOUSEHOLD West	POOL All	POOL Suburb	POOL West	MASTER All	MASTER Suburb	MASTER West
LIVAREA	.5916 (3s.57)	.6202 (34.98)	.5184 (21.64)	.6828 (8.11)	.7531 (9.31)	.6057 (5.96)	.7487 (13.52)	.8316 (15.79)	.7080 (9.89)
LOTSIZE	.0469 (10.09)	.0432 (9.40)	.0707 (8.97)	.0097 (o. 38)	.0440 (1.85)	.0090 (0.29)	.0020 (0.15)	.0536 (4.56)	.0617 (3.70)
MEDOCCT	-.0051 (-3.05)	-.0034 (-1.94)	.0065 (1.94)	-.0195 (-7.06)	-.0083 (-3.40)	-.0159 (-4.52)	-.0056 (-3.46)	-.0055 (-4.54)	-.0039 (-2.09)
SLOPE	-.0002 (-5.08)	-.0004 (-5.64)	-.0004 (-5.05)	.0001 (1.89)	-.00005 (-o. 73)	.00008 (1.08)	-.0001 (-2.42)	-.00004 (-1.25)	-.00007 (-1.57)
VIEW	.0144 (1.24)	.0002 (0.02)	-. 0003 (-0.02)	-.0019 (-0.04)	.0684 (1.51)	.0675 (0.98)	.2899 (8.52)	.1195 (3.96)	.1943 (5.00)
NONRES	-.8801 (-3.44)	.4246 (.99)	7.9903 (5.65)	-.4402 (-1.94)	-.2147 (-0.96)	-.5221 (-1.34)	-.0612 (-0.62)	-.0847 (-0.90)	.0418 (.3079)
NODEV	.0164 (4.24)	.0169 (3.15)	-.0182 (-2.21)	-.0005 (-o. 10)	-.0004 (-0.08)	.0005 (0.07)	.0181 (4.71)	.0001 (0.04)	.0133 (3.01)
DIST	-2.02 x10-a (-2.44)	9. 39 X1 O-9 (0.91)	$1.29x10^{-7}$ (3.50)	$2.41x10^{-8}$ (1.50)	$1.37x10^{-8}$ (0.98)	$6.79x10^{-8}$ (2.57)	$-2.95x10^{-9}$ (-o. 39)	$-3.68x10^{-9}$ (-0.66)	$-5.99x10^{-9}$ (-0.66)
VAC	-.0496 (-7.26)	-.0543 (-7.77)	-.2777 (-5.91)	-.0513 (3.52)	-.0453 (-3.70)	-.0222 (-0.92)	-.0582 (-5.28)	-.0349 (-4.48)	-.0261 (-1.47)
R^2	.8759	.8854	.8472	.9499	.9714	.9517	.8993	.9437	.8972
N	2489	2028	1261	264	195	160	791	555	456
SE	56.02	40.15	28.84	2.72	1.13	1.42	15.07	4.45	7.07

believe that more experiments, such as those performed here, should be carried out to test consistency of conclusions.