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Outpatient Medical Costs Related to Air Pollution in the Portland, Oregon Area

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OUTPATIENT MEDICAL COSTS RELATED TO AIR POLLUTION IN THE PORTLAND, OREGON AREA

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ABSTRACT

This study has attempted to quantify in monetary terms the effects of air pollution on the consumption of outpatient medical services. The hypotheses were that air pollution can aggravate a state of health resulting in increased consumption of outpatient medical services and in the number of contacts with the medical system for certain respiratory, cardiovascular, and other diseases aggravated by air pollution.

The study period was 1969-1970, and centered in the Portland, Oregon area. Statistical models were formulated, explaining individual outpatient consumption of medical services. Measures of suspended particulate air pollution and meteorological conditions, as well as socioeconomic-demographic variables thought to influence the consumption of medical services, were included in the models as explanatory variables.

The statistical results indicated that the procedures used in the study hold promise for quantifying the medical costs of air pollution. The results did show air pollution to have an effect on the consumption of outpatient medical services used to treat certain respiratory diseases.

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The U.S. Environmental Protection Agency supported this work financially. Mrs. Audree Berrey typed the final manuscript.

Last, but not least, the senior author is indebted to his wife, Carol Jaksch, for her unlimited assistance and encouragement throughout the two years of the research study.

I. CONCLUSIONS

The results of this study indicate that air pollution and meteorological conditions (lagged and unlagged) have an effect on the consumption of outpatient medical services used to treat respiratory diseases.

The regression results indicate that the procedures used in this study hold promise for quantifying the medical costs of air pollution.

As an economic cost, it would appear that air pollution has a minimal effect on increasing the quantity of outpatient medical services consumed per contact with the medical system. The main reason appears to be that many such visits are routine, and while air pollution may affect the number of visits, it does not materially affect the cost per visit.

II. RECOMMENDATIONS

Air pollution appears to have a minimal effect on increasing the quantity of outpatient medical services consumed per contact with the medical system. This is important to know, because it substantially reduces the need to do additional research on the effects of air pollution on outpatient medical consumption and suggests other areas in which research on the medical costs of air pollution may be more productive. The procedures developed in this study hold promise in quantifying medical costs attributed to air pollution. Hence, it is recommended that future research attempting to quantify such costs concentrate in three general areas.

1. Any future research on the outpatient medical costs of air pollution should investigate the effect of air pollution on the number of contacts with the medical system. While the consumption of medical services per visit may be fairly constant, the number of contacts with the medical system may be affected by air pollution. While a model on this was formulated and tested within this study, there were not enough observations to derive meaningful results.

2. An effort should be made to determine the effect of air pollution on the consumption of inpatient medical services. There should be more variety in the types of inpatient services consumed per contact with the medical system and, hence, more variability.[1]

3. A research effort should be made to examine and quantify the total medical costs attributable to air pollution; that is, outpatient and

[1] Under support of the United States Environmental Protection Agency (Washington Environmental Research Center, Washington, D.C., 20460), research in this area is in progress at the Department of Agricultural Economics at Oregon State University. The research is expected to be completed by December 31, 1974. Also, in-house research is being conducted by the Center in this area.

inpatient medical costs (so-called direct medical costs) plus indirect costs (days lost from work because of air pollution, etc.).[2]

[2]The United States Environmental Protection Agency (Washington Environmental Research Center, Washington, D.C., 20460) is in the process of negotiating a contract to accomplish this objective. The area of study will be the St. Louis Standard Metropolitan Statistical Area. The study is scheduled to be completed by June 1976.

III. INTRODUCTION

The Problem

For informed and economically efficient decisions to be made in managing the environment, adequate information must be provided to the decision-maker. One of the main problems of air quality management is balancing the benefits that society derives against the costs incurred from using the atmosphere for waste disposal. To strike such a balance, the decision-maker must have quantitative estimates of the costs and benefits associated with achieving certain environmental quality levels. The provision of such estimates involves difficult issues of measurement and evaluation.

While dependable systematic estimates of costs resulting from the effects of air pollution are still quite rare, progress is being made. Within the past decade several studies have been completed, estimating property and material costs of air pollution and the effects of pollution on property values [25, 38, 47]. An important cost yet to be measured, with any high level of confidence, is the medical costs attributable to air pollution. Considerable evidence in the medical literature exists to support the hypothesis that air pollution affects human health and, particularly, aggravates certain respiratory and cardiovascular diseases [19, 68, 69]. Adverse health effects of air pollution result in economic losses of unknown magnitudes. These losses to society emanate from two main sources: (1) the medical costs incurred in treating the disease, and (2) the value of the ill person's foregone production while sick. It is the purpose of this research to estimate some of the outpatient medical costs attributable to air pollution.

The data bases afforded this research appeared to offer an opportunity to overcome some data deficiencies observed in earlier medical studies investigating the effects of air pollution on health. More specifically, in the Portland, Oregon, Standard Metropolitan Statistical Area (S.M.S.A.) air pollution data were available from several air pollution control agencies, and were representative of the main air pollution problem in the study area, suspended particulate matter. Adequate meteorological data were available from several National Weather Service stations. An excellent source of individual medical data was provided by Kaiser Foundation Health Plan. This allowed the research effort to concentrate on the effects of air pollution on specific quantities of outpatient medical services consumed. This is in contrast to other air pollution-health effects studies which used a more aggregative approach (number of doctor office visits, number of hospital admissions, etc.) in attempts to delineate the effects of air pollution on health. Detailed socioeconomic-demographic data were maintained with the medical data. Hence, the fact there appeared to be available reasonably good data on a wide range of relevant phenomena affecting medical consumption (air pollution, meteorological, medical, and socioeconomic-demographic) held special promise for productive empirical research.

Objectives

The objectives to be accomplished by this research are as follows:

1. To present an economic model of consumer choice, from which relevant hypotheses about the consumption of medical services can be derived.

2. To identify certain cardiovascular, respiratory, and other diseases which can be aggravated by air pollution.

3. To estimate the effect of air pollution, if any, on the consumption of outpatient medical services used to treat the diseases.

4. If there is an effect of air pollution on the consumption of outpatient medical services, to quantify this effect in monetary terms.

5. To determine the effect, if any, air pollution has on the incidence rate of the diseases identified in (2) above.

The first of the above objectives is accomplished in Chapter IV of this report. It presents the economic framework, and the statistical models and hypotheses to be tested. The study area and the Kaiser Health Plan are described in Chapter V. Chapter VI details the compiling of the medical data and the construction of the dependent variables in the statistical models. The collection of the socioeconomic-demographic data and the formation of the socioeconomic variables included in the statistical models are discussed in Chapter VII. The collection and organization of air pollution and meteorological data, and the assigning of air pollution and meteorological values to the observations on medical costs are explained in Chapter VIII. Chapter IX presents the results of the analysis.

IV. THEORETICAL FRAMEWORK

The Economic Model

This section begins by specifying some of the assumptions used to formulate the economic model upon which this study is based. A graphic presentation of the economic model is given. From the graphic specification, two important implications are drawn which minimize the importance of medical service prices and income in explaining the consumption of medical services for certain cardiovascular-respiratory diseases.

In order to isolate the effect of air pollution on health, account must be taken of other variables which could influence the consumption of medical services. A general framework is specified, which delineates some of these characteristics. From the general framework, the hypotheses and the statistical models to test them are derived.

Some General Assumptions

Assume there is a representative consumer-patient who is suffering from, or has a tendency to become afflicted by, certain diseases associated with air pollution. This consumer is a free agent to enter the market for medical care. There are no physical constraints which would prohibit him from obtaining such care.

This study is concerned only with the short-term effects of air pollution on pre-existing (chronic) and acute cases of certain respiratory, cardiovascular, and other diseases. These diseases are thought by the medical profession to be aggravated by air pollution, or have been shown by previous studies to be associated with air pollution.

Diseases of the cardiovascular and respiratory system affect two essential life systems of the body. Many of these diseases, if left untreated, are fatal, or inflict such pain, suffering, and mental anguish upon the victim as to result in a decrease of life's enjoyment. It is assumed that any consumer presently having any of the diseases, or newly contracting one of them, would be aware of these consequences. Given the choice between the alternatives, it is assumed that the representative consumer will actively seek medical care to maintain or improve his state of health.[1]

It is argued that the consumer is unable to effectively evaluate medical care, and has to rely primarily upon the physician's advice for the treatment required to remedy the illness. Most consumers do not have the expertise to effectively evaluate alternative bundles of medical services which could be used to treat their disease, or to judge the quality of physician services provided to them. There are so many variables which affect diseases from one incident to the next that, in many instances, it is difficult even for the physician to determine what to do.

Each disease incident will have a different degree of acuteness or severity, requiring a different intensity of treatment. It is argued that there is a certain minimum amount of medical care, given the type of disease and its degree of severity, which will maintain or improve the consumer's state of health,[2] and that this will be the minimum treatment level prescribed by the physician.

Graphic Specification of the Economic Model

A consumer's expenditures on medical care evolve from his preference map for medical services and other goods. The shape of his indifference map will be different, *ceteris paribus*, depending on whether he is ill or not. If he is ill, the shape of the indifference curve will be affected by the severity of

[1] Obviously, for this to hold, it is necessary to assume that life is preferable to death and that, if given a choice, one would choose to be free of pain and suffering. A second supposition is that the consumer expects the consumption of medical services to alleviate his illness.

[2] A consumer's state of health will change over time, and will be dependent upon many socioeconomic-demographic characteristics as well as the type of disease contracted. The consumption of medical services may do no more than preserve a patient's health state, or retard the rate of change toward further deterioration (terminal cancer, for example, where treatment just postpones the inevitable). In other instances, the consumption of medical services may cure the patient of the disease and improve his health state.

the disease state. The severity of the disease state can be influenced by the air quality the patient is subject to, as well as the patient's socioeconomic-demographic status. In the following, attention is focused only on the hypothesized effect air pollution might have on the disease state.

Figure 1 refers to a consumer in a good state of health. Money is shown on the vertical axis, and services as a numerative for all commodities other than medical services. Medical services are shown on the horizontal axis, and are expressed as an index. The index denotes the physical quantities of all medical services consumed to treat an illenss. Excluded from this index are items which would be considered frills of medical care and which are not needed to treat the patient's illness.

The usual assumptions about the indifference curves in Figure 1 hold: utility is constant for movements along an indifference curve, a higher indifference curve is preferred to a lower indifference curve (I''' is preferred to I"; I" is preferred to I'), the indifference curves do not intersect, and they are concave from above.

The slopes of these curves play an important role in the analysis. It can be expected that the preference for the consumption of medical services is not strong for the well consumer. He may need medical treatment of a preventive nature (immunization shots and yearly physical checkups, for example), or anticipate the consumption of some medical services in case he does get ill. Under these circumstances, the marginal rate of substitution of medical services for money will be declining rapidly. A point of satiation is reached, and additional medical services become a discommodity. Points E, F, and G on I''', I", and I', respectively, in Figure 1 are such points of satiation.

OM in Figure 1 is defined as the consumer's permanent income. MW represents his budget constraint, given the price for medical services. M'S would be the optimum quantity of medical services consumed. If the consumer were to buy health insurance, MJ would represent the premium costs. The lower unit costs of medical services with insurance would be reflected in JP. This budget

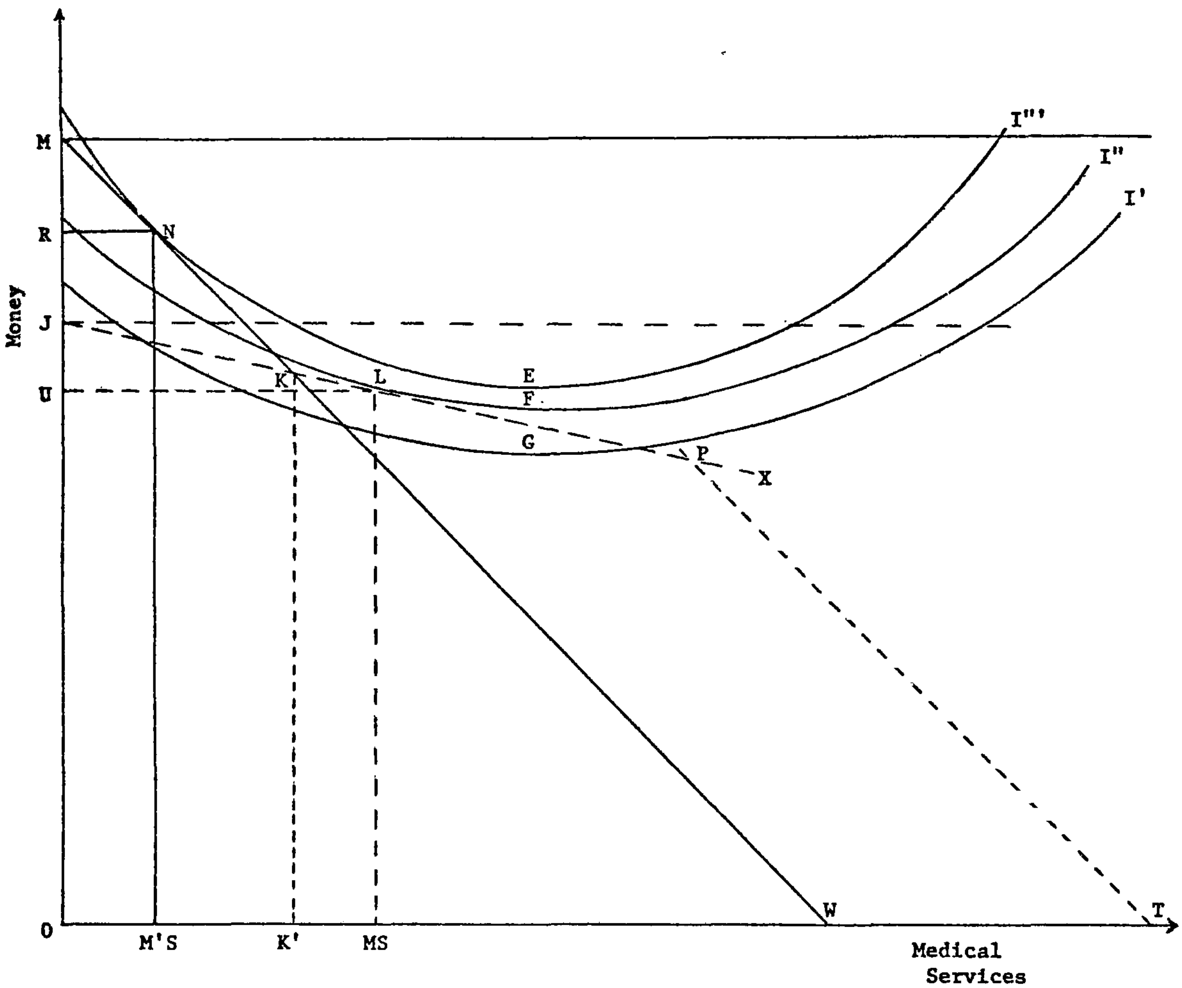

Figure 1. Preference map of a well consumer.

constraint continues as PT (with the same slope as MW) to the right of P as the limits of the insurance policy are exceeded.[1] With insurance, MS would be the optimum quantity of medical services consumed.

K' is an important point in the decision to purchase medical insurance. If the consumer expects that his consumption of medical services would be less than K', he would be better off not to purchase insurance. Up to K', the total monetary outlay for the same quantity of medical services would be less without insurance than with insurance (premium cost MJ plus the cost of medical services with insurance, as reflected by the price line JP).

Admittedly this framework is an oversimplification. It fails to address the question of the consumer's feelings about uncertainty. However, it will be apparent later that this issue is not central to this study.

Assume that the same consumer has become ill with a disease aggravated by air pollution. Reference is made to Figure 2, where MS_{a_1} is defined as the amount of medical services needed in attempts to preserve, improve, or prevent further deterioration of the consumer's state of health.[2] Except where it is noted, everything in Figure 2 is defined as in Figure 1. Any treatment level to the left of MS_{a_1} can be attributed to additional medical care beyond that needed to maintain the person's health state.

QSI''', QLI", QNI', and QVI are defined as indifference curves in Figure 2. Given the alternatives of premature death or continued pain and suffering when the treatment is not obtained, a consumer would be willing to give up any amount of money in order to receive the maintenance level of treatment. The marginal rate of substitution of medical services for money rapidly declines. Hence, as with

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[1] It is assumed, for the purposes of this discussion, that the limits of the policy are not exceeded. Thus, JP would be the relevant portion of the consumer's budget constraint.

[2] Hereafter the words "maintaining the consumer's state of health" will have the same meaning as "preserve, improve, or prevent further deterioration of the consumer's (patient's) state of health."

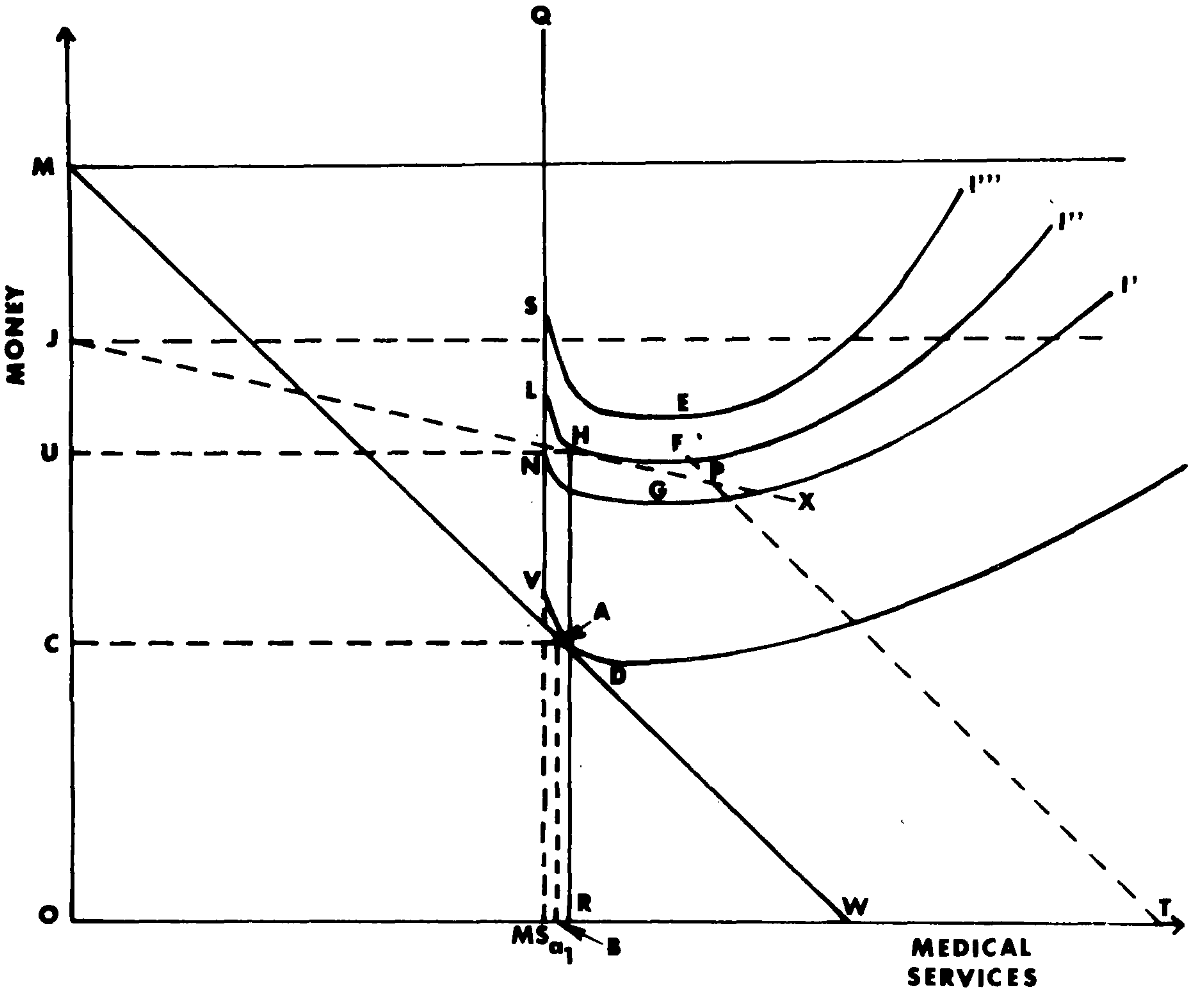

Figure 2. Preference map of an ill consumer given air quality a_1.

Figure 1, it does not take too much additional treatment for the consumer to become satiated of medical services. This satiation level is represented by E, F, G, and D on QSI''', QLI', and QVI, respectively.

Medical services, MS_{a_1}, are prescribed by the physician. The consumer will at least purchase MS_{a_1} of medical services in his desire to maintain his state of health. The relevant portion of the consumer's budget constraint, with insurance, is JP, which is tangent to the indifference curve QLI" at H. The consumer purchases slightly more medical services at R than the recommended MS_{a_1}. At this tangency, utility is maximized and the consumer will pay, in addition to MJ on health insurance, JU for the purchase of R medical services.

It should be noted that the optimum quantity of medical services purchased by the uninsured patient is not greatly different from R, although the patient will be worse off than he would be if he were insured. To see this in Figure 2, construct a line (MW) running through M and parallel to PT. To consume the required medical services MS_{a_1} without insurance would place the consumer on an indifference curve well below QLI". More specifically, utility is maximized at tangency point A on indifference curve QVI. The patient consumes B medical services and pays MC for it.

What happens if air quality deteriorates from a_1 to a_2? Assuming that the consumer is afflicted with a disease aggravated by air pollution, one would expect a tendency for the patient to become ill more often, and/or the severity of each disease incident to increase. In both instances the result implies an increase in demand for medical services. This situation is portrayed in Figure 3. All definitions that applied to Figure 2 are also applicable to Figure 3. The consumer's entire preference map for medical services has shifted to the right. Now MS_{a_2} is the quantity of medical services required to maintain the patient's state of health. The consumer's relevant budget constraint is again JP, which is tangent to QNI' at V. The consumer will pay the insurance premium plus JZ for the consumption of Y medical services.

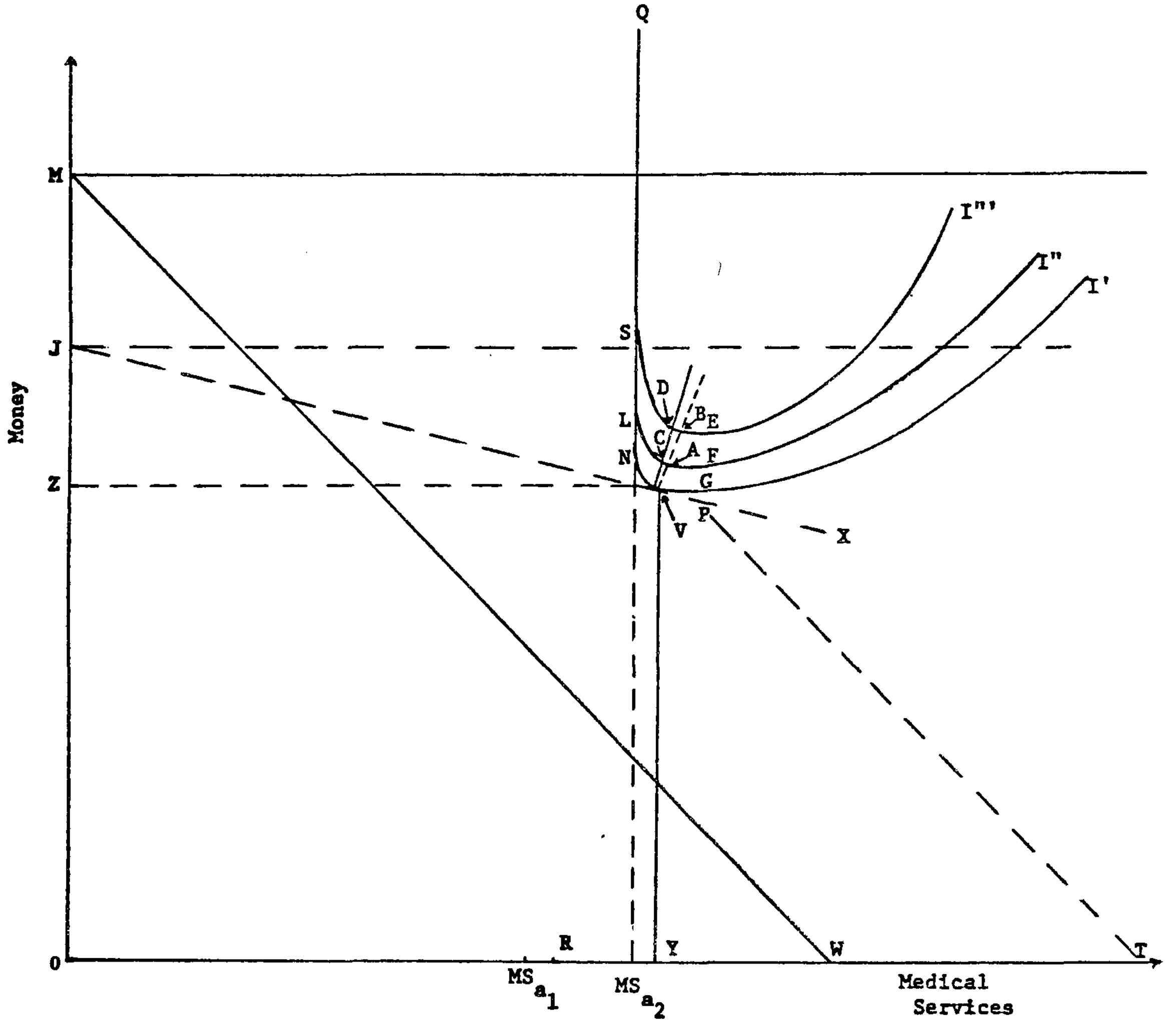

Figure 3. Preference map of an ill consumer given air quality a_2.

In comparison with Figure 2, MS_{a_1} is less than MS_{a_2} (the amount of medical services necessary to maintain the consumer's state of health has increased); JZ is greater than JU (total monetary outlay for medical services has increased). From a monetary standpoint the consumer is worse off. The increase in the consumption of medical services resulting from the deterioration in air quality, and the resulting increase in monetary outlay for medical services (the difference between JZ and JU), represents an economic cost which could have been foregone if air pollution had not increased.

Two important implications can be drawn from Figures 2 and 3 with respect to the price and income elasticities of demand for medical services. In Figure 3 the dashed line connecting points VAB represents a price consumption curve.[1] The curve is steeply, positively sloped, and shows that as the price of medical services changes, the amount of medical services demanded changes proportionately less: the price elasticity of demand for medical services is highly inelastic. Also in Figure 3 the solid line connecting points VCD represents an income consumption curve.[2] The curve is highly positively sloped and illustrates that the amount of medical services demanded will not change materially with changes in the consumer's income: income elasticity of demand for medical services is close to zero.

The demand for medical services to treat diseases affected by air pollution is assumed to be <u>price inelastic</u>. This assumption follows from the consumer's preference map discussed earlier.[3] This assumption is particularly relevant

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[1] The price-consumption curve is the locus of utility maximization points achieved when nominal money income and the price of one good are held constant, while the price of the other good is allowed to vary. The locus of equilibrium points is obtained graphically in Figure 3 by letting JX rotate about J until a tangency point is obtained with each indifference curve.

[2] The income-consumption curve is the locus of utility maximization points achieved when the nominal money income of the consumer is allowed to vary and the prices of the two goods are held constant. The locus of equilibrium points is obtained graphically in Figure 3 by drawing other lines parallel to JP and tangent to each indifference curve.

[3] The assumption of price inelastic demand is supported by empirical evidence. Other studies have shown price elasticity of demand for medical services (physician and hospital) to be highly inelastic [13, pp. 66-67, 72-76].

to the Kaiser data. The main cost of participating in the system is the insurance premium of a fixed amount. In many instances the premium is paid by the employer. Hence, the costs to the Kaiser patient of using the system, in addition to the insurance premium if he should pay it, are his private costs of time and transportation and some minimal charges for physician visits and drugs.

The assumption of low income elasticity of demand for medical services[1] does not deny the fact that certain amenities of medical care might be a function of income. Kaiser's emphasis is to provide the necessary medical services to treat an illness. Conveniences not necessary for such treatment are not provided. For example, amenities such as the use of a private room, when a bed in a ward would afford the same medical services, are not obtainable at Bess Kaiser Hospital in Portland.

Medical treatments for diseases associated with air pollution are not close substitutes for non-medical consumption goods; i.e., the cross-price elasticity between medical treatment for these diseases and other commodities is zero, or near zero. The acceptance of this assumption rests upon the nature of the diseases being examined. An assumption of zero cross-price elasticity does not negate the fact there might be treatment substitutes within a bundle of treatments used to treat a disease incident. However, once a treatment method is decided upon, a minimum amount is required and changes in the prices of other, non-medical goods will not affect the quantity of medical services purchased. This implies that shifts in the demand for medical care used in treating diseases affected by air pollution will be minimal as the prices of other goods change. Again, this assumption is not inconsistent with the Kaiser data.

With a prepaid medical system where, in many instances, the insurance premium is paid by someone other than the patient, the price of medical services

[1] Empirical evidence on relationship between income and physician services consumed has been found which, to some extent, supports this assumption. Anderson and Benham [2] found income elasticities, using permanent income and taking other variables into account (demographic characteristics and preventive care, among others) to be fairly low (less than 0.30). By substituting the quantity of physician services consumed for the monetary outlay (dollar expenditure by the consumer) on the same services, they found income elasticity to be as low as 0.01 [2, p. 90]. The measures of elasticity differ because of free medical care provided at low, or no cost to poorer consumers.

and the patient's income play a minimal role in his consumption of services. The assumptions with respect to price, income, and cross-elasticities of demand, backed to some extent by empirical evidence from other studies, allow the following argument to be made. The consumption of medical services in the treatment of certain diseases is not affected by the price of the services or the patient's income, regardless of the sources from which care was received. Hence, the use of a prepaid system such as Kaiser's can be used to approximate the medical costs of certain diseases associated with air pollution, and the estimates derived will be representative of other medical systems.

Before closing the discussion on the theoretical model, it is important to emphasize that the preference maps in Figures 1, 2, and 3 are based upon a prescribed set of assumptions. The maps are drawn to explain why a hypothetical consumer would seek medical care. This does not deny the fact that a person having a disease affected by air pollution may not seek medical care and, hence, have a preference map quite different from that described. While such occurrences can result in social costs (through value of production foregone, etc.), no demand for medical services is placed upon the system. These types of incidences and costs are not accounted for within the present model.

A Broader Framework of Analysis

In order to estimate the effect of air pollution on the consumption of medical services, account must be taken of some other conditions which could influence the consumption of medical services and disease incidence rates. These can be broadly grouped into socioeconomic-demographic variables and meteorological phenomena. This section expands on the graphic presentation given above, and examines such variables.[1]

The Kaiser membership contains N people. On a given day (j) there is a level of air pollution which is assumed (for illustrative purposes) to be higher than the previous day (j-1). The effects of air pollution on health, and the

[1]This section has been formulated with the Kaiser data base specifically in mind. However, with some modification, the concepts illustrated have applicability to other medical systems.

hypothesized increase in demand for medical services on day j, or shortly thereafter, can show up in two ways. Each establishes a testable hypothesis about air pollution effects on health: (1) deterioration in air quality can increase the severity of the disease (i), requiring additional, and perhaps more intense, medical care beyond that which would normally be incurred; and (2) increases in air pollution can precipitate an increase in the number of contacts with the medical system per certain disease categories.

The general framework to be developed for testing the first hypothesis is specified in Equation (1). The other explanatory variables needed to isolate the effect of air pollution on health are also indicated.[1]

$$I_{ijk} = h(A_{jk}, W_{jk}, S_{ijk}) \tag{1}$$

where I_{ijk} = an index of medical services consumed (inpatient and outpatient) for treatment of the i^{th} disease (per disease incident or episode) resulting from exposure to air pollution on the j^{th} day for the k^{th} person;

A_{jk} = a measure of air quality on day j for the k^{th} person;

W_{jk} = a measurement of meteorological conditions on day j for the k^{th} person;

S_{ijk} = the socioeconomic-demographic characteristics of the k^{th} person, on the j^{th} day of exposure, for the i^{th} disease; and $(i = 1, \cdots, n)$; $(j = 1, \cdots, m)$; $(k = 1, \cdots, \ell)$.

Index of Medical Services - An index of medical services consumed (I) would overcome some of the inherent disadvantages incurred by using dollar expenditures

[1] It is recognized in the formulation of this model, and all other models to follow, that there can be lags of several days between the onset of disease (i) and exposure to air pollution or meteorological conditions. While the lags are not specified within the definitions of the variables, the potential for them to exist is understood, and is explored in the statistical analysis.

for medical services. The index would be based on physical quantities of medical services consumed, would permit aggregation of different kinds of medical services, and would reflect the intensity of medical services[1] used to treat the disease state. The index, if constructed properly, would more adequately reflect the quantity of medical services consumed than would dollar expenditures on medical services, because of variations in fees charged for services performed, and the availability of free medical care to some patients.

Air Quality - The possible effects of a deterioration in air quality (A) on the demand for medical services are many. Exposure to most pollutants in sufficient concentrations and for long enough time periods can result in harmful physiological effects on the human body. This presentation will give a brief summary of some of these effects.

Particulate matter can affect human health by its chemical composition and size. The particle may be intrinsically toxic due to its innate chemical and/or physical characteristics [59, p. 141]. For example, sulfur dioxide, when absorbed on particulate matter, can impair lung tissue [41, p. 37]. Particles smaller than two or three microns[2] can penetrate deep into the respiratory system [41, p. 33].

A number of recent laboratory and clinical studies have led to a concern that subtle cardiovascular and central nervous system effects may be associated with elevated levels of carbon monoxide in the ambient air [62, p. 9-1]. Photochemical air pollution can cause eye irritation [1, p. 96] and aggravate respiratory diseases [64, p. 9-30]. Hydrocarbon air pollutants, which enter into and promote the formation of photochemical smog, have been associated with eye irritation. Aldehydes, also part of photochemical smog reactions, have been shown to irritate the eyes and upper respiratory tract [63, p. 7-27].

Sulfur dioxide, at high enough concentrations, irritates the upper respiratory tract [41, p. 37]. A significant correlation has been shown between mortality

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[1] For a given disease there may be several disease states, each state differentiated by its relative degree of severity. The intensity of medical treatment used in treating each state is dependent upon the severity of that state.

[2] A micron is approximately 1/25,000 of an inch [61, p. 1].

resulting from chronic bronchitis and sulfur dioxide in England and Wales [41, p. 69].

Meteorological - Meteorological conditions (W) can act independently of, as well as in conjunction with, air pollution to place additional stress on the body, and possibly increase the consumption of medical services. Temperature and humidity have an unquestioned effect on health [8, p. 200]. Extremes of temperature can place strain on the body and nervous system; prolonged cold spells can contribute to exhaustion [32]; cold temperatures can decrease mucous transport which, by means of the cilia, is one of the main methods of cleansing airborne matter from the lungs [29]. Winter, weather fronts, and fog are related to the onset and increased severity of chronic bronchitis [42, p. 11]. Exposure to cold, fog, or smog may need to be avoided by asthmatics [42, p. 64]. Low temperature, low humidity, a wide range in barometric pressure, and wind have been shown to be associated with the daily prevalence of common cold and cough symptoms [9, p. 524]. In another study, temperature (on the day the illness started, or a few days prior) seemed to be highly associated with upper respiratory disease incidence [49, p. 738].

Intense radiation can lead to heat stroke; intense cold can increase pulmonary disease [18, pp. 80-81]. Many physicians believe that shortness of breath, in those prone to heart attacks, is increased during spells of hot, muggy weather, and that fatigue worsens in foggy weather [36, p. XIV]. It was found in the Netherlands that the highest mortality from arteriosclerotic heart disease occurs during the coldest months of the year (January and February) [50, pp. 507-508].

Meteorological conditions can interact with air pollution to produce an environmental situation which can produce adverse health effects [9]. These effects are precipitated through chemical reaction of certain pollutants with each other and with certain environmental phenomena to produce new, and sometimes unknown, substances. These chemical reactions are affected by the presence of wind, sun, and humidity. The best known example of these chemical reactions is the photochemical reaction between oxides of nitrogen and other organics in the presence of sunlight. The effects on health of the resulting photochemical air pollution, or Los Angeles smog as it is more popularly known, have already been documented.

Certain meteorological conditions can increase the build-up of air pollutants in the environment. Many past air pollution disasters (Meuse Valley, Belgium, 1930; Donora, Pennsylvania, 1948; London, 1952 and 1962, among others) have been characterized by prolonged, anticyclonic high pressure with a secondary inversion [7, p. 2]. An inversion acts as a lid, and retains below it all pollution emissions to the atmosphere, hence effectively retarding their dispersion. Air pollutants build up and a minor air pollution problem can become a severe episode if the meteorological conditions under which it was incurred continue.

Chemical reactions of pollutants with each other, the interaction of pollutants with certain meteorological phenomena, and the resulting creation of new pollutants, or substantial increases in the amounts of pollution, will usually be reflected through adequate air monitoring. However, it is possible that meteorological conditions and air pollution may act interdependently to adversely affect a disease state. That is, the simple air pollution or meteorological condition by itself, and in the absence of the other, may not adversely affect a disease state. However, in combination with each other they may adversely affect the disease condition. Such combined effects would not be reflected by single measurements of different air quality or meteorological phenomena. Hence, in pursuing a study of this type, one should be aware of the interdependence possibility.

Socioeconomic-Demographic - Other studies have shown that certain socioeconomic-demographic variables (S) play an important role in the incidences of some diseases affected by pollution [34, 37, 68]. It would seem that, to the extent certain variables affect the health of the individual, they should also affect the amount of medical services consumed in treating the disease. Included within (S) are several socioeconomic-demographic variables which would appear to be important in explaining the consumption of medical services and the individual's state of health.

The smoking characteristics of the patient are expected to play an important role in his consumption of medical care. Heavy smoking can aggravate certain respiratory diseases (emphysema and bronchitis, for example), and place additional stress on the body's cardiovascular system.[1]

Cessation of cigarette smoking has been shown to be associated with a decrease in the prevalence of symptoms related to smoking (cough and shortness of breath, for example) [65, p. 146]. Numerous other studies have shown the prevalence of cough, sputum production, breathlessness (dyspena), and chronic bronchitis, among other respiratory conditions, to be consistently higher for ex-smokers when compared to nonsmokers, and lower when ex-smokers are compared to cigarette smokers [65, pp. 195-205]. Other studies (reported on in the Surgeon-General's report on the health consequences of smoking) reveal that the risk of developing lung cancer decreases with smoking cessation [65, p. 11]. Most studies indicate that after ten years of not smoking cigarettes, the ex-smoker's chances of dying a premature death due to a smoking-related disease is less than that for a smoker, and slightly greater than that for a nonsmoker.[2] The residual effects of past smoking habits can still aggravate certain respiratory diseases. The more recent the ex-smoker stopped smoking, the greater the potential for consuming more medical services. The studies also indicate that there are certain long-term effects of cigarette smoking, some of which are irreversible [65, p. 145].

The occupation of the individual could affect the consumption of medical care. It is known that exposure to dusts can aggravate asthma [27, p. 34] and chronic bronchitis [42, p. 13]. Hence, it would seem that dustier occupations could increase the consumption of medical services for individuals with a respiratory ailment.

The residential history of the patient is also important. Studies have shown that the incidence and death rates from emphysema and cancer are higher in cities than in the relatively non-polluted rural areas [41, pp. 71-72]. It is argued

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[1] See particularly the following [10, 27, 41, 42] for the effects of smoking and air pollution on certain respiratory-cardiovascular diseases.

[2] Obtained from the American Cancer Society, and based on its slide series, "The Time to Stop is Now."

that an individual's state of health would be better if he had lived most of his life in a rural area or other unpolluted environment. The writers feel that, if this were the case, when a patient does become ill his disease state would be less chronic, and require less consumption of medical services.

The incidence rates of certain diseases are more prevalent in certain age, race, and sex groups [10, p. 13; 42, p. 39]. Hence, it is felt race, age, and sex are three variables which could influence the demand for medical services by an ill person. If some diseases are more predominant in certain age, race, and sex groups, then persons within these groups having the diseases might be more acutely ill than individuals outside the groups who might also contract the disease. Also, with increasing age, the efficiency of the lung function declines. This is probably due to a decrease in elasticity of lung tissue, increasing inflexibility of the chest wall, and, perhaps, to impairment of the regulation of ventilation and the efficacy of cough [10, p. 16]. Such aging lung conditions would tend to impair the clearance of pollutants from the respiratory tract, which could result in increased aggravation of respiratory diseases and an increase in the consumption of medical services.[1] Also, increased aging could be one of the main causes of chronic obstructive pulmonary diseases [10, p. 16].[2] Generally, one would expect an older person to have a poorer state of health when compared to a younger person.[3]

Another social habit which might affect a patient's consumption of medical services is his drinking habits. Excessive consumption of alcohol can affect a person's state of health (emotionally, mentally, and physically). Alcoholism can play a role in pulmonary tuberculosis [42, p. 32]. Excessive consumption of alcohol leaves a person's body in such a physical state that, if he did become ill, the consumption of medical services could be increased. Alcoholism has been extensively associated with respiratory problems.[4]

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[1]Conversation with Sheldon Wagner, M.D., Oregon State University - Environmental Health Unit; Good Samaritan Hospital, Corvallis, Oregon; August 25, 1971.

[2]Chronic obstructive pulmonary disease is a term which applies to those patients with chronic bronchitis, asthma, and anatomic emphysema who exhibit persistent obstruction of bronchial flow [10, p. 7].

[3]Sheldon Wagner, M.D., August 25, 1971.

[4]Sheldon Wagner, M.D., August 25, 1971.

It is felt that the more physically active a person is, the better his state of health. This implies that when a person does become ill, the disease case could be milder, which would mean fewer medical services required in the treatment of the disease incident.[1] There is a suspected association between lack of physical exercise and coronary heart disease [20, p. 15].

The number of persons per room within the patient's home would be an indication of crowding within the patient's environment. Crowded conditions could result in increased consumption of medical care. More crowded conditions lead to increased physical and emotional strain being placed upon the individual, and the increased possibility of initial infection and reinfection with certain respiratory diseases (tuberculosis, for example) [42, p. 31.]

The income of the patient is included in an attempt to describe the consumer's ability to make expenditures, in lieu of medical expenditures or services, preserving and bettering his state of health. Examples of such expenditures would be those made for sound housing and nutritional food. One would expect the consumer to consume more medical services if he is unable to make such expenditures, and his state of health deteriorated as a result.

The marital status of the patient could explain some consumption of medical services. Available evidence indicates that single persons spend more total days in the hospital than married persons [13, p. 60]. This could simply be a reflection of the fact that the married person may have someone available at home to care for him when he is ill. There may also be other reasons for a better health state of the married person compared to the single person.[2]

The general framework specified in Equation (1) would afford a test whether air pollution increases can cause greater utilization of medical services by increasing the severity of a disease state. To determine whether deterioration in air

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[1] Sheldon Wagner, M.D., August 25, 1971.

[2] For the reader seeking a more detailed presentation of these reasons, see [26, pp. 41-42].

quality can precipitate an increase in the number of contacts[1] with the medical system for certain diseases requires another general model, which is illustrated by Equation (2).

$$n_{icj}/N_{cj} = t(\overline{A}_{cj}, \overline{W}_{cj}, \overline{S}_{cj}) \qquad (2)$$

where n_{icj} = the number of people in geographic area c making contact with the medical system for disease i on day j;

N_{cj} = the total number of people living in geographic area c on day j;

$\overline{A}_{cj}$ = an average measure of air quality over geographic area c on day j;

$\overline{W}_{cj}$ = an average measure of meteorological conditions over geographic area c on day j;

$\overline{S}_{cj}$ = an average of socioeconomic-demographic characteristics of people living within geographic area c on day j; and

$(c = 1, \cdots, p)$; $(i = 1, \cdots, n)$; $(j = 1, \cdots, m)$.

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[1] Other studies investigating the effect of air pollution on health have tested whether air pollution precipitates an increase in the incidence of disease i. After further investigation, incidence was discarded as a potential dependent variable, and the number of contacts with the medical system substituted in its place. The reasons are as follows. Incidence is defined as an expression of the rate with which a certain event occurs, such as the number of new cases of a specific disease occurring during a certain time period [11, p. 730]. The problem with incidence is that the disease must be a new case before it is measured; i.e., the disease must be a new episode. Many chronic and acute respiratory diseases can be part of a continuing episode, and be affected by air pollution such as to precipitate additional visits and/or contacts with the medical system. Use of the incidence would not reflect those additional contacts and, hence, would inadequately express demands placed on the medical system as they might be affected by air pollution. The problem is solved by using the number of contacts with the medical system, which includes not only new but continuing contacts for certain disease categories.

The independent variables in Equation (2) are expressed as a mean over a geographical area (census tract, for example). The approach outlined in (2) offers one method of seeing whether differences in air quality, meteorological, and socioeconomic-demographic conditions can play a role in people contracting disease i, irrespective of the amount of medical services consumed per disease incident.

The arguments for including the explanatory variables $\bar{A}_{cj}$, $\bar{W}_{cj}$, and $\bar{S}_{cj}$ in Equation (2) are similar to the arguments given for their inclusion in Equation (1). The principal influence of $\bar{A}_{cj}$, $\bar{W}_{cj}$, and $\bar{S}_{cj}$ in Equation (2) is that they affect a state of health, hence making the patient more susceptible to certain cardiovascular-respiratory problems. Therefore, $\bar{A}_{cj}$, $\bar{W}_{cj}$, and $\bar{S}_{cj}$ are expected, with some exceptions discussed below, to have the same causal relationships on disease incidences as A_{jk}, W_{jk}, and S_{ijk} had in the consumption of medical services in Equation (1).

Several additional variables are included in $\bar{S}_{cj}$ which were not considered in S_{ijk}. These variables would be expected to influence the contact rate with the medical system (n_{icj}/N_{cj}), but would not necessarily influence the consumption of medical services (I_{ijk}) per visit. The variables are reading of medical literature, distance to the nearest clinic or hospital, and a measure of the hypochondriac tendencies of the patient to contact the medical system.

The reading of <u>medical literature</u> could explain differential information and preferences toward recognizing the need for, and in appreciating the desirability of, seeking medical care. Such reading would increase the patient's medical awareness. This would, in many instances, imply contact with the medical system and the consumption of medical services. Even if medical services were not provided to the patient, contact with the system, where a disease is positively identified, would constitute a disease incident. It is expected that the increased awareness of the patient to medical phenomena will be positively related to disease incident, particularly with respect to patients having the cardiovascular-respiratory problems with which this study is concerned.

<u>Distance to the nearest hospital or clinic</u> reflects, in part, the out-of-pocket costs and inconvenience to the patient of obtaining medical care. All Kaiser

clinics are located within the immediate Portland area,[1] and the hospital is located in North Portland. Hence, it is quite possible that patients living in outlying areas would substitute (for Kaiser services) medical services closer to their place of residence. Longer distances could delay the patient from seeing the Kaiser doctor, or not seeing him as often. Such situations would have direct bearing on the contact rate with the system. Therefore, it is expected that the farther patients have to go in obtaining medical services from Kaiser, the lower will be the disease incidence reflected in the Kaiser data.[2]

The medical hypochondriac has a morbid fear or anxiety about his health state. While it is highly unlikely that such a mental state will actually affect the marginal consumption of medical services per visit, it could affect the incident rate because of the tendency for the patient to contact the system more often. Hence, a measure of the patient's tendency to contact the system at the first sign of a perceived illness should be included within the analysis.

The framework specified in Equation (2) would afford a test whether air pollution can precipitate an increase in the incidence of certain diseases. The next section will specify the null hypotheses to be tested, and delineate the statistical models by which they will be tested.

Specification of the Statistical Models

The first null hypothesis to be tested is as follows:

> Ho_1: Deterioration in air quality causes no increase in the consumption of medical services per outpatient contact with the medical system.

Equation (3) permits the testing of this hypothesis.

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[1] One clinic is in Vancouver and one is in Beaverton (see Figure 4 in Chapter V). The other three clinics are located within the Portland city limits.

[2] This would imply that as the out-of-pocket costs of using Kaiser facilities increase with distance, the demand for Kaiser medical services becomes more elastic. However, demand for medical services as a whole would still remain inelastic because medical services from other facilities closer to the patient could be substituted for the Kaiser services.

$$Y_{ijk} = \beta_0 + \beta_1 X_{1ijk} + \beta_2 X_{2ijk} + \beta_3 X_{3ijk} + \beta_4 X_{4ijk} + \beta_5 X_{5ijk}$$
$$+ \beta_6 X_{6ijk} + \beta_7 X_{7ijk} + \beta_8 X_{8ijk} + \beta_9 X_{9ijk} + \beta_{10} X_{10ijk}$$
$$+ \beta_{11} X_{11ijk} + \beta_{12} X_{12ijk} + \beta_{13} X_{13ijk} + \beta_{14} X_{14ijk} + \varepsilon_{ijk} \quad (3)$$

where Y_{ijk} = index of consumed outpatient medical services for disease i resulting from contact with the Kaiser system on day j by person k, converted to dollars.[1]

X_{1ijk} = age of the k^{th} person on day j who consumed outpatient medical services for disease i.

X_{2ijk} = sex of the k^{th} person who consumed outpatient medical services on day j for disease i (0 or 1 if the patient is male or female, respectively).

X_{3ijk} = marital status of the k^{th} person who consumed outpatient medical services for disease i on day j (0 or 1 if the patient is not married or married, respectively).

X_{4ijk} = number of people in the k^{th} patient's household who consumed outpatient medical services for disease i on day j.

X_{5ijk} = household income of the k^{th} patient who consumed outpatient medical services for disease i on day j.

X_{6ijk} = race (Negro) of the k^{th} patient who consumed outpatient medical services for disease i on day j (1 if Negro, 0 otherwise).

X_{7ijk} = race (others) of the k^{th} person who consumed outpatient medical services for disease i on day j (1 if of another non-White race, 0 otherwise).

X_{8ijk} = a great deal of time and energy expended by the k^{th} patient, who consumed outpatient medical services for disease i on day j, in being physically fit (1 if a great deal of time and energy expended, 0 otherwise).

X_{9ijk} = some time and energy expended by the k^{th} patient, who consumed outpatient medical services for disease i on day j, in being physically fit (1 if some time and energy expended, 0 otherwise).

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[1]As will be explained in Chapter VI, in order to express the effect of air pollution on health as an economic cost, the index was converted to dollar values. The conversions were undertaken in such a manner that, for the most part, variations in medical expenses would reflect direct variations in quantities of medical services consumed.

X_{10ijk} = a measure of the frequency of alcohol consumption by the k^{th} patient who is a heavy drinker, and consumes outpatient medical services for disease i on day j.

X_{11ijk} = an index expressing the cigarette smoking characteristics of the k^{th} patient consuming outpatient medical services for disease i on day j.

X_{12ijk} = an index of occupational exposure to job-related pollutants by the k^{th} patient consuming outpatient medical services for disease i on day j.

X_{13ijk} = a measure of the ambient air pollution that the k^{th} patient, who consumes outpatient medical services for disease i, is exposed to on day j (expressed as suspended particulates, micrograms per cubic meter per day).

X_{14ijk} = a measure of the meteorological conditions that the k^{th} patient, who consumes outpatient medical services for disease i, is exposed to on day j (expressed as degree days - the absolute difference between the average daily temperature and 65° F).

ε_{ijk} = a random error term, about which the usual statistical assumptions are made,[1] and

$(i = 1, \cdots, n)$; $(j = 1, \cdots, m)$; $(k = 1, \cdots, \ell)$.

$\beta_0, \beta_1, \cdots, \beta_{14}$ are the parameters to be estimated.

The second hypothesis to be tested by this study is as follows:

Ho_2: Deterioration in air quality does not precipitate an increase in the number of contacts with the medical system per disease category.

This hypothesis, using the framework specified in Equation (2), can not be tested directly because of an error made while specifying the statistical model. The independent variables were specified (per each census tract) only for Kaiser members who contacted the system. More specifically, the number of Kaiser members at risk for each census tract was known, and could be included within the dependent variables. However, the socioeconomic-demographic characteristics were

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[1]See [12, p. 17] for a detailed presentation of these assumptions.

known only for Kaiser members from each census tract who contacted the medical system. That is, the remaining socioeconomic-demographic characteristics of the population at risk were not included. Hence, a test of the model specified in the format was meaningless. The computer and programming expense to convert the error was prohibitive.

However, there did appear to be an alternative method of re-specifying the model which provided the possibility of testing the hypothesis indirectly. As previously mentioned, the socioeconomic-demographic characteristics of the population at risk could not be determined easily; however, the number of people at risk per census tract was known. Hence, an alternative to Equation (2) (Equation 5) was specified. Within its dependent variable are included the number of contacts per disease category which resulted in the consumption of medical services per census tract, and the number of people at risk per census tract.[1] The indirect test of the second hypothesis will become clearer with specification of the alternative model.

The dependent variable (Y_{icj}) of Model (5) is defined by (4) as follows:

$$Y_{icj} = \frac{\sum_{k=1}^{l} Y_{icjk}}{N_{cj}}, \qquad (4)$$

where $\sum_{k=1}^{l} Y_{icjk}$ = the summation of the index of consumed outpatient medical services for disease i for all k persons in census tract c on day j, converted to dollar values.

N_{cj} = the total number of Kaiser respondents residing in census tract c on day j; and

$(i = 1, \cdots, n); \quad (c = 1, \cdots, p); \quad (j = 1, \cdots, m); \quad (k = 1, \cdots, \ell).$

This leads to the specification of the statistical model (5).

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[1]As will be discussed in Chapter IX, even if the model to test the second hypothesis had been specified correctly, it could not have been tested because there were not enough observations per census tract.

$$Y_{icj} = \beta_0 + \beta_1\overline{X}_{1icj} + \beta_2\overline{X}_{2icj} + \beta_3\overline{X}_{3icj} + \beta_4\overline{X}_{4icj} + \beta_5\overline{X}_{5icj}$$
$$+ \beta_6\overline{X}_{6icj} + \beta_7\overline{X}_{7icj} + \beta_8\overline{X}_{8icj} + \beta_9\overline{X}_{9icj} + \beta_{10}\overline{X}_{10icj}$$
$$+ \beta_{11}\overline{X}_{11icj} + \varepsilon_{ijk}, \tag{5}$$

where $\overline{X}_{1icj}$ = the average age of patients consuming outpatient medical services for disease i from census tract c on day j.

$\overline{X}_{2icj}$ = the percentage of the female sex consuming outpatient medical services for disease i from census tract c on day j.

$\overline{X}_{3icj}$ = the percentage of married patients consuming outpatient medical services for disease i from census tract c on day j.

$\overline{X}_{4icj}$ = the average number of people per household in census tract c for individuals consuming outpatient medical services for disease i on day j.

$\overline{X}_{5icj}$ = the average household income in census tract c for individuals consuming outpatient medical services for disease i on day j.

$\overline{X}_{6icj}$ = the percentage of non-white patients in census tract c consuming outpatient medical services for disease i on day j.

$\overline{X}_{7icj}$ = the average frequency of alcohol consumption by heavy drinkers in census tract c who consume outpatient medical services for disease i on day j.

$\overline{X}_{8icj}$ = the average smoking index of patients in census tract c who consume outpatient medical services for disease i on day j.

$\overline{X}_{9icj}$ = average index of occupational exposure to job-related pollutants for patients from census tract c consuming outpatient medical services for disease i on day j.

$\overline{X}_{10icj}$ = the average measure of meteorological conditions for patients consuming outpatient medical services for disease i from census tract c on day j (expressed as degree days - the absolute differences between the average daily temperature and 65° F).

$\overline{X}_{11icj}$ = an average measure of ambient air pollution for patients consuming outpatient medical services for disease i from census tract c on day j (expressed in suspended particulate, micrograms per cubic meter per day).

ε_{icj} = a random error term, about which the usual statistical assumptions are made; and

$(i = 1, \cdots, n); (j = 1, \cdots, m); (c = 1, \cdots, p)$,

and $\beta_0, \beta_1, \cdots, \beta_{11}$ are the parameters to be estimated. Y_{icj} is as previously defined in (4) above.

The dependent variable in (5) is expressed as the per capita index of consumed outpatient medical services over census tract c on day j, converted to dollar values. Three separate items can influence the dependent variable in (5): (1) the consumption of outpatient medical services per visit (Y_{ijk} in (3)); (2) the number of contacts with the Kaiser system which result in medical services being consumed; and (3) the number of people at risk per census tract. More specifically, an increase, resulting from air pollution, in the number of contacts consuming medical services could cause the per capita index consumed of outpatient medical services (Y_{icj}) to increase (the number of people at risk and the amount of medical services consumed per visit assumed constant). Similarly, an increased consumption of medical services resulting or associated with air pollution would also increase (Y_{icj}) (the number of people at risk and the number of contacts with the Kaiser system assumed constant). It is highly probable that both of these effects operate together.

Assuming a significant association between air pollution and the per capita index of consumed outpatient medical services in (5), one could not determine whether the association would be caused by an increase in the number of contacts with the medical system or an increase in the consumption of medical services per contact. However, the null hypothesis associated with (3) permits a test on the consumption of outpatient medical services per visit and air pollution. If this hypothesis should not be rejected, and there is an association between air pollution and the per capita index in (5), then it could be implied that there is an association between air pollution and the number of contacts made with the Kaiser system.

The next four chapters deal with the collection, compiling, and processing of data for the variables in Models (3) and (5). Note that some of the socioeconomic-demographic variables discussed in the section titled <u>A Broader Framework</u>

of Analysis were not included in the statistical models. These variables were excluded because responses to questions eliciting the data were not specific enough to be included in the analysis. These variables are residential history, reading of medical literature, medical hypochondriac tendencies, and the distance to the nearest clinic.[1]

[1]See [26, pp. 111-114] for a more detailed discussion on this topic.

V. A DESCRIPTION OF THE STUDY AREA AND THE KAISER PLAN

The Study Area

The area of study centers within the Portland Standard Metropolitan Statistical Area (S.M.S.A.), with a population of 1,009,129 [53, pp. 39-175]. The S.M.S.A. is made up of Clackamas, Multnomah, and Washington Counties in Oregon, and Clark County in Washington. The study area is enclosed in the dashed lines in Figure 4. The study area boundaries were determined by the availability of air pollution data and proximity to the Kaiser medical facilities in Portland, Beaverton, and Vancouver. The study period was 1969 to 1970.

Portland, Oregon, population 381,927 [53, pp. 39-175], is the largest city in the S.M.S.A. and Oregon. The city is located in the northwestern part of the State, astride the Willamette River near its confluence with the Columbia River. Portland is an important trade, transportation, and manufacturing center for the Pacific Northwest. Racially, the S.M.S.A. is mostly white. The minority races are composed mostly of Orientals and Negroes [46, p. 394].

Portland is economically diversified. A number of national companies have branches located there [46, p. 395]. Food processing and related agricultural production, textiles, lumber and wood products including pulp and paper, chemicals, aluminum and other metal fabricating plants, shipping [46, p. 395], and tourism are Portland's major industries. Tourist visitation is particularly heavy in Portland during the summer, primarily because of the city's convenient location with respect to many seasonal recreational opportunities [58] and its annual Rose Parade held in early June.

Portland (including Vancouver) is located about 60 miles from the Pacific Ocean, and is enclosed by two mountain ranges, the low Coast Range to the west and the Cascade Range to the east. Each range is approximately 30 miles from the city. The Cascade Range provides a steep, high slope for the orographic lift of moisture-laden westerly winds and consequent heavy rainfall on the west side of the range. The Cascade Range provides a barrier, containing the interior Columbia Basin with

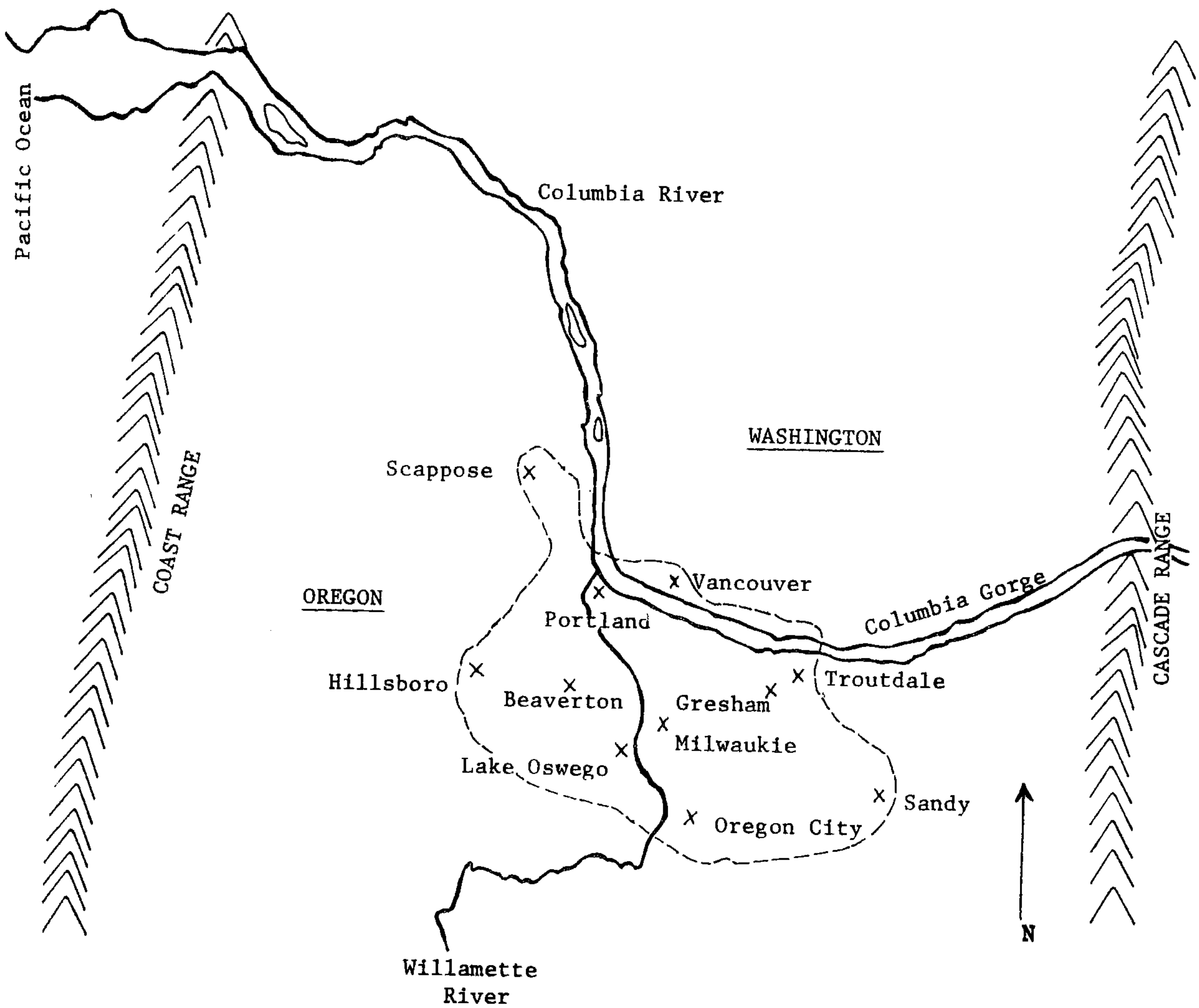

Figure 4. The study area.

its continental air masses. While most air flow in the Portland area usually is northwesterly in spring and summer and southeasterly in fall and winter, there are occasional movements of dry continental air from the east to the west through the Cascade passes and the Columbia Gorge. When this occurs, extreme high and low temperatures are experienced in the Portland area [58].

With the exception of these temperature extremes, Portland has a mild winter rainfall climate. Average annual temperature is 52.9° F. Annual rainfall averages 37.18 inches, with 88 percent of the annual total occurring between the months of October and May. On the average, there are only five days each year with measurable snow. Incursions of marine-tempered air are a moderating influence to any temperature extremes; i.e., extremes of heat or cold last only a few days before being broken [58].

The region's greatest area-wide pollution problem is suspended particulates [4, p. 4]. Periodic inversions during the fall and winter months (September to February) can trap these particulates for several days at a time, causing visibility and other problems. Sulfur dioxide, photochemical smog, and nitrogen dioxide are not presently a serious problem in the Portland area [4, pp. 3-4]. In many instances cloud cover rules out a photochemical smog problem. Only downtown Portland has a problem with pollutant gases, mainly carbon monoxide. While there is some heavy industry in Portland, pollution problems from these sources are usually localized.

The meteorological and air pollution problems of the Lower Willamette Valley, containing Lake Oswego, Milwaukie, Oregon City, Hillsboro, Beaverton, Sandy, and the southern part of Portland, are similar to the Portland-Vancouver area. Portland's suspended particulate problem extends southward from Portland to the Valley. The wind flow patterns in the Valley are somewhat simpler than they are within the immediate Portland-Vancouver area, due primarily to the lack of a Columbia River Gorge effect. Air flow patterns within the Valley are primarily channeled by the Coast and Cascade Ranges. Winds are predominantly from the north in summer and from the south in winter. The sea breezes are also an important moderating force on temperatures in the Valley [43, p. 159].

Characteristics of the Data Provided by the Kaiser Medical System

The Kaiser System

The Kaiser-Permanente Medical Care Program is a non-profit group insurance plan which provides comprehensive medical care to its members. Kaiser is one of the oldest (established in 1938) and largest (2.2 million members) prepaid medical plans in the nation [66, p. 1]. The Plan operates on a regional basis in California, Oregon, Hawaii, Colorado, and Ohio. It has 2,100 doctors, who represent nearly every medical specialty [66, p. 1]. The physicians are organized into a medical group, a partnership, which contracts with the Kaiser Foundation Health Plan to provide medical services. The monetary compensation to the physicians is usually competitive with what could be earned in private practice. Also, to the extent each region stays within its operating budget, the members of the medical group receive a year-end bonus [66, p. 21].

The emphasis of the Kaiser system in providing medical services has been to eliminate unnecessary health care[1] and to concentrate on outpatient care. Kaiser's inpatient admissions, and average length of hospital stay, are well below the national average.[2]

[1]Unnecessary health care, from Kaiser's viewpoint, is providing medical services to the patient which are of little medical value to him. For example, the use of a private room in a hospital, when a room of multiple occupancy would serve just as well; or dispensing to the patient services on an inpatient basis when an outpatient visit to a clinic would accomplish just as much.

[2]The national average in 1967 for hospital admissions averaged 137.9 a year per 1,000 people per year. The average length of hospitalization was 6.65 days for Kaiser members, compared to 7.8 days for the national average [66, p. 21]. As a comparison, the Oregon Region Kaiser Foundation Health Plan's average length of stay for hospitalization of health plan members was 5.2 days in 1970; the average hospital admissions per 1,000 members was 87. (Information obtained from Marilyn McCabe, Special Research Assistant, Kaiser Health Services Research Center, Portland, Oregon.)

The Oregon Region Kaiser Foundation Health Plan was established in 1943. In 1971 the plan provided prepaid, comprehensive medical care to approximately 146,000 members.[1] The plan is sold mainly to organized groups.

From a socioeconomic standpoint, the membership of the Oregon Region is quite diverse. Most occupational-socioeconomic groups are represented within the membership [15, p. 938]. It has been estimated that 15 percent of Portland-Vancouver residents are enrolled in the plan [17, pp. 298-299], and receive most of their medical care through Kaiser's hospital and six clinics. Kaiser also provides medical services to non-members on a fee-for-service basis.

The partnership of physicians contracting with the Kaiser Foundation Health Plan to provide medical services to the membership is known as the Permanente Clinic. The Permanente Clinic is paid a negotiated fee per health plan member. The fee is paid whether the member seeks medical care or not. The income of the Permanente Clinic is then distributed to the member physicians in a manner determined by them [15, p. 938].

The socioeconomic-demographic and medical data for this research came from the Kaiser Health Services Research Center. Kaiser Research is a separate division within the Kaiser system. The Center is federally funded. These monies provide a base of funds which the Center uses to attract qualified people of different professional backgrounds. These professionals are conducting research on ways of improving and making more efficient the delivery of health services.

There were several advantages in using the Kaiser system for this research: (1) the membership was large enough to provide a sufficient data base; (2) the population base at risk for medical services was continually known; (3) the Kaiser system provided a total range of medical services, from mental health to drugs; and (4) the Kaiser data system was readily amenable to use by modern data processing equipment.

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[1]This was the membership for the Oregon Region as of December 31, 1971. The information was obtained from Marilyn McCabe, Kaiser Health Services Research Center.

The Five Percent Sample

The objectives and intent of studies conducted by Kaiser Research were to explain the determinants of medical care utilization. To accomplish these goals a 5 percent, ongoing, random sample was drawn from the total membership in the Fall of 1966. A comprehensive system for computerizing the medical information for the sample was developed. The outpatient medical data for this study were obtained from this sample. This section discusses the drawing of the sample, and its socioeconomic-demographic characteristics.

All of the membership records of the Kaiser Health Plan were recorded on magnetic tape for ease of computer processing. Each family, and member within that family, were identified by a unique number called the Health Plan Identification Number (H.P.I.D.). This provided a reliable sampling framework for Kaiser to draw a random 5 percent sample of family units.[1]

The original sample was drawn from a list of people eligible for Kaiser Health Plan services on September 1, 1966. Each month since then a 5 percent random sample of all new families joining the Health Plan have been added to the sample [17, p. 300]. Once an individual is chosen for the sample, he will always be a member of the sample, even if he should become a non-member of the Health Plan. Hence, in the aggregate, the sample was actually larger than 5 percent of the membership at any point in time. Continuous medical care utilization is recorded whenever members of the sample use or contact the Kaiser System. The original sample had 1,487 member family units, with 4,123 individuals. By July 1968, 2,311 families and 6,514 individuals were sample members [17, p. 300].

The Kaiser 5 percent sample was designed to be representative of the Kaiser membership at any point in time [17, p. 300]. During 1967, 96 percent of the sample members resided in the Portland S.M.S.A. Sixty-four percent of the members

[1]A subscriber family may not necessarily include all the members of the family; that is, some members of the primary family may not be members of the Kaiser Health Plan.

See the following citation for a more complete presentation of this sampling procedure [22].

resided in Multnomah County [17, p. 302]. There was no reason to expect these distributions to change materially between 1967 and the beginning of the study period.

The Kaiser membership's representativeness of the population in the S.M.S.A. is an unanswered question. Using 1960 census data, some comparisons of the Kaiser membership to the population of the S.M.S.A. have been made. Four percent of the total membership was non-white, compared with 3 percent for the S.M.S.A. The Kaiser Health Plan membership had slightly more members in the under-25 age group and had slightly fewer in the over-65 age group than the S.M.S.A. [17, p. 302].[1] Dr. Merwyn Greenlick, Director of Kaiser Health Services Research Center, felt the Kaiser membership was not significantly different from the Portland S.M.S.A. However, since the Kaiser membership was not randomly drawn from the S.M.S.A., he was wary of making inferences from membership or sample results to the S.M.S.A.[2]

The Kaiser Household Interview

One of the specific aims of Kaiser Research was to examine association between socioeconomic-situational background characteristics and the consumption of medical services in different disease states. It was hypothesized that, for certain disease situations, different background characteristics were important determinants of medical care utilization [17, p. 299]. To accomplish its research objective, Kaiser developed a household interview survey to collect socioeconomic-demographic and other data from members of the 5 percent sample. It was from this survey that the socioeconomic-demographic data for use in this study were obtained.

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[1]Some other general characteristics of the Kaiser 5 percent sample membership which were not compared to the S.M.S.A., showed that 81 percent were Protestants and 16 percent were Catholic. Eighty-one percent of the sample subscribers were married. Eighty-seven percent of the subscribers were employed, with semiskilled (24 percent) and clerical sales (23 percent) appearing to be the main occupational categories [17, p. 302].

[2]Conversation with Merwyn R. Greenlick, Ph.D.; Director, Kaiser Health Services Research Center, Portland, Oregon, November 22, 1971.

The questionnaires were developed after a review of the sociological and social psychological literature on health and medical care. Information was gathered on four types of variables which were thought by Kaiser to primarily affect the need for medical care: (1) bio-social factors, such as age and sex; (2) situational or physical environmental conditions, such as type and place of work; (3) sociocultural agents, such as drinking, smoking, or conventional health procedures; and (4) psychological stress factors, socially and environmentally produced, including financial problems and family strife. Three types of variables thought to affect demand for the consumption of medical services were included: (1) sociocultural factors, including the valuation the individual places on health, the determination of normal health states, and opinions on proper sources of medical care; (2) social components, such as pressure resulting from interaction with family members, friends, and colleagues at work; and (3) psychological elements, such as sick-role orientation, optimism or pessimism, or self-acceptance [16, p. 3].

The questionnaire survey was administered to each eligible Kaiser Health Plan subscriber, or subscriber and covered spouse, in the 5 percent sample, beginning February 1970 and terminating August 1971. Kaiser processed and accepted a total of 2,409 interviews.[1]

The questionnaires were administered separately, but simultaneously, to husband and wife in two-parent families. A different, but related, questionnaire was administered to each spouse (questionnaires A and B). This interviewing technique was utilized because it was felt some data would be more reliable and valid if obtained separately from the husband/father and wife/mother. Other data, especially that of a subjective nature (such as perceptual-attitudinal data), must be obtained from each person independently [17, pp. 300-301]. In a one-parent or single-subscriber household, a C questionnaire was given which contained all the questions of the A-B set. On the average, it took one and one-half hours to administer the questionnaire.

[1]Unpublished Kaiser paper titled: West Coast Community Surveys Household Interview Sample Statistics, October 1, 1971.

VI. COMPILING THE MEDICAL DATA

Inpatient Medical Data

Since 1965, detailed socioeconomic and medical information has been obtained on each inpatient admission to Bess Kaiser Hospital. These data were stored on magnetic tape, and comprised 65,000 records. Annual inpatient admissions ran approximately 9 percent of the total Kaiser membership in any given year of the study period. It was originally intended to include in the analysis data from the inpatient records of the 5 percent sample members. However, several difficulties arose: (1) the type of laboratory and radiology procedures performed were not coded in sufficient detail to be compatible with the outpatient data; (2) major coding errors committed by Kaiser personnel would have necessitated going back to the raw data in order to correct them; (3) the inpatient service records of some patients were recorded under multiple H.P.I.D. numbers; and (4) two "International Classification of Diseases, Adapted" editions (I.C.D.A.)[1] were used to index admitting and discharge diagnoses and surgical procedures. The I.C.D.A. numbers of the two editions were not comparable. As the inpatient medical data were to be related to socioeconomic data obtained from the household interviews of the 5 percent sample, and as it appeared that fewer than 50 hospital discharges per year were made of patients in the relevant disease categories who were members of the 5 percent sample, the decision was made not to commit the cost and effort required to overcome the above obstacles. Therefore, only outpatient medical data were used in the study.

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[1]The I.C.D.A. is a code used for classification of morbidity (disease) and mortality (death) information for statistical purposes. The I.C.D.A. is periodically revised. Prior to January 1, 1970, Kaiser used the 1962 revised edition of the I.C.D.A. [40] for indexing inpatient records; the eighth revision of the I.C.D.A. [39] has been used since January 1, 1970. The 1968 edition of the I.C.D.A. has served as the basis for coding diagnostic data for the official morbidity and mortality statistics in the United States [39, pp. IX-X]. See [39, pp. IX-XXXII] for a complete history on development and use of the I.C.D.A.

Outpatient Medical Data

All outpatient medical services consumed by the 5 percent sample were coded and recorded by Kaiser's medical record technicians on forms specifically prepared for computer processing. All contacts with the Kaiser Health Plan system by the sample members, including telephone calls and letters, have been continuously recorded on magnetic tape since January 1967. Data recorded for each contact include, among others, date, time, place, and type of service. The major symptoms, and duration of these symptoms, were recorded for each presenting and associated morbidity.[1] The medical procedures rendered, including laboratory and X-ray, were coded in detail for each outpatient visit.

With one exception, the presenting and associated morbidities were coded according to the 1962 revised edition I.C.D.A. [40], as supplemented and adapted by Kaiser. The exception was the use of symptom codes (called "T codes") developed by Kaiser to be used in cases where a disease condition was not diagnosed before patient care terminated. Symptoms represented the final diagnosis for 10 percent of the patients utilizing outpatient services at Kaiser [23, p. 249]. Kaiser, finding symptoms codes in the I.C.D.A. not extensive or unique enough for many disease states, developed its own symptoms classification system. These codes, which facilitate ease of coding and analyzing presenting and associated morbidity data, were developed in the following manner. Each organ system was assigned a single block of numbers. Additional number groups were given to non-specific and psychiatric symptoms. Since the I.C.D.A. had some symptom codes, Kaiser used the letter "T" to distinguish its codes from the I.C.D.A.

The coding system used to identify each medical procedure rendered was an adaptation by Kaiser of the 1964 California Relative Value Fee Schedule (C.R.V.S.),

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[1] In the event care was given for two or more morbidities during the same contact with the system, the morbidity that provoked the contact was identified as the <u>presenting</u> morbidity, and the others as <u>associated</u> morbidities. The use of the term "associated" did not necessarily mean that the diseases were clinically linked to each other. The term "associated morbidity" means only that the diseases were associated in time. Nor should the distinction between presenting and associated morbidities be linked with the seriousness of either disease; a presenting morbidity could be minor, whereas the associated morbidity could be a major disease [28, pp. 16-17].

[6]. Each medical procedure performed on the patient was translated into a unique four-digit number for coding purposes. In essence, then, the Kaiser medical data system was established in such a way that most medical procedures rendered per outpatient contact could be associated with a specific disease.

However, there were two major shortcomings which existed with the outpatient data. As with the inpatient data, the consumption of drugs was not coded for the five percent sample during the study period. Also, if a patient received medical services outside the Kaiser system, such services were not included in the Kaiser data.

The outpatient medical data were received from Kaiser on two magnetic tapes. The tapes were ordered by H.P.I.D. number and date of service. The tapes contained 145,000 separate outpatient medical records on the five percent sample for 1967-1970. These tapes were searched by H.P.I.D. number to obtain only medical records for which socioeconomic data were available from the household interview.[1] A new tape containing 103,000 records was generated.[2]

A thorough search was made of the I.C.D.A. and T-Codes [24] used by Kaiser to prepare a list of over 500 diseases and symptoms which were thought to be aggravated by, or associated with, air pollution.[3] The codes were grouped into the eight categories shown in Table 1.

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[1]Each interview was identified by the member's H.P.I.D. number at the time of the interview. All members of the subscriber's health plan were identified by unique person numbers (part of the H.P.I.D. number). These numbers allowed data from the household survey to be attached to the member's medical records.

[2]A precaution had to be taken to discover H.P.I.D. numbers that had changed since the household interview date. The problem occurred, for example, when separations, divorces, or name changes took place. It was highly probable with such changes that covered dependents stayed under the old H.P.I.D. number. Hence, in creating the new medical tapes, medical records were accepted under both H.P.I.D. numbers.

[3]Appreciation is expressed to Sheldon Wagner, M.D., Head, Oregon State University Environmental Health Unit, Good Samaritan Hospital, Corvallis, Oregon, for his help in developing this list.

TABLE 1. THE DISEASE CLASSIFICATION SYSTEM

I. Respiratory System

   A. Upper respiratory neoplasms
   B. Upper respiratory infections
   C. Lower respiratory infections
   D. Lower respiratory neoplasms

II. Allergies Affecting Respiratory System

   A. Asthma
   B. Hay fever
   C. Specific diseases

III. Other Allergies and Skin Diseases

   A. Eczema
   B. Other allergies
   C. Other skin diseases
   D. Specific diseases - allergies

IV. Diseases of the Circulatory System

   A. Heart
   B. Circulatory system

V. Diseases of the Digestive System

   A. Upper gastrointestinal tract - neoplasms
   B. Ulcer of the upper gastrointestinal tract
   C. Lower gastrointestinal tract - neoplasms

VI. Diseases of the Eye

   A. Inflammatory diseases of the eye
   B. Non-specific eye complaints

VII. Diseases of the Genitourinary System

   A. Benign neoplasms
   B. Malignant neoplasms
   C. Nephritis and nephrosis

VIII. Other Diseases

   A. Symptoms and diagnoses referrable to nervous system and special senses
   B. Emotional, mental, and psychotic disorders
   C. Other specific diseases

Each disease is classified more specifically within the general outline presented in Table 1. Within the system, acute and chronic diseases were grouped separately, as were benign and malignant neoplasms. Each disease is identified by a code, such that any single disease or group of diseases can be selected for analysis. For example, I-A-1-a is a malignant neoplasm of the nose, contained within the category I-A, upper respiratory neoplasms. The complete listing of all the diseases and symptoms comprising Table 1 may be seen in Appendix A. The outline code (I-A-1-a), the I.C.D.A., and the T-Code number were coded for each disease. These were used to search the reduced outpatient medical tape discussed above to create a third outpatient tape containing only the medical records of household interview respondents and covered dependents afflicted by the diseases on the list. The "Outpatient I.C.D.A., T-Code Tape," as it is called, contained 24,000 records for the 1967-1970 period. It became the main medical tape, and was employed for generating other tapes used in the statistical analysis.

Derivation of the Dependent Variables

The California Relative Value Schedule Units

Chapter IV described the advantages of utilizing in the analysis, as a dependent variable, an index of the physical quantities of medical services consumed. While no such index was found, the California Relative Value Schedule (C.R.V.S.) appeared to be an appropriate substitute, and was already in extensive use by Kaiser Research for coding medical procedures. The first edition of the C.R.V.S. was formulated in 1956 by the Committee on Fees of the California Medical Association. The main objective of the Committee was to develop a set of principles to govern the development of fee schedules in California and, in so doing, provide some uniformity in the setting of fees [6, p. 64]. As part of this objective, the Committee also established a uniform nomenclature of medical procedures and a standardized code to designate each procedure.

The Committee found through a survey of the California Medical Association membership that, while the dollar value of fees varied widely throughout the state, the relationship between fees for the same procedure remained essentially the same [6, p. 64]. This observed stability in the relationships among various procedures became the basis of the C.R.V.S. Various factors could be applied to the C.R.V.S. units to convert them to dollar values, thus allowing the monetary fees charged by various physicians to differ from one another. To account for new factors and innovations in the field of medical practice, the Committee has issued a new edition of the C.R.V.S. every three to five years.

The C.R.V.S. was selected as the best approximation available of the desired index of medical care provided. Its use had the following advantages for this study: (1) all services are identified by a four-digit code, and most services are weighted by a unit value. (2) These codes and unit values are applicable to an entire range of medical services: medicine, anesthesia, radiology, surgery, and laboratory. (3) Kaiser Research used the C.R.V.S. procedure codes (1964 edition) to code medical services for outpatient care. (4) Kaiser, with some modification to fit its own purposes, had coded the procedure numbers and unit values for the 1964 edition of the C.R.V.S. on magnetic tape. The tape was continually updated by Kaiser to reflect changes in providing medical services. A copy of this tape was obtained from Kaiser. (5) The C.R.V.S. units are additive.

The C.R.V.S. tape received from Kaiser was modified for anesthesia procedures used in surgery. There were four such procedures used in outpatient treatment for which unit values had not been assigned. Calculation of the anesthesia units in the 1964 edition of the C.R.V.S. was done by adding the listed basic unit for anesthesia per surgical procedure to the time, converted to units, spent in administering the anesthesia. Kaiser had recorded on its tape only the C.R.V.S. units applicable to each surgical procedure, and not the basic units applicable to the anesthesia. The C.R.V.S. tape was modified by attaching the basic anesthesia units to each surgical procedure. Hence, whenever an outpatient surgical procedure required anesthesia, the basic anesthesia units were added to the units for the surgical procedure. Efforts to find some mean or median value of time spent on each surgical procedure were not successful. Hence, the time factor was not taken into account in calculating anesthesia units per surgical procedure.

Model 3

The Index of Medical Services (Y_{ijk}). It was required that, in order to express the effect of air pollution on health as an economic cost, the C.R.V.S. units per medical procedure be converted to dollar values. This had to be done in a manner that would not distort the quantity of medical services consumed, as approximated by the C.R.V.S. units. This was accomplished by taking each C.R.V.S. unit, per medical category, times a constant dollar equivalency (conversion) provided by Kaiser. The dollar equivalencies per medical category are shown in Table 2.

Table 2. OUTPATIENT CALIFORNIA RELATIVE VALUE SCHEDULE DOLLAR EQUIVALENCY FEES

Medical category	Dollar equivalency
Surgery	6.50
Pediatrics	7.00
Laboratory and radiology	7.00
All other	8.00

The dollar equivalencies came from two sources. The credit office, Bess Kaiser Hospital, provided the dollar conversions for surgery, pediatrics, and all other. The laboratory and radiology conversion factors were obtained from Kaiser Research Center. The credit office and research center used the C.R.V.S. units and dollar equivalencies to bill non-members and certain public grants for medical services rendered. These dollar equivalencies were established January 1, 1969. The equivalencies, taken times the C.R.V.S. units, reflected the going fee for service rates for professional outpatient medical services in Portland.[1] The resulting dollar values may not be representative of Kaiser's

[1] Conversation with Jack Thomas, Credit Manager, Bess Kaiser Hospital, Portland, Oregon, July 13, 1972.

costs of providing the services. Kaiser did not have a detailed enough cost accounting system to provide such information.

The C.R.V.S. units were converted to dollar values (Y_{ijk}) as follows: by code number, each medical procedure on the Kaiser outpatient tape was matched against the same procedure on the C.R.V.S. tape. The units on the C.R.V.S. tape were then multiplied by the appropriate dollar equivalencies. For pediatrics and surgical procedures, the appropriate dollar equivalencies to assign were determined by the numeric codes assigned to the doctors. The laboratory and radiology procedures were grouped on the outpatient tape within a given numeric field; procedures in these fields were matched and converted to dollar values. All other procedures and respective units were multiplied by the $8 equivalency.

Certain coded medical procedures in the 1964 C.R.V.S. edition did not have unit values assigned to them. This seemed to occur primarily when the services rendered were unusual and difficult to quantify. Kaiser sometimes modified the C.R.V.S. and assigned units to the procedures. However, no attempt was made by the authors to proxy values to procedures which Kaiser had failed to modify. The problem was not widespread enough to be considered important. However, to the extent these services were used by outpatients, Y_{ijk} would represent an understatement of the dollar value of medical services consumed.

Y_{ijk} then represents the summation of dollar values (converted C.R.V.S. units) for all outpatient medical services rendered to Kaiser questionnaire respondents in treating a presenting and/or associated morbidity in the same office visit, per individual, per day.

Model 5

Per Capita Index of Consumed Outpatient Medical Services, (Y_{icj}). The dependent variable of (5) represents the summation of dollar values (converted C.R.V.S. units) expressed on a per capita basis, for all outpatient medical services rendered (to Kaiser questionnaire respondents) in treating a presenting and/or associated morbidity in the same office visit, per day, per census tract.

VII. COMPILING THE SOCIOECONOMIC-DEMOGRAPHIC DATA

This section will discuss the derivation of the socioeconomic-demographic variables specified for the statistical models. Each variable in Equation (3) is also represented in Equation (5). The variables are the same, except for specification as individual or aggregate variables in the two equations. Except where noted, each variable has the same hypothesized relationship with the dependent variable.

The socioeconomic-demographic variables are matched in the statistical analysis by H.P.I.D. members. For purposes of this study, it was decided to use only the medical records of actual respondents to the household interviews for whom complete and specific socioeconomic-demographic data existed.

Most questions on the Kaiser household interview were coded with a numeric code, with each number representing a verbal response to the questions. The data were transformed into continuous data wherever possible. The transformations and other modifications performed on each variable will be discussed below.

Age of the Patient: X_{1ijk} - Model 3, $\bar{X}_{1icj}$ - Model 5

It is expected that older patients will consume more medical services. Hence, higher values of this variable are expected to be positively related to the consumption of medical services. The age of the patient is expressed in years as of the date of medical service.

Sex of the Patient: X_{2ijk} - Model 3, $\bar{X}_{2icj}$ - Model 5

This variable is expressed as a zero if the patient is male, or a one if the patient is female in (3). In (5) the variable is expressed as the percentage of female patients seeking medical care. The variable has been included because the incidence of certain diseases is more prevalent in one sex than in the other. For example, the incidence of emphysema has been reported to be ten times greater in men than in women [10, p. 13]. *A priori*, little can be said about the effect of sex on the consumption of outpatient medical services generally, since the relationship varies with the type of disease.

Marital Status: X_{3ijk} - Model 3, $\overline{X}_{3icj}$ - Model 5

In (3), this variable is expressed as a zero if the patient is not married, and as a one if he is. In (5) the variable is expressed as the percent of married patients seeking medical care per census tract. For reasons detailed in Chapter IV, this variable is expected to be negatively related to the consumption of medical services.

Number of People in the Patient's Household:
X_{4ijk} - Model 3, $\overline{X}_{4icj}$ - Model 5

It was desired to have some kind of density measure, such as the number of persons per room, as an indication of crowding within the patient's home. Increased crowding could result in more physical and emotional strain being placed upon all household members, and could also effect an increased potential for initial infection and re-infection of household members with certain respiratory diseases. This could result in the increased consumption of medical services.

A density measure could not be obtained or specified from the Kaiser data. The number of people residing in the patient's household was the best measure that could be obtained. The variable includes not only members of the immediate family, but anyone else living in the household at the time of the interview. Higher values of this variable are expected to be positively related to the dependent variable.

Household Income: X_{5ijk} - Model 3, $\overline{X}_{5icj}$ - Model 5

Household income is included to measure the ability of the patient's household to make expenditures in lieu of consuming medical services to preserve and improve its state of health. Since all Kaiser members have the same opportunity to consume Kaiser medical care, it is expected that this variable will be negatively related to the consumption of medical services. An estimate of the 1969 household income, before taxes and from all sources, was used as a measure of this variable.

It should be pointed out that, in most instances, the income question was asked of only one respondent per household. For example, in the A-B questionnaire only the A questionnaire was given to the male respondent. If B required medical service, A's answer would be assigned to her as a measure of household income. If two C questionnaires were administered to respondents living in the same household,[1] and the responses to the household income question were different between the two respondents, then the two responses were averaged to obtain an estimate of household income. Out of the 2,439 questionnaires, this happened approximately five times.

The household income question asked the respondent to indicate into which one of nine income classes his 1969 before-tax income fell. The midpoint of the relevant class was assigned to the respondent as his income. An exception to this rule had to be made for the highest open-ended class (greater than $20,000). Census data for the Portland S.M.S.A. relating to "incomes of families and unrelated individuals" [53, pp. 39-191] were used to estimate a median income of $32,000 for households indicating an income over $20,000. Table 3 shows the income response categories from the questionnaire, and the corresponding transformations per response category.

TABLE 3. HOUSEHOLD INCOME RESPONSE CATEGORIES AND TRANSFORMATIONS

Response category	Transformation
Under $2,500 per year	$ 1,250
$ 2,500 - $ 3,499	3,000
3,500 - 4,999	4,250
5,000 - 6,499	5,750
6,500 - 7,499	7,000
7,500 - 9,999	8,750
10,000 - 14,999	12,500
15,000 - 19,999	17,500
Over $20,000	32,000

[1] This happened only when husband and wife both worked, were separate subscribers to the Kaiser Health Plan, and were both members of the 5 percent sample.

Race: X_{6ijk}, X_{7ijk} - Model 3, $\overline{X}_{6icj}$ - Model 5

In Model (3) the race variable is expressed as a dummy variable in the following manner:

Race	X_{6ijk}	X_{7ijk}
Negro...............	1	0
Other non-white.....	0	1
White...............	0	0

On each variable the statistical test is whether the consumption of medical services is different for Negroes or other non-whites (mostly Oriental), as compared to the consumption of medical services by whites.

In Model (5) the Negro and other non-white variables are combined, and express the percentage of non-white patients consuming medical services. The variable permits a test on whether the consumption of medical services by non-whites is materially different from whites.

As with the sex variable, the relationship of the race variables to the consumption of medical services will depend upon the diseases aggregated in the dependent variable. If the relationship of race to disease incidence is not known, then, *a priori*, the sign of the variable's coefficient cannot be determined.

Physical Fitness: X_{8ijk} and X_{9ijk} - Model 3

A physically fit patient would be expected to consume fewer medical services. There was one question in the household interview which elicited information on physical fitness. It was stated to the respondent as follows:

> "How much time and energy do you spend being physically fit - a great deal, some, or very little?"

Dummy variables were used to describe the qualitative responses as follows:

Physical fitness	X_{8ijk}	X_{9ijk}
Great deal of time and energy...	1	0
Some time and energy............	0	1
Very little time and energy.....	0	0

The responses to the physical fitness question were subjective. Hence, there was difficulty in standardizing the answers as between responses. The question was the best assessment on physical fitness available from the interview. However, the use of qualitative (dummy) variables does permit explaining some differences between individual responses. The variables were expected to be negatively related to the dependent variable.

Physical fitness was not included as a variable in (5) because only qualitative variables could be used to represent each response. Aggregation of qualitative variables over census tracts, where variations in group behavior are being explained, presents a problem of adequately interpreting the results.

Consumption of Alcoholic Beverages:

X_{10ijk} - Model 3, $\overline{X}_{7icj}$ - Model 5

This variable expresses the number of times in the 12 months prior to the interview date the patient has had the equivalent of about six drinks, a bottle of table wine, or eight cans of beer. Higher values of this variable are expected to be associated with a greater consumption of medical services on the part of the patient.

Table 4 shows the transformations on each response category to the question. The transformations were constructed by taking the midpoint of each time period indicated in the response.

Cigarette Smoking: X_{11ijk} - Model 3, $\overline{X}_{8icj}$ - Model 5

Each patient's smoking characteristics were embodied in a single index. The index took a value of zero if the patient did not smoke, and went to a high of 1960 for current smokers smoking the longest period of time and the largest

Table 4. TRANSFORMATIONS PERFORMED ON THE RESPONSES TO THE DRINKING QUESTION

Response categories	Transformations
Every day or nearly every day..............	365.0
Three or four times a week.................	182.5
Once or twice a week.......................	78.2
Two or three times a month.................	30.0
About once a month.........................	12.0
Six to eleven times a year.................	8.5
One to five times a year...................	3.0
Never in the last twelve months............	0.0

number of cigarettes per day. The index also incorporated the smoking characteristics of former smokers, including the amount they smoked, how long they smoked, and how long it had been since they stopped smoking.

Two sets of questions from the household interview were used to obtain information on the smoking habits of current and former cigarette smokers. The first question asked the respondent if he currently smoked cigarettes, and if he did, how many cigarettes he smoked each day; and how many years he had smoked. The responses to this question are shown under (I) in Table 5. The second question asked former smokers how many cigarettes they used to smoke, how many years they had smoked, and how long it had been since they had stopped smoking. The responses to this question are under (II) in Table 5.

In Table 5, the transformations were constructed by taking the midpoint of each response interval. The following criteria were followed in quantifying the open-ended responses. A frequency distribution of the responses showed that fewer than nine respondents out of 2,439 indicated they currently smoked or had ever smoked more than 61 cigarettes a day. It was decided that 70 cigarettes would be a reasonable number to use for this group.

A frequency distribution on age was generated for the questionnaire respondents. Their median age was calculated to be 46. The legal age for smoking in Oregon is

Table 5. SMOKING CHARACTERISTICS AND TRANSFORMATIONS ON THE RESPONSE CATEGORIES

Response categories	Transformations
I. Current smokers:	
A. Number cigarettes per day:	
Under 10	5
10 to 20	15
21 to 40	30
41 to 60	50
61 and over	70
B. Number of years smoked:	
Under 1 year	0.5
1 to 3 years	2.5
4 to 5 years	5.0
6 to 10 years	8.5
11 to 20 years	15.0
Over 20 years	28.0
II. Former smokers:	
A. Number cigarettes per day:	
Under 10	5
10 to 20	15
21 to 40	30
41 to 60	50
61 and over	70
B. Number of years smoked:	
Under 1 year	0.5
1 to 3 years	2.5
4 to 5 years	5.0
6 to 10 years	8.5
11 to 20 years	15.0
Over 20 years	28.0
C. Number of years since cessation of smoking:	
Less than 3 months	0.13
4 to 6 months	0.42
7 months to 1 year	0.79
More than 1 to 3 years	2.50
4 to 5 years	5.00
6 to 10 years	8.50
Over 10 years	13.50

18. While some people start smoking earlier and others later, 18 is probably a good estimate of the median age when people start smoking. Therefore, 28 years (the difference between 46 and 18) appeared to be a reasonable number of years for those who indicated they smoked for 20 years or more.

The last response category in Table 5 (II-C) asked the former smoker how long it had been since he had stopped smoking. The American Cancer Society and other researchers have established that after 10 years of not smoking, the death rates of former smokers and lifelong abstainers are virtually the same [3, p. 131; 65, p. 145]. Given this evidence and the structuring of the last response category in (II-C), it was felt that 13.5 years would be a reasonable number of years for those who indicated they had quit smoking over 10 years ago.

There is a direct association between the number of cigarettes smoked per day, the number of years smoked, and mortality and morbidity incidences of lung cancer and coronary diseases [64; 65, p. 11]. It appears that as the number of years since cessation of smoking increases, the ex-smoker's state of health becomes comparable to that of a person who has never smoked. There is also an immediate response of the body to cessation of smoking. Within six months after discontinuance, the bronchial system improves to a steady state; i.e., pulmonary function or vital capacity stabilizes.[1] There is an immediate response of the cilia to cessation of smoking. Each cigarette paralyzes the cilia[2] for 20 minutes. It is the opinion of some medical authorities that it takes from 3 to 6 weeks after discontinuing smoking to make a reasonable difference in the ability of the body to ward off infection.[3]

It was desired to construct an index which would have at least some potential for reflecting the conditions described in the preceding paragraph. Extensive reading of the medical literature and conversation with medical authorities failed

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[1]Conversation with James F. Morris, M.D., Veterans Administration Hospital, Portland, Oregon, December 3, 1971.

[2]Cilia are hairlike cells that line the airways and, by their movement, propel the dirt and germ-filled mucous out of the respiratory tract [41, p. 91].

[3]Conversation with Arthur Koski, Head and Professor, Department of Health Education, Oregon State University, Corvallis, October 19, 1971.

to give any clues on the existence or on means of constructing such an index. Finally an index, described by Equation (6) and developed by the authors, was constructed for the Kaiser data:

$$S_k = \frac{(A_k + B_k)\ (C_k + D_k)}{1 + E_k} \tag{6}$$

where S_k = smoking index of the $k^{\underline{th}}$ person seeking outpatient medical care.

A_k = the number of cigarettes per day the $k^{\underline{th}}$ patient seeking outpatient medical care currently smokes per day.

B_k = the number of cigarettes per day the $k^{\underline{th}}$ patient seeking outpatient medical care used to smoke per day.

C_k = the number of years the $k^{\underline{th}}$ patient seeking outpatient medical care has smoked.

D_k = the number of years the $k^{\underline{th}}$ patient seeking outpatient medical care used to smoke before quitting.

E_k = the number of years since the $k^{\underline{th}}$ patient seeking outpatient medical services has quit smoking; and

$(k = 1, \cdots, \ell)$.

If a person currently smoked 70 cigarettes per day, and had done so for 28 years, his index would be 1960.0. If a patient quit smoking 13.5 years ago and, at the time he quit smoking, smoked 70 cigarettes per day for a period of 28 years, then his index would be 135.2. Patients who have never smoked in their lives assumed a value of zero in the index.

Higher values of the index represent more intense cigarette smoking. Because of the relationship between intense cigarette smoking and cardiovascular-respiratory problems, this index is expected to be positively related to the dependent variable in both models.

Occupational Air Pollution Exposure: X_{12ijk} - Model 3, X_{9icj} - Model 5

Job-related pollution can aggravate certain respiratory problems [27, p. 34; 42, p. 13]. Job-related pollution would not, in most instances, be measured by the regional, ambient air pollution stations. To take account of this fact, an occupation exposure index was constructed for each employed patient seeking out-patient medical care. A value of zero was assigned to patients who did not work. It is expected that higher values of this variable will be positively related to the dependent variable in both models.

The occupational exposure index was constructed in the following manner: the household interview contained a question asking each respondent to identify his specific job. The question was coded, using the numerical classification of occupations published in the 1960 Census of Population, Alphabetical Index of Occupations and Industries [52]. A listing of the occupations was submitted to Mr. Darryl D. Douglas,[1] who rated each classification on a scale of one to four. The ratings were assigned to each class, based on the probability of that occupation being characterized by a particulate problem which could aggravate certain cardiovascular-respiratory problems. The meaning of the scales was as follows: four equaled a high hazard to particulate exposure; three equaled an intermediate hazard; two equaled a moderate hazard; and one equaled a low hazard. Each weight, with its respective occupation code, was multiplied by the average number of hours, including regular overtime, the patient worked per day. The resulting product was the occupational exposure index.

[1]Mr. Douglas is the Director, Occupational Health Section, Health Division, Department of Human Resources, State of Oregon, Portland.

VIII. COMPILING THE AIR POLLUTION AND METEOROLOGICAL DATA

The Air Pollution Data

The air pollution data were collected from the various state and regional air pollution control agencies having jurisdiction in the Portland S.M.S.A. All of the agencies had similar methods of sample scheduling and collection, analysis, and data reporting. Hence, the air pollution data were comparable among the originating agencies.

Each air pollution station was identified by a unique number. The stations were located on a grid coordinate system, expressed in state plane coordinates.[1] The coordinates were used by one of the regional agencies to plot air pollution isopleth maps of the form shown in Figure 5. The suspended particulate stations operated continuously for 24 hours every fourth day. All stations in the Portland S.M.S.A. were operated simultaneously. The air pollution data were coded on 80-column cards for ease of data processing. Stations which had error in their data, or which were poorly sited such that they did not provide representative measures of ambient air pollution, were not used.

Selecting the Proper Measure of Air Pollution

Portland's main air pollution problem is particulate matter. The effects of particulate matter and other air pollutants were presented very briefly in Chapter IV. More specifically, particulate matter can physiologically affect human health in several ways. These effects would initially occur in the respiratory system, but the cardiovascular system could also be affected by additional

[1] In order to insure the location of original land survey measurements, the United States Coast and Geologic Survey has worked out for each state a system of state plane coordinates [48, pp. 29-30]. The coordinates are expressed in feet. To limit the size of the grids and to keep scale variations to a minimum, each state usually has two or more overlapping zones. Each zone is covered by a single coordinate system [30, pp. 345-346]. All Oregon air pollution and meteorological stations are located in the Oregon North Zone; all Washington air pollution and meteorological stations are located in the Washington South Zone.

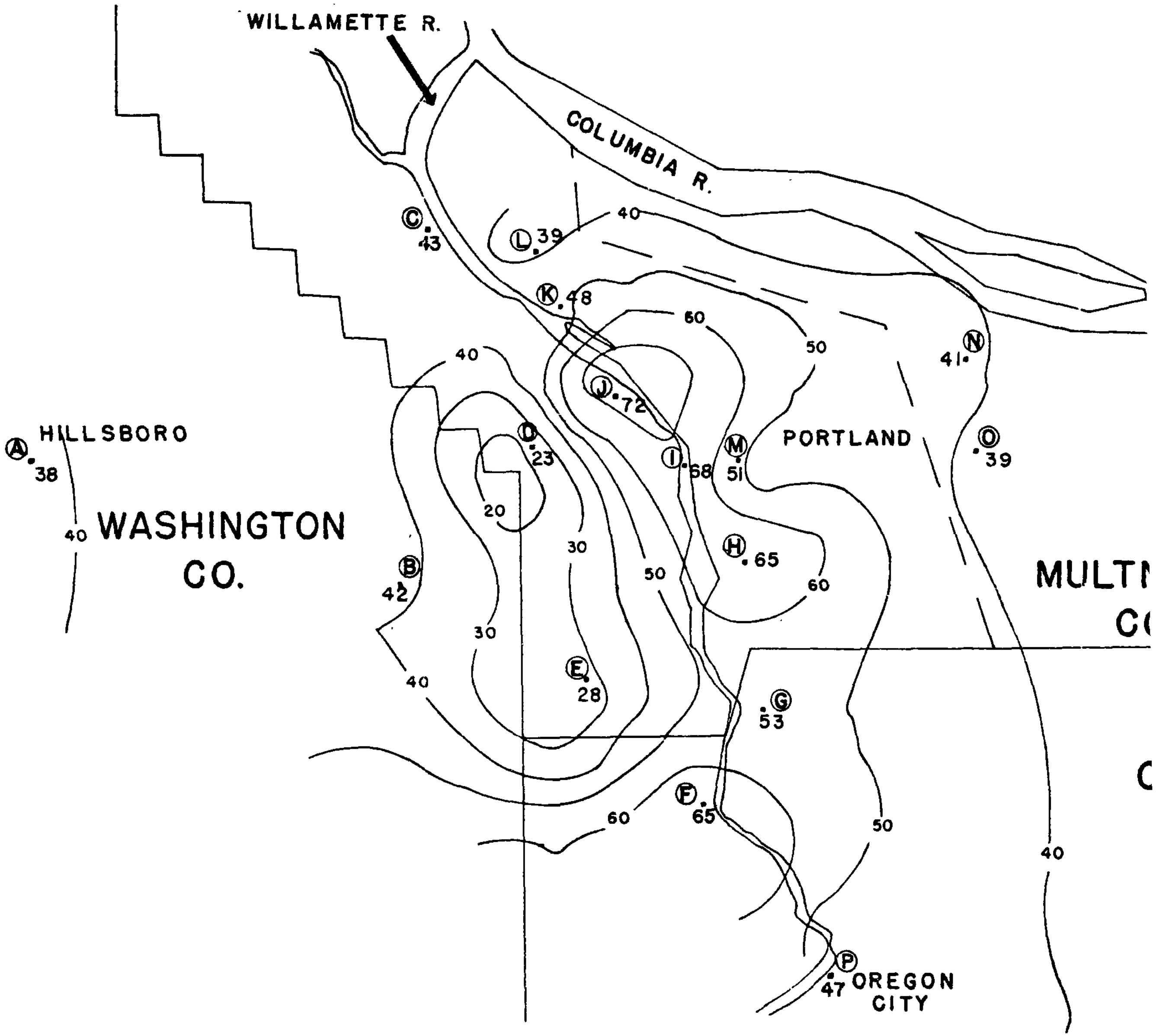

FIGURE 5: ISOPLETH MAP FOR PORTLAND AREA

stress being placed upon it by an impaired respiratory system. Particulate matter may exert a toxic effect on the human body via one or more of the following three mechanisms:

1. The effect of particles on human health can be due to the particle's inherent chemical and/or physical characteristics [59, p. 141]. The most important toxic aerosol is sulfur trioxide. Others of increasing importance are lead, beryllium, and asbestos [59, p. 129].

2. The particles may interfere with one or more of the clearance mechanisms in the respiratory tract [59, p. 141]. The particle size will determine the location of the toxic effect in the respiratory system. Small particles of less than two or three microns can penetrate deep into the respiratory system where no protective mucous blanket exists [41, pp. 33-34].

3. The particle can act as a carrier of an adsorbed toxic substance [59, p. 141]. The toxic effect of sulfur dioxide seems to be greater when the gas combines with an aerosol than either is alone [1, p. 62; 60, p. 111]. Sulfur oxides can produce immediate airway constriction [41, p. 66].

Some air contaminants (gaseous or particulate) could weaken the body's defense mechanism, making it more susceptible to germs, bacteria, or viruses which can precipitate an active disease [41, p. 65]. A review of numerous epidemiological studies indicated an association between air pollution, as measured by particulate matter accompanied by sulfur dioxide, and health effects of varying severity [60, p. 146].

There are two main types of atmospheric particulate matter in urban areas: suspended particulate matter and dustfall (particle fallout) [59, pp. 11-17]. In this study, suspended particulate data were selected over particle fallout as the measure of air quality in the study area. There are several reasons for this.

Dustfall consists of particulates 10 microns or larger [59, p. 16], which settle out of the air fairly rapidly [44, p. 7; 59, p. 28]. These particle sizes are too large to be respirable by the human body. Suspended particulate matter consists of particle sizes smaller than 10 microns [59, p. 16]. Suspended particulate matter is respirable. Hence, because of the settled particles' larger sizes, particle fallout measurements are not capable of assessing the health risks of air pollution. The large sampling period usually associated with collecting particle fallout (30 days) would prohibit measuring, or approximating, day-to-day changes in air quality.

High-volume samplers are used by the air pollution control agencies to collect suspended particulate matter. The operation of high-volume samplers consists of drawing air through a filter of low air resistence. The filters are felts of glass or some synthetic organic fiber [59, p. 22]. The filters can trap particle sizes as small as 0.3 microns [61]. The samples are collected over a 24-hour period. The filters are then analyzed, and the results reported as total weight in micrograms per cubic meter.[1] The total weight of suspended particulate matter was used as the air pollution parameter in this study.

Preparing the Air Pollution Data for Use in the Statistical Models

The suspended particulate stations were operated every fourth day during the study period. The medical and meteorological data were daily observations. It was desired to observe changes in the consumption of medical services with changes in air quality. This required the formulation of a procedure to estimate air quality on days for which data were not available. Two alternatives were considered to estimate the missing data: linear interpolation and spline fit. The spline fit was selected over linear interpolation for the reasons detailed below.

The spline fit is executed by connecting each pair of adjacent points (observations) with a third degree polynomial, matching up the sections such that the first and second derivatives are continuous at each point [45, pp. 404-405]; i.e., the spline fit is a piecewise cubic function which is twice continuously differentiable [67, p. 27].

The spline curve is a higher order fit of data points than is linear interpolation. The curve is of piecewise construction, which means that only part of the data for a given station is fitted at a time. More specifically, the spline fit,

[1] Some agencies perform analyses on the total weight of particulates to determine their chemical composition. These analyses are also reported in micrograms per cubic meter.

as employed in this study, used four observation points to fit each segment. For example, observation points A, B, C, and D would be used to fit one segment of the curve. Points B, C, D, and E would be used to fit the next segment. While estimated points between D and E would be most influenced by the actual observed values at D and E, points B and C would also have some influence. Using linear interpolation would have resulted in only two observation points being used to determine each linear segment.

Assigning Air Pollution Values to Residential and Job Addresses

A method was needed to assign air quality values to each household interview respondent for outpatient medical services consumed in the treatment of the disease categories listed in Table 1. The procedure had to be capable of accounting for air pollution levels at the patient's residence and his place of work.

The method for assigning air quality values to each patient made use of an Admatch computer program developed by the U.S. Census Bureau and local agencies. The program, in one of its forms, geocoded street addresses to state plane coordinates.[1] The meteorological and air pollution stations were also geographically located by state plane coordinates. These coordinates were used to assign air quality and meteorological values to each residence and job address.

Two techniques were considered for estimating air quality levels for each outpatient. The first was a least squares analysis employing various mathematical forms. This technique was not successful. In the second method, air pollution values of a certain address were calculated by weighting the observed air pollution values of the three closest stations by their distances from the address in question. The distance from each address to each station was calculated using state plane coordinates. The procedure is shown in Equation (7).

$$P_{ij} = \frac{1/D^2_{1ij}\ (S_{1j}) + 1/D^2_{2ij}\ (S_{2j}) + 1/D^2_{3ij}\ (S_{3j})}{1/D^2_{1ij} + 1/D^2_{2ij} + 1/D^2_{3ij}} \qquad (7)$$

[1] See [54] for a detailed description of the Admatch program.

where P_{ij} = the estimated air pollution value for address i on day j.

D_{1ij} = the distance (in feet) the closest station is from address i on day j.

S_{1j} = the observed air pollution values of the closest air pollution station to i on day j.

D_{2ij} = the distance (in feet) of the second closest station from address i on day j.

S_{2j} = the observed value of air pollution on day j for the second closest air pollution station to i.

D_{3ij} = the distance (in feet) of the third closest station from address i on day j.

S_{3j} = the observed value of air pollution on day j for the third closest air pollution station to i; and

$(i = 1, \cdots, d); \quad (j = 1, \cdots, m).$

The use of distance to weight each air pollution observation is simple and inexpensive to employ. The biggest disadvantage to its use is that only distance is taken into account. Admittedly, topographical and meteorological conditions can play important roles in fluencing the distribution of pollutants. Another disadvantage of using the distance system is that the air pollution values calculated for any address are constrained to a range of values, the limits of which are determined by the highest and lowest air pollution observations of the three closest stations used in Equation (7). However, given the structuring of the study's air pollution network, this disadvantage is not critical. The study's air pollution station network was designed to measure ambient air pollution. The air pollution station sampling sites were, for the most part, representative of the surrounding terrain, and were not subjected to contamination by a point source air pollution emission.

Several stations located in the immediate Portland Metropolitan area did not operate continuously during the two-year study period. The computer program used to calculate the weighted air pollution values took account of this non-operation. If a non-operating station was one of the three closest stations to a patient's work or residence address, then the non-operating station was passed over and the next closest station to the address was used in calculating the weighted air pollution value.

Derivation of the Ambient Air Pollution Variable: X_{13ijk} - Model 3, $\overline{X}_{11icj}$ - Model 5

Many of the Kaiser respondents work, and the place of work (in all but a few instances) was different from the residence address. One would expect, therefore, that on the same day air pollution values would be different as between the addresses, generally reflecting a suburban-urban gradient of ambient air quality. It was desired to reflect such differences in the air pollution values assigned to each patient. Hence, the air pollution variables in each model were weighted to reflect the patient's potential exposure to air pollution at both residence and job addresses.

The weighted air pollution value assigned to each patient was calculated by Equation (8):

$$\overline{P}_{ijk} = \frac{(J_{ijk} + T_{ijk})\, P'_{ijk} + [24 - (J_{ijk} + T_{ijk})]\, P^{*}_{ijk}}{24} \tag{8}$$

where

$\overline{P}_{ijk}$ = the weighted air pollution value assigned to the k^{th} patient who consumes outpatient medical services for disease i on day j.

J_{ijk} = the number of hours worked per day (including regular overtime) by the k^{th} patient consuming outpatient medical services for the i^{th} disease on day j.

T_{ijk} = the average transit time to and from work by the k^{th} patient consuming outpatient medical services for the i^{th} disease on day j.

P'_{ijk} = estimated air pollution at the job address for the k^{th} patient consuming outpatient medical services for the i^{th} disease on day j.

P^{*}_{ijk} = estimated air pollution at the residence address for the k^{th} patient consuming outpatient medical services for the i^{th} disease on day j; and

$(i = 1, \cdots, n)$; $(j = 1, \cdots, m)$; $(k = 1, \cdots, 0)$.

Whether the patient worked or not, and the transit time to and from work, was determined from the household interview. For purposes of calculating the weighted air pollution, it was always assumed that the patient was either at work, in transit, or at his place of residence. The transit time was added to the number of hours on the job, because it was felt the pollution in transit to and from the job site would be higher than air pollution at the place of residence.

A question in the household interview asked the respondent what days of the week he normally worked. Answers to the question allowed account to be taken in Equation (8) of normal work week patterns. If the patient indicated he worked Monday through Friday, then Saturday and Sunday were considered as days off; i.e., if he became ill on Saturday or Sunday, and consumed out patient medical services, the value of air quality assigned to him would be his residence air pollution. Unless it was indicated otherwise, Sunday was always considered a day off. An exception to this was when the patient indicated he worked through the weekend, but had a day off in the middle of the week. In this case, Wednesday was assumed to be that day. It was assumed that patients who had Mondays, Tuesdays, Thursdays, and Fridays off would be normally distributed about Wednesday. Patients who indicated they worked less than five days a week were assigned their residence air pollution values, because there was no way of telling, from the Kaiser data, which days they worked.

The Meteorological Data

Collecting and Analyzing the Meteorological Data

An attempt was made, via the selection of the meteorological data and the meteorological station sites, to account for the meteorological influences of the Columbia River Gorge. Areas affected by the Gorge are generally characterized by lower annual rainfall and cooler annual mean temperatures than other geographical areas located in the Willamette Valley. The differences result from the interaction of the dry, cold east Gorge winds with the moist marine air from the west.

Given the wide divergence of meteorological conditions between the Willamette Valley and the Columbia Gorge, and the initial decision to reflect in the analysis the effect of such variation on air pollution and health, it was important that any meteorological data selected for use in this study be representative of a large geographical area and be of good quality. Data from the National Weather Service (N.W.S.) of the U.S. Department of Commerce were used in this study.[1] The data were compiled from published sources [55, 56, 57].

There were many stations and data which could be coded within the study area. Several simple statistical tests and visual inspections of the data were conducted to determine what stations should be used and the frequency with which the data should be coded. The analyses dealt with variations of meteorological conditions in the study area over space and time. The period of record for these tests was 1967 through 1970.[2]

When one year was compared to another during the 1967 to 1970 period, mean annual temperature and total annual precipitation of all meteorological stations in the study area, with one exception, fluctuated together. That is, if Hillsboro was greater in mean annual temperature for 1967 compared to 1968, then so were the other stations. The exception was annual precipitation at Oregon City between 1969 and 1970 (see Figure 4 for a map of the study area).

A statistical test was conducted to determine whether annual weather patterns (as measured by temperature) were significantly different for the 1967-1970 period. For all meteorological stations taken as a group, the first test compared the highest and lowest annual mean temperatures recorded during the four-year period. The two stations exhibiting the largest difference between each other were Portland City (annual mean temperature 1967) versus Vancouver (annual mean temperature 1970). The test showed the means not to be statistically different at the 5 percent level.

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[1] In investigating and retrieving data available through the National Weather Service, the researchers are indebted to Stanley Holbrook, Oregon State Climatologist, National Weather Service, Portland, Oregon.

[2] The stations used in these analyses were located in or near the towns of Warren, Portland, Hillsboro, Oregon City, Troutdale, and McMinnville in Oregon; and Vancouver, Washington.

For all stations taken as a group, a similar test compared the highest and lowest monthly mean temperatures recorded (for the same months, but over the four-year observation period) in order to determine whether there were significant monthly fluctuations in temperature between the various stations. The statistical test showed the means to be statistically different from each other at the 1 percent level. The two stations exhibiting the largest difference were again Portland City and Vancouver for February 1970.

From these analyses it appeared that, while there may be monthly fluctuations between stations, the annual meteorological conditions within the study area were not materially different with respect to temperature. Where changes did occur from one year to the next with temperature and precipitation, the changes, with the exception noted, were all in the same direction.

Since this study was using daily medical records, and the air pollution values could be estimated daily, it was decided to use daily meteorological conditions. However, a judgment was made that, since all the stations seemed to fluctuate in the same direction, coding of daily data for all the stations would not materially add to the statistical analyses. Hence, the decision was made to code the daily meteorological observations of two stations, and assume that the stations would represent the meteorological changes occurring over the study area. The stations coded were Portland International Airport, located on the Columbia River, and Portland City Weather Bureau, located in downtown Portland. The Portland Airport station was assumed to be representative of the meteorological conditions affected by the Columbia Gorge. The Portland City station was selected because it was somewhat removed from the influence of the Gorge. Hence, data from the downtown station were considered representative of the southern portion of the study area. Patients consuming outpatient medical services were assigned the meteorological values of the station closest to their residence address (as determined using state plane coordinates).

Derivation of the Meteorological Variable: $\overline{X}_{14ijk}$ - Model 3, $\overline{X}_{10icj}$ - Model 5

The effect of temperature extremes on cardiovascular-respiratory problems was detailed in Chapter IV. It was desired to specify a measure which would incorporate both temperature extremes into one variable. Degree days, the absolute difference between the average daily temperature and 65° F, appeared to fulfill this requirement. As the average ambient temperature becomes colder, the value of the variable will increase. Similarly, as the average ambient temperature becomes warmer (above 65° F), the value of the variable will also increase. Higher values of this variable were expected to be positively related to the dependent variables of both statistical models.

IX. STATISTICAL RESULTS

Preliminary Analyses on the Air Pollution Data

An initial question which had to be answered was whether air quality levels vary over time and space in the Portland area. Several preliminary analyses were conducted on the air pollution data to determine whether such variation existed. The analyses included computing the monthly means, variances, and standard deviations for nine suspended particulate stations which had been in operation throughout the 1969-1970 study period. The results indicated quite an amount of within-month-variation for each station.

An analysis of variance was performed on the monthly means of nine suspended particulate stations operating during the entire 1969-1970 period. The analysis of variance may be seen in Table 6. It should be noted that the following holds for any analysis of variance containing interaction terms: if any of the first order interactions are significant (year by month, year by station, and month by station in Table 6), then the main effects (year, month, and station in Table 6) do not have any meaning.

Looking at the first interaction term (Y × M), the following hypothesis is tested: Ho_1: The differences between months are the same from one year to the next. The null hypothesis is rejected. The F test is significant at the 1 percent level. The differences between identical months are not the same from one year to the next. One could tentatively conclude from the analysis that the depth of the pollution surface (amount of pollution) in Portland changes from one year to the next within the same months.

The interaction M × S tests the following hypothesis: Ho_2: The differences between stations are the same from one month to the next within the same year. The F test was not significant; hence the null hypothesis is not rejected. One can tentatively conclude that the differences between stations do not change significantly from one month to the next. This would tend to indicate that while the depth of the pollution surface might change by month from one year to another, the shape of the surface will not change significantly from station to station over time.

Table 6. ANALYSIS OF VARIANCE TABLE FOR THE NINE SUSPENDED PARTICULATE STATIONS

Source	Sums of squares	Degrees of freedom	Mean square	F
Year....................	3967.2244	1	3967.2244	—
Month...................	17909.9682	11	1628.1789	—
Station.................	102040.3072	8	12755.0384	—
Year by month (Y × M)....	16389.1217	11	1489.9202	3.2279
Month by station (M × S).	5398.1639	88	613.3882	1.3289
Year by station (Y × S)..	3881.0485	8	485.1311	1.0510
Year by month by station (Y × M × S).........	40618.4404	88	461.5732	—
TOTAL...............	238784.2743	215	—	—

The interaction Y × S tests the following hypothesis: Ho_3: The differences between stations are the same from one year to the next. The F statistic is not significant, and Ho_3 is not rejected. This would tend to corroborate the M × S interaction: while there may be changes in the depth of the pollution surface, the relative shape of the surface does not change from one year to the next.

The tests of the above hypotheses allowed the following conclusions to be advanced about air pollution patterns in Portland. If annual or monthly isopleths of pollution loadings in Portland were compared, one would find that while the amount of pollution (depth of the pollution surface) in Portland may vary over time, the relative loadings (shape of the pollution surface) would remain unchanged; i.e., areas with high pollution would remain high in comparison to all other areas, and areas with low pollution would generally remain low in comparison to all other areas.

Preliminary Examination of the Statistical Models

Only outpatient medical records of respondents to the household interview were examined in this study. To obtain these records, a sort was made on the "Outpatient I.C.D.A., T-Code Tape," discussed in Chapter VI, to create a second magnetic tape containing only respondent outpatient medical records for 1969 to 1970. This tape will be referred to as "The C.R.V.S. Severity Tape." It contained approximately 6,000 outpatient medical records.

The medical records were matched to the socioeconomic-demographic data on the "Household Interview Tape." As the medical and socioeconomic-demographic records were being matched, the records of respondents not living in the study area were deleted.

Air pollution and meteorological values were estimated for each patient on the day of contact with the medical system, and for each of the three days prior to that contact. The lagging of air pollution and meteorological values was an attempt to determine how soon after meteorological and air pollution conditions change do morbidity patterns change.

There are two principal types of delays which can effect a postponement between exposure and the seeking of medical care: (1) a short time may elapse between exposure to environmental conditions and disease onset or aggravation; (2) once a patient is ill, it may take him awhile to recognize the fact and seek medical care. The quest for determining a time sequence in causality between exposure to air pollution and meteorological phenomena and the onset of an illness presupposes some reasonable length of time between cause and effect. Because several medical studies, using daily data, have used one-, two-, and three-day lags [14, pp. 1062-1063; 21, p. 594], this study did likewise.

Two statistical models were postulated for this study. The transformations which might be required on the models' variables, in order to obtain the best fit of the data, were not known beforehand. In most instances there were numerous transformations which could have been performed on each variable. Using all data to test each transformation would have been expensive and time-consuming. Hence, to pretest the statistical models, two 10-percent systematic samples were drawn from The C.R.V.S. Severity Tapes. One sample was used to derive the final specification of Model 3; the other was used on Model 5.

Many transformations were tried with each of the variables in the models. One method was to examine scatter diagrams between the dependent and each of the independent variables. The form of the scatter would often provide clues to transformations needed on the variables. These transformations were then tried in regression. Where several transformations were tried on the same variable, the criterion used to decide between the specifications was to choose the transformation giving the highest level of significance; i.e., the largest t statistic on the coefficient. Where this did not discriminate, the transformation which yielded the highest coefficient of multiple determination (R^2) was chosen. The following variables in both models were transformed to natural logarithms: the dependent variables, the air pollution variables (including all lags), and the meteorological variables (including all lags). The meteorological variable was respecified from degree days to a Temperature Humidity Index (T.H.I.).

Degree days was dropped from the models because the coefficients were not statistically significant and had negative instead of the expected positive signs. The discussion on the meteorological variable in Chapter IV demonstrated there are many meteorological conditions which can affect a state of health. *A priori*, it is difficult to identify the meteorological conditions which will affect a state of health within a given region; i.e., different meteorological variables must be tried. Degree days was included within the model because it was a variable which took account of extremes of temperature at both spectrums. Probably the prime reason the variable was not significant was the lack of variation exhibited in the variable. For example, on the 10 percent sample, degree days (unlagged) had a mean of 13.65 and a standard deviation of 8.89. This would tend to indicate that temperature extremes in Portland were not severe enough to affect states of health.

Temperature and humidity have been associated with both cardiovascular and respiratory problems. The T.H.I. allows both conditions to be expressed as one measure. Originally, the main purpose for developing the T.H.I. was to have a simple method of determining the effect of summer conditions in the United States on human comfort [51, p. 41]. There are several ways to calculate the T.H.I. The following formula [51, p. 41] was used in this study:

$$\text{T.H.I.} = 0.4(T_d + T_w) + 15 \qquad (9)$$

where T_d = dry-bulb (air) temperature in °F.

T_w = wet-bulb temperature in °F.[1]

Higher values of the T.H.I. mean increased discomfort to the patient. Empirical studies in the United States have shown that 10 percent of the general population becomes uncomfortable when T.H.I. reaches a value of 70. Fifty percent of the population becomes uncomfortable when the T.H.I. reaches 75 [51, p. 42]. For patients susceptible to circulatory and respiratory problems, higher T.H.I. values could aggravate existing health conditions and result in increased consumption of medical services. Hence, it is expected the coefficient of this variable will be positively related to the dependent variable.

The respecified statistical models resulting from the pretest are given below. Model 3 has been respecified as Model 10, and Model 5 has been respecified as Model 11.

$$\begin{aligned} \ln Y_{ijk} = {} & \ln\beta_0 + \beta_1 X_{1ijk} + \beta_2 X_{2ijk} + \beta_3 X_{3ijk} + \beta_4 X_{4ijk} \\ & + \beta_5 X_{5ijk} + \beta_6 X_{6ijk} + \beta_7 X_{7ijk} + \beta_8 X_{8ijk} + \beta_9 X_{9ijk} \\ & + \beta_{10} X_{10ijk} + \beta_{11} X_{11ijk} + \beta_{12} X_{12ijk} + \beta_{13} \ln X_{13ijk} \\ & + \beta_{14} \ln X_{14ijk} + \varepsilon_{ijk} \end{aligned} \tag{10}$$

where X_{14ijk} = a measure of the meteorological conditions that the k^{th} patient, who consumes medical services for disease i, is exposed to on day j, expressed as a Temperature Humidity Index; and

$(i = 1, \cdots, n)$; $(j = 1, \cdots, m)$; $(k = 1, \cdots, \ell)$,

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[1]Atmospheric humidity can be measured by use of a mercury thermometer with a moistened wick surrounding the mercury reservoir. With adequate ventlation, the wick's temperature is lowered by evaporation to a constant value, which is called the <u>wet-bulb temperature</u>. This, together with air temperature and suitable tables, can be used to determine dew point or relative humidity [36, p. 7].

The only meteorological station in Portland which measured wet-bulb temperature was at the Portland International Airport. Hence, both wet-bulb and dry-bulb temperatures used in calculating the T.H.I. were measured at the Portland Airport and inferred as being representative of the entire study area.

and

$X_{1ijk}, \cdots, X_{13ijk}$; $\beta_0, \cdots, \beta_{13}$; and ε_{ijk} are as previously defined in Model 3.

Model 5 is respecified as follows:

$$\ln Y_{icj} = \ln\beta_0 + \beta_1\overline{X}_{1icj} + \beta_2\overline{X}_{2icj} + \beta_3\overline{X}_{3icj} + \beta_4\overline{X}_{4icj} + \beta_5\overline{X}_{5icj} + \beta_6\overline{X}_{6icj} + \beta_7\overline{X}_{7icj} + \beta_8\overline{X}_{8icj} + \beta_9\overline{X}_{9icj} + \beta_{10}\ln\overline{X}_{10icj} + \beta_{11}\ln\overline{X}_{11icj} + \varepsilon_{icj} \quad (11)$$

where $\overline{X}_{10icj}$ = the average measure of meteorological conditions for patients consuming outpatient medical services for disease i from census tract c on day j, expressed as a Temperature Humidity Index; and

$(i = 1, \cdots, n)$ $(c = 1, \cdots, p)$; $(j = 1, \cdots, m)$,

and $\overline{X}_{1icj}, \cdots, \overline{X}_{9icj}$, and $\overline{X}_{11icj}$; $\beta_0, \cdots, \beta_9$, and β_{11}; and ε_{icj} are as previously defined in Model 5.

There were several results using the pretest which influenced the testing and respecification of the statistical models. Statistical tests were conducted to determine whether an interaction existed between the air pollution and meteorological variables. The interaction variable was included in the model separately from, and with, variables measuring meteorological and air pollution phenomena. The tests were not statistically significant.

Two air pollution variables were examined during the pretest. One variable was composed only of the patient's estimated exposure to air pollution at his place of residence. The second variable tested was weighted, as discussed in Chapter VIII, to reflect exposure to air pollution at place of residence and work. The weighted air pollution variable proved to be statistically more significant.

It was felt that if a relationship between air pollution and the consumption of medical services were to exist, then the association would most likely be reflected through medical services used to treat respiratory and circulatory illnesses (Categories I and IV in Table 1, Chapter VI). Air pollution was found to be statistically significant at the 5 percent level for respiratory diseases analyzed alone, and for circulatory-respiratory diseases analyzed together. Air pollution was not statistically significant when circulatory diseases were analyzed alone. For this reason, only respiratory and respiratory-circulatory diseases together were analyzed in the respecified models using all the data.

In the pretest regression on Model 11, air pollution was not statistically significant in affecting the consumption of outpatient medical services used to treat respiratory illnesses. The highest R^2 occurred when the air pollution and meteorological variables were lagged one day. Hence, given a severe budget constraint on the funds available for computer use, this model was not extended to analyze other disease categories.

It was expected there might be a problem with autocorrelation in the analysis. However, a plot of the residuals indicated that such a problem did not exist for either of the disease categories tested.

The results of the pretest regressions may be seen in Appendix Tables B-1, B-2, and B-3. Attention is now turned to discussing the analysis associated with the respecified statistical models using all of the data.

The Regression Results: Statistical Model 10

The respecified statistical models were tested for each of the selected disease categories. To be more specific, Model 10 was tested with respiratory diseases alone and with circulatory-respiratory diseases combined. The regression results for each disease category can be seen in Tables 7 and 8. Submodels 1 through 4 indicate the lags for the air pollution and meteorological variables. Submodel 1 is not lagged; Submodel 2 is lagged by one day; Submodel 3 is lagged by two days; and Submodel 4 is lagged by three days.

Before proceeding directly to the regression results, it is best to summarize again the characteristics assumed inherent in the dependent variable (Y_{ijk}) of Model 10. All the outpatient medical services used to treat a single disease

Table 7. REGRESSION RESULTS OF STATISTICAL MODEL 10: RESPIRATORY DISEASES

Variables	Submodel 1 - unlagged: Coefficients[a/]	Submodel 1 - unlagged: t statistics	Mean[b/]	Submodel 2 - lagged 1 day: Coefficients[a/]	Submodel 2 - lagged 1 day: t statistics	Mean[b/]
Sample size	1700			1700		
Constant	4.0995E-01			1.7224E-01		
Age	9.2984E-04 (1.7641E-03)	0.5271	46.0506 (16.0231)	9.4703E-04 (1.7625E-03)	0.5373	c/
Sex	-9.2609E-02 (4.4077E-02)	2.1011	0.6818 (0.5537)	-9.1826E-02 (4.4040E-02)	2.0851	c/
Marital status	4.9017E-02 (7.0571E-02)	0.6946	0.8424 (0.3645)	5.0257E-02 (7.0520E-02)	0.7127	c/
No. of people in household	-2.2342E-04 (1.6566E-02)	0.0135	3.3906 (1.7783)	-5.5410E-04 (1.6546E-02)	0.0335	c/
Household income	1.3839E-06 (3.2721E-06)	0.4229	12085.4412 (7525.6879)	1.3071E-06 (3.2683E-06)	0.3999	c/
Race-Negro	-1.2499E-01 (1.0598E-01)	1.1793	0.0524 (0.2228)	-1.2354E-01 (1.0587E-01)	1.1669	c/
Race - other non-white	1.1757E-01 (1.8843E-01)	0.6240	0.0159 (0.1251)	1.1621E-01 (1.8814E-01)	0.6177	c/
Physically fit	-3.6543E-02 (7.1782E-02)	0.5091	0.1753 (0.3803)	-3.6802E-02 (7.1711E-02)	0.5132	c/
Somewhat physically fit	-6.6018E-02 (5.5690E-02)	1.1855	0.5624 (0.4962)	-6.7155E-02 (5.5637E-02)	1.2070	c/
Drinking	1.4501E-03 (6.4242E-04)	2.2573	12.4064 (37.9688)	1.4583E-03 (6.4184E-04)	2.2721	c/
Smoking index	1.1919E-04 (9.8823E-05)	1.2061	152.0516 (247.8353)	1.4583E-03 (9.8761E-05)	2.2721	c/
Occupational exposure index	1.3806E-06 (4.5747E-03)	0.3018	3.4162 (5.3893)	1.5975E-03 (4.5681E-03)	0.3497	c/
Air pollution	8.1786E-02 (3.6601E-02)	2.2346	61.2532 (34.8633)	8.4906E-02 (3.5969E-02)	2.3605	61.7633 (35.2088)
Temp. humidity index	3.9050E-01 (1.5010E-01)	2.6017	53.0533 (8.0905)	4.4765E-01 (1.4798E-01)	3.0250	52.9020 (8.1066)
Outpatient medical services			14.7539 (12.0912)			
R^2	2.1991E-02			2.3885E-02		

(continued)

Table 7. (CONTINUED)

Variables	Submodel 3 - lagged 3 days Coefficients[a/]	t statistics	Mean[b/]	Submodel 4 - lagged 4 days Coefficients[a/]	t statistics	Mean[b/]
Sample size	1700			1700		
Constant	3.2088E-01			2.8884E-01		
Age	9.8659E-04 (1.7643E-03)	0.5592	c/	1.0105E-03 (1.7641E-03)	0.5728	c/
Sex	-9.3276E-02 (4.4085E-02)	2.1158	c/	-9.6809E-02 (4.4086E-02)	2.1959	c/
Marital status	4.6437E-02 (7.0569E-02)	0.6580	c/	4.3497E-02 (7.0582E-02)	0.6163	c/
No. of people in household	-4.1014E-04 (1.6564E-02)	0.0248	c/	2.3213E-04 (1.6565E-02)	0.0140	c/
Household income	1.2893E-06 (3.2721E-06)	0.3940	c/	1.1461E-06 (3.2724E-06)	0.3502	c/
Race - Negro	-1.2677E-01 (1.0600E-01)	1.1959	c/	-1.2602E-01 (1.0601E-01)	1.1887	c/
Race - other non-white	1.2076E-01 (1.8824E-01)	0.6415	c/	1.2032E-01 (1.8821E-01)	0.6393	c/
Physically fit	-3.2048E-02 (7.1742E-02)	0.4467	c/	-3.1869E-02 (7.1726E-02)	0.4443	c/
Somewhat physically fit	-6.5781E-02 (5.5702E-02)	1.1809	c/	-6.3444E-02 (5.5724E-02)	1.1385	c/
Drinking index	1.4623E-03 (6.4238E-04)	2.2763	c/	1.4348E-03 (6.4241E-04)	2.2334	c/
Smoking index	1.2433E-04 (9.8795E-05)	1.2585	c/	1.2607E-04 (9.8778E-05)	1.2763	c/
Occupational exposure index	1.7257E-03 (4.5709E-03)	0.3776	c/	1.9866E-03 (4.5709E-03)	0.4346	c/
Air pollution index	6.4037E-02 (3.6881E-02)	1.7363	62.1665 (35.1278)	4.6301E-02 (3.6696E-02)	1.2617	62.1979 (35.2225)
Temp. humidity index	4.3036E-01 (1.4653E-01)	2.9370	52.9290 (8.1986)	4.5616E-01 (1.4446E-01)	3.1577	53.0916 (8.3442)
Outpatient medical services						
R^2	2.1868E-02			2.1725E-02		

a/ The standard error of the regression coefficient is in parentheses. E-01, E 01, E 00, etc., indicate that the decimal place of the number is to be shifted to the left by one place; shifted to the right by one place; or not shifted at all, respectively.

b/ Means are untransformed; their standard deviations are in parentheses.

c/ The mean for this variable is the same as its mean in Submodel 1. Only the name of the lagged variables changed per model.

Table 8. REGRESSION RESULTS OF STATISTICAL MODEL 10: CIRCULATORY-RESPIRATORY DISEASES

Variables	Submodel 1 - unlagged Coefficients[a/]	t statistics	Mean[b/]	Submodel 2 - lagged 1 day Coefficients[a/]	t statistics	Mean[b/]
Sample size	3363			3363		
Constant	1.3190E 00			1.2441E 00		
Age	-1.6382E-03 (1.2708E-03)	1.2891	54.3717 (16.2918)	-1.6180E-03 (1.2698E 00)	1.2742	c/
Sex	2.4635E-04 (2.9157E-02)	0.0084	0.6375 (0.5613)	1.3022E-04 (2.9151E-02)	0.0045	c/
Marital status	2.9929E-03 (4.4089E-02)	0.0679	0.8112 (0.3914)	2.8894E-03 (4.4082E-02)	0.0655	c/
No. of people in household	1.7845E-03 (1.3087E-02)	0.1364	2.8944 (1.6443)	1.8327E-03 (1.3082E-02)	0.1401	c/
Household income	-1.1933E-06 (2.2427E-06)	0.5321	10765.5367 (7781.8663)	-1.1682E-06 (2.2433E-06)	0.5207	c/
Race - Negro	-9.6164E-02 (8.9548E-02)	1.0739	0.0324 (0.1771)	-9.6459E-02 (8.9532E-02)	1.0774	c/
Race - other non-white	8.0489E-02 (1.2691E-01)	0.6342	0.0167 (0.1280)	8.1491E-02 (1.2684E-01)	0.6425	c/
Physically fit	-6.2167E-02 (4.5984E-02)	1.3519	0.1861 (0.3893)	-6.2172E-02 (4.5976E-02)	1.3523	c/
Somewhat physically fit	-6.0504E-02 (3.6337E-02)	1.6651	0.5031 (0.5001)	-6.0654E-02 (3.6328E-02)	1.6696	c/
Drinking index	7.9656E-04 (4.0020E-04)	1.9904	10.8700 (40.2684)	7.9294E-04 (4.0011E-02)	1.9818	c/
Smoking index	6.0772E-05 (6.6437E-05)	0.9147	153.9242 (247.1794)	6.0766E-05 (6.6422E-05)	0.9148	c/
Occupational exposure index	6.2953E-03 (3.4506E-03)	1.8244	2.6489 (4.8684)	6.3640E-03 (3.4489E-03)	1.8453	c/
Air pollution index	2.1134E-02 (2.5430E-02)	0.8311	62.3909 (34.3420)	1.9713E-02 (2.5015E-02)	0.7881	62.6497 (34.6665)
Temp. humidity index	2.4138E-01 (1.0057E-01)	2.4001	54.3396 (8.1619)	2.6135E-01 (9.9166E-02)	2.6355	54.2546 (8.2262)
Outpatient medical services			13.9063 (12.6867)			
R^2	8.0063E-03			8.3310E-03		

(continued)

Table 8. (CONTINUED)

Variables	Submodel 3 - lagged 3 days Coefficients[a/]	t statistics	Mean[b/]	Submodel 4 - lagged 4 days Coefficients[a/]	t statistics	Mean[b/]
Sample size	3363			3363		
Constant	1.4245E 00			1.3690E 00		
Age	-1.5595E-03 (1.2698E-03)	1.2281	c/	-1.5932E-03 (1.2701E-03)	1.2544	c/
Sex	-9.2519E-04 (2.9156E-02)	0.0317	c/	-1.7524E-03 (2.9143E-02)	0.0601	c/
Marital status	2.6729E-03 (4.4103E-02)	0.0606	c/	1.4193E-03 (4.4101E-02)	0.0322	c/
No. of people in household	1.9317E-03 (1.3086E-02)	0.1476	c/	2.0741E-03 (1.3083E-02)	0.1585	c/
Household income	-1.2578E-06 (2.2455E-06)	0.5601	c/	-1.3074E-06 (2.2458E-06)	0.5821	c/
Race - Negro	-9.6901E-02 (8.9581E-02)	1.0817	c/	-9.6205E-02 (8.9583E-02)	1.0739	c/
Race - other non-white	8.3529E-02 (1.2687E-01)	0.6584	c/	8.1589E-02 (1.2684E-01)	0.6432	c/
Physically fit	-6.1298E-02 (4.5995E-02)	1.3327	c/	-6.0687E-02 (4.5995E-02)	1.3194	c/
Somewhat physically fit	-6.1317E-02 (3.6338E-02)	1.6874	c/	-6.0791E-02 (3.6335E-02)	1.6731	c/
Drinking index	7.9628E-04 (4.0027E-04)	1.9894	c/	7.9438E-04 (4.0019E-04)	1.9850	c/
Smoking index	6.2927E-05 (6.6441E-05)	0.9471	c/	6.1176E-05 (6.6455E-05)	0.9206	c/
Occupational exposure index	6.3350E-03 (3.4490E-03)	1.8368	c/	6.3415E-03 (3.4484E-03)	1.8390	c/
Air pollution index	-1.3033E-03 (2.5491E-02)	0.0511	62.8473 (34.6274)	-8.4495E-03 (2.5556E-02)	0.3306	62.7691 (34.5243)
Temp. humidity index	2.3656E-01 (9.8931E-02)	2.3912	54.2279 (8.2513)	2.5834E-01 (9.9073E-02)	2.6076	54.3663 (8.2780)
Outpatient medical services						
R^2	7.6485E-03			7.9576E-03		

a/ The standard error of the regression coefficient is in parentheses. E-01, E 01, E 00, etc., indicate that the decimal place of the number is to be shifted to the left by one place; shifted to the right by one place; or not shifted at all, respectively.

b/ Means are untransformed; their standard deviations are in parentheses.

c/ The mean for this variable is the same as its mean in Submodel 1. Only the name of the lagged variables changed per model.

incident per contact with the medical system were expressed in California Relative Value units. The units were transformed to dollar values. Hence, the dollar values would reflect the quantity of medical services consumed per contact.

This section will discuss the regression results of Model 10 by independent variable. The regression results for the respiratory disease model will be analyzed first (table 7), then the results of the circulatory-respiratory diseases combined will be discussed (table 8).

Age of the Patient (X_{1ijk})

Respiratory Diseases - The estimated coefficients were not significantly different from zero and, hence, do not appear to influence the consumption of outpatient medical services per contact with the Kaiser system. The average age of the patient consuming outpatient medical services for respiratory diseases was 46 years.

Circulatory-Respiratory Diseases - The estimated coefficients for age were significantly different from zero at the 20 percent level for Submodel 1 in Table 8.[1] The coefficients in the other models were not statistically significant.

The signs of the coefficients in Model 10 were negative. The hypothesized sign for this variable was positive, i.e., the older the patient becomes, the more medical services he consumes. The negative coefficient indicates that he consumes fewer medical services.

Two explanations can be given for the negative sign on the coefficient. One, since the variable is barely significant at 20 percent, the results should be discounted; i.e., there is a one in five chance of committing a Type I error on the statistical test. However, the average age for patients consuming outpatient medical services for circulatory-respiratory illnesses is 54 years; for respiratory diseases it was 46. This indicates that an older group of patients are

[1]Because of the nature of the study and the type of data being used, it was decided that any coefficient not significantly different from zero at the 20 percent level would be considered not statistically significant.

obtaining treatment for circulatory-respiratory problems. Hence, the second reason the age coefficient may be negative is as follows: Most circulatory-respiratory diseases in older people may be severe enough to require hospitalization. Therefore, fewer medical services are consumed on an outpatient basis. Younger patients, with a probable better state of health, would most likely not be hospitalized. Treatment of the diseases for the younger patients would be at a clinic and, proportionately, they would consume more outpatient medical services per visit.[1]

Sex of the Patient (X_{2ijk})

Respiratory Diseases - The estimated coefficients (for all lags) of this variable were significantly different from zero at the 5 percent level in Model 10. The signs of the coefficients were negative, which indicated that women consumed fewer medical services than men. This is not unexpected when one considers that the incidence of many respiratory diseases are lower for women than men.

Circulatory-Respiratory Diseases - The regression coefficients were not statistically significant. This would tend to indicate that, at least with circulatory-respiratory diseases combined, sex does not have a discriminating role in the consumption of outpatient medical services. In all the disease categories, over 60 percent of the patients consuming outpatient medical services were women.

Marital Status (X_{3ijk})

Respiratory Diseases - The coefficients of the marital status variable were not statistically significant. This implies that marital status has no effect on the consumption of medical services. Over 84 percent of the patients receiving outpatient medical services were married.

Circulatory-Respiratory Diseases - As with respiratory diseases, the marital status coefficients were not statistically different from zero. Over 81 percent of the

[1]This is not to argue that older patients may not visit a clinic more than younger patients. It is argued that, proportionately, they may consume fewer medical services per visit.

patients receiving treatment for circulatory-respiratory diseases were married.

Number of People in the Patient's Household (X_{4ijk})

Respiratory Diseases - The estimated coefficients of this variable were not statistically significant. Although the average number of people within the patient's household was 3.39, this appeared not to influence the consumption of outpatient medical services per visit to the clinic. However, while crowding appears to have no effect on the severity of the disease state, it may still affect the number of visits to the clinic. The latter point was not tested by this model.

Circulatory-Respiratory Diseases - Since crowding had no effect on the consumption of medical services used in treating respiratory diseases, it was not surprising to find it statistically insignificant with circulatory-respiratory diseases. The average number of people in the patient's household who were suffering from circulatory-respiratory diseases was 2.89. Once more this indicates that an older set of people were being analyzed in the circulatory-respiratory disease category.

Household Income (X_{5ijk})

Respiratory Diseases - Household income was included in this study in an attempt to describe the patient's ability to make expenditures in lieu of consuming medical services which would preserve or improve his state of health. Examples of such expenditures would be those made for sound housing and nutritional food. The coefficients of the household income variables were not statistically significant in any of the submodels of 10.

It would appear, at least for outpatient medical services, that household income does not play a significant role in this respect. One reason for this, perhaps, is the availability of income supplements within the Portland area to low-income families. These would include welfare, availability of surplus foods, and/or food stamps. The income supplements, and the opportunity for all Kaiser members to consume the same kinds of medical services, would tend to minimize any differences in the consumption of medical services as between families having different income levels. The mean household income of patients consuming medical services for respiratory illnesses was $12,085.

Circulatory-Respiratory Diseases - The coefficients were not significantly different from zero. The reasons for the nonsignificance are the same as those given above for the respiratory diseases.

The household income for patients consuming outpatient medical services for circulatory-respiratory illnesses was $10,766. Again, this reflects the older age group being examined in this disease category. Based on age, family size, and income, it would appear that more patients in the circulatory-respiratory category are retired than is the case for those afflicted with respiratory diseases only.

Race (X_{6ijk}, X_{7ijk})

Respiratory Diseases - The coefficients of the two race variables were not statistically significant. This would imply that race is not important in the consumption of outpatient medical services as between Negroes (X_{6ijk}), other non-whites (X_{7ijk}), and whites. Of the contacts with the Kaiser system which resulted in outpatient medical services being consumed, approximately 5.2 percent of the contacts were by Negroes, 1.6 percent by other non-whites, and 93.2 percent by whites.

Circulatory-Respiratory Diseases - Neither of the race coefficients were statistically significant. Of the contacts with the Kaiser system resulting in the consumption of medical services, approximately 3.2 percent of the contacts were by Negroes, 1.7 percent by other non-whites, and the other 95.1 percent by whites.

Physical Fitness (X_{8ijk}, X_{9ijk})

Respiratory Diseases - Physical fitness was expressed by two qualitative variables. X_{8ijk} represented "a great deal of time and energy expended by the patient in being physically fit;" X_{9ijk} represented "some time and energy expended by the patient in being physically fit." Statistically these were tested against the third category, expressed as "very little time and energy expended being physically fit." It was expected that the more physically fit patient would consume fewer medical services.

With respiratory diseases, the coefficients were not significant at the 20 percent level. It would appear that physical fitness (as measured here) does not influence the consumption of outpatient medical services for respiratory diseases.

Of the contacts with the Kaiser system which resulted in the consumption of medical services, 17.53 percent indicated they spent a great deal of time and energy being physically fit; 56.24 percent indicated they spent some time and energy being physically fit; 26.23 percent spent very little time and energy being physically fit.

Circulatory-Respiratory Diseases - The coefficient of X_{8ijk} was significantly different from zero at the 20 percent level in all submodels. X_{9ijk} was statistically significant at the 10 percent level in all submodels. The signs on both of the coefficients were negative, as expected. The coefficient of X_{8ijk} was larger than X_{9ijk} (-0.0622 versus -0.0605, respectively). This would imply that more physically fit patients consume fewer medical services. There is a suspected association between lack of physical exercise and coronary heart disease [20, p. 15], and lack of exercise and circulatory problems in general. Hence, with circulatory-respiratory diseases it was not a surprise that the physical fitness variables were statistically significant, but not statistically significant when the respiratory diseases were analyzed alone.

Of the patients contacting the Kaiser system and consuming outpatient medical services for circulatory-respiratory diseases, 18.6 percent, 50.3 percent, and 31.1 percent indicated they spent a great deal, some, and very little time and energy, respectively, being physically fit.

Drinking (X_{10ijk})

Respiratory Diseases - The estimated coefficients for X_{10ijk} were significantly different from zero at the 5 percent level in all submodels. The variable measured how many times a year a respondent drank six drinks, eight cans of beer, or a bottle of table wine. The estimated coefficients of the variable had the expected positive signs. This would tend to support the hypothesis that heavy drinking can affect a state of health and influence the consumption of outpatient medical services.

The average number of times a year patients consumed alcohol excessively (as defined in the paragraph above) was 12.4. The mean reflects many zero values assigned to respondents who indicated they had not consumed alcoholic beverages excessively during the 12 months prior to the household interview date. The standard deviation of the mean was 37.9.

Circulatory-Respiratory Diseases - For all the submodels, the coefficients were statistically significant at the 5 percent level. All the coefficients had the expected positive signs. The average number of times per year patients indicated they drank excessively was 10.9. The standard deviation for the mean was 40.3.

Cigarette Smoking Index (X_{11ijk})

Respiratory Diseases - While the coefficients had the right positive signs, none were significantly different from zero at the 20 percent level. The coefficient in Submodel 4 came closest to being significantly different from zero at the 20 percent level. The index took a value of zero if the patient indicated he had never regularly smoked cigarettes in his life. Of the 2,439 respondents to the household interview, 991, or 40.6 percent, indicated they had not smoked regularly in the past. The mean smoking index for patients consuming medical services was 152.1, with a standard deviation of 247.2.

If any disease category would have been most affected by cigarette smoking, respiratory diseases should have been. There were a number of potential problems with the cigarette smoking index variable which could have resulted in its not being significant. Perhaps not enough weight in the index was attached to the cigarette smoking habits of former smokers. The variable could be respecified to include only the number of cigarettes smoked per day, the number of years the patient has smoked, or whether the patient has ever smoked or not.

It is also quite possible that patients suffering from diseases most affected by cigarette smoking (chronic bronchitis and emphysema) would receive proportionately more of their medical services in the hospital. This would particularly be true in more severe disease cases. Also, once a patient has a disease affected by smoking, he may visit the doctor more often but the amount of medical services consumed per visit would remain constant.

Circulatory-Respiratory Diseases - The coefficients were not statistically significant in any of the models. If the coefficients were not statistically significant with respiratory diseases, the fact they were not significant with circulatory-respiratory diseases combined was not surprising. Again, the lack of statistical significance may be due to the same reasons indicated for the respiratory disease category above. The mean smoking index for patients consuming medical services was 153.9, with a standard deviation of 247.2.

Occupational Exposure Index (X_{12ijk})

Respiratory Diseases - This variable was expressed as an index. A value of zero was assigned to patients who did not work. Values greater than zero were assigned to each working patient, based upon the number of hours worked per day times a weighting factor representing job-related exposure to particulates.

The coefficients were not significantly different from zero at the 20 percent level. This is not surprising given the fact that 23 percent of the subscribers in the 5 percent sample were employed in clerical-sales [17, p. 301], resulting in a low occupational exposure index. Also, approximately 39 percent of the respondents to the questionnaire did not work at all. The mean occupational exposure index of those seeking medical services was 3.4; the standard deviation was 5.4.

Circulatory-Respiratory Diseases - The coefficients were statistically significant at the 10 percent level. The signs of the coefficients were positive, as expected. Why the coefficients would be statistically significant for circulatory-respiratory diseases, and not for respiratory diseases alone, is not known. The mean occupational exposure index for those consuming medical services was 2.6; the standard deviation was 4.9.

Air Pollution (X_{13ijk})

Respiratory Diseases - The coefficients of the air pollution variables were significantly different from zero for each of the submodels in Table 7, as follows:

Submodel 1 - significantly different from zero at the 5 percent level;
Submodel 2 - significantly different from zero at the 2 percent level;

Submodel 3 - statistically significant at the 10 percent level;

Submodel 4 - not statistically significant at the 20 percent level.

All coefficients had positive signs, as expected. The null hypothesis that deterioration in air quality causes no increase in the consumption of medical services per outpatient contact with the medical system is rejected.

The highest level of statistical significance for the air pollution coefficient occurred in Submodel 2, where the variable was lagged by one day. This model also had the highest R^2 of the four models. This would tend to confirm the belief expressed earlier that there is a delay between exposure to air pollution and contact with the medical system.

Using the coefficients from each of the submodels in which they were statistically significant, a 20 microgram increase in air pollution, from 60 to 80 micrograms per cubic meter, would increase outpatient medical costs per contact as follows:

Submodel 1 - an increase of 3.3 cents;

Submodel 2 - an increase of 3.5 cents;

Submodel 3 - an increase of 2.4 cents.

The average exposure to air pollution (lagged one day) of patients seeking outpatient medical services was 61.8 micrograms per cubic meter. The standard deviation was 35.2. The means and standard deviations for each of the variables may be seen in Table 7.

<u>Circulatory-Respiratory Diseases</u> - The air pollution coefficients were not statistically significant. The null hypothesis that deterioration in air quality causes no increase in the consumption of medical services per outpatient contact with the medical system is not rejected.

One reason, perhaps, why air pollution is not statistically significant is that many circulatory problems may be severe enough to require hospitalization. Any outpatient medical services consumed for treatment of circulatory problems would be routine, thereby limiting the amount of medical services consumed. The average unlagged exposure to air pollution for patients obtaining medical care was

62.4 micrograms. The standard deviation about the mean was 34.3. The means and standard deviations for each of the other lags may be seen in Table 8.

Meteorological Conditions (X_{14ijk})

Respiratory Diseases - The estimated coefficients for the T.H.I. variable were statistically significant at the 1 percent level for all the models in Table 7, with the most significance occurring when the variable was lagged three days. All of the coefficients had the expected positive signs. This would tend to support the hypothesis that the combined factors of temperature and humidity influence the consumption of medical services.

The mean T.H.I. value (unlagged) of those consuming outpatient medical services for respiratory diseases was 53.0, with the standard deviation being 8.2. The mean does not compare to the empirical evidence (previously cited) establishing a T.H.I. of 70 as causing 10 percent of the population to become uncomfortable. However, since this study is dealing with respiratory diseases, one would expect the patients to be considerably more susceptible to temperature and humidity than would members of the general population. This would imply that the T.H.I. values for these patients could be lower than those cited in the empirical studies, still cause discomfort to the patient afflicted with respiratory diseases and, hence, precipitate an increase in the consumption of outpatient medical services used to treat the diseases.

Circulatory-Respiratory Diseases - The coefficients of the T.H.I. variable were significantly different from zero in each of the models in Table 8, as follows:

Submodel 1 - significantly different from zero at the 2 percent level;
Submodel 2 - significantly different from zero at the 1 percent level;
Submodel 3 - statistically significant at the 2 percent level;
Submodel 4 - statistically significant at the 1 percent level.

The signs of the coefficients were positive, as expected.

The mean T.H.I. value (lagged two days) for patients suffering from circulatory-respiratory diseases was approximately 54.2, with a standard deviation of 8.3.

The same argument applies to circulatory-respiratory diseases as was used with the respiratory diseases above. One would expect that patients suffering from circulatory-respiratory illnesses would be more susceptible to temperature and humidity and, hence, consume more medical services.

Summary

Respiratory Diseases - The following coefficients of the variables were significantly different from zero in Model 10 at 20 percent or higher: Sex (X_{2ijk}); Drinking habits (X_{10ijk}); Air pollution (X_{13ijk}), except in Submodel 4 of (10); and Meteorological conditions - T.H.I. (X_{14ijk}). The overall F tests for regression on all four models were statistically significant at the 1 percent level.

Circulatory-Respiratory Diseases - In Model 10 the following coefficients were statistically significant at 20 percent or higher: Age (X_{1ijk}), significant only in Submodel 1 and with a negative sign; Physical fitness (X_{8ijk} and X_{9ijk}); Drinking habits (X_{10ijk}); Occupational exposure (X_{12ijk}); Meteorological conditions - T.H.I. (X_{14ijk}). The overall F tests for regression on all four models were statistically significant at the 5 percent level.

The Regression Results: Statistical Model 11

Model 11 was specified in an attempt to determine whether air pollution has an effect on the number of contacts with the medical system where the cost per contact may be more or less constant. If the hypothesis that air pollution has no effect on the consumption of medical services per contact with the medical system were accepted, then it was felt the effects of air pollution on the number of contacts with the system could be tested indirectly with (11). The main fault with (11) was that only socioeconomic-demographic characteristics of patients contacting the Kaiser system were accounted for. That is, the socioeconomic-demographic characteristics of those who were at risk (at risk to contract a disease and use the Kaiser facilities) in each census tract were not taken into account within the independent variables unless they contacted the Kaiser system.

As a result of the pretest regressions, only respiratory diseases were included in the analysis. Given a severe budget constraint on the funds available for computer use, Model 11 was tested using only a one-day lag. The regression results of these models may be seen in Table 9, which also contains the means and standard deviations of the variables used in the model.

The following variables were statistically different from zero at the 20 percent level or higher in statistical Model 11: Sex ($\overline{X}_{2icj}$); Household income ($\overline{X}_{5icj}$), which had a positive relationship with the dependent variable instead of the negative relationship hypothesized; Drinking habits ($\overline{X}_{7icj}$); and Smoking ($\overline{X}_{8icj}$). The overall F test for regression was statistically significant at the 5 percent level.

The results of Model 11 should be interpreted with caution. There were too few multiple observations per census tract per day resulting in the consumption of outpatient medical services. Table 7 shows that 1700 patients with respiratory illnesses contacted the Kaiser system and consumed outpatient medical services. Table 9 shows that even after aggregation over the census tract for the two-year study period, there were still 1,569 observations that entered regression. This means that during the study period only 131 observations came from the same census tract on the same day; the other 1,569 observations were single observations per census tract. In most instances, then, the independent variables were individual patient characteristics and not aggregate data as originally specified. Hence, a lack of a sufficient number of observations per census tract prohibited testing whether air pollution had an effect on the number of contacts with the medical system.

Statistical Results: A Discussion

The statistical results of the air pollution coefficients in Model 10 (respiratory diseases) tend to lead to a rejection of the null hypothesis that deteriorations in air quality cause no increase in the consumption of medical services (per contact with the medical system) to treat respiratory diseases. Also, the results would tend to confirm that there is a delay between exposure to air pollution and meteorological conditions and contact with the medical system. Using the best prediction model - Submodel 2 - an increase in air pollution by 20 micrograms (from 60 to 80 micrograms per cubic meter) would result in an estimated 3.5 cent increase in outpatient medical costs (for respiratory diseases) per contact with the medical system.

Table 9. REGRESSION RESULTS OF STATISTICAL MODEL 11: RESPIRATORY DISEASES - ONE DAY LAG

Variables	Coefficients[a/]	t Statistics	Mean[b/]
Sample size	1569		
Constant	-2.4077E 00		
Age	1.0900E-03 (2.2164E-03)	0.4918	46.0153 (16.0014)
Sex	9.6563E-04 (5.9370E-04)	1.6265	65.6474 (51.8897)
Marital status	-4.7287E-04 (8.9162E-04)	0.5303	84.4806 (36.1985)
No. of people in household	3.5658E-03 (2.0714E-02)	0.1722	3.3996 (1.7804)
Household income	6.9822E-06 (4.1046E-06)	1.7011	12112.6119 (7540.2050)
Race - non-white	3.1119E-04 (1.1727E-03)	0.2654	7.0746 (25.6481)
Drinking	1.0742E-03 (7.8481E-04)	1.3687	12.8749 (39.1389)
Smoking index	1.7571E-04 (1.2237E-04)	1.4359	154.0181 (250.5819)
Occupational exposure index	4.0458E-03 (5.7227E-03)	0.7070	3.4413 (5.4109)
Air pollution	-4.7287E-04 (8.9162E-04)	0.5303	61.7121 (34.9227)
Temperature humidity index	3.1119E-04 (1.1727E-03)	0.2654	53.0149 (8.0738)
Per capita costs			1.6083 (2.4151)
R^2	1.1830E-02		

a/ The standard error of the regression coefficient is in parentheses. E-01, E 01, E 00, etc., indicate that the decimal place of the number is to be shifted to the left by one place; shifted to the right by one place; or not shifted at all, respectively.

b/ The standard deviation about the mean is in parentheses; means are untransformed.

The regression results indicate that the procedures used in the study hold promise for quantifying the medical costs of air pollution. The R^2's for each regression are low; however, this is not surprising. While the X_{ijk}'s may be the pertinent explanatory variables, their influence on Y_{ijk} may be weak compared to the influence of the random disturbances. This particularly seems to be the case for relationships describing household behavior that have been estimated from cross-sections data [31, p. 234]. Other health studies research using multiple regression have also been characterized by low R^2's [33, 34, 35]. In a study of this kind there is more concern about the reliability of the estimated structural parameters than about the size of the coefficient of multiple determination [5, p. 248].

The theoretical framework for this study, and the statistical models derived from it, were a simplified description of a complex phenomenon. The consumption of medical services is dependent not only on happenings in the present time period, but also on occurrences which may have happened in the patient's past and, hence, are difficult to determine and quantify.

As an economic cost it would appear that air pollution has a minimal effect on increasing the quantity of outpatient medical services consumed in treating respiratory diseases. The reasons are that many such visits are routine and, while air pollution may affect the number of visits, it does not dramatically affect the cost per visit. This is important to know, because it substantially reduces the need to do additional research on the effects of air pollution on outpatient medical consumption, and suggests other areas in which research on the medical costs of air pollution may be more productive. These recommendations for future research have been previously addressed in Chapter II.

One cannot finish this section without a brief comment concerning the adequacy of using the C.R.V.S. in the models as a proxy for the quantity of medical services rendered, particularly as it refers to outpatient medical services. There are a variety of different medical services that can be provided within a given office call. To adequately reflect the multitude of potential outpatient medical services, the C.R.V.S. (Kaiser adapted), while detailed, would have to be infinitely more so than they are now. As a first step toward quantifying the output of physician and associated medical personnel in rendering medical services, a detailed study of each office and medical procedure would have to be undertaken. This would require a detailed manpower study. Some kind of weighting scheme could then be developed for each medical procedure, reflecting the difficulty of the tasks performed. While the C.R.V.S. is a good approximation of the quantity of medical services consumed, it does have limitations which should be recognized in its use.

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XI. APPENDICES

APPENDIX A

DISEASE DATA RETRIEVAL SYSTEM

Disease Classified	I.C.D.A.	T Codes
I. Respiratory System		
A. Upper respiratory neoplasms		
1. Malignant neoplasms, upper respiratory		
a. Malignant neoplasm of nose (internal and nasal cavities)..................	160.0	
b. Malignant neoplasm of maxillary sinus.	160.2	
c. Malignant neoplasm of other specified accessory sinuses....................	160.8	
d. Malignant neoplasm of site unspecified.................................	160.9	
e. Malignant neoplasms of larynx.........	161.0	
2. Benign neoplasms, upper respiratory		
a. Benign neoplasm, nose, nasal cavities, middle ear, and accessory sinuses...............................	212.0	
b. Benign neoplasm of larynx............	212.1	
B. Upper respiratory infections		
1. Influenza - acute		
a. Influenza with pneumonia..............	480.0	
b. Influenza, unqualified................	481.0	
c. Influenza, respiratory................	481.1	
d. Influenza, respiratory and digestive system..............................	481.2	
2. Other and unspecified upper respiratory infection - chronic		
a. Hypertrophy of tonsils and adenoids...	510.0	
b. Chronic pharyngitis..................	512.0	
c. Chronic nasopharyngitis...............	512.1	
d. Chronic maxillary sinusitis...........	513.0	
e. Chronic frontal sinusitis............	513.1	
f. Chronic sinusitis, other specified....	513.8	
g. Chronic sinusitis, unspecified and pansinusitis.........................	513.9	

Disease Classified		I.C.D.A.	T Codes
h.	Deflected nasal septum................	514.0	
i.	Nasal polyp...........................	515.0	
j.	Chronic laryngitis....................	516.0	
k.	Turbinate hypertrophy.................	517.6	
3.	Other and unspecified upper respiratory infections - acute		
a.	Acute nasopharyngitis (common cold)...	470.0	
b.	Acute maxillary sinusitis.............	471.0	
c.	Acute frontal sinusitis...............	471.1	
d.	Acute sinusitis, not specified........	471.4	
e.	Acute sinusitis, viral................	471.5	
f.	Acute sinusitis, bacterial............	471.6	
g.	Acute sinusitis, not specified, antibiotic given......................	471.7	
h.	Acute sinusitis, other specified sites................................	471.8	
i.	Acute sinusitis, unspecified and pansinusitis..........................	471.9	
j.	Acute pharyngitis, not specified......	472.0	311
k.	Acute pharyngitis, viral..............	472.1	
l.	Acute pharyngitis, bacterial..........	472.2	
m.	Acute pharyngitis, not specified, antibiotic given......................	472.3	
n.	Acute pharyngitis, other..............	472.9	
o.	Acute tonsillitis, not specified......	473.0	
p.	Acute tonsillitis, viral..............	473.1	
q.	Acute tonsillitis, bacterial..........	473.2	
r.	Acute tonsillitis, not specified, antibiotic given......................	473.3	
s.	Acute laryngitis and tracheitis, not specified, no antibiotic given........	474.0	
t.	Acute laryngitis and tracheitis, viral................................	474.1	
u.	Acute laryngitis and tracheitis, bacterial............................	474.2	
v.	Acute laryngitis and tracheitis, not specified, antibiotic given...........	474.3	

Disease Classified	I.C.D.A.	T Codes
w. Acute upper respiratory infection of multiple or unspecified sites.....	475.0	
x. Epistaxis............................	783.0	
y. Change in voice......................	783.5	335, 337
z. Stridor..............................	783.6	336
4. Nonspecific respiratory complaints		
a. Hemoptysis...........................	783.1	
b. Dyspnea..............................	783.2	
c. Cough NOS............................	783.3	
d. Excess of sputum.....................	783.4	
e. Chest pain...........................	783.7	401
f. Sighing respiration, wheezing........		407
g. Choking..............................		408
h. Sneezing.............................		409
i. Purulent sputum......................		414
j. Other respiratory symptoms...........		419
k. Other diseases of the respiratory system.............................	517.9	
11. Nasal discharge.................		284
22. Nasal obstruction...............		285
33. Nasal congestion................		290
44. Pain of sinuses.................		291
55. Post-nasal discharge............		294
66. Chronic post-nasal drip.........		298
77. Other symptoms of nose..........		299
88. Recurrent sore throat...........		310
C. Lower respiratory infection		
1. Tuberculosis		
a. Pulmonary tuberculosis, active, minimal.............................	002.0	
b. Pulmonary tuberculosis, active, moderately advanced..................	002.1	
c. Pulmonary tuberculosis, active, far advanced.........................	002.2	
d. Pulmonary tuberculosis, active, stage unspecified....................	002.3	

Disease Classified			I.C.D.A.	T Codes
	e.	Pulmonary tuberculosis, miliary NOS...	002.4	
	f.	Status following surgical collapse of lung..............................	002.5	
	g.	Chromogenic acid-fast bacilli.........	002.6	
	h.	Activity unspecified.................	002.9	
	i.	Pleurisy specified as tuberculosis....	003.0	
	j.	Pleurisy with effusion, without mention of cause......................	003.1	
	k.	Primary tuberculosis complex with symptoms.............................	004.0	
	l.	Other respiratory tuberculosis........	007.0	
	m.	Suspected tuberculosis................	793.2	
2.	Acute bronchitis			
	a.	Bronchitis, not specified, no antibiotic given.........................	500.0	
	b.	Bronchitis, viral....................	500.1	
	c.	Bronchitis, bacterial.................	500.2	
	d.	Bronchitis, not specified, antibiotic given.........................	500.3	
	e.	Bronchitis, unqualified...............	501.0	
3.	Chronic bronchitis and emphysema			
	a.	Bronchitis with emphysema.............	502.0	
	b.	Emphysema without mention of bronchitis............................	527.1	
4.	Chronic bronchitis without mention of emphysema			
	a.	Other (without emphysema).............	502.9	
	b.	Bronchiectasis (with or without bronchitis)..........................	526.0	
5.	Pneumonia			
	a.	Friedlander's B. (lobular)............	490.0	
	b.	Pneumococcus (lobular)................	490.1	
	c.	Staphylococcus (lobular)..............	490.2	
	d.	Streptococcus (lobular)...............	490.3	

Disease Classified	I.C.D.A.	T Codes
e. Other specified organism or cause (lobular)............................	490.8	
f. Unspecified organism or cause (lobular)............................	490.9	
g. Bronchopneumonia, Friedlander's......	491.0	
h. Bronchopneumonia, pneumococcus.......	491.1	
i. Bronchopneumonia, staphylococcus.....	491.2	
j. Bronchopneumonia, streptococcus......	491.3	
k. Bronchopneumonia, other specified organism or cause....................	491.8	
l. Bronchopneumonia, unspecified organism or cause....................	491.9	
m. Primary atypical pneumonia...........	492.0	
n. Friedlander's B......................	493.0	
o. Pneumococcus.........................	493.1	
p. Other specified organism or cause....	493.8	
q. Unspecified organism or cause........	493.9	
6. Respiratory diseases of the newborn		
a. Pneumonia of newborn.................	763.0	
b. Hyaline membrane (disease) (lung)....	773.0	
c. Other respiratory distress...........	773.1	
7. Other and unspecified diseases of the respiratory system - chronic		
a. Nonspecific respiratory disease, secondary to smoking.................	503.0	
b. Empyema..............................	518.0	
c. Abscess of lung......................	521.0	
d. Pain in chest........................	783.7	
8. Other and unspecified diseases of the respiratory system - acute		
a. Unspecified respiratory infection, bacterial............................	476.2	
b. Unspecified respiratory infection, organism unspecified, antibiotic given................................	476.3	
c. Pleurisy, without mention of effusion or tuberculosis.................	519.0	

Disease Classified	I.C.D.A.	T Codes
d. Pleurisy with effusion, with bacterial cause other than tuberculosis..............................	519.1	
e. Pleurisy with effusion of unknown etiology............................	519.2	
f. Pleurisy, other specified forms of effusion, except tuberculosis........	519.9	
g. Spontaneous pneumothorax.............	520.0	
h. Pulmonary congestion and hypostasis..	522.0	
i. Pulmonary collapse (1 year and over).	527.0	
j. Acute pulmonary edema without mention of heart........................	527.2	
9. Specific diseases to be analyzed		
a. Spontaneous pneumothorax.............	520.0	
b. Acute pulmonary edema without mention of heart........................	527.2	
c. Hemoptysis...........................	783.1	
d. Dyspnea..............................	783.2	
e. Cough NOS............................	783.3	
f. Excess sputum........................	783.4	
D. Lower respiratory		
1. Malignant neoplasm, lower respiratory		
a. Malignant neoplasm of trachea (primary or NOS)....................	162.0	
b. Malignant neoplasm of bronchus and lung..............................	162.1	
c. Malignant neoplasm, pleura, specified as primary.....................	162.2	
d. Malignant neoplasm of lung, unspecified as to whether primary or secondary..............................	163.0	
e. Malignant neoplasm of mediastinum...	164.0	
2. Benign neoplasm of the lower respiratory system		
a. Benign neoplasm of trachea..........	212.2	
b. Benign neoplasm of bronchus and lung..............................	212.3	

Disease Classified	I.C.D.A.	T Codes
c. Benign neoplasm of pleura............	212.4	
d. Benign neoplasm, mediastinum.........	212.5	
e. Benign neoplasm, unspecified site....	212.9	
II. Allergies affecting respiratory system		
A. Asthma		
1. Asthma due to pollen.....................	241.0	
2. Asthma due to dander or dandruff.........	241.1	
3. Asthma due to feathers....................	241.2	
4. Asthma due to dust........................	241.3	
5. Asthma due to food........................	241.4	
6. Asthma due to cosmetics...................	241.5	
7. Asthma due to drugs.......................	241.6	
8. Asthma with multiple allergens...........	241.8	
9. Asthma due to other and unspecified causes..................................	241.9	
B. Hay Fever		
1. Hay fever due to pollen..................	240.0	
2. Hay fever due to dander or dandruff......	240.1	
3. Hay fever due to feathers................	240.2	
4. Hay fever due to dust....................	240.3	
5. Hay fever due to cosmetics...............	240.5	
6. Hay fever due to drugs...................	240.6	
7. Hay fever with multiple allergens........	240.8	
8. Hay fever due to other and unspecified causes..................................	240.9	
C. Specific diseases		
1. Hay fever due to dust....................	240.3	
2. Hay fever due to other and unspecified causes..................................	240.9	
3. Asthma due to dust.......................	241.3	
4. Asthma due to other and unspecified causes..................................	241.9	

Disease Classified	I.C.D.A.	T Codes
III. Other Allergies and Skin Diseases		
A. Eczema		
1. Allergic eczema or dermatitis, pollen.....	244.0	
2. Allergic eczema or dermatitis, dander or dandruff..............................	244.1	
3. Allergic eczema or dermatitis due to internal agent, feathers.................	244.2	
4. Allergic eczema or dermatitis due to internal agent, dust.....................	244.3	
5. Allergic eczema or dermatitis due to internal agent, food.....................	244.4	
6. Allergic eczema or dermatitis due to internal agent, cosmetics................	244.5	
7. Allergic eczema or dermatitis due to internal agent, drugs....................	244.6	
8. Allergic eczema or dermatitis due to other and unspecified internal agents.....	244.9	
B. Other allergies		
1. Angioneurotic edema due to pollen.........	242.0	
2. Angioneurotic edema due to dander or dandruff.................................	242.1	
3. Angioneurotic edema due to dust...........	242.3	
4. Angioneurotic edema due to food...........	242.4	
5. Angioneurotic edema due to cosmetics......	242.5	
6. Angioneurotic edema due to drugs..........	242.6	
7. Angioneurotic edema with multiple allergens................................	242.8	
8. Angioneurotic edema, other and unspecified....................................	242.9	
9. Urticaria due to pollen..................	243.0	
10. Urticaria due to dander or dandruff.......	243.1	
11. Urticaria due to feathers................	243.2	
12. Urticaria due to dust.....................	243.3	
13. Urticaria due to food.....................	243.4	
14. Urticaria due to cosmetics................	243.5	
15. Urticaria due to drugs....................	243.6	
16. Urticaria with multiple allergens.........	243.8	

Disease Classified	I.C.D.A.	T Codes
17. Urticaria, other and unspecified..........	243.9	
18. Other allergic disorders due to pollen....	245.0	
19. Other allergic disorders due to dander or dandruff................................	245.1	
20. Other allergic disorders due to feathers..	245.2	
21. Other allergic disorders due to dust......	245.3	
22. Other allergic disorders due to food......	245.4	
23. Other allergic disorders due to cosmetics.	245.5	
24. Other allergic disorders due to drugs.....	245.6	
25. Other allergic disorders with multiple allergens................................	245.8	
26. Other allergic disorders due to other and unspecified causes....................	245.9	
C. Other skin diseases		
1. Eczema.....................................	701.0	
2. Other dermatitis due to plants............	703.0	
3. Other dermatitis due to oils and greases..	703.1	
4. Other dermatitis due to solvents..........	703.2	
5. Other dermatitis due to drugs in contact with skin................................	703.3	
6. Other dermatitis due to other chemicals in contact with skin......................	703.4	
7. Other dermatitis due to radiation.........	703.5	
8. Other dermatitis due to cosmetics.........	703.6	
9. Other dermatitis due to dyes..............	703.7	
10. Other dermatitis due to other specified agents in contact with skin...............	703.8	
11. Other dermatitis due to unspecified agent in contact with skin......................	703.9	
D. Specific diseases - allergies		
1. Angioneurotic edema due to dust...........	242.3	
2. Urticaria due to dust.....................	243.3	
3. Allergic eczema or dermatitis due to internal agent - dust.....................	244.3	
4. Other allergic disorders due to dust......	245.3	
5. Other allergic disorders due to other and unspecified causes....................	245.9	

Disease Classified	I.C.D.A.	T Codes
6. Other dermatitis due to other specified agents in contact with skin...............	703.8	
IV. Diseases of the Circulatory System		
A. Heart		
1. Hypertensive cardiovascular disease		
a. Hypertensive heart disease with arteriolar nephrosclerosis............	442.0	
b. Other hypertensive heart disease......	443.0	
2. Arteriosclerotic heart disease, including coronary heart disease		
a. Arteriosclerotic heart disease so described, with or without angina pectoris.............................	420.0	
b. Myocardial infarction.................	420.1	
c. Healed coronary occlusion.............	420.2	
d. Coronary insufficiency................	420.3	
e. Angina pectoris without mention of coronary disease......................	420.4	
f. Aneurysm of coronary artery and heart.	420.5	
g. Arteriosclerotic heart disease with atrial fibrillation..................	420.6	
h. Arteriosclerotic heart disease with angina pectoris.......................	420.9	
i. Arteriosclerotic heart disease with myocardial infarction and angina pectoris.............................	421.5	
3. Hypertensive and arteriosclerotic heart disease		
a. Hypertensive heart disease and arteriosclerotic heart disease...............	436.0	
b. Hypertensive and arteriosclerotic heart disease with atrial fibrillation.................................	436.6	
c. Hypertensive and arteriosclerotic heart disease with angina pectoris....	436.9	
4. Chronic rheumatic heart disease		
a. Other endocarditis, specified as rheumatic (chronic), inactive.........	414.0	

Disease Classified	I.C.D.A.	T Codes
b. Other myocarditis, specified as rheumatic (chronic), inactive........	415.0	
c. Rheumatic heart disease with multiple valve involvement...............	417.0	
5. Other heart diseases		
a. Congestive heart failure.............	434.1	
b. Left ventricular failure.............	434.2	
c. Other disease of heart...............	434.3	
d. Cardiac enlargement or hypertrophy...	434.5	
e. Cardiac or ventricular dilatation....	434.6	
f. Cor pulmonale (right ventricular failure).............................	434.7	
g. Past congestive heart failure (compensated at time of service).........	434.8	
h. Other unspecified diseases of heart..	434.9	
i. Precardial pain......................	782.0	
j. Palpitation..........................	782.1	
k. Tachycardia..........................	782.2	
6. Specific heart diseases to be examined		
a. Myocardial infarction................	420.1	
b. Coronary insufficiency...............	420.3	
c. Angina pectoris without mention of coronary disease.....................	420.4	
d. Arteriosclerotic heart disease with angina pectoris......................	420.9	
e. Arteriosclerotic heart disease with myocardial infarction and angina pectoris............................	421.5	
f. Cor pulmonale........................	434.7	
B. Circulatory system		
1. Diseases of arteries, veins, and other diseases of the circulatory system		
a. Pulmonary embolism and infarction....	465.0	
b. Pallor and cyanosis (not of newborn).	782.3	
c. Edema and dropsy (not of newborn)....	782.6	

Disease Classified	I.C.D.A.	T Codes
2. Hypertensive disease		
a. Hypertension with arteriolar nephrosclerosis......................	446.0	
b. Other hypertensive diseases..........	447.0	
c. Hypertensive heart disease with atrial fibrillation..................	447.6	
3. Acute brain syndromes associated with circulatory disturbance		
a. Acute brain syndrome associated with circulatory disturbance..............	303.0	
b. Acute brain syndrome associated with metabolic disturbance................	305.0	
c. Cerebral arteriosclerosis............	334.0	
d. Cerebral encephalopathy due to arteriosclerosis or hypertension.....	334.1	
4. Chronic brain syndromes associated with a circulatory disturbance		
a. Chronic brain syndrome cerebral arteriosclerosis....................	313.0	
b. Chronic brain syndrome, senile brain disease............................	315.0	
c. Chronic brain syndrome, presenile brain disease.......................	315.1	
5. Arteriosclerosis		
a. Arteriosclerosis not further specified...........................	450.0	
b. Other...............................	450.9	
6. Non-specific circulatory complaints		
a. Precardial pain......................	782.0	351
b. Dyspnea, orthopnea..................	783.2	368
V. Diseases of the Digestive System		
A. Upper gastrointestinal tract - neoplasms		
1. Benign neoplasms, upper gastrointestinal tract		
a. Benign neoplasms of the esophagus....	211.0	
b. Benign neoplasms of the stomach......	211.1	

Disease Classified	I.C.D.A.	T Codes
c. Benign neoplasm of small intestine, including duodenum....................	211.2	
d. Benign neoplasms of liver and bilary passages.............................	211.5	
e. Benign neoplasm of pancreas...........	211.6	
f. Benign neoplasm of peritoneum.........	211.7	
2. Malignant neoplasms		
a. Malignant neoplasm of esophagus.......	150.0	
b. Malignant neoplasm of stomach.........	151.0	
c. Malignant neoplasm of duodenum........	152.0	
d. Malignant neoplasm of jejunum.........	152.1	
e. Malignant neoplasm of ileum...........	152.2	
f. Malignant neoplasm, part unspecified..	152.9	
g. Malignant neoplasm, liver stated to be primary site.......................	155.0	
h. Malignant neoplasm gall bladder, extrahepatic gall ducts including ampulla of vater......................	155.1	
i. Malignant neoplasm of liver, secondary or unspecified..................	156.0	
j. Malignant neoplasm of pancreas........	157.0	
k. Malignant neoplasm of peritoneum......	158.0	
B. Ulcer of the upper gastrointestinal tract		
1. Ulcer of stomach, without perforation and without hemorrhage....................	540.0	
2. Ulcer of stomach, without perforation but with hemorrhage.......................	540.1	
3. Ulcer of stomach, with perforation but without hemorrhage........................	540.2	
4. Ulcer of stomach, with perforation and with hemorrhage...........................	540.3	
5. Peptic ulcer without mention of stomach or duodenum..............................	540.8	
6. Ulcer of duodenum, without perforation and without hemorrhage....................	541.0	
7. Ulcer of duodenum, without perforation but with hemorrhage......................	541.1	

Disease Classified	I.C.D.A.	T Codes
8. Ulcer of duodenum, with perforation but without hemorrhage....................	541.2	
9. Ulcer of duodenum, with perforation and with hemorrhage..........................	541.3	
10. Gastrojejunal ulcer, without perforation and without hemorrhage....................	542.0	
11. Gastrojejunal ulcer, without perforation but with hemorrhage.......................	542.1	
12. Gastrojejunal ulcer, with perforation but without hemorrhage....................	542.2	
13. Gastrojejunal ulcer, with perforation and with hemorrhage..........................	542.3	
C. Lower gastrointestinal tract - neoplasms		
1. Benign neoplasms, lower gastrointestinal tract		
a. Benign neoplasm of large intestine, excluding rectum......................	211.3	
b. Benign neoplasms of rectum...........	211.4	
2. Malignant neoplasms, lower gastrointestinal tract		
a. Malignant neoplasm of cecum, appendix, and ascending colon..................	153.0	
b. Malignant neoplasm of transverse colon, including hepatic and splenic flexures..............................	153.1	
c. Malignant neoplasm of descending colon................................	153.2	
d. Malignant neoplasm, Sigmoid..........	153.3	
e. Malignant neoplasm, large intestine, part unspecified.....................	153.8	
f. Malignant neoplasm, intestinal tract, part unspecified.....................	153.9	
g. Malignant neoplasm of rectum.........	154.0	
VI. Diseases of the Eye		
A. Inflammatory diseases of the eye		
1. Infective conjunctivitis..................	370.0	
2. Conjunctivitis of unknown etiology, with antibiotic given.........................	370.1	

Disease Classified	I.C.D.A.	T Codes
3. Conjunctivitis of unknown etiology, with antibiotic not given	370.2	
4. Allergic conjunctivitis	370.4	
5. Infectious blepharoconjunctivitis	370.5	
6. Unspecified blepharoconjunctivitis, with antibiotic given	370.6	
7. Allergic blepharoconjunctivitis	370.8	
B. Non-specific eye complaints		
1. Diseases of the eyeball, ocular muscles, and orbit	388.2	
a. Pain around eye		221
b. Pain of eye		231
2. Discharge of eye		224
3. Excessive tearing, watery		234
4. Blepharitis	371.0	
a. Inflammation of eyelid		255
5. Other pruritic conditions	708.9	
a. Itching of eye		237
6. Feeling of foreign body in eye		258
VII. Diseases of the Genitourinary System		
A. Benign neoplasms		
1. Benign neoplasm of ovary, other and unspecified	216.9	
2. Benign neoplasm of kidney and ureter	219.0	
3. Benign neoplasm of bladder	219.1	
4. Benign neoplasm, other and unspecified urinary organs	219.9	
B. Malignant neoplasms		
1. Malignant neoplasm of ovary	175.0	
2. Malignant neoplasm of kidney and ureter	180.0	
3. Malignant neoplasm of bladder	181.0	
4. Malignant neoplasm, other urinary organs	181.9	

Disease Classified	I.C.D.A.	T Codes
C. Nephritis and nephrosis		
1. Acute nephritis..........................	590.0	
2. Nephritis with edema, including nephrosis................................	591.0	
3. Functional edema, idiopathic.............	591.1	
4. Chronic nephritis........................	592.0	
5. Nephritis not specified as acute or chronic.................................	593.0	
6. Other renal sclerosis....................	594.0	
VIII. Other Diseases		
A. Symptoms and diagnoses referrable to nervous system and special senses		
1. Neurologic symptom - tic, tremor, other abnormal voluntary movements, disturbances..................................	780.4	
a. Tic.................................		165
b. Tremor..............................		166
c. Other abnormal involuntary movements...............................		167
d. Twitching of muscles................		709
e. Muscle spasm........................		710
f. Nocturnal leg cramp.................		719
g. Leg cramps..........................		720
2. Neurologic symptom - other abnormal voluntary movements, disturbances of coordination............................	780.5	
a. Other abnormal voluntary movements...		168
b. Disturbance of coordination..........		170
c. Other disturbances in writing........		198
3. Tetany...................................	788.5	169
4. Neurologic symptom - vertigo.............	780.6	
5. Neurologic symptom - disturbance of sleep....................................	780.7	
a. Hypersomnia.........................		025
b. Insomnia............................		026
c. Somnambulism........................		027

Disease Classified	I.C.D.A.	T Codes
d. Nightmares............................		047
e. Sleepiness............................		068
6. Neurologic symptom - disturbance of memory................................	780.0	175
a. Amnesia...............................		176
7. Neurologic symptom - meningismus..........	780.9	
8. Disturbance of vision, except defective sight..................................	781.0	
a. Spots in field of vision..............		248
9. Occulomotor disturbances..................	781.1	
a. Diplopia..............................		246
b. Drooping of eyelid....................		247
10. Photophobia..............................	781.2	241
11. Disturbance of hearing, except deafness...	781.3	
a. Tinnitus..............................		268
b. Other extraneous noises in ear; and sensitivity to noises.................		269
12. Disturbance of cranial nerves, except optic, occulomotor, and auditory..........	781.4	
13. Other disturbances of sensation...........	781.7	190
a. Lightheadedness.......................		020
b. Loss of sense of smell................		185
c. Loss of taste.........................		186
d. Anesthesia............................		187
e. Hyperesthesia.........................		188
f. Paresthesia...........................		189
g. Frigidity.............................		626
h. Burning skin..........................		661
B. Emotional, mental, and psychotic disorders		
1. Non-specific psychosomatic symptoms		
a. Nervousness...........................	790.0	100
b. Debility and undue fatigue............	790.1	
11. Cachexia.........................		028
22. Fatigue..........................		030
33. Weakness.........................		035

Disease Classified		I.C.D.A.	T Codes
	c. Lethargy...............................		029
	d. Depression of functional activity.....	790.2	
	e. Illness which prevents sleep, except insomnia.......................	790.4	
	f. Headache...............................	791.0	151
	g. Observation, mental..................	793.0	
	h. Malingering...........................	795.3	115
	i. Multiple chronic symptoms............		059
	j. Multiple complaints..................		060
	k. Vague feeling of not feeling well.....		066
	l. Euphoria..............................		105
	m. Loss of affect........................		109
	n. Slow learning in school...............		120
	o. Other psychiatric symptoms............		149
2.	Non-specific psychosomatic diagnoses and/or symptoms of nervous system		
	a. Simple schizophrenic reaction, negativism............................	320.0	117
	b. Paranoid state, delusions............	321.1	107
	c. Psychoneurotic, anxiety reaction......	324.0	
	d. Dissociative reaction.................	324.1	
	e. Conversion reaction..................	324.2	
	f. Phobic reaction......................	324.3	077
	g. Obsessive compulsive reaction.........	324.4	
	h. Depressive reaction..................	324.5	076
	i. Tranquilizers or sedatives prescribed; reason not stated...........	324.7	
	j. Hypochondriasis......................	324.8	
	k. Psychoneurotic disorders, other and unspecified...........................	324.9	
	l. Inadequate personality...............	325.0	
	m. Schizoid personality.................	325.1	
	n. Cyclothymic personality..............	325.2	
	o. Paranoid personality.................	325.3	
	p. Other personality pattern disturbance, abnormal sexual behavior.............	325.4	125

Disease Classified			I.C.D.A.	T Codes
q.	Emotionally unstable personality.....		325.5	
r.	Passive-aggressive personality.......		325.6	089
s.	Compulsive personality...............		325.7	079
t.	Other and unspecified personality disturbance.........................		325.9	
	11.	Feelings of excess demands on self.........................		078
	22.	Mental immaturity...............		098
	33.	Bizarre or disorganized behavior........................		108
	44.	Failure to adjust to school.....		119
u.	Antisocial reaction..................		326.0	087
v.	Dissocial reaction...................		326.1	095
w.	Alcohol addiction....................		326.3	
x.	Special symptom reactions............		327.0	
y.	Hyperactive behavior.................		327.1	
z.	Transcient anxiety provoking situation; sedative or tranquilizer prescribed..........................		327.8	
aa.	Gross stress reaction................		328.0	
bb.	Adult situation reaction.............		328.1	
cc.	Other and unspecified................		328.9	
	11.	Hostile behavior................		085
	22.	Asocial behavior................		086
	33.	Failure to conform with behavior standards of family......		088
	44.	Lack of mature behavior.........		118
3.	Adjustment reactions			
a.	Adjustment to infancy................		328.2	
		Hyperactive behavior............		080
		Tantrums........................		090
		Cruelty.........................		096
		Destructiveness.................		097
b.	Adjustment reaction of childhood.....		328.3	
		Hyperactive behavior............		080
		Tantrums........................		090

Disease Classified	I.C.D.A.	T Codes
Cruelty...........................		096
Destructiveness...................		097
Breathholding.....................		116
c. Adjustment reaction of adolescence...	328.4	
Hyperactive behavior..............		080
Tantrums..........................		090
Cruelty...........................		096
Destructiveness...................		097
d. Adjustment to late life.............	328.5	
Hyperactive behavior..............		080
Marital problems..................		099
e. Hyperactive behavior................		080
f. Tantrums............................		090
g. Cruelty.............................		096
h. Destructiveness.....................		097
i. Marital problems....................		099
j. Breathholding.......................		116
4. Non-specific psychosomatic diagnoses of other systems		
a. Skin reaction.......................	323.0	
b. Musculoskeletal reaction............	323.1	
c. Respiratory reaction................	323.2	
d. Cardiovascular reaction.............	323.3	
e. Hemic and lymphatic reaction........	323.4	
f. Gastrointestinal reaction...........	323.5	
g. Endocrine reaction..................	323.7	
h. Nervous system reaction.............	323.8	
i. Reaction of organs of special sense..	323.9	
5. Psychotic disorders		
a. Involutional psychotic reaction......	318.0	
b. Manic depressive, reaction manic type...............................	319.0	
c. Manic depressive, depressive type....	319.1	
d. Manic depressive, other.............	319.2	
e. Psychotic depressive reaction........	319.3	

Disease Classified			I.C.D.A.	T Codes
	f.	Schizophrenic reaction, hebephrenic type	320.1	
	g.	Schizophrenic reaction, catatonic type	320.2	
	h.	Schizophrenic reaction, paranoid type.	320.3	
	i.	Schizophrenic reaction, acute undifferentiated type	320.4	
	j.	Schizophrenic reaction, chronic undifferentiated type	320.5	
	k.	Schizophrenic reaction, schizo-affective	320.6	
	l.	Schizophrenic reaction, childhood	320.7	
	m.	Schizophrenic reaction, residual	320.8	
	n.	Schizophrenic reaction, other and unspecified	320.9	
	o.	Paranoia	321.0	
	p.	Other psychotic reaction	322.0	
C.	Other specific diseases			
	1.	Sarcoid of Boeck	138.0	
	2.	Porphyria (except due to drugs)	289.4	
	3.	Disaccharidase deficiency	289.7	
	4.	Hyperventilation syndrome	324.6	
	5.	Cirrhosis of liver without mention of alcoholism	581.0	
	6.	Cirrhosis of liver with alcoholism	581.1	

APPENDIX B

Table B-1. PRETEST REGRESSION RESULTS OF STATISTICAL MODEL 10: RESPIRATORY DISEASES - UNLAGGED

Variables	Coefficients[a/]	t Statistics	Mean[b/]
Sample size	153		
Constant	-1.8736E 00 (1.9241E 00)	0.9738	
Age	-6.7890E-05 (5.9527E-03)	0.0114	45.5294 (16.0538)
Sex	1.1035E-01 (1.4408E-01)	0.7659	0.7386 (0.5823)
Marital status	2.8038E-01 (2.2013E-01)	1.2737	0.8039 (0.3983)
No. of people in household	2.4386E-02 (5.0846E-02)	0.4796	3.5033 (1.9639)
Household income	-7.7191E-06 (1.0137E-05)	0.7615	12178.1046 (7869.8121)
Race - Negro	-2.4771E-01 (3.4051E-01)	0.7275	0.0523 (0.2233)
Race - other non-white	4.6733E-01 (6.6923E-01)	0.6983	0.0131 (0.1140)
Physically fit	-1.9884E-01 (2.4558E-01)	0.8097	0.1307 (0.3382)
Somewhat physically fit	-4.8518E-01 (1.6731E-01)	0.2900	0.5556 (0.4985)
Drinking	4.8631E-04 (2.1145E-03)	0.2300	13.5157 (38.2885)
Smoking index	4.5499E-04 (4.0694E-04)	1.1181	118.9319 (198.2665)
Occupational exposure index	7.7237E-03 (1.3866E-02)	0.5570	4.3030 (5.9661)
Air pollution	2.7269E-01 (1.2159E-01)	2.2427	60.2792 (32.0161)
Temp. humidity index	7.0107E-01 (4.5198E-01)	1.5511	52.7171 (8.5303)
Outpatient medical services			13.8386 (11.2557)
R^2	0.1156		

a/ The standard error of the regression coefficient is in parentheses. E-01, E 01, E 00, etc., indicate that the decimal place of the number is to be shifted to the left by one place; shifted to the right by one place; or not shifted at all, respectively.

b/ The standard deviation about the mean is in parentheses; means are untransformed.

Table B-2. PRETEST REGRESSION RESULTS OF STATISTICAL MODEL 10: CIRCULATORY-RESPIRATORY DISEASES - UNLAGGED

Variables	Coefficients[a/]	t Statistics	Mean[b/]
Sample size	333		
Constant	-5.9326E-01 (1.2102E 00)	0.4902	
Age	9.6186E-04 (3.9557E-03)	0.2432	54.4924 (16.0471)
Sex	2.3956E-01 (8.3891E-02)	2.8557	0.6666 (0.5859)
Marital status	2.2654E-01 (1.2799E-01)	1.7713	0.8018 (0.3992)
No. of people in household	3.5947E-02 (3.8202E-02)	0.9410	2.9399 (1.7552)
Household income	-9.1927E-06 (6.5999E-06)	1.3929	10704.9549 (7900.4679)
Race - Negro	-2.1188E-01 (2.6783E-01)	0.7911	0.0300 (0.1709)
Race - other non-white	-5.1321E-03 (3.3190E-01)	0.0155	0.0210 (0.1437)
Physically fit	-3.1567E-02 (1.3458E-01)	0.2346	0.1772 (0.3824)
Somewhat physically fit	3.4824E-02 (1.0458E-01)	0.3330	0.4955 (0.5007)
Drinking	-6.9087E-04 (1.0267E-03)	0.6729	12.3330 (46.1372)
Smoking index	3.5109E-04 (2.1380E-04)	1.6421	136.7889 (224.4347)
Occupational exposure index	1.4589E-02 (9.6653E-03)	1.5095	3.1037 (5.2676)
Air pollution	2.1064E-01 (7.4181E-02)	2.8396	59.8635 (31.8933)
Temp. humidity index	3.9523E-01 (2.9039E-01)	1.3610	54.1314 (8.2007)
Outpatient medical services			13.6919 (11.4310)
R^2	0.0864		

a/ The standard error of the regression coefficient is in parentheses. E-01, E 01, E 00, etc., indicate that the decimal place of the number is to be shifted to the left by one place; shifted to the right by one place; or not shifted at all, respectively.

b/ The standard deviation about the mean is in parentheses; means are untransformed.

Table B-3. PRETEST REGRESSION RESULTS OF STATISTICAL MODEL 11: RESPIRATORY DISEASES - LAGGED ONE DAY

Variables	Coefficients[a/]	t Statistics	Mean[b/]
Sample size	166		
Constant	-2.2162E 00 (2.6239E 00)	0.8466	
Age	-1.1754E-02 (7.2070E-03)	1.6309	44.9036 (16.1028)
Sex	-2.2007E-04 (1.9796E-03)	0.1112	68.0723 (52.8453)
Marital status	7.2529E-04 (2.8123E-03)	0.2579	80.1205 (40.0301)
No. of people in household	-1.0366E-01 (7.4044E-02)	1.4000	3.3373 (1.6933)
Household income	-2.8430E-06 (1.4136E-05)	0.2011	11974.3976 (7154.9744)
Race - non-white	9.3073E-04 (4.0313E-03)	0.2309	6.6265 (24.9497)
Drinking	3.1881E-04 (2.9840E-03)	0.1068	11.9235 (35.8459)
Smoking index	-2.1284E-04 (3.9639E-04)	0.5370	156.8643 (260.8312)
Occupational exposure index	2.0080E-02 (1.7792E-02)	1.1286	3.8560 (5.9076)
Air pollution	2.0219E-01 (1.4319E-01)	1.4121	52.8506 (7.8279)
Temp. humidity index	5.1959E-01 (6.3601E-01)	0.8170	62.1369 (34.5265)
Per capita costs			1.7724 (3.3421)
R^2	0.0603		

a/ The standard error of the regression coefficient is in parentheses. E-01, E 01, E 00, etc., indicate that the decimal place of the number is to be shifted to the left by one place; shifted to the right by one place; or not shifted at all, respectively.

b/ The standard deviation about the mean is in parentheses; means are untransformed.

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15. Supplementary Notes

16. Abstracts

This study has attempted to quantify in monetary terms the effects of air pollution on the consumption of outpatient medical services. The hypotheses were that air pollution can aggravate a state of health resulting in increased consumption of outpatient medical services and in the number of contacts with the medical system for certain respiratory, cardiovascular, and other diseases aggravated by air pollution. The study period was 1969-1970, and centered in the Portland, Oregon area. Statistical models were formulated, explaining individual outpatient consumption of medical services. Measures of suspended particulate air pollution and meteorological conditions, as well as socioeconomic-demographic variables thought to influence the consumption of medical services, were included in the models as explanatory variables. The statistical results indicated that the procedures used in the study hold promise for quantifying the medical costs of air pollution. The results did show air pollution to have an effect on the consumption of outpatient medical services used to treat certain respiratory diseases.

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17b. Identifiers/Open-Ended Terms

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