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AIR POLLUTION AND PROPERTY VALUES IN
URBAN AREAS

A Dissertation
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

by
Kenneth Wayne Paxton

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ABSTRACT

The problem of air pollution is a worldwide phenomenon. One manifestation of the problem is the existence of air pollution regulations. The general objective of this study was to provide information useful in establishing air quality standards as well as adding to the body of knowledge about the economics of air pollution. To accomplish this objective, the hypothesis that the level of air pollution and property values were negatively related was tested.

In order to do this, it was necessary to accomplish two specific objectives. The first was to determine the association between levels of air pollution and property values. This objective was accomplished for an individual city as well as a group of 60 cities across the United States. Secondary data on variables thought to be important in explaining property values were utilized in a regression model to accomplish the first objective.

The second objective of this study was to explore alternative methods of estimating economic loss attributable to air pollution. This objective is connected with the first in that the analysis involving 60 cities represents a different approach to estimating economic loss. In addition, some work was done with consumer expenditure data, but these results were inconclusive and are not reported in this study.

Results of the single-city analysis did not support the hypothesis that property values were negatively influenced by air pollution. Instead, they suggest that property owners acted as if air pollution did not influence them in their estimation of property values.

Alternatively, the real estate market may not have functioned properly so that if air pollution did exert a negative influence, it was not communicated to the owners. However, caution is urged in interpreting the results because of data inadequacies which may seriously hamper the validity of the results obtained.

The results of the analysis involving 60 cities did indicate a negative relationship between the level of air pollution and property values. To the author's knowledge, this approach to measuring the economic loss attributable to air pollution has not been used previously. As was the case in the single-city analysis, income proved to be very important in explaining variations in property values. The negative effect of air pollution, while statistically significant, was small compared to the influence of other variables in the model. When evaluated at the mean, the loss estimates obtained in this study ranged from \$3.50 to \$4.00 decrease for each 1% increase in pollution level.

This study led to the following conclusions:

1. Air pollution does exert a negative influence on property values.
2. Attempts at measuring the extent of this influence can benefit from utilizing more accurate measures of pollution.
3. Owner-occupied housing units were more responsive to the level of air pollution than renter-occupied units.
4. The actual size of the economic loss attributable to air pollution is not known.
5. Alternative approaches to estimating the size of this loss should be pursued.

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CHAPTER I

INTRODUCTION

The quality of the atmosphere has been recognized as an important variable in the environment in recent decades. There has long been an awareness of the changes that were occurring in the atmosphere, but these changes were considered "normal." Only when drastic changes occurred in relatively short periods of time did the importance of the quality of the atmosphere become apparent. An example of such drastic changes is found in the many acute air pollution episodes.

Within the dynamic system of the atmosphere, great change has been wrought since prehistoric times. Scientists believe that the primeval environment may have contained very little, if any, free oxygen. This contrasts significantly with the present oxygen content of about 21 percent. Also, the study of fossils indicates that there have been substantial variations in CO₂ content. Persistent life forms exhibited a remarkable adaptive ability. Evidence also suggests that many species of plants and animals, some of which were dominant, were not able to adapt to the changing environment. This evidence, coupled with man's knowledge and awareness that his activities also cause change in that environment, gives rise to misgivings about man's ability to adapt to his changing environment. The problem arises because man's activities cause environmental changes over a period of a few years while his adaptive process may take generations (34, pp. 1-2).

Air pollution, the name given the deterioration in the atmosphere, is a problem of growing importance. It is ubiquitous, embracing not

only the local, regional, and national environment, but the international atmosphere, as well. Likewise, the concern for the problem is world-wide, and is manifest at the local and national level by more stringent controls and regulations, stepped-up enforcement of existing regulations, and increased efforts at studying the various aspects of pollution. This study is concerned with the economic aspects of the air pollution problem and the following sections of this chapter give some of the sources and effects of air pollution before setting the air pollution problem in an economic context.

I. SOURCES OF AIR POLLUTION

The beginning of the major source of air pollution was the discovery of fire. Since that time, man has used some of the by-products of combustion to improve his life style; while other by-products of combustion--pollutants--have done much to degrade the environment. Combustion is used for heating and cooling, cooking food, generating electric power, and power for all forms of transportation. Combustion sources of air pollution can be divided into two general categories: stationary and mobile.

Stationary sources are made up of furnaces, incinerators, open fires, fireplaces, and the manufacturing processes. Combustion processes release both solid and gaseous substances. The solid is the incombustible portion of fuels which escapes into the atmosphere as fly ash. This is what settles out onto the surfaces of objects and can easily be observed. Combustion also results in the release of large amounts of gases such as carbon dioxide and nitrogen. In addition,

small amounts of other gases such as sulfur dioxide, sulfur trioxide, carbon monoxide, nitric oxide, nitrogen dioxide, aldehydes, and other hydrocarbons are emitted. Even though the emission of sulfur oxides is relatively small, they are important because they are eventually oxidized and form sulfuric acid which is converted to sulfates. These are then washed out of the air by rainfall (36, pp. 5-6). In addition to the gases mentioned, smoke is also emitted. Smoke is a submicron particulate aerosol which is important because it obscures vision (36, p. 15).

Table 1 shows the emissions of three pollutants from stationary sources for the years 1966 through 1968. The largest apparent change was in the emission of sulfur oxides by utilities. This is due to using more coal that has a high sulfur content (26, p. 17). Nitrogen oxide emissions from all sources show an increase from an estimated 6.7 million tons per year in 1966 to 10.0 million tons per year in 1968. This increase is due to the inclusion of new sources and new fuels (26, p. 17). Residential and commercial source emissions of all pollutants changed very little over the three-year period. From the information presented in Table 1, a very drastic change in emission of pollutants from stationary sources would not be expected in the immediate future.

The mobile sources of air pollution all involve the internal combustion engine. Of the various internal combustion engine users, the automobile is the dominant source of air pollution (36, p. 55). Components of emissions of the internal combustion engine are not in themselves objectionable, but they react with the atmosphere to

Table 1. National Fuel Combustion Emissions by
Stationary Source, 1966 Through 1968

Source	Particulates	Sulfur Oxides	Nitrogen Oxides
	million tons/year		
<u>1966</u>			
Utilities	5.6	14.4	3.5
Industrial	3.0	5.5	2.4
Residential-commercial	0.6	2.6	0.8
Total	9.2	22.5	6.7
<u>1967</u>			
Utilities	5.6	15.4	3.6
Industrial	2.7	5.1	5.0
Residential-commercial	0.6	2.6	0.9
Total	8.9	23.1	9.5
<u>1968</u>			
Utilities	5.6	16.8	4.0
Industrial	2.7	5.1	5.1
Residential-commercial	0.6	2.5	0.9
Total	8.9	24.4	10.0

Source: Nationwide Inventory of Air Pollutant Emissions, 1968.
National Air Pollution Control Administration, Publication No. AP-73
(Raleigh, North Carolina: U.S. Department of Health, Education, and
Welfare, 1970), p. 17.

form smog (36, p. 55). The combustion-related emissions from automobiles are shown in Table 2. From this table, it is apparent that hydrocarbons make up a large portion of the emissions from automobiles. Emissions for transportation sources are shown in Table 3.

Table 3 illustrates how the emission of transportation changed over the three-year period from 1966 to 1968. The largest change occurred in the emissions of hydrocarbons. This change was due primarily to the federal regulations on exhaust emissions (26, p. 13). Exhaust emission controls also accounted for the 0.7 million ton decrease in carbon monoxide emissions (26, p. 5). The increase in emission of nitrogen oxides resulted from increased use of vehicles and an increased emission factor because of exhaust emission controls (26, p. 16).

A summary of the emissions of various sources of pollution for 1968 is shown in Table 4. From this table, one can see that approximately 4% of the carbon monoxide emissions during 1968 came from transportation sources. Transportation also accounted for about 42% of the total emissions. The next largest amount of pollutants (21% of the total) was emitted by stationary sources. Miscellaneous sources, which ranked third with 17%, included such things as forest fires, agricultural burning, and so forth. The remainder of the pollution was accounted for by industrial processes (14%) and solid waste disposal (5%). In terms of pollutants, the most prevalent was carbon monoxide, which made up 46.7% of the national emissions. The emissions of other pollutants were fairly equally divided, with sulfur oxide accounting for 15.5%, particulates 13.2%, and hydrocarbons 14.9%. Nitric oxide

Table 2. Combustion Related Emissions from Automobiles
in the United States, 1966

Component	Emissions ^a			
	Blow-By		Exhaust	
	Concentration	Weight (lb./day)	Concentration	Weight (lb./day)
Carbon monoxide	Trace	Nil	3.12%	4.160
Oxides of nitrogen	Trace	Nil	850 ppm	0.202
Hydrocarbons	15,060 ppm	0.216	1,365 ppm	0.363

^aMass emissions calculations based upon 31.0 ft.³/mi., STP average exhaust gas flow rate or 71.0 ft.³/mi., STP.

Source: R. W. Hurn, "Mobile Combustion Sources," Air Pollution, Vol. III, Arthur C. Stern, ed. (New York: Academic Press, 1968), p. 62.

Table 3. Emission of Pollutants by Transportation^a
by Type of Pollutant in the United States
for 1966-1968

Pollutant	1966	1967	1968	Change for 1966-1968
	million tons			
Carbon monoxides	64.5	65.0	63.8	-0.7
Particulates	1.2	1.1	1.2	N ^b
Sulfur dioxide	0.6	0.7	0.8	+0.2
Hydrocarbons	17.6	17.3	16.6	-1.0
Nitrogen oxides	7.6	7.6	8.1	+0.5

^aTransportation includes motor vehicles, aircraft, railroads, vessels, and non-highway use of motor fuels.

^bN = negligible.

Source: Nationwide Inventory of Air Pollutant Emissions, 1968.
National Air Pollution Control Administration, Publication No. AP-73.
(Raleigh, North Carolina: U.S. Department of Health, Education, and
Welfare, 1970), pp. 6-16.

Table 4. Estimates of Emission of Air Pollutants from Various Sources in the United States, 1968

Source	CO	Percent of Total	Parti- culates	Percent of Total	SO _x ^a	Percent of Total	HC	Percent of Total	NO _x ^a	Percent of Total	Total	Percent
million tons												
Transportation	63.8	63.74	1.2	4.24	0.8	2.41	16.6	51.88	8.1	39.32	90.5	42.25
Fuel combustion in stationary sources	1.9	1.89	8.9	31.45	24.4	73.49	0.7	2.19	10.0	48.54	45.9	21.43
Industrial processes	9.7	9.69	7.5	26.50	7.3	21.99	4.6	14.38	0.2	0.98	29.3	13.68
Solid waste disposal	7.8	7.79	1.1	3.89	0.1	0.30	1.6	5.00	0.6	2.91	11.2	5.23
Miscellaneous	16.9	16.89	9.6	33.92	0.6	1.81	8.5	26.55	1.7	8.25	37.3	17.41
Total	100.1	100.00	28.3	100.00	33.2	100.00	32.0	100.00	20.6	100.00	214.2	100.00
Percent	46.8		13.2		15.5		14.9		9.6		100.0	

^aSO_x and NO_x are primarily SO₂ and NO₂, but other oxides are also included.

Source: Nationwide Inventory of Air Pollutant Emissions, 1968. National Air Pollution Control Administration, Publication No. AP-73 (Raleigh, North Carolina: U.S. Department of Health, Education, and Welfare, 1970), pp. 6-16.

made up the remaining 10% of the total emissions. Table 4 shows that transportation is the single largest source of pollutants, and carbon monoxide accounted for most of the emissions.

II. EFFECTS OF AIR POLLUTION

Obviously, if air pollution is cited as the cause of certain problems, it must have some effect on various objects. This section will briefly describe some of the effects associated with air pollution. The effects of air pollution may be classified in many ways. This section classifies these effects into four categories: (1) effects on the atmosphere; (2) effects on plants and animals; (3) effects on humans; and (4) effects on materials.

Effects on the Properties of the Atmosphere

These effects are, perhaps, among the first to be noticed by the casual observer. Included in this category are effects on visibility, weather, and atmospheric constituents. The reduced visibility is usually due to haze and smoke, both of which can easily be seen. Weather is not as easily observed. Fogs are easy to see, but the frequency of fogs over a period of time is not readily determined by the casual observer. The general conclusion of several studies on the relationship between air pollution and fog is that ". . . the urban area experiences more frequent fog and, furthermore, the fog usually persists longer than in the surrounding countryside" (34, pp. 379-380). The relationship between air pollutants and precipitation has not been determined. There are two reasons why this relationship is difficult to specify. First, the rain formation mechanism is very complex and

a city can influence this mechanism in ways which are unrelated to its air pollution. Secondly, rain cannot be reproduced in the laboratory and studied (34, p. 383).

In addition to the above, air pollution also effects the make-up of the atmosphere. Stern point out that changes have occurred in the following items:

(a) carbon dioxide, where there is little doubt about a long-time concentration increase linked to air pollution emissions; (b) lead aerosols, where there is some evidence from geochemistry of increased large-scale pollution in recent years; (c) atmospheric electricity which is affected by an increase in the fine particle concentration; and (d) possible changes in concentrations of carbon monoxide and sulfur dioxide (34, p. 392).

Effects on Plants and Animals

The effects of air pollution on plants and animals have given rise to most of the current concern about air pollution. As Stern indicates, the presence of smoke and odors from factories may be unpleasant to humans, but a crop failure or the death of vegetation due to air pollution dramatizes its adverse effect. There are no accurate estimates of the annual cost in terms of damage to vegetation, but it is thought that the cost would run close to a billion dollars (34, pp. 401 and 403).

No attempt will be made here to outline the specific effects of air pollution on various plants. Generally, the visible injury to the leaves of plants may be classified into three categories: "(1) leaf tissue collapse with necrotic patterns, (2) chlorosis or other color changes, and (3) growth alterations" (34, p. 404). Stern also points out that many of the toxic agents produce characteristic

such research encounters a few difficulties, all of which are not minor.

In the case of animals, these difficulties may be illustrated by the fact that the mix of pollutants may act in several ways.

They may produce an effect that is additive, amounting to the sum of the effects of each contaminant acting alone; they may produce an effect that is greater than simply additive (synergism) or less than simply additive (antagonism); or they may produce an effect that differs in some other way from the simply additive (12, p. 78).

Effects on Humans

The fact that air is essential for life is well known. Perhaps less well known are the effects impurities in the air have on both the quality and quantity of life. Earlier in the chapter some of the qualitative factors were pointed out. These included such things as reduced visibility and altered climatological conditions. There are also some quantitative health effects of air pollution. J. R. Goldsmith has enumerated the effects of air pollution on health as follows.

1. Acute sickness or death.
2. Insidious or chronic disease, shortening of life, or impairment of growth.
3. Alteration of important physiological functions, such as ventilation of the lung, transport of oxygen by hemoglobin, dark adaptation (the ability to adjust eye mechanisms for vision in partial darkness), or other functions of the nervous system.
4. Untoward symptoms, such as sensory irritation, which in the absence of an obvious cause, such as air pollution, might lead a person to seek medical attention and relief.
5. Discomfort, odor, impairment of visibility, or other effects of air pollution sufficient to lead individuals to change residence or place of employment (34, pp. 548-49).

More specifically, air pollution has been cited as a causal factor in chronic pulmonary diseases. Goldsmith points out that the causal link between a specific disease and air pollution is likely to be very

complicated. Studies involving the relationship between air pollution and specific diseases have generally found that in the case of lung cancer, deaths attributable to lung cancer are more frequent in the city than in the country (34, p. 568). Similar results were obtained in studies involving bronchitis and emphysema (34, p. 583). The findings concerning asthma have not been as dramatic. Results of such studies indicate that "generalized community air pollution is a suggested causal factor, but only for a small proportion of all adult asthma patients" (34, p. 594).

While the above effects have been documented to a certain extent, the full extent of the damage caused by air pollution is not yet known. As one author explained, ". . . what is known is plainly miniscule in the light of what must be learned" (12, p. 79). One area involving humans in which research and knowledge is lacking is in the area of psychological effects. These effects involve many of the aesthetic values of man and are difficult to deal with.

Material Effects

Chemicals and other foreign substances in the air have long been a source of damage to inanimate objects. Such damage is evidenced by paint chipping and peeling and by soiling of material surfaces. Yocom and McCaldin classify the mechanisms by which air pollutants damage materials into five categories.

1. Abrasion. Solid particles of sufficient size and traveling at high velocities can cause destructive damage.
2. Deposition and removal. Solid and liquid particles deposited on a surface may not damage or change the material itself, except perhaps to spoil its appearance. However, removal of the particles may cause some deterioration. . . .

3. Direct chemical attack. . . . for example, the tarnishing of silver by H_2S and the etching of a metallic surface by an acid mist.

4. Indirect chemical attack. . . . Sulfur dioxide absorbed by leather is converted to sulfuric acid, which deteriorates the leather.

5. Electrochemical corrosion. Much of the atmospheric deterioration of ferrous metals is by an electrochemical process (34, p. 618).

These mechanisms act to damage various materials in what may be referred to as a typical manner. The typical manifestation of damage of air pollution on various materials is shown in Table 5. Also shown in the table are the method of measuring the damage, principal pollutant, and the other environmental factors important in material damage.

III. PROPOSAL FOR STUDY

Statement of the Problem

The above sections have enumerated some of the sources of air pollution and the effect air pollution has on various things. It was noted in the section on sources of pollutants that many of the major sources are increasing. Given that the number of sources of pollutants is increasing with no matching increase in control technology, then the amount of air pollution will increase. The application of control technology has lagged behind the increase in pollution so that clean air as we have known it is becoming an increasingly scarce resource. Air pollution, along with other forms of environmental pollution, is of great national concern if one judges concern on the basis of the frequency of articles on the subject in newspapers and popular magazines. Some of the articles appearing in the news media

Table 5. Material Damage by Air Pollution

Materials	Typical Manifestation	Measurement	Principal Air Pollutant	Other Environmental Factors
Metals	spoilage of surface, loss of metal, tarnishing	weight gain of corrosion products, weight loss after removal of corrosion products, reduced physical strength, changed reflectivity or conductivity	SO ₂ , acid gases	moisture, temperature
Building materials	discoloration, bleaching	not measured quantitatively	SO ₂ , acid gases, sticky particles	moisture, freezing
Paint	discoloration, softened finish	not usually measured quantitatively	SO ₂ , H ₂ S, sticky particles	moisture, fungus
Leather	powdered surface, weakening	observation, loss of tensile strength	SO ₂ , acid gases	physical wear
Paper	embrittlement	decreased folding resistance	SO ₂ , acid gases	sunlight
Textiles	reduced tensile strength, spotting	reduced tensile strength, altered fluidity	SO ₂ , acid gases	moisture, sunlight, fungus
Dyes	fading	fading by reflectance	NO ₂ , oxidants, SO ₂	sunlight, moisture
Rubber	cracking, weakening	loss in elasticity, increase in depth of cracks when under tension	oxidants, O ₃	sunlight
Ceramics	changed surface appearance	changed reflectance measurements	acid gases	moisture

Source: John E. Vocom and Roy O. McCaldin, "Effects of Air Pollution on Materials and the Economy," Air Pollution, Vol. I, Arthur C. Stern, ed. (New York: Academic Press, 1968), p. 624.

have taken an extreme alarmist position. However, this over-emphasis on the part of the media has provided impetus for many scientific studies on air pollution.

Such studies have pointed out the fact, which is implicit in the foregoing section, that the air pollution problem is extremely complex. This complexity is apparent when it is realized that air pollution comes from many sources, affects a wide range of objects, and can produce different changes on the same object. All of the effects of air pollution are not immediately discernible; there is a time lag in the effects. In addition, scientists--especially the social scientist--have found that there is a general lack of appropriate data in sufficient quantities for adequate analysis of the problem. These difficulties are multiplied by the fact that air pollutants act synergistically with other types of pollutants so that the separation of the effects of air pollution is very difficult.

These difficulties notwithstanding, a solution to the general problem of air pollution must be sought. As alluded to above, the air pollution problem is multidimensional. One of these dimensions concerns the reasons behind pollution, or "why do pollutants pollute?" (15, p. 10). From an economist's point of view, the answer lies in what are generally referred to as "externalities." These arise, in the case of air pollution, when the air is used as a dumping ground for waste and the firm or individual doing the dumping is not forced by the market mechanism to bear the costs it imposes on others. To prevent such dumping, some form of regulation is necessary.

Regulation setting is at best a difficult task. Three questions

which are important in the setting of regulations are: (1) What is the socially acceptable level of pollution? (2) How is this standard obtained? (3) Who pays, and how much? (31, p. 1). Once these questions are answered, the information is needed which permits the regulation-setting body to estimate the net benefits of attaining a certain level of ambient air quality. Ridker cites the many ways in which controls and net benefits are connected (31, p. 2). These include how polluters will respond to a given change in controls, how emission levels are connected to air quality, the relationship between ambient air quality and economic loss, and how people act to offset economic losses and the consequences of these actions. Ridker points out that these causal relationships may be somewhat obscured by the fact that there are many factors other than the level of pollution which may exert an influence on the relationship. This study proposes to examine only one of the causal links above: ambient air quality and economic loss. Specifically, the problem to which this study is directed is a lack of knowledge about the relationship between ambient air quality and economic loss.

Justification

It was pointed out above that pollution has been with us from the beginning. However, pollution was not considered a major problem until recently. This recognition is due to the technological, industrial, and urban growth experienced in the United States and to the knowledge available about the sources and effects of pollution. Accelerating this recognition has been the knowledge that the trends in the industrial and urban growth would continue. The first official

recognition of the problem on a national scale probably occurred when the first comprehensive federal legislation was enacted in 1955 (41, p. 11).

Air pollution has long been recognized as a problem, especially when the pollution was so severe as to cause illness or death. History records several instances where the level of air pollution was sufficient to cause sickness and death. In 1930, 100 persons were made ill and 63 died in the Meuse Valley of Belgium. The Monongahela River Valley in Pennsylvania was covered by fog and a temperature inversion in 1948. Around the town of Donora, nearly half the population became ill and 17 died. During a two-week period in December 1952, London recorded 4000 excess deaths which coincided with heavy smog conditions. Ten years later, in December 1962, London experienced an air pollution episode which caused the deaths of more than 300 people (41, p. 23).

These are isolated incidents, and, while the figures are spectacular, they do not adequately define the extent of damage caused by air pollution. "The greatest health problems and the greatest property damage appear to arise from persistent exposure at many different locations" (41, p. 23). The extent of the air pollution problem is reflected in a survey showing that at least 6000 American communities are affected by air pollution to one degree or another (41, p. 23).

On a regional basis in 1957 the Tennessee Department of Public Health and the United States Department of Health, Education, and Welfare issued a joint report on air pollution in Tennessee (9). The findings of this report indicated that air pollution was a problem in a large portion of the state, with the urban areas being the most severely affected. Following this, the City of Knoxville commissioned

a study of its air pollution problem in 1967. Data gathered in this study indicated that air pollution was, indeed, a problem in Knoxville. Specifically, this study indicated that past attempts at control had fallen short of their goal because controls were not mandatory (18, p. 94). The report also made the implication that there was not enough information on how effective standards could be set. This study finds its justification in attempting to provide some information on the relationship between economic loss and the level of air pollution so that more effective regulations can be established. It is an attempt to determine the cost of air pollution and to develop ways of measuring that cost.

Not only does this study seek justification on a local and regional basis, but on a national basis as well. One section of the analysis in this study is concerned with attempting to measure the cost of air pollution on a national basis. This cost estimate can be interpreted as the benefit to be received by reducing air pollution by a given amount. Therefore, this estimate can be utilized in cost benefit analyses of air pollution control regulations. The federal government is concerned with the problem of establishing effective regulations as evidenced by the lengthy hearings held recently in Congress and various reports issued by Congress (1, 2, 13, and 38).

It is important to know the costs of air pollution and just as important to have reliable methods for estimating such costs, because if current projections are accurate the air pollution problem is not going to diminish in the near future. This can be illustrated with the projection made concerning sulfur dioxide. Middleton made the projections

for sulfur dioxide shown in Table 6. This table shows the estimated emissions of sulfur dioxide for 1967 through 2000. The most notable increase in emissions was from coal and oil burning powerplants where emission of sulfur dioxides was projected on the basis of current abatement practices to increase more than 6 times from 15 million tons in 1967 to almost 95 million tons in 2000. This amount accounted for over 75% of projected emissions of sulfur dioxide in 2000. The evidence presented here illustrates the magnitude of the problem and points to the need to obtain estimates of the damage done by these emissions so that some economic guidelines may be used in determining at what level to establish controls.

Research Objectives

General objective. The main purpose of the study is to add to the body of knowledge about the economics of air pollution and to provide information useful in setting air quality standards. This information will be provided by determining the relationship between economic loss and air pollution in the City of Knoxville, Tennessee, along with a cross-section of 60 cities throughout the United States.

Specific objectives.

1. To determine the statistical relationship between air pollution and the value of individual residences.
2. To explore alternative methods of estimating economic loss due to pollution.

Procedure. The first objective will be accomplished by using secondary data in a regression model. Specifically, the procedure

Table 6. Estimated Sulfur Dioxide Emission for the United States,
Without Abatement Practices, 1967-2000

Source	1967	1970 ^a	1980	1990	2000
	million tons				
Powerplant operation (coal and oil)	15.0	20.0	41.1	62.0	94.5
Other combustion of coal	5.1	4.8	4.0	3.1	1.6
Other combustion of petroleum products	2.8	3.4	3.9	4.3	5.1
Smelting of metallic ores	3.8	4.0	5.3	7.1	9.6
Petroleum refining operations	2.1	2.4	4.0	6.5	10.5
Miscellaneous sources ^b	2.0	2.0	2.6	3.4	4.5
Total	30.8	36.6	60.9	86.4	125.8

^a1970 estimates by the National Air Pollution Control Administration.

^bIncludes coke processing, sulfuric acid plants, coal refuse banks, refuse incineration, and pulp and paper manufacture.

Source: "Air Pollution-1970." Hearings Before the Subcommittee on Air and Water Pollution of the Committee on Public Works, U.S. Senate, 91st Congress, March and April, 1970 (Washington: Government Printing Office, 1970), p. 172.

will be to regress a group of explanatory (independent) variables, one of which is air pollution, on the dependent variable, the median value of owner-occupied single-family housing units initially within census tracts in Knoxville, Tennessee. In the case of the 60 cities, these data will be on housing units within each city. Explanatory variables in both cases may be generally classified as those pertaining to (1) characteristics specific to the property (median number of rooms, age of residence, houses per square mile, etc.); (2) location characteristics; (3) neighborhood characteristics; and (4) a measure of air pollution levels. The dummy variable technique will be used to incorporate some of the explanatory variables into the model.

Data to accomplish this objective will be obtained from the U.S. Census of Population and Housing: 1960, Final Report, PHC(1)-71 (11) for the Knoxville portion. Air pollution data for Knoxville will be obtained from a publication of the Metropolitan Planning Commission (19). Relevant data for the 60 cities will be obtained from the County and City Data Book, 1967 (39), and a publication on air quality criteria for suspended particulate matter (5).

The second objective will be accomplished by developing at least one alternative estimate of the economic loss associated with air pollution. This objective is partially completed with the accomplishment of the first objective. To the author's knowledge the procedure outlined for the first objective has not been used to obtain an estimate of economic loss attributable to air pollution. Another approach involves the use of consumer expenditure data to obtain an estimate of the cost of air pollution. Specifically, the procedure will be to employ

regression techniques with consumer expenditures, or certain classes of consumer expenditures thought to be influenced by air pollution levels, as the dependent variable. The explanatory variables will consist of some measure of air pollution and a group of socioeconomic characteristics.

This chapter has presented an overview of the general air pollution problem with a description of some of the sources and effects of various air pollutants. The latter portion of the chapter outlined the objectives of this study and how these objectives were to be accomplished. Chapter II reviews some of the work that has been done on the air pollution problem. Specific emphasis is given to work involving economic analysis of the problem. Later chapters will present the results of empirical investigations carried out in the course of this study.

CHAPTER II

A REVIEW OF SELECTED LITERATURE

Since Rachel Carson's Silent Spring (10), much has been written on the subject of pollution. There has been a large increase in the number of technical reports resulting from stepped-up research programs in the field of pollution. Articles in the so-called popular press have increased both in intensity and frequency, so much so that most current issues of popular magazines include at least one article on pollution. All of these publications, both scientific and popular, point up the importance of the problem under discussion. This recapitulation includes work encompassing areas of interest to the physical scientist and the social scientist.

The remainder of this chapter is divided into two parts. First is a review of some of the non-economic, but scientific, work done in the area of air pollution. The second part presents a summary of studies on the economic aspects of air pollution and, more specifically, a review of studies especially concerned with the relationship between air pollution and property values.

I. NON-ECONOMIC LITERATURE

This section focuses specifically on some of the many scientific undertakings regarding the problem of air pollution. One of the most imposing works done, to the author's knowledge, is that edited by Stern (34, 35, and 36). It is published in three volumes and covers the air pollution problem from its origins to possible solutions. It is

especially good on the technological aspects of air pollution. Volume I contains the genesis of the air pollution problem followed by definitions, descriptions, and properties of the various air pollutants. This volume also has four chapters dealing with air pollution meteorology which discuss dispersion of air pollutants and factors which are important in influencing dispersion. Also included in this section is a discussion of the management of air pollution from a meteorological standpoint. The final section of Volume I explains the nature and extent of the effects of air pollution on various objects. Among the objects mentioned are atmosphere, vegetation, animals, human health, materials, and the economy.

The main points of Volume I are that, first, air pollution has existed since the beginning of time. Secondly, it was not a problem at first, but became a serious problem with the advent of the industrial revolution. The problem will continue to exist in the future, based on current assessments of the situation. Another major point of this volume is that air pollution affects a wide variety of objects, both animate and inanimate. Many of the effects of air pollution on various objects have not been adequately studied so that the extent of damage in many instances is not known. In addition, air pollution is thought to have some effect on the economy; however, estimates of the extent of such damage vary considerably (34, p. 651).

Volume II is concerned with the analysis, monitoring, and surveying of air pollution. Part IV of Volume II covers the sampling of air pollution and includes some techniques of sampling. Also included in this section is a treatment of the analysis of various

classes of pollutants. Some of the classes of pollutants covered are organic and inorganic particulates. Part V of Volume II deals with air quality and meteorological monitoring. Included in this part are chapters on measurement of odor, meteorological measurement, monitoring airborne radioactivity, air quality monitoring, and the production of controlled test atmospheres. The final part of this volume covers measuring and testing air pollution sources along with a discussion on community air pollution surveys.

Volume II points out the importance of determining the concentration of the various pollutants in the atmosphere (35, p. 3). After the samples are taken, their contents must be analyzed, and several chapters were used to explain the analyses of various types of pollutants. It was pointed out that inorganic gaseous pollutants are the most important class of air pollution (35, p. 54). The importance of monitoring air pollution sources was pointed out with a discussion of the techniques available for monitoring. From a social scientist's point of view, one of the most interesting sections of Volume II was the section dealing with the community survey. These surveys serve to determine the nature and extent of an air pollution problem in a particular location. Results of such surveys may be used in planning for the long range management of local air resources.

The third volume is devoted to the sources of air pollution and their control. Sources of air pollution are enumerated and discussed in the first nine chapters of this volume. Included in the list of sources are both stationary and mobile combustion sources, in addition to several types of industries. The next part covers methods and

equipment. Many of the latest control measures are discussed, including their relative efficiency, practicality, and applicability. Volume III concludes with a section on the control of air pollution. This includes a summary of legislation currently in effect and some proposals for future legislation. A section on air pollution standards is also presented. Following this, a chapter on the air pollution control administration explains the functions and philosophy of the organization in charge of air pollution problems at the national level. A later chapter outlines the need for more public information and education on air pollution. The book concludes with a compilation of air pollution literature which should prove helpful to those engaged in research on air pollution.

In summary, this three-volume book gives a very comprehensive treatment to the air pollution problem. Its contents provide the reader with much information essential to understanding the technical aspects of the problem. It also provides the social scientist with basic information in studying the social aspects of the air pollution problem.

In addition to the work by Stern, there have been several other works on the technical and scientific aspects of air pollution. Much of the work which has been done in this area has been under the auspices of the federal government through the National Air Pollution Control Administration. For example, a series of publications (3, 4, 5, 6, and 7) cover the air quality criteria for various air pollutants. This series of publications sets forth some air quality criteria that indicate the extent to which the obvious and insidious effects of air pollution have affected man and his environment. These criteria serve

as a basis for determining a "safe" level of the various pollutants in the air. For purposes of this study, a review of publications on criteria for five pollutants will be presented.

The first publication to be discussed is concerned with particulate matter (5). The general procedure followed in this and the other publications of this nature is to first define and identify sources of the pollutant--in this case, particulate matter--and then present the effects of that pollutant on various classes of objects. Several substances were identified as being in the atmosphere in the form of particulate matter. However, it was pointed out that other substances not yet identified, but which may have some adverse effects, may also be present (5, p. 81). The general conclusions of this publication were that

adverse health effects were noted when the annual geometric mean level of particulate matter exceeded $80 \mu\text{g}/\text{m}^3$ *. Visibility reduction to about 5 miles was observed at $150 \mu\text{g}/\text{m}^3$, and adverse effects on materials were observed at an annual mean exceeding $60 \mu\text{g}/\text{m}^3$ (5, p. 189).

It was pointed out that in setting standards a safety margin should be considered and, therefore, standards would be set below those levels mentioned above.

Air quality criteria for sulfur oxides (7) follows the same format as described above. It was noted in this publication that in outlining the effects of various pollutants it was very difficult to assert that the cited effects arose solely because of the presence of the particular pollutant under consideration (7, p. 153). The difficulty arises because

* $\mu\text{g}/\text{m}^3$ = micrograms per cubic meter.

of the synergistic action of the various pollutants and the inability to hold other pollutants constant. Combustion of coal accounted for approximately 58% of the emissions of sulfur oxides in 1966 (7, p. 154). The general conclusions of the studies reported in this publication were that

. . . adverse health effects were noted when the annual mean level of sulfur dioxide exceeded $111 \mu\text{g}/\text{m}^3$. Visibility reduction to about 5 miles was observed at $285 \mu\text{g}/\text{m}^3$; adverse effects on materials were observed at an annual mean of $345 \mu\text{g}/\text{m}^3$; and adverse effects on vegetation were observed at an annual mean of $85 \mu\text{g}/\text{m}^3$ (7, p. 162).

Again, it was noted that a margin of safety should be included so that standards would be set below the figures cited above.

The two publications discussed above are concerned with what may be considered the two most important air pollutants. There are other important pollutants, and air quality criteria have been developed for these also. Air quality criteria for carbon monoxide have been published which indicate that standards should be set somewhere below about $15 \mu\text{g}/\text{m}^3$ (3, p. 10-6). Studies reported in this publication indicate that exposure to levels greater than $15 \mu\text{g}/\text{m}^3$ results in adverse health effects and may cause an increase in fatality rates in patients with certain types of heart ailments (3, p. 10-6). However, no adverse effects of carbon monoxide on vegetation or materials were found. It should be noted that the studies in this publication were concerned only with levels of CO found in the atmosphere; not with extremely high levels.

Photochemical oxidants make up another group of air pollutants which adversely affect health, vegetation, and materials. The National Air Pollution Control Administration has established air quality standards

study indicate that coal burning accounted for 85% of the sulfur oxide emissions in Nashville. Gasoline use was cited as a major source of nitrogen oxides and organic gases (40, p. 1). A considerable portion of the emissions of particulate matter was accounted for by industries. In addition, the results of the study show that air pollution and certain morbidity rates were directly related (40, pp. 2-3). Also, this report made some recommendations for an air resource management program. These recommendations included:

- (1) a continuous air quality monitoring program; (2) a current and continuous air emission inventory; (3) a full knowledge and use of conditions influencing the transport of air pollutants; (4) air quality goals; (5) community planning decisions based on air quality goals; and (6) air pollution control decisions and ordinances based on the information and scientific determinations made regarding air quality (40, pp. 3-4).

This study in Nashville has been one of the most comprehensive studies of the air pollution problem. Several aspects of the general problem were considered as evidenced by the results cited above.

The City of Knoxville, Tennessee, also conducted a survey of its air pollution problem (18). This report consisted primarily of readings from the various sampling stations on several types of pollutants. Also included were sections on the topography and climatology of Knoxville. Coal smoke was cited as the major air pollution problem (18, pp. 4-5). Generally the report served the purpose of establishing the extent of the air pollution problem in Knoxville. The report also indicated that the expenditure of much more time and effort was necessary to adequately assess the air pollution problem in Knoxville, Tennessee.

This section has attempted to present a sampling of the kinds of

studies being undertaken to assess and place in perspective the air pollution problem. It is obvious from the above that a great deal of scientific work has gone into investigating the air pollution problem. Modern technology has aided in the investigation of this problem by providing better ways of monitoring the various air pollutants and assessing the effects of these pollutants. In addition to the scientific aspects of the problem, the social and political aspects were also mentioned. Studies on these aspects of air pollution indicate that they are at least as important as the purely technical aspects. One reason they are important is that the undesirable effects of air pollution are imposed on individuals and society in many interrelated and complicated ways. One of the ways in which the effects of air pollution is felt is through the pocketbook. Air pollution can and does impose economic losses on individuals and society. It is the purpose of this study to attempt to estimate one form of economic loss and to that end a survey of economic studies dealing with this general topic is presented below.

II. ECONOMIC LITERATURE

Economists have long recognized the existence of external diseconomies, of which air pollution was the classic example, but economists have generally lagged behind other scientists in investigating the air pollution problem. This lag is not as apparent now as it was only a few years ago. Now there are scores of publications in the economic literature dealing with the economic aspects of the air pollution problem. The remainder of this section reviews some

of the more important recent economic studies on air pollution with specific emphasis on those studies dealing with property values.

One of the first books published solely on the economics of air pollution was the work edited by Wolozin entitled The Economics of Air Pollution (41). This book is a compilation of the papers presented at a symposium held at American University supported by the Public Health Service. The papers presented in this book covered a wide range of topics and were authored by persons from several disciplines, ranging from the theorist to the practitioner. Allen V. Kneese presented a paper which set the problem within the context of economics. He contrasted water pollution with air pollution and pointed out that the major common attribute was external diseconomies. Kneese then discussed various methods of eliminating these diseconomies. He ended his paper with a discussion of the problem created by carbon dioxide buildup. Kneese concluded that generators of pollutants must be made to take account of the external costs they impose on others. This necessitates the establishment of an entity large enough to internalize these costs. He also advocated the use of the "air-shed" concept in dealing with air pollution problems

Mills presented a paper on the economic incentives involved in the control of air pollution. He pointed out that there are two types of intervention possible, direct and indirect, with the latter being preferred. Indirect intervention through the market mechanism can be achieved within the framework of the market either by subsidies or fines. Mills preferred fines to subsidies because:

- (1) There is no natural "origin" for payment (of subsidies). . . .
 (2) Payments violate feelings of equity which many people have on this subject. . . . (3) If the tax system is used to make the payments, e.g., by permitting a credit against tax liability for reduced discharge of pollutants, a "gimmick" is introduced into the tax system which, . . . it is better to avoid (41, pp. 45-46).

Mills ended his paper with a proposal:

. . . that air pollution control authorities be created with responsibility to evaluate a variety of abatement schemes, to estimate benefits and costs, to render technical assistance, to levy charges for the discharge of effluents, and to adopt other means of abatement (41, p. 46).

In this paper Mills started with the premise that the market mechanism should not be abandoned, but rather the solution to the problems created by the discharge of pollutants lies in restructuring the market. It should be restructured so as to preserve the decentralized free decision making, characteristic of a free market, but the defects in the market should be remedied. Part of this remedy should be the levying of fines on the polluters. To handle the administration Mills recommended the establishment of control authorities in areas not dictated by political considerations, but rather by the pollution problem.

Chambers presented a paper on the risks and costs in environmental health. He summed up the point of his paper by saying:

. . . we are concerned with deliberate or inadvertant tinkering with a perplexing complex ecological system, and with the prediction of the consequences of change in a concentration, or in a rate, or in some other single constituent of the system on its other parts (41, p. 58).

Crocker dealt with the structure of pollution control systems. Specifically, he delved into the question of how far should an air pollution control authority go in interfering with the market mechanism,

i.e., deciding who pays what to whom. He expressed the belief that the price system may have been sold short and that the answer may lie somewhere between complete control and the free market.

Crowder and Lamale presented papers on governmental statistics and their potential use in air pollution research. Crowder concluded in his paper that there was a need for more data on a local level. Lamale's paper on consumer expenditure data provided a summary of consumer expenditure studies and offered a possible use of such data in research on air pollution.

A case study of air pollution control in Boston was presented in a paper by Goldner. The paper consisted of the problems arising when the air became polluted. He described how these problems were attacked and some of the political, as well as economic, pressures applied in seeking a solution to the problems. Goldner summarized the situation by stating

On one hand we have an irate minority of the populace, and on the other hand we have businessmen concerned with the increased cost of doing business, municipal officials concerned about instituting a more costly procedure and in many cases unable to effect any change, and the majority of people concerned primarily with their tax rate (41, p. 158).

Wolozin then presented a paper on some of the limitations of economic theory involved in air pollution control. He pointed out that economics must be integrated with the social and psychological factors which are a part of the total problem of air pollution control. Wolozin indicated that the use of benefit-cost analysis in the study of air pollution is difficult, and he ended his paper by making some proposals for further study of guides used in determining public expenditures on air pollution control.

The final section of the book consisted of a staff report to the Committee on Public Works, U.S. Senate, September 1963. This report defined the problem, identified pollutants, gave some idea as to the magnitude of pollution, and outlined the effects of pollution on various objects. In addition, a history of the federal program on air pollution was presented. This section contained a summary of some of the grants and other forms of technical assistance that have been made available by the federal government, as well as a summary of the state, local, and non-governmental programs.

Since the appearance of the work edited by W6lozin, several other studies on the economic aspects of air pollution have been made. One such study was conducted by Teller, entitled "Air Pollution Abatement: An Economic Study into the Cost of Control" (37). This study was done while Teller was a graduate student at The Johns Hopkins University and the result is his doctoral dissertation. Teller presented a theoretical economic basis for air pollution control. According to his theoretical construct, the most economical way to achieve a given air quality standard is with selective abatement. An empirical example is used to demonstrate his theoretical construct, in which the cost of selective abatement is less than equiproportional abatement. In addition, he developed a cost of fuel substitution model using linear programming techniques. This model considered two fuels (one less polluting) and the cost involved in shifting from the high polluting fuel to a lower polluting fuel while holding the amount of BTU's provided constant. All of the empirical examples cited are taken from the study conducted in Nashville cited earlier in this chapter (40). In addition to the

theoretical and empirical work, Teller concluded his study with some recommendations for governmental intervention since the market mechanism does not work properly in the case of air pollution (i.e., external diseconomies).

One of the earlier attempts at measuring the costs of air pollution was done by Ridker (31). Portions of Ridker's work have been published in various places. A portion of his earlier work and alternative approaches to the problem of measuring is presented in the book edited by Wolozin (41). The analytical procedure and results were also printed in an article authored by Ridker and Henning published in The Review of Economics and Statistics (32). The following review of Ridker's work is based on his book which includes the material in the two articles noted above (31 and 41). Ridker first developed a frame of reference for setting air pollution control standards which is based on equating the marginal cost of control with the marginal benefits derivable from control. In the second chapter, three strategies for measuring the cost of air pollution are presented. The three strategies are based on effects of a deterioration in the atmosphere. First there are the direct and immediate effects such as sore throats and irritated eyes. The measurement strategy based on these effects involves determining the relationship between each pollutant and the amount of damage it does per unit of each object and then summing over all pollutants and objects to get the total cost involved.

One category of costs which presents particular problems using this approach is "psychic costs" or aesthetic values for which no market values exist. Ridker points out that there are many difficulties

involved in the use of this approach (31, pp. 19-20). The most serious shortcoming is that it fails to take into account the social interactions of people adjusting to offset losses due to a change in environmental quality.

The second category of effects associated with a determination in air quality are those which induce people to make adjustments to offset the direct effects of pollution (31, p. 14). For example, air pollution may cause homeowners to increase maintenance on their homes, or persons with respiratory ailments may be forced to relocate. The measurement strategy based on this category of effects involves three steps (31, p. 22). First, all possible mutually exclusive categories of adjustments that can occur to minimize the effects of a particular pollutant on a particular object must be identified. Next, all variables which could possibly account for such behavior must also be identified and measured. Then some type of statistical analysis is necessary to separate the effects of air pollution from the other variables which could cause the observed adjustments. Whereas, the first strategy involves an over-statement of costs, this approach involves an understatement because it includes only the costs of adjustments of the affected individual (31, pp. 23-24).

The third category involves the effect on others of the adjustments made to the direct effects. The difference between the second and third category of effects is that one person's adjustment has some effect on another who was not initially directly affected by the pollution. For example, if air pollution forces a crop out of a particular area, this may cause the price of that crop to increase in

that area and some jobs related to that crop will be eliminated while others may be created by the entrance of another crop. Therefore, the third strategy outlined by Ridker attempts to take these interactions into account. Ridker indicates that the proper way to measure effects under this approach is to estimate the change in the consumer plus producer surpluses in each market affected by this change in pollution and then sum over the markets. Ridker goes on to say that the information needed to accomplish this is virtually impossible to obtain. For this reason, he points to the land or real estate market as the one market which probably reflects the majority of these effects. These effects can be measured by observing how property values change in association with changes in the level of air pollution (31, p. 25).

Ridker concludes that the use of property values offers the best hope for success, but it is not without some shortcomings, as the author points out. Among the problems mentioned are: (1) markets do not work perfectly; (2) it is not clear just what is being discounted in property values; and (3) there is a problem of interpreting the numerical results (31, pp. 25-28). However, Ridker points out that the potential advantages of this approach are sufficient to justify its use (31, p. 28). The remainder of the book is devoted to empirical studies involving the three strategies outlined above.

Using the first strategy, measuring direct loss, Ridker attempted to develop price or cost weights for different diseases. Under the second strategy, Ridker presented a series of studies concerned with adjustments to soiling and materials damage. All the studies presented under this strategy reached negative or inconclusive

results. The author does discuss the reasons behind--and possible explanations of--these negative results and makes a constructive proposal in the way of the type of data needed to conduct such a study more successfully.

Studies utilizing the third strategy were presented in two chapters, one using cross-sectional data and the other employing time series data. In the cross-sectional study, Ridker applied regression techniques to a cross-section of observations on single-family dwelling units in St. Louis to determine the effect of variations in air pollution on property values. His major finding was that property value was, indeed, negatively influenced by air pollution. The magnitude of the influence ranged from \$83.00 to \$245.00 for each 0.25 μg of $\text{SO}_3/100 \text{ cm}^2/\text{day}$ (31, p. 136).

In summary, Ridker considered three approaches to measuring economic loss due to air pollution: (1) cost in the absence of adjustments; (2) cost estimates involving individual adjustments; and (3) property value studies. Of the three, Ridker indicated that property value studies should be pursued further (31, p. 157). The first approach could be used if adequate functions could be established. Also, it could provide an accurate method whereby losses could be estimated using laboratory techniques (controlled experiments) since individual or group adjustments are not considered. These three strategies presented by Ridker represent a tremendous step toward being able to adequately assess the economic loss associated with air pollution and his work will serve as a guide for other studies on the economics of air pollution.

A follow-up to the work done by Ridker was the study by Anderson and Crocker (8). This study was specifically concerned with the arguments used by Ridker for the inclusion of certain variables in the model he used and the interpretation of his results. More specifically, Anderson and Crocker disagreed with Ridker and Henning's concept of the role of income in property value determination (8, p. 6). Ridker and Henning asserted that income should be used only as a proxy for omitted property value attributes while Anderson and Crocker maintained that income should be included as an explanatory variable in its own right. They cited many property value studies which support their contention (8, p. 7). In their development of the theory of real estate value determination, they argued that if the model is to be properly specified, then income must be included as an explanatory variable.

After developing the theoretical construct, Anderson and Crocker presented a study involving three cities (8, pp. 11-32). In this study, they used two measures of air pollution--sulfur dioxides and suspended particles. Their general procedure was identical to Ridker's, with the exception pointed out above (i.e., inclusion of income as a variable in its own right). Their purpose was to compare the costs of air pollution in the three cities. The analysis included four types of regressions for each city. Differences between the types of regressions involved owner-occupied versus renter-occupied housing units, and, within the owner-occupied units, one type imposed the condition that single-family residential units made up at least 75% of all housing units. Within the renter-occupied units, median gross rental was used in one

type, while median contract rent was used in another. Their general conclusion supported the work done earlier by Ridker and Henning which found that air pollution does exert a negative influence on residential property values (8, p. 31).

Another study done in the St. Louis area was one by Nourse (27, pp. 181-189). Nourse developed a theory of residential property values based on the premise that the best houses will be occupied by those willing and able to pay the most for a particular house. The ability to pay is judged by the level of income, and the quality of houses is determined by a number of attributes. Therefore, the market solution to the allocation of houses among families can be found by arranging the houses available from worst to best and the families from lowest to highest on the basis of income thus forming what Nourse calls the matrix demand approach. Then it can be assumed that the lowest income family will occupy the "worst" house (27, pp. 183-185). Nourse developed the theory further by adding more realism than is apparent above. For example, he assumed that a higher-income family would be willing to pay more for an increase in quality of a house than a lower-income family. This is saying that the different income groups have different income elasticities for quality. Nourse presented a hypothetical example illustrating how the theory works to allocate houses. He then demonstrated how it could take into consideration the detrimental effects of air pollution on housing values. This approach was consistent with that used by Ridker (31), Ridker and Henning (32), and Anderson and Crocker (8). Nourse also presented a slightly different approach in which a change in air quality occurred and the resulting

impact on property values was observed. The "matrix demand" approach was used here also. This approach was then applied to an empirical example in the St. Louis area. He found two areas with similar socioeconomic characteristics--one with a pollution problem and the other area without a serious problem. The procedure was to construct indices of recorded sales in the two areas, both before and after pollution became a problem in the affected areas. He hypothesized that the price indices for the two areas would be different after the pollution episode but not before. The results of the study generally supported his hypothesis, and a divergence of approximately \$1000.00 per house was found (27, p. 189). Nourse's results support the findings of Ridker whose estimate of loss was \$245.00 for each 0.5 milligram increase in $\text{SO}_3/100 \text{ cm}^2/\text{day}$. However, the two estimates are not comparable because they are calculated under different circumstances.

This chapter has presented a brief summary of the literature on air pollution. It included representative works from both the physical and social scientists. The contributions of the social scientists--and especially the economists--are of most concern to this study.

The last three studies reviewed form the basis for much of the work done in this study. To the author's knowledge, these studies represent the bulk of the work that has been done on estimating economic loss attributable to air pollution. Since the work represented by these studies is pioneering in nature, this dissertation draws on the knowledge gained in these earlier attempts and, hopefully, avoids or minimizes many of the problems encountered in the earlier studies. In addition, the present work utilizes some of the ideas presented in these earlier studies to explore new approaches to

estimating economic losses attributable to air pollution. The following chapters apply the knowledge gained in these early studies to an empirical application.

CHAPTER III

SINGLE-CITY ANALYSIS

I. INTRODUCTION

The previous chapter cited several studies and surveys which indicated that air pollution did, indeed, cause undesirable effects. Some alternative approaches were presented for estimating the magnitude of these undesirable effects in terms of economic loss. Basically three approaches were mentioned: (1) measure the direct loss to individuals and sum over individuals to obtain total economic loss; (2) measure losses incurred when people act to offset the direct losses; and (3) measure losses taking into account social interaction of individuals. The last method was put forth as the most accurate and also the most difficult if it is properly executed. However, the proper execution is virtually impossible because it requires knowledge of supply and demand curves in every market affected by pollution and knowledge of what causes shifts in these curves, so that any unexplained shift can be attributed to air pollution. Faced with this seemingly impossible task, the studies cited above asserted that the real estate market is likely to reflect the majority of the effects of air pollution because of the inability to shift the negative effects of air pollution to other markets to any significant degree. If the real estate market works perfectly, the negative effects of air pollution will be reflected in property values. The magnitude of these effects can then, theoretically, be measured by observing the association between the level of air pollution and property values.

II. THEORETICAL UNDERPINNINGS

This study draws heavily on the theory put forth by Nourse (27) and by Anderson and Crocker (8). Ridker also uses a similar theoretical model, but does not spell it out in detail (31). As mentioned earlier, the presence of air pollution is thought to have a detrimental effect on property values. Obviously, air pollution is not the only influential factor, and there is some reason to suspect that its influence may not be very great (31, p. 119). Property values, then, are determined by several factors or a bundle of attributes, one of which is the level of air pollution. Other factors (attributes) are important and they will be introduced into the model in a later section.

The theory of property values expounded by Nourse is based on the notion that each house will be occupied by a household willing and able to pay the most for that house. According to Nourse, the value of each property can be determined by first arranging the houses of a particular city in an array from worst to best. Judgment as to worst and best is based on the bundle of attributes or factors important in determining the value of property mentioned earlier. For example, a piece of property possessing attributes which make people demand it may be best, while an absence of these attributes would dictate a classification of worst. Some of the more important of these attributes are ". . . access to stores, entertainment, churches, and schools, but primarily, access to a job" (27, p. 183). However, journey-to-work studies have shown that access to job (as measured in actual distance from job) is not as important as the time (27, p. 183). Thus, households tend to locate within a certain driving time of a job, and

then, within this area, house values are influenced by other factors. Therefore, given that the available housing facilities in any city are relatively fixed at any time, the economic problem of who occupies which house is solved by the person willing and able to pay the most for a particular house. The decision each individual household makes regarding how much they are willing to pay for a particular piece of property depends on the attributes which the property possesses along with the income of the household. Some of the attributes which may make a piece of property more desirable are absence of air pollution, economic and social characteristics of one's neighbors, and neighbor's family size and age (27, p. 183). This suggests that a person desires to locate in a neighborhood composed of people with characteristics similar to his own. This is taken to be the rationale for using neighborhoods (census tracts) as the unit of observation. In addition to the factors mentioned above, house size also influences property value.

Another, but quite similar, theory is set forth by Anderson and Crocker (8). They approach the theory of residential real estate value as analogous to the liquidity preference theory of interest rates. Again, the worth of a piece of property is said to be dependent on the bundle of attributes possessed by that property. The theory says that at a given point in time a certain stock of residential properties exists and a price for this stock will tend to be established such that the entire stock is held by someone (8, p. 7). More realistically, a price structure is established because of the different kinds of properties available, and differences in tastes and purchasing power of consumers.

The demand side of the model follows closely the theory of consumer behavior expounded by Lancaster (21). Lancaster's theory involves three new assumptions which make it especially suited to a theory of property values. These assumptions are:

- (1) that utility derives from characteristics embodied in goods rather than from goods per se; (2) that, in general, goods possess more than one characteristic, and particular characteristics are embodied in more than one good; (3) that goods consumed in combination with other goods generally embody characteristics different from those embodied in goods consumed by themselves (8, p. 8).

These assumptions state that individuals consume and derive utility from goods because of the characteristics embodied in goods. For example a person eats an apple because he likes the smell, taste, texture, or other characteristic embodied in the apple, not just because he likes apples. Also the apple, or any other good contains several characteristics and these characteristics may be present in other goods. In addition, an apple consumed with cheese possesses different characteristics than apples consumed alone. These assumptions are not radically different from those of traditional theory, but are an extension of the traditional assumptions. Traditional theory states that ". . . a consumer gets utility or satisfaction from the consumption of commodities" (22, p. 49). Lancaster states that utility is derived not from the commodities alone, but rather from the characteristics embodied in them. At the heart of the theory is what Lancaster calls consumption technology which is made up of the relationships between activities and goods and activities and characteristics. These relationships are presumed to be objective. An activity is goods consumed in combination. If the transformation between activities and

characteristics and activities and goods is linear, the problem of the consumer is similar to the traditional utility maximization problem. Using the first-order conditions for consumer equilibrium, Anderson and Crocker show that ". . . consumption technology is instrumental in the determination of marginal rates of substitution among commodities and, hence, is instrumental in determining demands" (8, p. 10). They further show that since complete aggregation does not occur in their study of property values, household income must be included in the model. When there is not complete aggregation over the market, the observations are ". . . many submarket equilibrium, with each observation expressing, in part, an equilibrium relation between an individual's or a group's income and the price" (8, p. 11). Therefore, since income is variable, parameter estimates must be obtained by regressing the price of the property on income of the household and other attributes of the property. It should be pointed out that this theory and that presented earlier by Nourse are entirely consistent provided it is assumed that each household occupies the most expensive property it is willing and able to buy (8, p. 11).

These theories are based on the fundamental hypothesis that the majority of the detrimental effects of air pollution to people and objects associated with residences are negatively capitalized into property value. Anderson and Crocker point out that there is considerable confusion regarding the role air pollution plays in determining property values (8, p. 3). Critics of this approach argue that buyers of properties need to know that the level of pollution varies between sites, when, in fact, buyers rarely think about the level of

pollution unless there is an obvious irritant present (8, p. 3). In rebuttal, Anderson and Crocker state that

. . . for pollution to result in differential property values, buyers need only know that they prefer some properties to others, and, other things being equal, are willing to pay more for the preferred properties. It is hypothesized that one of the factors which causes some properties to be preferred to others is relative absence of the effects of air pollution. . . . The notion of cause and effect, thus rests wholly in the mind of the theorist, and not necessarily in the mind of the property buyer (8, p. 3).

Based on the theories, the impact of air pollution on property values can be seen by regressing the value of a piece of property on various characteristics of that property, the socioeconomic characteristics of the household—including level of income, and some measure of pollution (pollution could be included in property attributes). Coefficients obtained for the variable measuring pollution would then indicate the impact of air pollution on property values. This chapter and Chapter IV apply the theoretical constructs presented above to two empirical examples. The first application involves a cross-sectional study of an individual city. This is followed by an analysis involving 60 cities throughout the United States in Chapter IV.

From a theoretical point of view the presence of air pollution affects a wide variety of objects. The present study utilizes the negative effects of air pollution on property value to estimate economic loss due to air pollution. Theoretically, changes in the level of air pollution also cause changes in consumer expenditures. The hypothesis of this theoretical construct is that as the level of air pollution increases, consumers will increase expenditures for certain items to offset the negative effects of air pollution, such as painting more frequently, taking out-of-town vacations, etc. In the course of this

study an attempt was made to estimate economic loss utilizing consumer expenditure data. Several categories of consumer expenditures were employed as dependent variables in a regression model with socioeconomic characteristics and air pollution levels as independent variables. However, the lack of sufficient secondary data for the various categories of expenditures caused this investigation to be terminated.

III. MODEL AND VARIABLES USED

The basic type of model and variables to be included were presented in the preceding section. Basically, the model employed attempts to determine the impact of air pollution on property values by including explanatory variables which account for the bundle of attributes each property possesses in addition to air pollution variables. Subsequent paragraphs describe each variable and the rationale used for its inclusion in the model.

The model as specified for the single city analysis is:

$$X_1 = b_0 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8$$

where:

X_1 = median property values (MPV)

b_0 = constant

X_2 = median number of rooms (MNR)

X_3 = percent nonwhite (PNW)

X_4 = percent dilapidated buildings (PDB)

X_5 = median family income (MFI)

X_6 = 1 if suspended particulate matter (SPM) is below 100 $\mu\text{g}/\text{m}^3$ *;
0 otherwise

* $\mu\text{g}/\text{m}^3$ = micrograms per cubic meter.

$X_7 = 1$ if $101 \leq \text{SPM} \leq 130 \text{ } \mu\text{g}/\text{m}^3$; 0 otherwise

$X_8 = 1$ if $\text{SPM} \geq 131 \text{ } \mu\text{g}/\text{m}^3$; 0 otherwise.

Reasons behind the use of MPV as the dependent variable have been alluded to earlier. This variable is the value of owner-occupied single-family housing units, estimated by owners, as of April 1, 1960. The unit of observation is the census tract which cordons off statistically areas of roughly 4,000 residents who have similar socioeconomic characteristics (11, p. 1). Because of this uniformity within census tracts, measures of central tendency for individual tracts presumably accurately characterize all units in that tract. Ridker points out at least three reasons why observations on census tracts may be more desirable than observations on individual houses within each tract.

Errors in estimating the value of individual houses tend to wash out; few explanatory variables, particularly those related to the idiosyncrasies of individual houses and their owners, need be considered; and the air pollution data available are more accurate when applied to neighborhoods than when applied to individual houses within a neighborhood (31, p. 117).

Since the owners originally estimated the value of each piece of property, there is the possibility of response errors. However, Ridker cites a study which found that--on the average--owners' and appraisers' estimates for a group of homes were very close (31, p. 117). For this study, tracts in which single family housing units did not make up over 50 percent of total housing units were deleted from the analysis. This process does at least two things; first, it eliminates predominantly industrial tracts which may be highly correlated with pollution levels, and, secondly, it eliminates tracts with a large portion of multi-family dwelling units which are assumed to have a different value base than single family residences.

The first explanatory variable listed in the model is median number of rooms (MNR) which is employed as a measure of space within a house (or size) and the amount of privacy which a structure affords. As the number of rooms increases, it is assumed that privacy will increase with the increased space. Therefore, it is expected that the sign assumed by the coefficient of this variable will be positive.

To assess the impact of nonwhites on property values, this study employs the explanatory variable percent nonwhites (PNW). Various property value studies suggest that this variable does have an impact on property values, but the direction of this impact varies from place to place, depending on the market situation of nonwhite housing and the trend in percent nonwhites (29). Therefore, this study makes no a priori judgment as to the relationship between PNW and median property value. In defense of the expectation of a positive relationship, Anderson and Crocker state:

. . . if pricing is discriminatory as commonly alleged, with nonwhites paying higher prices for properties than would whites for the same properties, PNW exerts a positive influence since, as the proportion of people in a tract paying a relatively high price for property increases, so also does the median property value for the tract . . . if nonwhites attach a premium to living apart from whites, whereas whites are indifferent or discount willingness to pay because of the presence of nonwhites less than nonwhites augment willingness to pay, PNW and MPV again tend to be positively related (8, p. 17).

For these reasons, it seems best not to make any judgment regarding the specific relationship between the two variables PNW and MPV.

Another neighborhood characteristic which is thought to influence property values is the physical appearance of a neighborhood. This study makes use of a proxy variable to capture the influence of the

appearance of a neighborhood. This proxy variable is the percent of each tract's living units classified as dilapidated (PDB). In addition, PDB presents a composite characteristic of the housing units available in a particular tract. It is true that the dilapidated condition of a census tract or neighborhood can be corrected, but the cost is likely to be high. Anderson and Crocker point out that--except for some small improvements--if several members of the neighborhood do not make improvements, the improvements made by a few are at least partially negated (8, p. 15). Obviously, as the percentage of dilapidated buildings increased, one would expect property values to decline. Therefore, it is expected that the coefficient of this variable would assume a negative sign. There may be one exception to this general rule. If a tract is largely dilapidated and is being considered as a site for some development project of industrial use, and if owners of the property are aware of the pending change in use, their estimate of property value may reflect the property's intended use rather than its current use.

Median family income (MFI) is also included as an explanatory variable. There is some disagreement as to the rationale for including it in the model. Should it be entered as a proxy for housing and neighborhood characteristics not otherwise accounted for, or as a legitimate explanatory variable? This study chooses the latter primarily on the work done by Anderson and Crocker (8). They point out that income has been used in many noteworthy cross-section studies (8, pp. 6-7). Ridker and Henning argue that at a given point in time, with no market discrimination, all houses are available to all persons. The demand for these houses is determined by such things as aggregate

income, family size, and income distribution for a particular market, which are constant in cross-sectional data. Therefore, they argue that differences in property values must be explained in terms of differences in property characteristics rather than differences in household characteristics. On the other hand, Anderson and Crocker argue that each observation in the cross-section sample is not one market equilibrium, but rather several sub-market equilibria (8, p. 7). They go on to point out that while income is constant in the market, it is variable within the sample and, therefore, each observation expresses, in part, results of an equilibrium relationship between property value and income (8, p. 7). For this reason, Anderson and Crocker argue that income must be included if the model is to be correctly specified (8, p. 11). This argument is consistent with the theory proposed by Nourse. Recall that Nourse's theory was based on the premise that a house of a given quality will be occupied by the household willing and able to pay the most for that house. Ability to pay is directly connected to the income level of the household. In light of available evidence, it seems more appropriate to include MFI in the model as an explanatory variable in its own right rather than a proxy for property attributes not otherwise accounted for.

To assess the impact of air pollution on property values, some measure of air pollution had to be chosen. This study chose suspended particulate matter, both as a matter of convenience and because no commonly acceptable measure of air pollution is available. Also, the Chairman of the Knoxville Air Pollution Control Board advised the author that the measurement of this particular class of pollutants was

more accurate than measures of other classes of pollutants and that the level of particulate matter probably accurately reflected the general air pollution situation for Knoxville (19). It was pointed out in Chapter I that particulate matter does have detrimental effects on a wide range of objects. These effects are more fully explained in a publication by the National Air Pollution Control Administration (5). For these reasons, the measure of suspended particulates was chosen as the measure of air pollution in Knoxville. Data for this and other variables are discussed in the following section.

IV. THE DATA

Data for all variables, with the exception of the air pollution variable were obtained from U.S. Census of Population and Housing: 1960, Final Report, PHC(1)-71 (11). The unit of observation is the individual census tract within the City of Knoxville. In the 1960 census, Knoxville had only 30 census tracts. In the final stage of analysis, four of these tracts had to be deleted because they did not conform to certain requirements deemed essential to the validity of the results. It was expected that such a small sample size would create problems of analysis. Data on the air pollution variable were obtained from the Knoxville Air Pollution Control Board Office. Only six recording stations were used to obtain the air pollution data and the procedure used to assign air pollution figures to individual census tracts is not as precise as might be desired.

The procedure of assigning air pollution levels to the various census tracts consisted of first obtaining the annual mean level of

suspended particulates at the six stations. Next, the six levels of pollution were arrayed from the lowest to the highest and divided into three groups or zones of concentration. The data ranged from $86 \mu\text{g}/\text{m}^3$ to $141 \mu\text{g}/\text{m}^3$ for suspended particulates, and the three groups were (1) $100 \mu\text{g}/\text{m}^3$ and below; (2) $101\text{--}130 \mu\text{g}/\text{m}^3$; and (3) $131 \mu\text{g}/\text{m}^3$ and over. These data do not encompass the entire range over which suspended particulates have been shown to cause damage. Suspended particulates have been shown to cause damage at levels ranging from $60 \mu\text{g}/\text{m}^3$ to over $750 \mu\text{g}/\text{m}^3$ (5, pp. 188-189). The present study may have benefited if the air pollution data covered a wide range of concentration. The main benefit would probably be to dramatize the effect of air pollution on property values. To assign the air pollution data to the individual tracts, a procedure similar to one used by Ridker was used (31). The procedure is also set out in a thesis by Purvis (28). This involved drawing isolines on the basis of the pollution measurements taken at the various stations, thus forming zones of concentration. Then census tracts were assigned to the zone in which they were located or the zone in which the majority of the tract was located. It is recognized that this procedure is a rough approximation, but, in light of available alternatives, it is the only one which is feasible.

Another property of the data which is undesirable--and at the same time unavoidable--is the time discrepancy in measurement of the observations. It was noted that the data on housing characteristics were as of April 1, 1960, while the data on pollution were gathered during 1968. Obviously, this introduces a measurement error into the analysis, the seriousness of which is unknown. Other studies of

this nature have encountered the same problem, and at least one has gone to some lengths to demonstrate that the introduction of such an error causes the negative influence of pollution to be understated (8). This study proceeds on the assumption that the argument presented by Anderson and Crocker is valid and estimates of the negative impact of air pollution obtained in this study will tend to be understated. It is recognized that the problems inherent in the data, as well as the limited number of observations, may cause problems in the final analysis. However, this study was undertaken not only to obtain an estimate of economic loss attributable to air pollution, but also to discover problems inherent in making such estimates and to make suggestions concerning the solution of these problems.

At one point in the study an attempt was made to determine the zoning ordinances in effect in the various tracts because it was thought that the zoning classification of property influenced its value. This proved unsatisfactory because most of the tracts contained a mixture of classifications with the residential classification generally predominating. In addition it seemed possible that the classification in effect on neighboring property would also exert an influence and there was no clear way to incorporate this into the model. This does not indicate that zoning classifications do not have an influence on property values, but only that appropriate data to assess the extent of influence could not be obtained for this study.

V. THE RESULTS

A stepwise regression program was utilized to analyze the data. Several runs were made on the computer using alternative specifications

of the model. However, the alternative specifications proved less satisfactory than the one presented earlier and were dropped from the analysis. In addition, several functional forms were fitted. In all cases, the linear (in both variables and parameters) form gave better results, as judged by size of standard error, amount of variation in property values explained, F ratio, and significant variables. Two runs were made using the model as specified in the linear form of estimating equations. The first run was using all census tracts, and the following estimating equation resulted (standard errors shown in parentheses):

$$(1) \quad X_1 = 1137.7 - 1279.8X_2 + 28.2X_3 + 5.7X_4 + 2.6X_5 - 1098.5X_6 - 59.9X_7$$

$$(323.9) \quad (9.07) \quad (3.06) \quad (0.15) \quad (542.9) \quad (480.5)$$

$$S_y = 914.9$$

$$R^2 = 0.947$$

where

X_1 = median property value (MPV)

X_2 = median number of rooms (MNR)

X_3 = percent nonwhite (PNW)

X_4 = percent dilapidated buildings (PDB)

X_5 = median family income (MFI)

X_6 = 1 if suspended particulate matter (SPM) $\leq 100 \mu\text{g}/\text{m}^3$;
0 otherwise

X_7 = 1 if $101 \mu\text{g}/\text{m}^3 \leq \text{SPM} \leq 130 \mu\text{g}/\text{m}^3$; 0 otherwise

X_8 = 1 if $\text{SMP} \geq 131 \mu\text{g}/\text{m}^3$; 0 otherwise.

Since the dummy variable technique is used to incorporate the air pollution variable into the model, equation (1) is the estimating equation obtained when using the highest zone as the base or point from which the other dummy variables are measured. It will be noted that X_7 , which is the

dummy for the intermediate range of pollution, was not significantly different from X_8 , the dummy for the higher range of air pollution. Therefore, X_7 and X_8 can be considered as approximately the same, with little effect on the explanatory power of the equation, as illustrated by equation (2).

$$(2) \quad X_1 = 1123 - 1287.3X_2 + 28.1X_3 + 5.8X_4 + 2.6X_5 - 1050.7X_6$$

$$(311.8) \quad (8.84) \quad (2.9) \quad (0.15) \quad (376.9)$$

$$S_y = 895.9$$

$$R^2 = 0.947$$

This equation is very similar to equation (1) except in this equation the two upper ranges of pollution are treated as equal so the estimating equation for these two zones would be equation (2) with $X_6 = 0$. It should be pointed out here that equation (2) has an R^2 almost equal to equation (1) and a lower standard error of the estimate. These measurements give some idea as to the explanatory power and goodness of fit of the equation. Based on these, equation (2) is superior to equation (1).

In addition to these runs, another run was made in which some of the observations included in equations (1) and (2) were deleted. It was expected at the beginning of the analysis that the impact of air pollution would be small, relative to the other variables. With this in mind, tracts containing less than 50% single-family housing units were deleted. This was done to remove the tracts not used primarily for residential purposes. By deleting tracts with less than 50% of single-family housing units, four observations were lost. The results obtained are shown in equation (3):

$$(3) \quad X_1 = 2619.3 - 1710.1X_2 + 31.2X_3 + 4.0X_4 + 2.7X_5 - 1085.3X_6$$

$$(542.7) \quad (10.1) \quad (3.5) \quad (0.199) \quad (393.6)$$

$$S_y = 927.4$$

$$R^2 = 0.950$$

Again, X_7 and X_8 were not significantly different, so the estimating equation for these two zones would be the same.

VI. INTERPRETING THE RESULTS

Equations (1) and (3) show the end result of the runs made on the computer. To facilitate comparison, these three equations are shown in Table 7. Information in this table indicates that all three equations are significant, as judged by the F ratio. The F ratio indicates the significance of the model and deals with the entire relationship. It indicates that at least one of the independent variables is important in explaining the variation in the dependent variable and is computed by dividing the regression mean square by the residual mean square. If the computed F ratio is greater than that shown in an F table, then the relationship is significant and the R^2 is also significant. For the three equations in Table 7 the critical values at the 1% level are: 3.71 for equation (1), 3.90 for (2) and 4.10 for (3). These statistics may be interpreted as saying that a value larger than the table value could occur by chance only once in every 100 times. Therefore, the relationships depicted by the three equations in Table 7 have a low probability of occurring by pure chance.

The first independent variable (MNR) has assumed a negative sign. This is contrary to what was expected, as explained earlier. Since this variable was originally entered as a proxy for house size

Table 7. Summary of Coefficients in Knoxville Analysis^a

Variables	Equation (1)	Equation (2)	Equation (3)
Dependent (X_1)			
Constant	1137.7	1123.0	2619.3
MNR (X_2)	-1279.8 (323.9)**	-1287.3 (311.8)**	-1710.1 (542.7)**
PNW (X_3)	28.2 (9.07)**	28.1 (8.84)**	31.2 (10.1)**
PDB (X_4)	5.7 (3.06)**	5.8 (2.9)*	4.0 (3.5)
MFI (X_5)	2.6 (0.15)**	2.6 (0.15)**	2.7 (0.19)**
SPM ₁ (X_6)	-1098.5 (542.9)**	-1050.7 (376.9)**	-1085.3 (393.6)**
SPM ₂ (X_7)	-59.9 (480.5)		
R^2	0.947	0.947	0.950
S_y	914.9	895.9	927.4
F ratio	69.29	86.71	76.4
N	30	30	26

^aStandard error shown in parentheses.

*Coefficient significant at 10% level.

**Coefficient significant at 1% level.

and the amount of privacy afforded by a particular house, it should reflect the expectation that property values increase as house size and privacy increase. Census data contained no other information which could be used to determine house size. Perhaps the result obtained can be explained by the confounding caused by the census practice of taking a median over both owner-occupied and renter-occupied units. It was mentioned earlier that those tracts in which single-family housing units made up less than 50% of total housing units were dropped from the analysis. The 50% cut-off figure was arbitrarily chosen, based on some previous work and the author's judgment. Equation (3) shows the results obtained when the 50% cut-off was used. This resulted in a loss of four observations and the results are essentially unchanged from equations (1) or (2) when all tracts are included. In all equations, the coefficient is negative and significant, with equation (3) having the largest coefficient. Apparently the deletion of the four observations had little effect on the results of the analysis. If the cut-off point were changed so as to require each tract included to be made up of a larger portion of single-family dwelling units, degrees of freedom would quickly become an acute problem. The reason being that there are several tracts composed of approximately 60% single-family units, and if these were dropped, too many degrees of freedom would be lost.

Earlier, it was pointed out that the coefficient of the PNW variable might assume either sign. In this study, PNW has assumed a positive sign. It is positive in all three equations, and is of about the same magnitude. These results somewhat support the work done by Anderson and Crocker (8), and indicate that as the percentage of nonwhites

in a census tract increases, so does the property value. This result could be due to the fact that if pricing was discriminatory, with nonwhites paying a higher price than whites, then--as the portion of the persons paying a higher price increases in a tract--so does the property value. Also, this result could be accounted for by the willingness of nonwhites to pay a premium to live apart from whites sufficient to offset any discount in willingness to pay by whites because of the presence of nonwhites. These results do not prove that discrimination did occur in the Knoxville housing market, and this study draws no such conclusion because such evidence is too oblique to support such a conclusion. It merely supports one of the many theories on how housing values behave in racially mixed neighborhoods. For a summary of these theories, see Chapter 6 of a book entitled The Demand for Housing in Racially Mixed Areas, by Rapkin and Grigsby (29).

The variable, PDB, representing the physical characteristics of a neighborhood was significant at the 5% level of significance in equation (1) and equation (2). Whereas in equation (3), which is the equation upon which the conclusions of this study will be based, the coefficient of PDB is not statistically different from zero at the 5% level. In the discussion of the model, it was theorized that as the percentage of dilapidated buildings in a tract increased, the property value would decrease. With only property value and PDB considered, this relationship holds. The simple r or correlation between MPV and PDB as shown in Table 9 of the Appendix is -0.3 , while the simple b is -18.69 , which indicates that as PDB increases by one percentage point, property values decrease by \$18.69. However, when the interaction

of other explanatory variables is considered, PDB exerts a positive influence on MPV. While the positive sign in equation (3) is not significant at the 5% level, such a sign could occur if owners valued their property for its intended use and not its present use. For instance, if a particular tract which had a high percentage of dilapidated buildings was being considered for an industrial site, owners might indicate the value of their property as if it were being sold for industrial use. The appearance of such signs in this analysis points to the need for additional studies on what is being discounted in property values.

Median family income (MFI) accounted for a large share of the variations in property values. The simple r between MPV and MFI was 0.9274, or an R^2 of 0.8601, which means that income accounted for 86% of the variation in property values. Results shown in Table 7, page 64, indicate that for every one dollar increase in income, property values increased 2.7 dollars. It was hypothesized that persons having higher incomes would be occupying the more expensive properties. The results indicate that this is the case in Knoxville. There was no hypothesis about the size of this variable's coefficient other than that it would be positive. Property characteristics have not generally been used as arguments in the demand function for housing. Anderson and Crocker argue that property characteristics, as well as housing characteristics, properly appear in a housing demand function. On this basis, they compare the income elasticity estimates obtained from their results to elasticity estimates obtained by others. The results obtained by Anderson and Crocker allegedly support their contention that income

elasticities can--and should--be inferred from a cross-sectional model such as they employed (8, pp. 26-27).

Results of this study, while consistent with other studies on estimates of income elasticities, indicate that caution should be exercised in inferring elasticities from models as used in this study. The "income elasticity" estimate, with respect to property values obtained in this study, was approximately 1.7. This is similar to the results obtained by Margaret G. Reid (30). In the study by Reid, elasticity of housing with respect to income ranged from 1.5 to 2.0 (30, p. 351). Specifically, the estimate for Knoxville ranged from 1.73 to 1.86 (30, p. 355). A problem arises in interpreting these results because they were based on data at the census tract level. While the sample was restricted to tracts with a fairly high percentage of owner-occupied units (65% in the Reid study and 50% in this study), there was still some variation in the relative percentages of owner versus renter-occupied units. The income measure was taken over all families, regardless of tenure. Therefore, in no case was it a precise income measure. This being the case, there may be a tendency for the estimated income elasticities to be inaccurate. Or--as Anderson and Crocker suggest--given that renter income is less than owner income, estimates of elasticities for owners tend to be understated; while, for renter occupied, the opposite is true (8, p. 27). Therefore, some caution is urged in interpreting income elasticities from this study.

The main purpose for inclusion of the income variable was its ability to account for variation in property values, and not for the estimation of income elasticity of the demand for housing. It was mentioned

above because of the similarity of the estimate obtained in this study and the estimates obtained elsewhere. In addition to the sidelight, the income variable (MFI) proved to be very significant in the model, as shown in equation (3) of Table 7, p. 64. This table indicates that MFI has a very low standard error (0.19) with a coefficient of 2.7; therefore, the variable is significant at the 1% level.

The remaining explanatory variables reflect the impact of air pollution on property values. Initially, the air pollution data were divided into three zones of concentration and these zones were superimposed on the census tracts so that each tract could be assigned a zone of concentration. The tracts were then entered into the model on the basis of which zone they represented through the use of 0,1 dummy variables on each zone as outlined above. All equations in Table 7 show that there was no significant difference between the medium zone (represented by SPM_2 or X_7) and the higher zone (SPM_3 or X_8). This being the case, the estimating equation for these two zones would be the same. For example, using equation (3), this equation would be

$$MPV_{2,3} = 2619.3 - 1710.1X_2 + 31.2X_3 + 4.0X_4 + 2.7X_5$$

This equation is taken as the base from which the equations for other zones are calculated. X_6 does not appear in the equation because if the equation is for the higher zones, $X_6 = 0$ and, therefore, it is dropped. The estimating equation for the lowest zone is as shown in Table 7, equation (3).

The sign of this dummy variable is of particular importance, and is in fact, the focal point of the study. It was noted above that equation (3), Table 7, without X_6 was the estimating equation for

tracts located in zones containing the higher concentration of air pollution. With X_6 included, the equation was an estimate for the lower zones. It would be expected, therefore, that the coefficient for X_6 would be positive (i.e., as the level of air pollution decreases from a higher zone to a lower zone, the property value increases). Instead, the results indicate just the opposite. Specifically, they indicate that as the level of air pollution decreases from higher zones of concentration to the lower zones, the line estimating property values is shifted down by \$1,085.30. This is illustrated in Figure 1 depicting a hypothetical demand curve for houses (Q_h). The line, D_1 , represents the estimating equation for the lower zone. The two lines, D_1 and D_2 , are separated by the amount of the coefficient of X_6 (\$1,085.30). In effect, this indicates that houses (property) located in the zones of lower pollution levels also have lower value. In other words, all the dummy variable does is shift the intercept value for the various levels of pollution, and it was expected that this intercept value would have been higher for the lower levels of pollution. It will be noted that the slopes of D_1 and D_2 in Figure 1 are identical. This indicates that only the intercept value is changed.

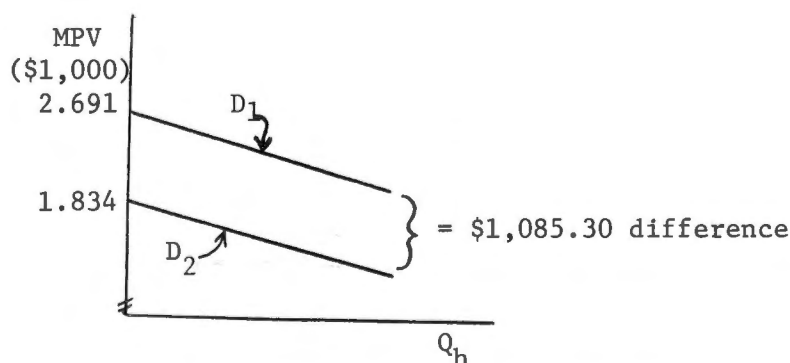


Figure 1. Hypothetical Demand Curve for Housing

These results, which may be considered negative since they do not conform to expectations, should be interpreted with care. Recall that it was pointed out earlier that the influence of air pollution, while expected to be negative, was also expected to be very small. This being the case, it is possible that the measurement error introduced by the time discrepancy in observations--together with the small sample size--has acted so as to indicate a relationship opposite to that expected. At the outset of the study, it was realized that the number of observations was limited and, therefore, the model was constructed so as to obtain maximum explanatory power with as few variables as possible. At the same time it was also realized that to obtain meaningful results, variables with explanatory power at least equal to the variable of prime consideration must also be included. Upon these considerations the model as specified earlier was constructed. Since the model seems to be correctly specified, it is felt that the results accurately reflect the contents of the data rather than shortcomings inherent in the model. This statement is based on the experience gained in using alternative specifications of the model and work done elsewhere (8 and 31). Some of the alternative specifications will be given in a later portion of this chapter, but none shed any additional light on the analysis.

Using the model as specified earlier, a run was made using what may be called 1, 2, 3 dummy variables to incorporate the measure of air pollution into the model. While this formulation imposes a further constraint on the model, it was deemed worthwhile to explore. The additional constraint is that the intercept values for the various levels of air pollution are forced to be equidistant apart. The results

of this are shown in the following equation (standard errors are shown in parentheses).

$$\text{MPV} = -722 - 1267.9X_2 + 29.7X_3 + 5.5X_4 + 2.7X_5 + 449.2X_6 \quad R^2 = 0.942$$

$$(331.3) \quad (9.3) \quad (3.1) \quad (0.16) \quad (204.1) \quad S_y = 940.35$$

All variables here are defined as above with X_6 as the only variable measuring air pollution. Comparing these results with those shown in Table 7, page 64, it can be seen that there is very little difference. Both the size and signs of the coefficients, with the exception of the constant term, are similar. The R^2 here is slightly lower and the standard error of the estimate is slightly larger than those shown for equation (3), Table 7. This is not unexpected since an additional constraint has been placed on the model. Focusing on the pollution variable, X_6 , it is noted that its coefficient is positive. This positive coefficient indicates that as the pollution level rises from one zone to another, so does property value. In this case the pollution variable assumes a value from 1 to 3, depending on the zone of concentration, with the higher number corresponding to the zone of higher concentration. These results indicate that as pollution increases from one zone to another property values increase \$449.20 per zone. With 24 degrees of freedom, the critical value for t is 2.06 at the 5% level. Hence for the coefficient of the pollution variable the 5% confidence interval is $18.75 \leq b_6 \leq 869.65$. There is a 5% chance that b_6 falls outside the range of the values indicated. The sample mean for X_6 was 2.5 with a standard deviation of 1.07.

These results are similar to those presented earlier except the size of the shift is smaller in this case.

The correlation matrix obtained under this formulation contains some interesting information. For instance the simple r between pollution and property values is -0.25 which indicates that when only these two variables are considered, they are negatively related. In fact the simple b between these two variables is $-\$80.75$ which indicates that as the level of pollution moves from one zone to a higher zone the property values decline. As pointed out earlier this simple estimate is small, and when the impact of other variables is considered this impact becomes smaller and finally emerges as positive in the final analysis.

The above results suggest that perhaps the problem, if one exists, lies in the data and that a similar analysis on more adequate data would yield results more in line with theoretical expectations. There are perhaps some plausible explanations why such results could occur. One such explanation is that the implicit assumptions of the model did not apply for the particular time the data were taken. However, in view of the alternative specifications of the model, this does not appear to be a very probable explanation. Another plausible explanation is that it is just a property of the data. In either case it appears reasonable to assume that more emphasis needs to be placed on gathering data specifically for studying air pollution problems.

In particular, more data on the level of various air pollutants are needed. While it may be true that most of the deleterious effects of air pollution are reflected in the real estate market, it is not so evident that all these effects are caused by one pollutant. To fully grasp the impact of air pollution, data on all pollutants are needed if models like the one employed here are to produce meaningful results.

On the other hand, available data do not lend themselves readily to any other type of analysis. The problems which arise in models such as the one used here are the result of--or the symptom of--the intercorrelation between the various measures of pollution. This intercorrelation could account for the apparent "wrong" signs assumed by the air pollution coefficients in this analysis. This possibility is pointed out by Fox in Intermediate Economic Statistics (14, pp. 256-263) and by Anderson and Crocker (8, p. 21). For this reason Anderson and Crocker suggest that major emphasis should not be placed on estimates based on a single measure of air pollution. However, this is in contrast with the approach used by Ridker (31). In the study by Ridker, only the sulfation rate was used as a measure of pollution. Since Ridker used only one measure of pollution and obtained results consistent with his expectations, it is not clear if alternative measures of air pollution are necessary to obtain valid estimates. Results of the present study, based on a single measure of air pollution, support the assertion by Anderson and Crocker that alternative measures of pollution should be employed.

In an attempt to determine if the specifications of the model were in error, alternative specifications were tried. The model, as set out above, was constructed on the basis of work done in other studies (8 and 31). Because the results were contrary to those expected, additional runs on the computer were made employing a variety of other explanatory variables. This variety was somewhat limited by the available data.

The alternative specifications included the addition of such variables as highway accessibility, the number of persons per unit,

the percent of units recently built, and school years completed by residents of each census tract. In addition, the air pollution data were divided into five categories instead of three. However, none of these variables contributed significantly to the explanatory power of the model. Also, in an attempt to determine if land use or zoning regulations could have influenced the owner's estimate of property values, zoning regulations then in effect were imposed on a map of the census tracts and each tract was assigned an overall zone classification--either residential, commercial, or industrial. This proved unsatisfactory, because it was impossible to accurately incorporate into the model the various zones. For example, any one tract might have all three classifications equally distributed over the land area, or it might have any mixture of any combination of the three. There was no clear way to assign each tract to a zone, since the zoning boundaries did not follow census tract boundaries. In addition, a further complication arose because any one census tract's zone classification not only could have affected property values in that tract, but it could have also affected neighboring tracts. In view of the difficulties involved and some doubts about its final worth, this attempt was abandoned.

In summary, the analysis conducted in this chapter has produced results contrary to those expected from theory. These results, while not like those hypothesized, are useful. They do point to the importance of income as a determinant of property value. While estimates of income elasticities of demand for housing based on this analysis must be interpreted with great care, they do point up the importance of the income variable. The fact that the income variable explained so much

of the variation in property value may have caused some difficulties with the other explanatory variables entering the equation. Another interesting result was produced by the variable depicting the percent nonwhite in each census tract (PNW). These results indicate that as the percent of nonwhites increases, so does the property value. This apparently supports the results obtained in other studies which found nonwhites paid more for their property as the percent of nonwhites increased (8). Such results hint at discrimination in the housing market for nonwhites. However, this study refrains from implying discrimination in the housing market solely on the basis of the sign of the PNW variable in this model.

The results, as far as the air pollution variable was concerned, were not as theorized. As pointed out, the relationship between air pollution and property value may only be in the mind of the theorist and not necessarily in the minds of those buying property. For the theorized relationship to hold, it is not necessary for buyers to be aware of air pollution, but they must act as if they were. That is, buyers must pay less for property located in a more polluted location, if pollution is the only difference between it and alternative properties. The results of this analysis could indicate that people acted as if they were not aware of the detrimental effects of air pollution. However, it is the contention of the author that severe data restrictions have seriously limited the analysis. In particular, it is felt that the inability to employ a better measure of air pollution caused serious problems in the model. It is possible that these problems led to the results being in contrast to the results hypothesized.

CHAPTER IV

MULTIPLE-CITY ANALYSIS

I. INTRODUCTION

The previous chapter employed regression techniques to assess the impact of air pollution on property values in a single city. This chapter employs similar techniques in an attempt to arrive at an estimate of loss on a national basis. A cross-section of sixty cities was used as the basis for this analysis. Since such an analysis has not been previously attempted, it represents a different approach to the problem of determining the cost of air pollution. Even though this approach may be considered new, it is very similar to that presented in Chapter III. The theory used in constructing the model for this analysis is almost identical to that employed earlier. Therefore, the underlying theoretical framework will be only briefly reviewed in the following section.

II. THEORETICAL UNDERPINNINGS

As previously pointed out, the theory used as the basis for the model employed here is only slightly modified from that described in Chapter III. Briefly, the basic idea of the theory presented earlier was that the effects of air pollution were negatively capitalized into the value of property or the land and the real property thereon. The land market was chosen as the market to best observe the deleterious effects of air pollution because land is location specific and it cannot

be moved to avoid any of the undesirable consequences of local air pollution. Therefore, in the land market the negative effects of air pollution are less likely to be shifted to other markets. Theoretically then, the negative effects can be measured by observing changes in property values associated with changes in levels of air pollution. This is taken to be the underlying rationale for the analysis carried out in this chapter.

There are, of course, additional problems involved in this type of analysis not found in the single-city analysis. These problems stem from the added difficulty of explaining variations in property values between cities. Generally the problems arise because of differences in measuring the air pollution levels and the effect of varying the mix of air pollution and meteorological conditions from city to city. In addition, there are other considerations which influence property values not evident in the intracity analysis. However, it is hoped that the model--as specified below--takes account of significant variables important in the determination of property values between cities. Therefore, from a theoretical viewpoint both the intercity and intracity analyses are identical, with slightly different variables used to explain the variation in property values. From a theoretical point of view, income is still thought to have a significant impact on property values. Also, the size and type of housing units available and the level of air pollution are both thought to exert an influence on property values. Based on these considerations, the following section explains the specification of the model used for this analysis.

III. THE MODEL AND VARIABLES USED

As mentioned earlier the model employed in this analysis is very similar to the one used in the single-city analysis. There are, of course, slightly different variables used which hopefully minimize some of the problems mentioned in the previous section. On the basis of the theory presented earlier, the following model was constructed to assess the impact of air pollution on property values:

$$X_1 \text{ or } X_2 = b_1 \text{ or } b_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + b_{10}X_{10}$$

where:

X_1 = median property value (MPV)

X_2 = median gross rent (MGR)

b_1 = constant for MPV

b_2 = constant for MGR

X_3 = micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) of suspended particulate matter (SPM)

X_4 = median family income (MFI)

X_5 = percent one-unit structures (OUS)

X_6 = school years completed (SYC)

X_7 = $\mu\text{g}/\text{m}^3$ benzene soluble particles (BSP)

X_8 = median number of rooms (MNR)

X_9 = annual mean temperature (AMT)

X_{10} = annual precipitation in inches (API).

This model is different from the model employed previously in that this model uses alternative measures for the dependent variable (MPV and MGR) and the pollution variable (SPM and BSP). In addition it should be

noted that the pollution variables are incorporated into the model as continuous variables as opposed to dummy variables used in the previous model. However, one run was made using dummy variables on the pollution measures and the results of this will be discussed later. Additionally, this model employs some explanatory variables which are slightly different from those used earlier.

As mentioned before, two dependent variables are used, median property values and median gross rent (respectively, MPV and MGR). MPV is the owner's estimate of what his property was worth on April 1, 1960. MGR is the contract rent plus the average monthly cost of utilities if these are paid by the renters in addition to contract rent. Thus according to the census ". . . gross rent eliminates rent differentials which result from varying practices with respect to the inclusion of heat and utilities as part of the rental payment" (11, p. 7). Therefore, gross rent is used as a measure of property values rather than contract rent. Gross rent does not provide an entirely satisfactory alternative measure of property value since the payment is for items other than the property and immobile improvements thereon. Nevertheless the use of MGR as a dependent variable was thought to be worthy of investigation.

In addition to the two measures of property values, this study employs two measures of pollution. Because there is no commonly accepted indication of the level of air pollution, two measures were employed in an attempt to capture as much as possible the entire effect of air pollution. A study similar to this used suspended particulates and sulfation rates as alternative measures (8). Perhaps the present study could have

benefited by using the same pollutants; however, measures of sulfur oxides were not available for all cities in the analysis. Available data were on suspended particulates and benzene soluble particles. The simple r between these two is about 0.65 for the cities in this analysis. Other studies have found a similar relationship between sulfation rates and suspended particulates (8 and 31). This evidence, combined with the fact that benzene soluble particles are primarily particles from incomplete combustion--the source of most of the sulfur oxides--suggests that BSP could be considered a proxy for sulfur oxides (7, p. 20). This study chooses not to enter BSP as a proxy for sulfur oxides, but rather as a measure in its own right. Both measures of pollution are entered into the model as continuous variables rather than dummy variables which were used earlier. Since both types of pollutants have been shown to have deleterious effects on a wide variety of objects, it is expected that the sign of both variables will be negative (7). Again the impact of these variables is thought to be small in relation to the other variables.

This model also employs median family income (MFI) as one of the explanatory variables. It is argued here that this variable should be included in its own right and not as a proxy for the other variables not otherwise accounted for. Since this variable is expected to exert a positive influence on property values, it is expected that its coefficient will assume a positive sign. The primary role of this variable will be that of explaining variation in property values as they relate to air pollution, and not in the estimation of income elasticities of the demand for housing. However, the similarity

between elasticity estimates obtained in this study and those obtained elsewhere will be noted.

A new variable that was added to this model is the percent of housing in one-unit structures (OUS). This variable was employed to account for the relative amount of single unit structures available in each city. It is not clear what the precise relationship between OUS and MPV should be and, therefore, no a priori judgment is made regarding the sign of this variable. Hopefully it captures something of the nature of the housing market in each city. The use of this variable in this function is analogous to the use of quantity in the demand functions of agricultural products. In the case of agricultural commodities, the amount of a particular crop is fixed at any point in time and the price is largely determined by the size of this fixed supply. Similar conditions exist in the housing market where the supply of houses is fixed at a given time. It could be argued, then, that the number of housing units available rightfully appears in the demand function for housing. On this basis, OUS appears in this model as a measure of the relative availability of single family units.

To account for the general socioeconomic characteristics of the population, the number of school years completed (SYC) was used as one of the explanatory variables. This variable was included to account for several population characteristics which could influence the choice of housing facilities. It was hypothesized that people with higher levels of education tend to reside in the more expensive housing units. Under this hypothesis the coefficient for this variable should assume a positive sign. To the extent that people seek quality education

for their children, this variable could be considered a proxy for school quality. However, this study does not employ SYC as a proxy. Also it is expected that because the variation within cities is greater than between cities, this variable will explain only a small portion of the total variation in property values. It is thought that the explanatory variable MFI probably captures the majority of the influence of socioeconomic characteristics.

Median number of rooms (MNR) is employed in this model as a measure of housing space and the privacy afforded by each unit. It is expected that as room numbers per unit increase so does available space, and, along with the increased space, privacy should also increase. These increases in privacy and space should bring about increases in property value. This hypothesized positive relationship between MNR and MPV or MGR should be reflected in the positive sign of the coefficient of this variable. This hypothesized relationship may not hold where a substantial percentage of the housing units are apartment complexes in which the number of rooms per unit is much lower than in single unit houses. This problem was attacked in the single-city analysis by limiting the sample to those tracts with over 50% of the housing units in single-unit dwellings. However, in this analysis such a restriction proved to be ineffective. In some preliminary work, this restriction was imposed, but the results of the analysis were not significantly altered. As was the case in the single-city analysis, to be effective, this constraint would have to be set at approximately 75%. At least this seems to be the figure suggested by other studies (8 and 31). While this level may be appropriate for individual cities, the composition of housing

units in a city is generally such that if the restriction is set at the 75% level where the city is the unit of observation, most of the observations are lost. For this reason a higher restriction could not be used in this analysis.

It was mentioned at the outset of this chapter that one of the problems of the analysis was the varying meteorological mix with the various air pollutants in the several cities. To minimize this problem two variables were used, one measures annual precipitation (API) and the other measures average temperature (MAT). In some runs not reported in this analysis another variable, windspeed, was entered into the model. Results with this variable indicated that little was to be gained by its inclusion. Hopefully, these two variables will adequately capture the influence of varying meteorological conditions on property values through the meteorological influence on air pollution.

These two variables were chosen both as a matter of convenience and because of the relationship between these variables and air pollution. It was pointed out in Chapter I that suspended particles had an effect on precipitation and also on temperature. However the effect on surface temperature is likely to be small (5, p. 39). The precise relationship between property value and these two variables is not known. One hypothesis is that property value may tend to be lower in the most temperate zones, the underlying reason being the cost of construction, which should be lower in warmer climates because there is less need for building safeguards against freeze damage. None of the property value studies examined by the author contained any reference to an actual or hypothetical relationship between temperature and housing value.

In the absence of any evidence to the contrary, this study adopts the hypothesis that residential property values are lower per unit area in temperate zones. Based on the above, it is expected that the coefficient of the temperature variable will assume a negative sign indicating that a lower property value is associated with a higher average annual temperature. In addition to this argument, it could also be said that the warmer climates promote deterioration of materials caused by air pollution. Some studies have shown that a higher temperature increases the damage done by a given amount of a specific pollutant. Likewise other studies have shown that moisture also acts with pollutants to produce adverse effects (5, pp. 65-74). If it can be assumed that precipitation adequately reflects the amount of moisture in the atmosphere, then there should be a negative relationship between property value and precipitation. It should be pointed out that the influence of either of these variables on property value is likely to be very small.

The rationale given above for the inclusion of specific variables in the model are extensions and modifications of those given for the single-city model to fit the multiple-city case. Data for the analysis were taken from similar sources and are explained below.

IV. THE DATA

Data for the multiple-city analysis were obtained primarily from the County and City Data Book, 1967 (39). These data were compiled from the 1960 census. Air pollution data were obtained from Air Quality Criteria for Particulate Matter (5). A listing of the air pollution data for the sixty cities is shown in Table 10 in the Appendix.

Since the air pollution data are from a later time period than the census data, the possibility of measurement error is introduced into the analysis. The extent of damage done by the introduction of such an error is unknown. Previous studies indicate that such an error will produce estimates which are biased downward (8). That is, the coefficient of the pollution variable will understate the true negative influence of air pollution.

This model employs continuous variables for the air pollution measures as opposed to the discrete variables employed in the single-city analysis. In addition to the continuous variables, some runs were made using a dummy variable technique like that employed in the single-city analysis. Generally these did not shed any additional light on the analysis and the results are not reported here. The data on the air pollution variables were taken over a five-year period at single sampling stations located in the center of each city. These readings are assumed to be characteristic of the general pollution level existing in the various cities. It is true that there is considerable variation in the level of air pollution within a city, but variation between cities is also evident. Since the data for air pollution are given for standard metropolitan statistical areas, the data for the remaining variables were also taken on the same basis. The model as described above and these data were used to obtain the results presented below.

V. THE RESULTS

This analysis uses the model as outlined above with two dependent variables and two measures of pollution. Several functional forms were

fitted, the results of which are presented in Table 8. The four equations represent only two of the functional forms fitted, linear and logs. Equations (1) and (2) were fitted using the linear form, while equations (3) and (4) were fitted using the log form. Aside from the functional form, the difference between (1) and (3) and (2) and (4) is the dependent variable. Equations (1) and (3) use MPV as the dependent variable, while (2) and (4) employ MGR as the dependent variable. There is also a slight difference in sample size, as equations (1) and (2) are based on 55 observations while (3) and (4) are based on 60 observations.

Generally these results substantiate the work done by Anderson and Crocker (8) and Ridker (31). The explanatory power and goodness of fit obtained in these results compare favorably with those obtained in other single-city analyses. There are some differences in variables used and in some cases variables have different signs. However, the major emphasis is on the pollution variables and at least one of these exerts a negative influence on property values. The following section explains the results presented in Table 8.

VI. INTERPRETING THE RESULTS

In comparing the four equations in Table 8 it will be noted that equations (1) and (3) which use MPV as the dependent variable are generally better than equations (2) and (4). This also conforms closely to results obtained by Anderson and Crocker (8). Equations (1) and (3) are very close in terms of the standard tests by which goodness of regression equations are judged.

Since R^2 is independent of the units in which the variables are

Table 8. Summary of Coefficients Obtained in Multiple-City Analysis^a

Variable	Equation (1)	Equation (2)	Equation (3)	Equation (4)
Dependent	MPV	MGR	log MPV	log MGR
Constant	\$13,704.00	-17.74	0.9476	-1.443
SPM (X ₃)	-0.35 (8.21)	0.045 (0.04)	-0.106 (0.065)*	-0.013 (0.061)
MFI (X ₄)	2.18 (0.25)**	0.0092 (0.0015)**	1.124 (0.112)**	0.751 (0.096)**
OUS (X ₅)	-98.10 (13.30)**	-0.053 (0.058)	-0.410 (0.063)**	---
SYC (X ₆)	---	2.61 (1.16)**	---	0.443 (0.154)**
BSP (X ₇)	-36.40 (108.26)	-0.74 (0.478)*	0.074 (0.066)	0.015 (0.047)
MNR (X ₈)	-1354.5 (484.12)**	---	-0.277 (0.140)**	0.049 (0.101)
AMT (X ₉)	---	0.175 (0.129)	---	---
R ²	0.829	0.738	0.806	0.755
S _y	1158.35	4.91	0.0416	0.0291
F ratio	47.51	22.51	44.80	41.92
N	55	55	60	60

^aStandard errors shown in parentheses.

*Coefficient is significant at 5% level.

**Coefficient is significant at 1% level.

measured, all three equations may be compared on this basis. If R^2 is the test, then equation (1) is best because approximately 83% of the variation in the dependent variable is explained by the independent variables. In equation (3) approximately 81% of the variation is explained. This slight difference could be accounted for by the difference in degrees of freedom between equations (1) and (3) which causes equation (1) to have a lower total sum of squares, or--in other words--there is less variation to be explained in equation (1). The R^2 's for equations (2) and (4) are lower, indicating that less of the variation is explained in these two than in equations (1) and (3). In the case of equations (2) and (4), equation (4) has a higher R^2 and also more degrees of freedom; therefore, on this basis it is superior to equation (2) because it explains more of the variation in the dependent variable.

The F ratio is the ratio of the mean square error due to regression and mean square error due to residuals, or the ratio of explained variation to unexplained variation in the dependent variable. If the calculated ratio is greater than shown in the F table, the relationship is significant and R^2 is also significant. For the equations shown in Table 8 the table values at the 1% level are as follows: 3.42 for (1), 3.20 for (2), and 3.41 for (3) and (4). All equations in Table 8 could occur by chance only one time in 100. In comparing the equations in Table 8, it is appropriate to compare (1) with (3) because they are essentially the same--with the exception of the functional form. The same is true for equations (2) and (4). The difference (in F ratio) between (2) and (4) is more pronounced

than between (1) and (3). In the case of (1) and (3), this difference could be due to the difference in the number of observations. However, the difference between (2) and (4) cannot be attributed to differences in sample size. On the basis of the F ratio, it can be said that equation (4) is clearly superior to (2), while there is little difference between (1) and (3).

Another criterion used to judge regression equations is the standard error of the estimate (S_y). Essentially, this statistic is the square root of the residual mean square and roughly two-thirds of the observations will be within the range of $\pm S_y$ of the regression line. Since the calculation of S_y is not independent of the units used, it is not possible to readily compare the standard errors of the estimate presented in Table 8, page 88, because equations (3) and (4) are in logs. If these statistics are converted to a percentage of their mean, then they may be compared on that basis. For (1), the mean is \$13,041.82, so the standard error is 8.9% of the mean; the S_y of (2) is 6.6% of the mean, while the S_y of (3) is 1% and the S_y of (4) is 1.6%. Obviously, equations (3) and (4) have much lower standard errors than (1) and (2), and on this basis (3) and (4) are preferred to (1) and (2). On the basis of the three tests given above, equations (3) and (4) are better than (1) and (2) in terms of R^2 , F ratio, and S_y . The following paragraphs discuss the results in terms of all equations, with emphasis on equations (3) and (4).

The first explanatory variable is SPM. This variable was a measure of suspended particulate matter in micrograms per cubic meter. The coefficient of SPM was -0.035 in equation (1) which indicates that

as SPM increased by one unit, property value declined by 3.5 cents. However, the coefficient is not statistically different from zero. Recall that in the section in which the rationale for the inclusion of each variable was given, it was pointed out that a second measure of air pollution was used in an attempt to capture the full influence of air pollution. This being the case, the variable BSP must be considered with SPM. The coefficient for BSP is -36.40, indicating a decline of \$36.40 in property values for every one-unit increase in BSP. Taken together, both variables indicate an approximate \$36.75 decrease in property value associated with a one-unit increase in air pollution (i.e., $1 \mu\text{g}/\text{m}^3$ each of both SPM and BSP). In order to compare these results with those obtained in the log form of the equation discussed below, the elasticity of property values with respect to air pollution was calculated. Taking both measures of pollution together, their coefficients imply an elasticity of approximately 0.027 calculated at the mean values for the relevant variables. When evaluated at the mean, this translates into a loss of approximately \$3.57 per property for each 1% increase in the level of each of the measures of air pollution used in the present study. For the two measures of air pollution, the means and standard deviations (S_{x_i}) are: $\bar{X}_3 = 118.91 \mu\text{g}/\text{m}^3$ and $S_{X_3} = 29.33$; $\bar{X}_7 = 8.72 \mu\text{g}/\text{m}^3$ and $S_{X_7} = 2.24$. Accurate comparisons of these results with those obtained elsewhere are not possible because of the different measuring units used. However, the estimate obtained here and the one obtained by Ridker appear to be fairly close (31, p. 136). While the estimates obtained in this study support the findings of other studies, the coefficients on which these estimates are based are not

statistically different from zero. While the results of equation (1)--with respect to pollution--are not statistically significant, they do conform to the a priori expectations of this study. Equation (1) asserts that if air pollution, as measured in this study, is reduced one unit then property values can be expected to increase by \$36.75 per property. This figure is taken to be the benefits to be received, i.e., the economic loss avoided by reducing the level of air pollution by one unit ($1 \mu\text{g}/\text{m}^3$ each of both SPM and BSP). Therefore, these results indicate that if the cost of bringing about a one-unit decrease in the level of air pollution is less than or equal to \$36.75 per property, it would be economically feasible to do so. The derivation of costs and benefits from the reduction of air pollution is not as straight forward as implied above.

The coefficient for SPM in equation (3) is negative and significant at the 10% level. Considering only SPM, there is a negative relationship between air pollution and property values. The other measure of air pollution, BSP, has assumed a positive sign in equation (3). Statistically this coefficient is not different from zero at the 10% level. However, if the two variables are considered together they imply an elasticity of median property value for owner-occupied housing units with respect to air pollution of -0.032. Evaluated at the mean, this translates into slightly more than a \$4.00 decrease for each 1% increase in the pollution level. This estimate of elasticity is slightly higher than that obtained using the coefficients in equation (1). Also the estimate obtained from equation (3) is based on a larger sample and the relevant means and standard deviations are slightly

different from those presented for equation (1). For equation (3) $\log \overline{\text{MPV}} (X_1) = 4.1047$, log standard deviation $X_1 = 0.0902$; $\log \overline{\text{SPM}} (X_3) = 2.063$, log standard deviation $X_3 = 0.1108$; and $\log \overline{\text{BSP}} (X_7) = 0.9304$, log standard deviation $X_7 = 0.1103$.

In the formulation stages of the analysis, it was thought that the negative influence of pollution was small. The size of the influence shown here was also expected due to the nature of the sample. It was pointed out that there was perhaps more variation within each city than between cities, both with respect to the level of air pollution and also with respect to other variables. If this is true, then it would be expected that an estimate of air pollution damage obtained from a cross-section of cities would be lower than estimates based on a cross-section of an individual city. This being the case, the estimate obtained here represents an understatement of the negative influence of air pollution. The extent of this understatement is unknown. There is at least one other reason why the estimate obtained is an understatement. This reason was presented by Anderson and Crocker and rests on the time discrepancy in observations on variables used in the model. They maintain that ordinary least squares estimates, based on data with this time discrepancy, tend in the probability limit to understate the negative influence of at least one of the pollutants (8, p. 13). They further state that "If only one pollutant exerts an effect on property values, the conclusion can be strengthened in that the OLS estimates tend in the probability limit to understate the negative influence of pollution" (8, p. 13). In the case of equation (3), Table 8, page 88, the coefficient of BSP is not statistically different

from zero. This implies that BSP does not exert a statistically significant influence on property values. Therefore, the results here support the assertion by Anderson and Crocker that the negative influence of air pollution tends to be understated.

Whether or not the negative influence of air pollution on property value is understated, the results of the pollution variable indicate that the influence of at least one of the pollutants is negative. Estimates of the size of this negative influence vary. The size of this variation is evident in a comparison of estimates obtained in this study with estimates obtained elsewhere (8 and 31). For comparison, the estimates obtained by Anderson and Crocker range from \$300 to \$700 per property for each additional $10 \mu\text{g}/\text{m}^3/\text{day}$ of SPM and $0.1 \mu\text{gSO}_3/100\text{cm}^2/\text{day}$ of sulfation (8, p. 21). Ridker's estimates of loss ranged from about \$83 to \$245 (31, p. 134). While these estimates are not strictly comparable because of the different units in which the pollution variable is measured, they do point up the wide range of estimates so far obtained.

Although the results of the pollution variable presented above were of prime importance in this analysis, the results of the remaining variables are also of some importance. The remaining variables are dominated by the influence of median family income. As in the single-city analysis, income explained a large portion of the total variation in property values, accounting for about 59% of the variation. While the income elasticities obtained elsewhere have employed household characteristics as the other variables in the demand functions, the elasticities calculated in this study, which include property

characteristics in the demand function, seem worth noting. Similarities between estimates obtained in other studies and those obtained here are striking. The estimates obtained here lie between those obtained by Reid (30) and those reported by Anderson and Crocker (8). Reid obtained income elasticity estimates ranging from 1.5 to 2.0 (30, p. 355). Anderson and Crocker estimated an income elasticity with respect to property value that ranged from 0.6720 to 0.7677 (8, pp. 22-24). While the estimates obtained here closely resemble estimates obtained elsewhere, they must be interpreted with caution. This is due to the fact that the income measure used is a median over all families and not for a specific tenure class, so it is not a true estimate of income for a particular group such as owner-occupants. It may be worth noting here that elasticity estimates for renters were somewhat lower (0.751) than the same estimates for owners (1.124). Similar results were obtained by Anderson and Crocker (8, p. 27). The above elasticity measures are mentioned as a possible interesting sidelight. Median family income was included because of its role in determining property values, and the results show that MFI did account for a large portion of the variation in MPV.

The percentage of housing in one-unit structures (OUS) was entered into the model to depict the relative number of single-unit dwellings, which would give some indication of the conditions existing in the housing market. The coefficient of the variable assumed a negative sign as hypothesized. In equations (1) and (3), the coefficient is significant at the 1% level. The negative coefficient indicates that as the percentage of one-unit structures increases the property value

declines, or lower property values are associated with higher percentage one-unit structures. This result seems plausible since it is reasonable to assume that a multiunit dwelling would be more valuable than a single-unit dwelling. OUS does give an indication of the conditions existing in the housing market, but because there are apt to be wide variations in quality among the one-unit structures, it may not adequately reflect these conditions. Nevertheless this variable proved to be relatively important in accounting for the variation in property values. This is evidenced by the fact that the simple r between OUS and MPV is -0.737 which means that it explains approximately 54% of the variation in property values. Simple correlations between the remainder of the variables are shown in Tables 11 and 12 of the Appendix. While the variable OUS is important in explaining the variation, its impact on property values is also fairly large as indicated by the value of its coefficient shown in Table 8, page 88. This coefficient indicates that for every percentage point increase in OUS, associated property values decline by approximately \$98. It can be concluded from the evidence that OUS ranks next to MFI in order of importance in accounting for variations in property values between cities.

The model as specified earlier contained the explanatory variable school years completed, which hopefully would capture the influence of several factors otherwise not accounted for. It was expected that the influence of this variable would be small. Results shown in Table 8 indicate the smallness of that influence. In equations (1) and (3) including only owner-occupied units the variable never entered the model, because the stepwise program utilized in the analysis enters the

variables one at a time in the order of their importance in explaining the variation in the dependent variable. It is interesting to note that the variable did enter equations (2) and (4) concerning all housing including renter-occupied units. While the coefficients are only marginally significant, they indicate that there is a positive association between level of education and the amount paid for rent, which is consistent with the hypothesis presented earlier. The results indicate in equation (1) that for each additional school year completed MGR increased \$2.61. SYC did not enter the equations for owner-occupied units probably because of the hypothesis made earlier that income and education were positively correlated and if income was important, then the level of education could also explain some of the variation in property values. The correlation between SYC and MFI is 0.56 while the correlation between SYC and MPV is 0.41. Since SYC and MFI are fairly highly correlated, there is some question as to whether measures of one convey distinctly different information from that depicted by measures of the other. If they do convey essentially the same information, then either one may be deleted with little effect on the analysis. Thus the explanatory power of the equation is not seriously altered by the exclusion of the SYC variable.

Median number of rooms (MNR) was put into the model to account for both size of the house and the privacy provided by the house. It was hypothesized that the coefficient of this variable would assume a positive sign. Results shown in Table 8, page 88, indicate that the coefficient has assumed a negative sign in equations (1) and (3) and a positive sign in equation (4). The variable was not of sufficient

significance to enter equation (2). Coefficients for this variable with negative signs are only marginally significant, while the coefficient with the positive sign is of even lower significance (i.e., less than 50%). These results may have been confounded by the census practice of taking a median over all units; thus, a city with a substantial portion of apartments could seriously affect the behavior of this variable. Earlier it was pointed out that this problem could be attacked by limiting the observations to those cities having a high percentage of single family dwelling units. As also mentioned earlier, such a restriction was imposed, but it proved ineffective. The reason for its ineffectiveness was the level which was defined as a high percentage. For this analysis the cut-off was set at 60% single family units. Since this restriction was not effective, a higher figure was attempted. In trying to further restrict the sample, too many observations were lost. The restriction has proven to be effective in other studies involving single cities, but for the intercity study attempted here it was ineffective. This is because in considering the city as a unit of observation, the composition of housing units is generally such that there is a fairly large percentage of apartments which tend to confound the statistics on median room numbers. This confounding occurs because the statistic for MNR is taken over all housing units--including apartments which tend to have fewer rooms than single-family units. Therefore, if a city contains a large proportion of apartments, the median number of rooms is likely to be small while the value of owner-occupied units may be large. Thus, the negative relationship between

MNR and MPV occurs. If the data were segregated on the basis of tenure, this problem could be avoided.

Meteorological conditions were thought to influence property values through the pollution variables. However the extent of this influence was thought to be small. The results in Table 8, page 88, indicate the smallness of the influence. The two variables used to reflect weather were precipitation (API) and temperature (AMT). These two variables were included in the model used for equations (1) and (2) only; they were deleted from (3) and (4) because of their inability to add to the explanatory power of the equation. What was actually desired in these two variables was a good measure of weather. If such a measure existed, some way of showing the correct interaction between air pollution and the various weather conditions would be needed. To the author's knowledge, no commonly accepted index of weather exists, nor does any agreed upon specified relationship between air pollution and weather. Some attempts were made in this study to utilize an interaction term which was the product of multiplying the weather variables times the air pollution measures. Since no specification of the relationship existed, this naive specification was used with generally negative results. Failing in this attempt, the two variables were entered alone as depicting weather. The correlation matrix obtained in this analysis somewhat substantiates the naive hypothesis presented earlier regarding the relationship between these variables and damage done by pollution as reflected in property values. The simple r between MPV and both weather variables is approximately $-0.2+$. This indicates that property values are generally lower in the higher

rainfall and temperature areas. The simple r between the two weather variables is 0.35, indicating that the two are positively correlated and tend to occur together. While the simple relationship is as hypothesized, it is not sufficient to exert a significant influence on property values. This is indicated by the fact that one of the variables (API) initially included in the model did not enter either equation (1) or (2). In terms of importance, it should be noted that temperature exerts more influence on property values than does precipitation. The extent of this influence is questionable since AMT only entered equation (2) and it was not statistically different from zero in this case. Results presented in Table 8, page 88, are those obtained using the stepwise regression program. When both variables were forced to enter the equations, they were not statistically different from zero. Equations including these two variables are not shown because they were judged inferior to those shown in Table 8. These results indicate that perhaps the problem of weather variability between cities is not as important as hypothesized. Alternatively, the relationship specified in this analysis may not have fully captured the influence of weather variability--if, in fact, such influence exists.

In summary, the findings of this portion of the analysis do indicate a negative association between the level of air pollution and property values. Essentially two estimates of loss were obtained; one indicated a loss when evaluated at the mean values of approximately \$4.00 for every 1% increase in the pollution level, and the other estimate of loss was approximately \$36.00 per unit increase in the air pollution level where this level is given in $\mu\text{g}/\text{m}^3$. When elasticity

estimates were made from the linear form (equation (1)) each 1% increase in the level of each pollutant produced a loss of approximately \$3.50 when evaluated at the mean. Therefore the two estimates obtained in this analysis are very close. The primary difference between the two estimates is that the estimate of loss obtained from equation (3) is based on at least one statistically significant coefficient, while neither of the coefficients of pollution variables in equation (1) were statistically significant.

While not strictly comparable, the results obtained in this study substantiate the results obtained elsewhere (8 and 31). The equations on which these estimates are based represent significant relationships as judged by the F ratio. Since the F ratio is significant in each case, the R^2 is also significant. In equations (1) and (3), approximately 80% of the variation in the dependent variable was accounted for. About 75% of the variation was accounted for in equations (2) and (4). The results of the pollution variables in the equations in Table 8, page 88, are significant because they illustrate the direction in which property values are influenced by air pollution.

It is important to note that the impact of air pollution is more evident when measured in terms of value of owner occupied housing units (MPV) than when measured in terms of rent (MGR). This result indicates that perhaps rental fees are not as sensitive to the level of air pollution as is the value of owner-occupied property. There may be several reasons why this insensitivity could exist--many of which may have to do with the nature of the market for rental properties. It is outside the scope of this study to speculate why such a condition

exists--if, in fact, it does. These results may be explained in terms of the nature of the measure of property values used (MGR). Recall that MGR was used as an alternative measure for property value whereas if rent was capitalized this figure could be used to represent property value. It was pointed out earlier that this measure of property value might not prove to be entirely satisfactory. Therefore, it is possible that the results which imply that rental payments are less sensitive to air pollution levels than owner-occupied property could be valid or could have been obtained because MGR is not an entirely satisfactory alternative measure of property value since it includes payments for items other than property and immobile improvements thereon.

In addition to the results of the pollution variable, some other aspects of the results may be worth noting. Generally the results of the income variable were similar to those obtained in other studies. Income proved to be the most important variable in terms of the amount of variation accounted for in the dependent variable. Also the income elasticity estimates were very close to estimates obtained in other studies (8 and 30). Another variable that proved to be important in explaining the variation in property values was percentage one-unit structures. This variable ranked next to income in the amount of variation explained. The variables employed to account for the variation in weather from city to city generally proved unsatisfactory. Annual precipitation originally included in the model, was of such low statistical significance that it failed to enter the final equations. It is unclear as to whether these variables failed to capture the influence of weather, or such influence is not as strong as hypothesized. Results

of the variable on median number of rooms was not as expected since it did not exert a positive influence on property value. This could have been due to the manner in which the data were gathered and not indicative of any misspecification in the model building. Generally, the overall results were encouraging in that at least one estimate of pollution damage was based on a statistically significant coefficient.

In addition to the results presented above, some other work was undertaken, the results of which were not reported above. At this point it may be appropriate to briefly discuss some of the results obtained in this work. Most of the work involved the use of additional variables in the model. For example, some of the runs included some variables to account for population characteristics. Some of these variables were the percent nonwhite persons per mile and percent over age 21. In no case did the addition of any of these variables add significantly to the analysis. These results, with respect to nonwhites, may be worthy of mention because they somewhat substantiate some results obtained in other studies. The fact that this variable did not enter the model indicates that it did not vary in such a manner as to explain the variation in property values. This result was not unexpected since other studies have found that the influence of nonwhites on the housing market was significant, but the direction of influence varied from place to place (29). Therefore, since this analysis covered several cities, it is likely that the positive influence in one city was offset by a negative influence in another.

Several variables relating to housing were included in some of the runs. To assess the condition of the house, a variable indicating

the percent of housing units which were sound with plumbing was used. As with the variables above, this one also added nothing to the analysis. The number of persons per unit was used to gain some information on housing space, but it did not add significantly to the analysis. An index of home equipment was also employed as an explanatory variable, but again the results were negative.

In some runs an attempt was made to discover if there were any variables suitable to serve as proxy variables for air pollution. Essentially three variables were employed in this endeavor--value added by manufacturing, percent of the labor force employed in manufacturing, and automobile dealer sales. None of these variables were highly correlated with the measures of pollution used here. On the surface it appeared that the level of pollution emitted by the two alleged prime sources of air pollution, manufacturing and automobiles, would be reflected somewhat by the amount of these polluters present in the various cities. It was thought that these variables would adequately reflect the level of these activities. However, none of the variables employed here appeared to serve such a purpose. Aside from their suspected role in the determination of air pollution levels, it was thought that these variables would exert some influence on the housing market. Such was not the case, and the model remained as presented earlier.

The findings of this study indicate again the serious lack of appropriate data necessary in analyzing the air pollution problem. While this study did find a negative relationship between the level of air pollution and property value, the exact size of the negative influence has not been determined. Estimates obtained here indicate that property

values could be enhanced by reducing the level of air pollution but no estimate is made about the costs involved in bringing about such a reduction. Some studies have shown that pollution control is a superior good (8, p. 26). This would tend to indicate that such controls are not inexpensive. Estimation of the costs of control was outside the scope of this study and will not be discussed in detail. Using the benefit-cost approach, controls would be set where the marginal benefits from setting controls at a certain level just equal the marginal cost of attaining that level of control. The estimates of damage obtained in this and other studies serve as a measure of the benefits to be received if air pollution levels are reduced by a given amount.

In summary, one of the significant findings of this analysis was that air pollution does have a negative impact on property values. Secondly, this impact seems to be more pronounced when property values are measured in terms of owner-occupied properties. This suggests that rental payments are insensitive to air pollution. Also, the benefits to be derived from a reduction in air pollution levels are substantial, based on the estimates obtained in this analysis, but the cost of bringing about such reductions is not known. In addition, this analysis has been faced with serious data shortages and gaps. Most notable is the lack of data on housing and population segregated by tenure and data on air pollution, especially in view of current concern about ecology. Nevertheless, the results of this analysis are encouraging, and further studies along these lines should be undertaken.

CHAPTER V

SUMMARY AND CONCLUSIONS

Environmental quality has only recently received widespread attention. The environment has changed over time, but this change has been regarded as natural. Only when drastic alterations occur in the environment in a relatively short period of time does man become concerned. Interest in environmental quality has arisen because of misgivings about man's ability to adapt to a rapidly changing environment. Man is especially concerned because he is aware that his activities bring on or are the basis for much of this change.

This study has been concerned with air pollution which is only one aspect of the general problem of environmental quality. The problem of air pollution is world-wide in scope and is manifest at the local, state, and national level by the imposition of more stringent controls and regulations coupled with stepped-up enforcement of existing regulations. Regulation setting is a difficult task at best, and if these regulations are to be established, those setting the regulations should have more information about the problem. This study provides some of the information necessary for the establishment of air pollution regulations.

The information provided by this study is the result of its investigation into the relationship between air quality and economic loss. In this study it was hypothesized that air pollution causes economic loss. To test this hypothesis the real estate market was chosen as the market most likely to reflect the negative effects of

air pollution. The choice was based on the inability to move real estate to avoid the negative effect of air pollution and thereby shift the negative effects to other markets. Estimates of economic loss thus obtained would fulfill the overall objective of this study which was to provide information useful in the establishment of air pollution regulations. To accomplish this general objective, two specific objectives had to be accomplished. The first of these objectives was to determine the association between levels of air pollution and property values for a single city as well as a group of 60 cities across the United States. In an effort to more precisely depict the extent of economic loss, the second objective of this study was to explore alternative methods of estimating economic loss attributable to air pollution.

To test the basic hypothesis and accomplish one of the objectives of this study, data were collected from various secondary sources. The data consisted of observations on variables thought to be important in explaining variations in property values, including a measure of air pollution, as well as property value data. Multiple regression techniques were used to analyze these data.

In the case of the single city analysis, there were initially 12 explanatory variables, three of which were dummy variables. Preliminary work showed that five of these variables could be deleted without seriously reducing the explanatory power of the equation and at the same time degrees of freedom would be increased. In addition, some later work indicated that two of the dummy variables were not statistically different so they were combined. Originally the data consisted

of 30 observations on census tracts within Knoxville. Later four of these observations were lost because they did not meet the requirements of the analysis.

The results of the single-city analysis indicated that median family income was most important in explaining variation in property values, accounting for approximately 85% of the variation. Two other variables, median number of rooms per unit and percent nonwhite residents, also proved important in explaining the variation. The 0,1 dummy variables, used to incorporate the measure of air pollution into the model, indicated a positive association between property values and level of air pollution. These results are based on a regression equation with an R^2 of 0.95, a standard error of the estimate of \$927.39, and an F ratio of 78.4 which indicated that the relationship depicted by the regression equation was significant.

Thus the hypothesis that property values were negatively influenced by air pollution was not supported by the results of the single-city analysis. These results suggest the owners of property in Knoxville did not act as if the level of air pollution influenced their judgment as to the worth of their property. Alternatively these results suggest that the real estate market may not work perfectly, thus the negative influence of air pollution, if present, was not reflected in the results obtained in this analysis. In either case these results may be suspect because they are based on a limited sample and there was only one measure of air pollution. Because only one measure was used it is possible that some of the negative influence was not captured and reflected in the results.

An analysis involving 60 cities across the United States was also completed to furnish an additional test for the basic hypothesis of this study. In addition to a test of the hypothesis that property values and air pollution were negatively related, this analysis also represented a different approach to estimating the extent of this hypothesized negative influence. The data for this analysis were taken from secondary sources and consisted of 60 observations on variables thought to be influential in determining property value. In one phase of the analysis five observations were lost because of gaps in data on the weather variables. Some preliminary work with alternative specifications of the model indicated that a model consisting of eight explanatory variables--two of which were measures of air pollution--gave the best results, as judged by an R^2 of 0.83, standard error of \$1158.35, and an F ratio of 47.5. The final specification included alternative dependent variables, median property value, and median gross rent, plus alternative measures of air pollution, suspended particulate matter, and benzene soluble particles.

Results of the multi-city analysis indicated that median family income alone accounted for about 56% of the variation in property values and 68% of the variation in median gross rent. While median gross rent was used as an alternative measure of property value, it was not an entirely satisfactory measure because it included payment for items other than the property and the improvements thereon. Median number of rooms was also an important variable in explaining variation in property value, but the results with respect to this variable are somewhat obscured because of the census practice of taking a median

over all housing units irrespective of tenure.

The results of the pollution variable in the multi-city analysis support the hypothesis that property values are negatively related to air pollution. A loss of approximately \$36 per property was indicated for each unit increase in air pollution, where a unit of air pollution equals $1 \mu\text{g}/\text{m}^3$ each of suspended particulates and benzene soluble particles. In addition to the linear form upon which the \$36 estimate was made, a log form of the equation was also fit. Estimates based on this form indicated a loss of approximately \$4 per property for each 1% increase in air pollution when evaluated at the mean.

When median gross rent was used as the dependent variable the results were slightly altered. In this case the linear form indicated an approximate \$0.70 decrease in monthly rental rates for each unit increase in air pollution. The log form yielded a substantially lower estimate of loss. However, the log form did not yield coefficients which were statistically different from zero.

A comparison of the results based on using rent and property values as dependent variables indicated that renters are less sensitive to pollution levels than property owners. Results of both analyses support the basic hypothesis of this study, but suggest owner-occupied housing responds more readily to changes in pollution levels. This result may stem from differences existing in the rental property market and owner-occupied housing market.

The results of the present study support the hypothesis that property values are inversely associated with levels of air pollution. The results also indicate that regression techniques are sufficient to

assess the impact of air pollution on property value based on currently available data. It can be concluded from these results that while the level of air pollution did not exert a dominating influence on property values, it is important in the determination of property values. The results also suggest that while both owner and renter-occupied units were negatively affected by air pollution, owner-occupied housing was more sensitive to the level of air pollution. Results obtained with respect to the pollution variables suggest that two measures of pollution more accurately captured the full influence of air pollution than did a single measure of pollution employed alone. Data inadequacies may have obscured some of the results obtained in this study. Most notable among these inadequacies was a lack of pollution and housing data by tenure and insufficient air pollution data.

The present study led to the following conclusions and recommendations regarding future research in this area: air pollution does exert a negative influence on property values. This influence can best be measured by employing as many alternative measures of air pollution as possible in future property value studies. Carried further, this implies that air pollution should not be considered in isolation from other forms of environmental pollution. If the full influence of environmental deterioration is to be captured in estimates of economic losses, then measures of the various forms of pollution giving rise to this deterioration should be included. Perhaps the answer lies in an approach similar to the systems balance approach suggested by Kneese and d'Arge (20). Another possible solution lies in developing a commonly accepted index of the various forms of pollution which

accurately reflects the damage potential of each form of pollution. Such an index would of necessity include information on weather and allow for the interaction of the various weather elements on the mix of pollutants. Admittedly this is a tall order, but such an index would facilitate the intercity comparison of pollution levels and also enhance the validity of economic loss estimates based on intercity data.

Owner-occupied housing was more responsive to the level of air pollution than renter-occupied housing. To more accurately assess the impact of air pollution on the basis of the tenure of residents, more comprehensive data are needed. Specifically, data as reported in the census needs to be reported by tenure class rather than disregarding tenure in the reporting of certain statistics. This applies especially to statistics on size of house and family income. The present study was made aware of this problem especially with regard to median room numbers.

The size of the economic loss attributed to air pollution is not known. This study produced two estimates which represent a range in estimates of economic loss. There may be several possible explanations for the wide range in estimates that have been obtained in studies so far. It was a conclusion of this study that data problems were at the base of the widely separated estimates. Specifically, more attention is needed toward arriving at acceptable air pollution data. This involves standardizing the measuring techniques both within and between cities as well as reporting data on a more comprehensive scale. For analyses such as the present study, it would be desirable to have data on air pollution as well as other variables reported on an

rural, suburban, urban, and possibly center-city basis instead of a single figure for an entire city. The development of a pollution index recommended earlier is a complex undertaking and something is needed in the meantime to facilitate analysis of the problem. Much work has already been done in the use of computers to permit continuous monitoring of the atmosphere, but more than just banks of data are needed. Researchers in all fields need to ascertain the data needs of their field and make these needs known to avoid data gathering for the sake of gathering data.

Alternative means of estimating economic loss should be pursued. The multi-city analysis of this study represented an alternative means of estimating economic loss which proved encouraging. Another attempt involving consumer expenditures was not as successful; again primarily because of insufficient data. While the economic loss estimated in this manner does not take into account the social interaction of individuals, it could still be useful in estimating the size of the social cost involved in air pollution. This could be accomplished by subtracting the loss estimated using consumer expenditures from an estimate such as that obtained in this study with the resulting residual being the social cost of air pollution. If consumer expenditure estimates of loss are deemed worthwhile, more work needs to be done on discovering which categories of expenditures are most effected by air pollution. If the categories can be narrowed, analysis will be expedited. Some improvements in the reporting of consumer expenditure data could also be made. At present the most critical need for this type of study is more data on consumer expenditures, preferably reported on areas

within the various cities such as census tracts.

This study has been primarily exploratory in nature and, as such, the findings may be regarded as tentative. Though tentative in nature, they demonstrate the ability of existing techniques of analysis to ascertain the impact of air pollution on property values. More thought is needed toward developing alternative methods of estimating economic loss. Additional research is also needed to discover what is being discounted in the property value studies. It is hoped that the results of the present study will provide some insights to those interested in determining the economic impact of alterations of the environment.

LIST OF REFERENCES

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1. "Air Pollution--1969." Hearing Before the Subcommittee on Air and Water Pollution, of the Committee on Public Works, U.S. Senate, 91st Congress, St. Louis, Missouri, October 27, 1969. Washington: Government Printing Office, 1970.
2. "Air Pollution--1970" (Parts 1, 2, 3, and 4). Hearings Before the Subcommittee on Air and Water Pollution of the Committee on Public Works, U.S. Senate, 91st Congress, March and April, 1970. Washington: Government Printing Office, 1970.
3. Air Quality Criteria for Carbon Monoxide. National Air Pollution Control Administration, Publication No. AP-62. Washington: Government Printing Office, 1970.
4. Air Quality Criteria for Hydrocarbons. National Air Pollution Control Administration, Publication No. AP-64. Washington: Government Printing Office, 1970.
5. Air Quality Criteria for Particulate Matter. National Air Pollution Control Administration, Publication No. AP-49. Washington: Government Printing Office, 1969.
6. Air Quality Criteria for Photochemical Oxidants. National Air Pollution Control Administration, Publication No. AP-63. Washington: Government Printing Office, 1970.
7. Air Quality Criteria for Sulfur Oxides. National Air Pollution Control Administration, Publication No. AP-50. Washington: Government Printing Office, 1969.
8. Anderson, Robert J., Jr. and Thomas D. Crocker. "Air Pollution and Housing: Some Findings." Paper No. 264. Lafayette, Indiana: Purdue University, Krannert School of Industrial Administration Institute, January 1970.
9. Appraisal of Air Pollution in Tennessee, 1957. Joint Report by the Tennessee Department of Public Health and the U.S. Department of Health, Education, and Welfare. Nashville: Tennessee Department of Public Health, September 1957.
10. Carson, Rachel L. Silent Spring. Greenwich, Connecticut: Fawcett Publications, Inc., 1964.
11. "Census Tracts, Knoxville, Tennessee." U.S. Census of Population and Housing: 1960. Final Report, PHC(1)-71. Washington: Government Printing Office, 1961.

12. "Cleaning Our Environment: The Chemical Basis for Action." A Report by the Subcommittee on Environmental Improvement, Committee on Chemistry and Public Affairs. Washington: American Chemical Society, 1969.
13. Duprey, R. L. Compilation of Air Pollution Emission Factors. Public Health Service Publication No. 999-AP-42. Durham, North Carolina: Department of Health, Education, and Welfare, 1968.
14. Fox, Karl A. Intermediate Economic Statistics. New York: John Wiley and Sons, Inc., 1968.
15. Goldman, Marshall I. (ed.). Controlling Pollution: The Economics of a Cleaner America. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1967.
16. Hobbs, C. S., et al. Fluorosis in Cattle and Sheep. Bulletin 235. Knoxville: The University of Tennessee, November 1959.
17. Hobbs, C. S. and G. M. Merriman. Fluorosis in Beef Cattle. Bulletin 351. Knoxville: The University of Tennessee Agricultural Experiment Station, October 1962.
18. Johnson, Martin L. Air Pollution Control Survey--Knoxville and Knox County, Tennessee. Interim Technical Report. Knoxville: Metropolitan Planning Commission, February 1968.
19. Johnson, Martin L. Personal interview. 1970.
20. Kneese, Allen V., and Ralph C. d'Arge. "Pervasive External Costs and the Response of Society." Reprint No. 80. Washington: Resources for the Future, Inc., July 1969.
21. Landcaster, Kelvin J. "A New Approach to Consumer Theory," The Journal of Political Economy, 74(2):132-157, April 1966.
22. Leftwich, Richard H. The Price System and Resource Allocation. New York: Holt, Rinehart, and Winston, 1960.
23. MacIntire, W. H., L. J. Hardin, and Mary H. Buehler. Fluorine in Maury County, Tennessee. Bulletin 279. Knoxville: The University of Tennessee Agricultural Experiment Station, March 1958.
24. Medalia, Nahum Z., and A. L. Finkner. Community Perception of Air Quality: An Opinion Survey in Clarkston, Washington. Public Health Service Publication No. 999-AP-10. Cincinnati, Ohio: Robert A. Taft Sanitary Engineering Center, 1965.
25. Merriman, G. M., and C. S. Hobbs. Bovine Fluorosis From Soil and Water Sources. Bulletin 347. Knoxville: The University of Tennessee Agricultural Experiment Station, September 1962.

26. Nationwide Inventory of Air Pollution Emissions, 1968. National Air Pollution Control Administration, Publication No. AP-73. Raleigh, North Carolina: U.S. Department of Health, Education, and Welfare, 1970.
27. Nourse, Hugh O. "The Effect of Air Pollution on House Values," Land Economics, 43:181-189, May 1967.
28. Purvis, John C. "The Problem of Air Pollution and Its Relationship to Land Use in Columbia, South Carolina." Unpublished Master's thesis, The University of South Carolina, Columbia, 1969.
29. Rapkin, Chester, and William G. Grigsby. The Demand for Housing in Racially Mixed Areas. Berkeley: The University of California Press, 1960.
30. Reid, Margaret G. Housing and Income. Chicago: University of Chicago Press, 1962.
31. Ridker, Ronald G. Economic Costs of Air Pollution. New York: Frederick A. Praeger, 1967.
32. Ridker, Ronald G., and John A. Henning. "The Determinants of Residential Property Values with Special Reference to Air Pollution," The Review of Economics and Statistics, 49:246-257, May 1967.
33. Sheehy, James P., William C. Achinger, and Regina A. Simon. Handbook of Air Pollution. Public Health Service Publication No. 999-AP-44. Washington: Government Printing Office, 1968.
34. Stern, Arthur C. (ed.). Air Pollution, Volume I. New York: Academic Press, 1968.
35. Stern, Arthur C. (ed.). Air Pollution, Volume II. New York: Academic Press, 1968.
36. Stern, Arthur C. (ed.). Air Pollution, Volume III. New York: Academic Press, 1968.
37. Teller, Azriel A. "Air Pollution Abatement: An Economic Study into the Cost of Control." Unpublished Doctoral dissertation, The Johns Hopkins University, Baltimore, 1969.
38. "The Cost of Clean Air." Second Report of the Secretary of Health, Education, and Welfare to the Congress of the United States, 91st Congress, Document 91-65. Washington: Government Printing Office, 1970.
39. U.S. Bureau of the Census. County and City Data Book, 1967. A Statistical Abstract Supplement. Washington: Government Printing Office, 1967.

40. Williams, James D., and Norman G. Edmisten. An Air Resource Management Plan for the Nashville Metropolitan Area. Public Health Service Publication No. 999-AP-18. Washington: Government Printing Office, 1965.
41. Wolozin, Harold (ed.). The Economics of Air Pollution. New York: W.W. Norton Co., Inc., 1966.

APPENDIX

Table 9. Correlation Matrix for Single-City Analysis

Variable	MPV	MNR	PNW	PDB	MFI	SPM ₁	SPM ₂	SPM ₃
MPV	1.000	0.662	-0.234	-0.352	0.927	0.001	0.180	-0.208
MNR		1.000	-0.137	-0.568	0.807	0.204	0.363	-0.655
PNW			1.000	0.403	-0.394	-0.157	-0.058	0.249
PDB				1.000	-0.548	-0.308	-0.205	0.592
MFI					1.000	0.198	0.152	-0.404
SPM ₁						1.000	-0.625	-0.433
SPM ₂							1.000	-0.433
SPM ₃								1.000

Table 10. Air Pollution Data for the Multiple-City Analysis

Standard Metropolitan Statistical Area	Suspended Particulates	Benzene Soluble Particles
	Micrograms per Cubic Meter	
Chattanooga	180	14.5
Chicago-Gary-Hammond-East Chicago	177	9.5
Philadelphia	170	10.7
St. Louis	168	12.8
Canton	165	12.7
Pittsburgh	163	10.7
Indianapolis	158	12.6
Wilmington	154	10.2
Louisville	152	9.6
Youngstown	148	10.5
Denver	147	11.7
Los Angeles-Long Beach	145.5	15.5
Detroit	143	8.4
Baltimore	141	11.0
Birmingham	141	10.9
Kansas City	140	8.9
York	140	8.1
New York-Jersey City, Newark-Passaic- Patterson-Clifton	135	10.1
Akron	134	8.3
Boston	134	11.7
Cleveland	134	8.3
Cincinnati	133	8.8
Milwaukee	133	7.4
Grand Rapids	131	7.2
Nashville	128	11.9
Syracuse	127	9.3
Buffalo	126	6.0
Reading	126	8.8
Dayton	123	7.5
Allentown-Bethlehem-Easton	120.5	6.8
Columbus	113	7.5
Memphis	113	7.6
Portland (Oreg.)	108	9.5
Providence	108	7.7
Lancaster	108	6.8
San Jose	105	14.0
Toledo	105	5.6
Hartford	104	7.1
Washington	104	9.4

Table 10 (continued)

Standard Metropolitan Statistical Area	Suspended Particulates	Benzene Soluble Particles
	Micrograms per Cubic Meter	
Rochester	103	6.1
Utica-Rome	102	7.0
Houston	101	6.8
Dallas	99	8.8
Atlanta	98	7.8
Richmond	98	8.3
New Haven	97	7.3
Wichita	96	5.2
Bridgeport	93	7.2
Flint	93	5.3
Fort Worth	93	7.8
New Orleans	93	9.7
Worcester	93	8.2
Albany-Schenectady-Troy	91.5	6.6
Minneapolis-St. Paul	90	6.5
San Diego	89	8.5
San Francisco-Oakland	80	8.0
Seattle	77	8.3
Springfield-Holyoke	70	7.0
Greensboro-High Point	60	6.3
Miami	58	5.7

Source: Air Quality Criteria for Particulate Matter. National Air Pollution Control Administration, Publication No. AP-49 (Washington: Government Printing Office, 1969), pp. 13-14.

Table 11. Correlation Matrix for Equations (1) and (2) of Multiple-City Analysis

Variable	MPV	MGR	SPM	MFI	OUS	SYC	BSP	MNR	AMT
MPV	1.000	0.737	-0.087	0.753	-0.737	0.406	-0.060	-0.241	-0.236
MGR		1.000	-0.104	0.827	-0.345	0.621	-0.165	-0.019	-0.270
SPM			1.000	-0.002	0.064	-0.362	0.695	0.163	-0.233
MFI				1.000	-0.395	0.565	-0.086	0.031	-0.453
OUS					1.000	-0.115	0.024	0.159	0.248
SYC						1.000	-0.162	-0.188	-0.015
BSP							1.000	-0.177	0.137
MNR								1.000	-0.573
AMT									1.000

Table 12. Correlation Matrix for Equations (3) and (4) of Multiple-City Analysis

Variable	Log MPV	Log MGR	Log SPM	Log MFI	Log OUS	Log SYC	Log BSP	Log MNR
Log MPV	1.000	0.761	-0.113	0.777	-0.645	0.483	-0.001	-0.247
Log MGR		1.000	-0.137	0.836	-0.288	0.669	-0.084	-0.082
Log SPM			1.000	-0.006	0.057	-0.332	0.642	0.104
Log MFI				1.000	-0.327	0.577	-0.022	-0.063
Log OUS					1.000	-0.131	0.021	0.139
Log SYC						1.000	-0.072	-0.272
Log BSP							1.000	-0.126
Log MNR								1.000

VITA

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