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Socioeconomic Environmental Studies

# IMPACT OF AIR POLLUTION ON THE CONSUMPTION OF MEDICAL SERVICES - - Cost of Hospitalization in the Portland Metropolitan Area

Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Corvallis, Oregon 97330

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# IMPACT OF AIR POLLUTION ON THE CONSUMPTION OF MEDICAL SERVICES
## Costs of Hospitalization in the Portland Metropolitan Area

by

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## Disclaimer

## FOREWORD

Effective regulatory and enforcement actions by the Environmental Protection Agency would be virtually impossible without sound scientific data on pollutants and their impact on environmental stabililty and human health. Responsibility for building this data base has been assigned to EPA's Office of Research and Development and its 15 major field installations, one of which is the Corvallis Environmental Research Laboratory (CERL).

The primary mission of the Corvallis Laboratory is research on the effects of environmental pollutants on terrestrial, freshwater, and marine ecosystems; the behavior, effects and control of pollutants in lake systems; and the development of predictive models on the movement of pollutants in the biosphere.

This report completes research initially funded through the Washington Environmental Research Center, Washington, D.C.

A. F. Bartsch
Director, CERL

## ABSTRACT

This study was undertaken to ascertain the possibility of measuring from available data the impact of air pollution on the consumption of inpatient services which patients consume per hospital stay.

The study area was the Portland, Oregon metropolitan area, and the period of study was 1970-72. The diseases which were thought to be associated with air pollution were first identified. A sample of the patients was taken from a hospital population and the medical costs incurred by them were calculated. Suspended particulates as a measure of air pollution, temperature-humidity index as a measure of meteorological conditions of the area, and socio-economic characteristics of patients were used in a regression model to explain variations in medical costs.

The analysis did not indicate a quantitative relationship between air pollution in the Portland area and the consumption of inpatient medical services per hospital stay. Age, family income, and drinking habits of a patient, and the number of past hospital visits by the patient do significantly affect inpatient medical costs, but the variables included in the analysis accounted for less than 15 percent of the statistical variation in the dependent variable.

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# SECTION I

# INTRODUCTION

## THE PROBLEM

Public awareness of deterioration of air quality during the past two decades has prompted a number of studies in the estimation of the damage done by air pollution. The most common effects of air pollution are considered to be visibility reduction, economic damage to property, physical and psychological damage to human health, and substantive change in the ecology of the natural environment. The Environmental Protection Agency estimated that air pollution costs about $16 billion per year in terms of damage to vegetation, materials, property and health [6, p. 12].

Damage to health is foremost in most peoples' minds. There is now enough evidence in the environmental and health literature that the increasing levels and high concentration of carbon monoxide, photochemical oxidents, sulfur dioxide, nitrogen dioxide, and particulates in the ambient air cause and aggravate physical and psychological impairment to such an extent that the person exposed may have to seek medical attention. Pollution related illnesses may cause reductions in job productivity, loss of wages due to absenteeism, increases in health insurance, and a general decline in living standards, and perhaps a shortened life span.

Concerns over these and other air pollution problems has been manifested in the passage and increased enforcement of local, state, and federal legislation and in extensive research by universities and other institutions to find ways of abating or controlling the emission of pollutants. On the one hand, the contamination of the environment, as a by-product of urbanization and industrialization, poses dangers to human health, on the other, control of air pollution may cause shut-downs of firms, increase unemployment, and may jeopardize the economic stability of a community. Thus, the costs and benefits from industrialization must be weighed in order to make meaningful economic decisions. In order to achieve this, it is most important to know about the severity of damage caused to human health by the deterioration of air quality.

## OBJECTIVE

It is the objective of this report to experiment with data available for an urban area to ascertain the possibility of determining the effects of deteriorating air quality on the medical services consumed by patients per hospital stay. It is also attempted to express this effect in monetary terms.

## CHARACTERISTICS OF THE STUDY AREA

The study area is the Portland Standard Metropolitan Statistical area with a population of over 900,000 [17, p. 1]. It is composed of four counties: Multnomah, Washington, and Clackamas Counties in Oregon, and Clark County in the state of Washington.

Portland, with a population of 381,927, is the largest city in the study area and is an important trading, transportation, and manufacturing center. It has seven major industries: food processing and related agricultural production, textiles, lumber and wood products including pulp and paper, chemical, aluminum, and other metal fabricating plants, shipping, and tourism [11, p. 59].

Like most industrial cities and metropolitan areas, Portland has air pollution problems, though not of a very severe nature. Suspended particulates are the greatest pollution problem faced by the area. During the fall and winter months the particulates are trapped for several days at a time by inversions and cause visibility, health, and other problems. The suspended particulate problem extends southward from Portland to the entire Willamette Valley. Sulfur dioxide, photochemical smog, and nitrogen dioxide are not presently a serious problem in the Portland area. However, downtown Portland does suffer from carbon monoxide pollution.

Portland has a mild winter rainfall climate. Annual temperatures average about 52.9°F and average annual rainfall is 37.18 inches, with 88 percent of the annual total occuring between the months of October to May [20]. Marine-tempered air moderates temperature extremes.

## ORGANIZATION OF THIS REPORT

After a brief summary of the conclusions [Section II] and recommendations [Section III] resulting from this study, the economic model employed in this analysis is discussed in Section IV. The empirical model is presented in Section V. The results fo the analysis are recorded in Section VI. Sections VII and VIII contain references and an appendix, respectively.

## SECTION II

## CONCLUSIONS

In this study it was not possible to demonstrate that deterioration of air quality in the Portland metropolitan area independently aggravates a person's condition in such a way as to affect significantly his or her consumption of inpatient medical services, as measured by total medical costs per disease episode in a hospital. Age of the patient, his family income, drinking habits, and number of hospital visits during the past three years do appear to be related to the variation in medical costs incurred by the patient per hospital stay.

## SECTION III

## RECOMMENDATIONS

The results of an earlier study conducted by Jaksch [11, 12] and of the current one must be interpreted together. The former work focused on outpatient medical services while the interest of the work reported here was in the relationship between air pollution and the consumption of inpatient medical services. Both of these efforts used data which had been collected for other purposes. It is recommended that further refinements in the study approach be made for the analysis of outpatient data, but not for the specification of the relationship between variations in air quality and the consumption of hospital services.

For reasons spelled out in this Report it was not possible to derive a significant air pollution-medical cost relationship. This is not to say that there may not be significant effects of air pollution on inpatient medical costs. But a new research strategy is required to uncover them. Specifically, a new approach is required which focuses on the medical, psychological, economic, and administrative processes by which exposure to air pollution may be reflected in hospital admissions and the delivery of hospital services. Such a research program would be of relatively long duration and expensive. Still, it appears to be a necessity for isolating the effects of air pollution on this type of medical costs.

## SECTION IV

## AN ECONOMIC MODEL OF THE CONSUMPTION OF MEDICAL SERVICES

### REVIEW OF LITERATURE

An earlier study of the relationship between deterioration of air quality and the consumption of medical services in the Portland-Vancouver area was done by Jaksch and Stoevener [11, 12]. That study measured the impact of suspended particulates on the consumption of outpatient medical services per disease episode. To isolate this effect, air pollution and meteorological conditions of the area in which patients resided and worked and socioeconomic-demographic characteristics of the patients were considered. Data were drawn from a five percent, ongoing random sample of the membership of Kaiser Foundation Health Plan, a prepaid group medical plan. Each medical procedure, treatment, and clinical visit was assigned a dollar value according to the California Relative Value System, which was used by Kaiser Foundation Health Services to quantify medical services performed.

Jaksch used single stage least-squares regression analysis to relate the effects of air pollution on medical costs for respiratory diseases and circulatory-respiratory diseases. The model used no lag and one-, two-, and three day time lags to relate air pollution and meteorological conditions to outpatient medical costs. The statistical results indicated a significant effect of air pollution on respiratory diseases. The analysis also brought out that the sex of the patient and his drinking habits were important factors in explaining the variation in the medical costs for respiratory diseases. Physical fitness, drinking habits, and the occupational exposure of patients and meteorological conditions were found to be significant in influencing medical costs for circulatory-respiratory diseases. Air pollution was not significant as a variable influencing circulatory-respiratory diseases.

Several other studies concerning health effects of air pollution are reviewed. They help mainly in identifying diseases which may be aggravated by the deterioration of air quality.

A medical study measuring the effect of air pollution on urban disease incidence was done by Sterling, et. al. [18]. They found that the groups of diseases most affected by air pollution are: infectious diseases, malignant neoplasms of the respiratory system, allergic disorders, diseases of the hematopoistic system, personality disorders, diseases of the heart (darditis, valvular, arteriosclerotic heart disease, and congestive failure), and acute upper respiratory infections, pneumonia, bronchitis, diseases of tonsils and adenoids, and other diseases of the respiratory system. In all these categories there was a significant difference between days of low pollution and high pollution. Specific pollutants were used to find the relationship between air pollution and the occurance of the diseases but it was concluded that the difference between the effects of specific pollutants are less important since, at best, each one of the pollution measurements is a general index of the level of pollution rather than a specific indicator for a particular chemical. The only other variable in this study was a temperature-humidity index. No socioeconomic variables were included in the analysis.

A New York study by Cassell [5] concluded that it is not possible to isolate the effects of individual pollutants. It was found that low temperature and humidity and a wide range in barometric pressures are highly associated with the prevalence of the common cold and cough symptoms. High temperature and the occurence of eye irritation are positively associated with each other. The study also found association of the common cold and cough with wind and particulate matter. Carbon monoxide appeared to be associated with respiratory symptoms.

Lave and Seskin [1, p. 727] cite work by Hammond in which he studied over 50,000 men to find the relationship between emphysema, age, occupational exposure to pollution, urban exposure, and smoking. His results indicate that the effect of air pollution is significant. Heavy smokers have a much higher morbidity rate in cities than in rural areas, and the effect becomes more marked as age increases.

Epidemiological studies have shown a relationship between air pollution and respiratory disease, both chronic (long-continued) and acute (short and relatively severe). A study of 38,207 deaths in Nashville, Tennessee during 1949-1960, adjusted for differences in income and social status, indicated that more deaths from respiratory ailments occured in the sections of the city where air pollution was heaviest [16, p. 64]. In another study a comparison of selected high and low air pollution days indicated that air pollution may well be responsible for a 16.7 percent increase in respiratory symptoms (in particular, laryngitis, bronchitis, tonsillitis, colds, and sore throat) in Los Angeles schools situated in the highest, as compared to the lowest, contaminant concentrations [7, p. 241].

A study by Zeidberg, et. al. [24] associates both morbidity and mortality rates for heart diseases with air pollution levels in Nashville. The morbidity rate was about twice as high in areas where air was polluted than in areas of clean air. The mortality rate was found to be less closely associated: it was 10 percent to 20 percent higher in areas of polluted air than in areas of clean air.

Cardiovascular diseases are related to air pollution in that any pollutant placing stress on pulmonary functions may affect the heart [8]. Air pollution (especially sulphur dioxide and photochemical smog) appears to cause burning, tearing, and other irritations of the human eye, although the damage in most cases is not permanent [8]. Some pollutants irritate sensitive membranes, those of the eyes, nose, throat, and lungs.

A list of disease categories[1] which are thought to be associated with air pollution was prepared from the foregoing general discussion of several epidemiological and clinical studies in consultation with the medical authorities.[2] For specific diseases under each category, the reader is referred to the study done by Jaksch and Stoevener [12, pp. 102-122].

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[1] See Appendix Table 1.

[2] Discussion with Dr. Sheldon Wagner, M.D., O.S.U. Environmental Health Unit.

## EFFECTS OF METEOROLOGICAL CONDITIONS

Independently, or in combination with air pollution, various weather conditions may place stress on the human body. Intense and continuous cold temperatures can contribute to exhaustion and decrease mucous transport which is one of the main methods of cleansing airborne matter from the lungs. Severity of chronic bronchitis or asthma can result from exposure to severe colds. Low temperature, accompanied by low humidity, has been associated with the common cold and cough symptoms. High temperature and eye irritations are positively correlated. Shortness of breath in those prone to heart attacks may increase during spells of hot weather [12, p. 20].

Atmospheric conditions are a factor affecting the impact of odors, a source of air pollution. Wind velocity, wind direction, temperature, and humidity all are involved.

The structures and activities associated with urban areas tend to impair wind velocity and favor the development of inversion layers that block the diffusion that normally takes place when warm air rises. This, in turn, may result in the generalized "heat dome" effect of cities [1, p. 150]. All pollution emissions are retained below the inversion level and in many instances a minor pollution problem becomes severe.

Meteorological conditions of an area play an important role in episodes of air pollution. The city which is suffering from a severe smog blanket on one day may enjoy beautiful smogfree weather after two or three days even though the operation of factories or the number of vehicles driven may not change. A strong wind may blow the smog away, or a heavy rain may wash it out of the air.

## FORMULATION OF THE ECONOMIC MODEL

"Medical Services" for this study is defined as the entire bundle of commodities and services aimed directly at preventing, curing, and abating physical and psychological illnesses. We follow the Jaksch formulation [11, 12] that most medical needs are highly specific and alternative goods do not provide the same or even approximate satisfaction. In most cases, the income and wealth of the patient or his family and his health insurance coverage, do not restrict him from consuming medical care. Thus the cross-elasticity of price, income elasticity, and own price elasticity for the consumption of medical care for a sick person is very low. Medical care is a necessity of life for an ill person.

Existence of real physiological needs and perception of real and supposed needs are the first ingredients of any consumption function. Before a physiological need can be translated into a desire to consume a commodity, a willingness to meet the need by undertaking consumption of the commodity must exist. Finally, the consumer must be economically able to satisfy his wants.

The following discussion focuses on some of the variables which are thought to be important in determining physiological needs, perception of needs, and willingness to consume medical services to treat air pollution related diseases.

## Physiological Needs

Many physiological needs are age-specific, or sex-specific [23]. For example, with an increase in age, beyond the youth period, efficiency of lung function declines, due mainly to a decrease in the elasticity of lung tissue and an increasing inflexibility of the chest wall. This lung condition would tend to impair the clearance of pollutants from the respiratory tract, which could result in aggravated respiratory diseases. In general, young people do not become ill easily. Thus, a positive relationship between age and consumption of medical services tends to exist. Some diseases are common among one sex. Comparison of Los Angeles schools analyzed for male and female sub-groups revealed that respiratory diseases among men were more highly associated with air pollutants than the identical illnesses in women.

## Perception of Physiological Needs

One of the important elements in evaluating the perception of real or supposed needs may be the level of education which a patient or his family has. Reading of medical literature is also important, but it may be included in the education variable. Education is also relevant in willingness to secure medical attention. An educated person will better appreciate the desirability of seeking medical care. The willingness to seek medical attention also depends upon the environment in which a person has been brought up. The number of physical disabilities and hospitalizations during the past years are also important factors which may be worth examining when considering willingness to secure medical care.

## Ability to Satisfy Physiological Needs

Ability to secure medical attention is expected to depend upon various economic and other considerations. The most important variables are family income and wealth, health insurance coverage, eligibility for a welfare program, availability of home care, and sick leave provisions. All these variables can dictate the length of hospitalization. In a prepaid medical system income is not expected to play as important a role as it would otherwise. However, higher income individuals generally are able to afford preventive care and, therefore, be healthier and may have to spend less on medical care [23]. Thus, income acts as a proxy for other variables which affect medical cost.

## Other Considerations

The influence of smoking on the prevalence of respiratory symptoms and bronchitis is very important [9, 10]. Cigarette smoking is an irritant, can cause bronchospasms, can inhibit ciliary activity, and provoke secretion of mucus. The latter interference with bronchial clearance may be critical [12, 35]. Lawther points out that there is no doubt that the overwhelmingly major cause of lung cancer is cigarette smoking [14]. Cigarette smoking is so important a factor in chronic respiratory diseases that it may cloud or even conceal the effects of air pollution. Similarly, excessive drinking by an individual is expected to play a role in causing and aggravating pulmonary tuberculosis and other respiratory and cardio-vascular diseases, and mental and emotional problems.

Allergens or unusual concentrations of similar substances may be encountered in a patient's working environment. Many asthmatic subjects develop wheezing when exposed to any irritating dust or fumes. Some dust from cotton may contain histamine releasing agents which are considered to cause asthmatic symtoms and metallic substances such as platinum, nickel, etc., in an aerosol form, are considered to cause asthma-like syndromes [15, p. 61]. High concentrations of some organic dusts cause an allergic response in the aveolar tissue of the lung. Thus, the occupational exposure to air pollution may be an important factor in the demand for medical services.

Crowding at an individual's residence and at work can place physical and emotional stress on the individual and can cause or aggravate certain respiratory diseases. The marital status of an individual may be considered an explanatory variable in the model in that a married person is expected to spend fewer days in the hospital than a single person because of availability of care for the patient and perhaps better nutrition at home. The physical disabilities and hospitalization during past years may be indicative of his physical condition and explain, in part, consumption of medical services.

This study is concerned with those cases of air pollution related diseases which result in hospital admission. Based upon the discussions in this section, a basic severity model was developed. This model hypothesizes the relationship between the inpatient consumption of medical services and air pollution, and also takes into account the impact of meteorological and socioeconomic factors.

$$M_{ijk} = f(A_{jk}, W_{jk}, S_k)$$

where

$M_{ijk}$ = an index of inpatient medical services consumed for treatment of the $i^{th}$ disease episode on the $j^{th}$ day for the $k^{th}$ person;[3]

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

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

$S_k$ = the socioeconomic characteristics of the $k^{th}$ person.

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[3] Specification of this form of the variable was dictated largely by considerations of data availability.

## SECTION V

## THE VARIABLES OF THE EMPIRICAL MODEL

The Oregon Region Kaiser Foundation Health Plan provides prepaid comprehensive medical care to approximately 165,000 members, 18 percent of Portland's metropolitan population [17, p. 2]. Medical care includes physician service in the hospital and office, hospitalization, surgery, laboratory tests, radiology, special nursing, emergency services, mental health, and routine physical examination. During 1971, the average hospital admissions per 1,000 members was 84 and the average length of stay was 5.3 days [17, p. 12]. The total number of hospital admissions for air pollution related diseases during 1970-72 was 4,478.

Since 1965, detailed medical and socioeconomic and demographic information has been recorded on a personal history questionnaire for each patient who is admitted to Bess Kaiser Hospital. A magnetic tape containing this information was obtained from Kaiser Research Foundation. Identification numbers of patients (rather than their names) were used and these were scrambled so that the privacy of the patient's record was safeguarded.

The Kaiser tapes indicated the inpatient consumption of medical services. If a patient had a surgical operation, the surgery code of the International Classification of Disease, Adopted (ICDA) was given. Surgery time, which is an indication of the extent of use of the operating room and anesthesia was not coded, nor were drugs and injections. The inpatient medical data contained information on dates of hospitalization and discharge, admitting and discharge diagnoses (ICDA code) surgery, laboratory tests, radiology, and consultations, the number of physical disabilities of the patient, hospitalization during the last three years, and the number of serious illnesses. The information on X-rays was sketchy, only two categories were recorded: chest X-rays and "other" X-rays. The socioeconomic and demographic data included information on age, sex, race, place of birth, family income bracket, number of family members, rooms in patient's residence, employment status, occupational class, education, and smoking and drinking habits.

### THE COST OF MEDICAL SERVICES

The dependent or response variable of the model is the consumption of medical services by a patient per hospital stay. Since for every medical service a specific dollar amount is charged, the total dollar value for all services rendered a patient was thought to be an appropriate representation of the consumption of medical services. In cases where the patient does not have to pay medical expenses personally because of the prepaid Kaiser insurance system, the dollar amount was calculated on the basis of what he would have paid if he were not a member of the insurance plan.

Inpatient medical costs are composed of charges for hospital room rent, surgical procedures, laboratory and radiological examinations, operating and recovery room rent, anesthesia, physician's time, medication, and consultations.[1] Since most of these charges are based upon the California Relative Value Schedule (CRVS) units, a note on CRVS is in order. The first edition of the CRVS was published in 1956 by the Committee on Fees of the California Medical Association. The main objective of the Committee was the development of a set of guidelines to govern fee schedules. It provides a basis in the setting of fees for medical services [12, p. 462].

The doctor's component for the primary surgical procedure is $6.50 per CRVS unit. Each secondary procedure is charged at $3.25 per unit. The Kaiser tape, coded according to ICDA, was decoded by CRVS units. The number of CRVS units multiplied by $6.50 for primary surgical procedures and $3.25 for secondary procedures yielded the value of the doctor's component of surgery costs.

CRVS fees contained information on anesthesia. However, the Bess Kaiser Hospital charged according to time a patient spent in the operating room where anesthesia was applied rather than by CRVS units. Medical authorities were consulted to relate CRVS units with anethesia time.[2] The following rate structure resulted: the charges for anesthesia time were $14.00 for each first and second 15 minute period and $7.00 for each subsequent 15 minute period. These charges were for 1970-72. The charge for use of the recovery room was made on a flat $24.50 basis for 1971 and 1972, and $23.00 for 1970.

The operating room charges to a patient were $23.40 for the first 15 minute period and $15.25 for each second, third, and fourth 15 minute period, and thereafter $11.25 for each subsequent 15 minute period. These charges were for 1971 and 1972. In 1970, the operating room charges were $21.00, $13.65, and $10.50 for the respective periods.

Charges for wound dressing, orthopedic implants, and traction were considered to be minor and were not included in the study.

The Kaiser tape contained ten separate categories of laboratory tests. These included urine, hematology, blood chemistry, transfusions, bacteriology, serology, coagulation-bone marrows, pap smear-cervical/vaginal, pathology, and miscellaneous tests. The 1969 CRVS units, each valued at 35 cents, were used to derive total laboratory test charges.

Radiological procedures on the Kaiser tape were divided into chest and"other" X-ray categories. The hospital charged $3.15 per 1969 CRVS unit. A routine single view of the chest represented one chest X-ray. The "other" X-ray category was broad, the average of CRVS units of routine X-rays in those categories of diseases was used to represent the "other" X-ray category.

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[1] This section has benefited from conversations with Jack Thomas, Credit Manager, Bess Kaiser Hospital, Portland, May 15, 1974.

[2] A discussion with Dr. Sheldon Wagner, M.D., on November 12, 1974.

The number of electrocardiograms with interpretation and report was on the Kaiser tape. The CRVS units with $3.15 per unit yielded the charges for electrocardiograms.

Consultations, which include the services rendered by a physician whose opinion or advice is requested by another physician in the evaluation or treatment of a patient's illness, are charged at $8.00 per CRVS unit. Thus, a consultation requiring limited examination and evaluation of a given system but not requiring a complete diagnostic history and examination, and which has a value of 3 CRVS units, will cost a patient $24.00. Because the Kaiser tape was not clear on the extent or intensiveness of consultation, it was assumed that each consultation cost a patient $24.00.

Hospital room rent is charged on the number of patient days spent in the hospital. Rent is paid on the day of admission irrespective of the time of admittance, but the day of discharge is not counted. The hospital room rent was $55.00 per day in 1970 and $61.50 per day in 1971 and 1972. The charge includes meals, routine drugs, and services of a nurse.

Drugs consumed in the hospital are not coded on the Kaiser tape. A pharmacist at Bess Kaiser Hospital was consulted to estimate these costs. The average drug cost per patient day was estimated at $3.50, representing an average of 10 doses per patient per day at 35 cents per dose.

## AIR POLLUTION

Suspended particulates was chosen as the air pollution variable. This choice was made for three reasons: (1) the major source of air pollution in the Portland Metropolitan Area is particulate matter; (2) suspended particulates consisting of particles smaller than 10 microns in size are respirable, and as such initially affect the respiratory system; and (3) the Jaksch-Stoevener study indicated an association between particulates and health effects [11, 12]. The total weight of suspended particulates is used as a single statistical variable. Although particulates include benzene, calcium, copper, iron, lead, manganese, nickel, chloride, fluoride, nitrate and sulfate particles, no attempt was made to separate the effect os these components.

Data for suspended particulates from air pollution control stations were obtained from the Department of Environmental Quality for Multnomah, Washington, and Clackamas Counties, and for Clark County in Washington. The air pollution control stations reported particulate levels every four days. A special procedure used by Jaksch, called the spline curve, was used in this study to convert particulates level reporting from a four day to a single day basis to be consistent with the daily meteorological and medical data [12, p. 63].

### Assignment of Air Pollution Values to the Patient's Residential Address

Each air pollution measurement station was assigned a geographic reference using a two-dimensional coordinate plane. The coordinate plane was used to assign a specific air pollution value to each patient on the basis of his resident address. Resident addresses were obtained for all 4,478 inpatients admitted to Bess Kaiser Hospital during 1970, 1971, and 1972 for diseases associated with air pollution. A computer program known as Admatch [12, p. 64], was used to match addresses with census tracts of the area and assign air pollution values to each address. The number of addresses used in the analysis was 3,756. The air pollution value at a certain address was calculated by weighting the observed air pollution values of the three closest stations by their distances from that address $\left(\frac{1}{\text{Distance squared}}\right)$ [12, p. 64].

The Meteorological Variable

Meteorological data for the study were obtained from the National Weather Service of the U.S. Department of Commerce. Data were available on dry bulb temperature, relative humidity, wet bulb temperature, wind velocity and direction, barometric pressure, and precipitation.

Hot and cold temperature extremes were expected to be related to the consumption of inpatient medical services. Thus, degree days, the absolute difference of the actual temperatures from 65°F, was used as a meteorological variable in an analysis. Preliminary investigation indicated that degree days was not a statistically significant variable to explain variations in inpatient medical costs. The temperature-humidity index (THI), which takes into account both temperature and relative humidity, was used instead.

The formula for calculating the THI is:

$$THI = o.4\ (Td + Tw) + 15$$

where Td = dry-bulb air temperature in °F and Tw = wet-bulb temperature in °F.

Empirical studies have shown that in the United States, life becomes unpleasant for 10 percent of the population when the discomfort index (THI) reaches 70; and 50 percent of the population suffer if the THI reaches 75 [19, p. 42]. This variable was expected to have a positive relationship with the consumption of medical services.

Only the Portland International Airport had wet-bulb readings from which to construct the THI. However, the Portland Airport THI was thought to be representative of the area since the temperatures in the entire Portland Metropolitan Area generally fluctuate in the same direction.

SOCIOECONOMIC VARIABLES

Ten socioeconomic and demographic variables and two past medical history variables of the patient are discussed in this section. Information on these variables comes from the questionnaire completed by the patients who were admitted to Bess Kaiser Hospital.

The age of a patient is expressed in years on the date of admission. This variable is expected to have a positive relationship with the consumption of medical services.

The sex of the patient is expressed as a one if the patient is a female and a zero if the patient is a male. Little can be said about the relationship between the sex of the patient and the consumption of medical services in general because the relationship varies with the type of disease.

The education of the patient was divided into nine categories on the Kaiser inpatient tape: (1) under high school unspecified, (2) 0-6 years, (3) 7-8 years, (4) 9-12 years, (5) high school graduate, (6) some college, (7) college graduate, (8) other post-high school degrees and (9) post-graduate college. The variable was expressed as a number from 1 to 8, leaving out the first category which is not meaningful. This weighting system, though a subjective one, is closely associated with the period of an individual's formal education. An educated person may read medical literature, and take preventive care. This may lead to more or less consumption of medical services depending upon the individual's state of health.

The number of hospital visits in the last 3 years was expressed as the actual number of serious illnesses. Nine or more of these were coded as 9. If the same illness was listed by the patient more than once, each episode counted as a separate illness. This variable was hypothesized to be positively related to consumption of inpatient medical services.

The number of disabilities a patient had were also listed as 0 to 9. This variable, like the number of serious illnesses, is expected to have a positive relationship with the consumption of inpatient medical services.

A figure on the total number of persons residing at the patient's residence was available. This included the patient, spouse, number of children, brothers, sisters, and all others. The number of people at the patient's residence, as a proxy for crowding, was expressed as this number and was hypothesized to be positively related to medical costs incurred per hospital stay, as crowding is thought to place an undue physical and emotional stress on a person. Another variable reflecting the same phenomenon was also available. But this one, the number of persons per room, was discarded later as a variable as analysis showed it to be non-significant in explaining medical costs.

The Kaiser inpatient tape contained information only on whether the patient smoked cigarettes, cigars, or pipe, or did not smoke at all. The number of patients who smoked cigars or pipe was negligible. A zero was assigned to the patients who did not smoke at all, and a one was assigned to those who smoked. Smoking was expected to be positively related to the consumption of medical services per hospital stay.

Some information of the patient's consumption of alcoholic beverages was available. The patient was asked whether he consumed alcoholic beverages: "often", "occasionally," "never (or seldom)." What (how many drinks or how often consumed) constitutes "often" or "occasionally" was not clear from the available data. Thus, "never (or seldom)" was entered in the analysis as a zero, and "occasionally" and "often" were grouped together and expressed as a one. The consumption of alcohol, like smoking, is expected to have a positive relationship with the consumption of medical services.

Marital status was coded on the Kaiser inpatient tape in 9 categories: adult and never married, married, remarried, divorced, widowed, separated, pediatric, new born, adopted. The last three categories were not used in the analysis. Married or remarried persons were grouped together and were expressed as a one, and all remaining categories were assigned a zero. A married person was expected to consume fewer medical services than an unmarried one.

Each patient specified one out of seven categories in which his family's gross annual income fell. The categories were: under \$2,500, between \$2,500 to \$5,000; \$5,000 to \$7,500; \$7,500 to \$10,000; \$10,000 to \$12,500; \$12,500 to \$15,000; and over \$15,000. The midpoints of the first six categories were used in the study. For the open category (over \$15,000), the figure of \$25,000 was used. The latter was derived by calculating the weighted average of midpoints of income classes over \$15,000 obtained from the Federal income tax returns for Oregon for 1970. Weights used were the number of returns filed [21, p. 33]. These income figures were used in the analysis as the "family income" variable. Jaksch [11] discussed the function of this variable in explaining the consumption of medical services. Given the likely preferences for medical services and the nature of the prepaid medical insurance plan by which patients in this study were covered, income does not play the same role as it does in the consumption of a normal good. Instead the income variable was included in this study as a proxy for other socioeconomic factors which may be associated with it. The sign on this variable is difficult to predict.

A race variable was expressed as a zero for a white and as a one for a non-white. It was included for similar reasons as the income variable.

There were seven broad categories of occupational class on the Kaiser questionnaire: (1) executives of large concerns, proprietors, and major professionals; (2) business managers, proprietors of medium-sized businesses (value \$35,000 to \$100,000) and lesser professionals; (3) administrative personnel; (4) clerical and sales workers, technicians, and owners of small businesses; (5) skilled manual employees (auto body repairmen, bakers, blacksmiths, bulldozer operators, firemen, mechanics, policemen; (6) semi-skilled employees (delivery men, taxi drivers, welders); and (7) unskilled employees (ash removers, parking lot attendants, farm helpers, janitors, woodchoppers). The first three categories were thought to be of the lowest air pollution exposure and were expressed as a one in the analysis. Fourth, fifth, sixth, and seventh were expressed as two, three, four, and five, respectively. A five equaled a high hazard to air pollution exposure at one's occupations. This weighting scheme is based upon inadequate data and is highly subjective. To the extent that it does indicate the approximate degree of exposure to pollutants, it is expected to have a positive relationship with the consumption of medical services.

The statistical model with all variables as discussed above may be written as:

$$Y_{ijk} = f\ (X_{1ijk};\ X_{2ijk};\ X_{3ijk};\ \ldots;\ X_{14ijk};\ e_{ijk})$$

where

$Y_{ijk}$ = index of medical costs incurred by the $k^{th}$ patient during his hospital stay, who was hospitalized on the $j^{th}$ day for the $i^{th}$ disease.

$X_{1ijk}$ = a measure of suspended particulate (micrograms per cubic meter per day) in the ambient air for the $k^{th}$ patient's residence, who was hospitalized on the $j^{th}$ day for the $i^{th}$ disease.

$X_{2ijk}$ = a measure of meteorological conditions (expressed as temperature-humidity index) for the $k^{th}$ patient's residence, who was hospitalized on the $j^{th}$ day for the $i^{th}$ disease.

$X_{3ijk} \ldots X_{14ijk}$ = age, sex, race, marital status, education, the number of disabilities, the number of serious illnesses, crowding at the patient's residence, smoking habits, drinking habits, family income, and occupational exposure to air pollution, respectively, of the $k^{th}$ person, who was hospitalized on the $j^{th}$ day for the $i^{th}$ disease.

$e_{ijk}$ = a random error term to account for the variables which may have been omitted.

SECTION VI

# RESULTS OF THE ANALYSIS

## EVALUATION OF THE STATISTICAL MODELS

Due to the large number of observations a 5 percent sample of observations for all diseases that were thought to be related to air pollution was randomly selected for a preliminary analysis. The purpose of preliminary investigation was to pretest the statistical model in an inexpensive way for determining the form of the model with the best fit. The multiple regression analysis was performed on the sample using a linear combination of variables as a first step. Scatter diagrams between the dependent variable and each of the independent variables indicated the transformations required in the least-squares analysis. Several transformations were tried on the variables to obtain the best fits. The selection of the best model was made on the basis of calculated t-values for the individual variables and $R^2$ for the whole model.

The results indicated that the coefficient of the air pollution variable was statistically significant at the 5 percent level and the coefficient of multiple determination ($R^2$) was .18, .17, .19, and .20 for air pollution and temperature-humidity index unlagged, lagged one day, lagged two days and lagged three days, respectively. Temperature-humidity index was not statistically significant. Degree days (the absolute difference of the temperature from 65°F) was also tried but it did not improve the results. The coefficients of age, race, family income, occupational exposure, the number of hospital visits, and education were statistically significant at least at the 20 percent level. The coefficients of sex, marital status, the number of people per household, drinking and smoking habits were not significantly different from zero.

The above results from the 5 percent sample showed promise and a program was written for performing multiple regression analysis on all available observations. The transformation of the observations on medical costs, air pollution and meteorological variables to natural logarithms gave the best fit. This was true in all models for unlagged, and one-day lagged, two-lagged, and three-day lagged values of the variables. Thus, the final statistical model became

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

where $Y_{ijk}$ = medical costs incurred by the $k^{th}$ patient who was hospitalized on the $j^{th}$ day for the $i^{th}$ disease; $X_1$ to $X_{12}$ are characteristics related to the patient and, respectively, represent age, sex, race, marital status, family income, number of people in household, alcohol consumption, smoking habit, occupational exposure to air pollution, the number of disabilities of the patient, the number of hospital visits by the patient in the last 3 years, and education of the patient. $X_{13}$ and $X_{14}$ are temperature-humidity index and air pollution values, respectively, associated with the patient's residence.

## RESULTS OF THE REGRESSION ANALYSIS

There was a total of 3650 observations in all relevant disease categories combined and 2808 observations for respiratory diseases only. Respiratory illnesses were analyzed separately because of their manifestation in several studies as important in considering effects of air pollution.

In both models the coefficeint of air pollution was not statistically significant. The coefficient of multiple determination was about .08 for all disease categories and less than .10 for respiratory diseases only. These magnitudes of $R^2$ held in all four submodels, that is, when air pollution and meteorological values were unlagged, lagged one day, lagged two days and lagged three days.

The difference of this magnitude between a random sample and population results is unusual. The medical costs and air pollution values were plotted for all diseases and respiratory diseases only to see whether or not there is any association between the two variables, and if there is, what sort of association it is. The maps of plottings indicated that the sample relationships may be superficial and, hence, the sample may not have been a representative one. However, the plottings also showed that some relationship other than a linear one should be tried for obtaining the best fit.

Results of the regression analysis are presented in Table 1 for respiratory diseases only and Table 2 for all diseases analyzed in this study. Correlation matrices of variables are shown in Appendix Tables 1 and 2.

Each coefficient is accompanied by the standard error of the estimate and the t-statistic to indicate the statistical significance of the coefficient. The mean value of each variable is also presented along with its standard deviation. Both tables are divided into four parts: the first part refers to the results of regression analysis which uses unlagged values of air pollution and meteorological variables, and the second, third and fourth parts use one-day, two-day and three-day lags, respectively, on these two variables. The results for the individual variables of the regression analysis are discussed below.

TABLE 1. ESTIMATED REGRESSION EQUATIONS: RESPIRATORY DISEASES

| | Unlagged[a] | | | Lagged 1 day[a] | | Lagged 2 days[a] | | Lagged 3 days[a] | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | Coefficient[b] | t-statistic | Mean[c] | Coefficient[b] | t-statistic | Coefficient[b] | t-statistic | Coefficient[b] | t-statistic |
| Sample size | 2,808 | | | | | | | | |
| Constant | 5.256 | | | 5.205 | | 5.136 | | 5.218 | |
| Age | .0080 (.00064) | 12.373* | 32.87 (28.17) | .0080 (.00064) | 12.356* | .0079 (.00064) | 12.165* | .0080 (.00064) | 12.346* |
| Sex | .0499 (.0268) | 1.869** | 0.42 (0.49) | .0500 (.0268) | 1.865** | .0502 (.0268) | 1.872** | .0502 (.0268) | 1.875** |
| Race | .0431 (.0530) | 0.813 | 0.05 (0.233) | .0435 (.0530) | 0.819 | .0435 (.0531) | 0.819 | .0438 (.0530) | 0.826 |
| Marital Status | .0584 (.0038) | 1.728** | 0.31 (0.46) | .0501 (.0338) | 1.747** | .0598 (.0338) | 1.767** | .0602 (.0338) | 1.779** |
| Family Income | .0000072 (.0000025) | 2.852* | 9.149 (5.190) | .0000072 (.0000025) | 2.845* | .0000072 (.0000025) | 2.827* | .0000072 (.0000025) | 2.851* |
| Number of people in household | .0091 (.0075) | 1.225 | 3.19 (2.10) | .0091 (.0075) | 1.222 | .0093 (.0075) | 1.243 | .0092 (.0075) | 1.234 |
| Drinking | .110 (.034) | 3.155* | 0.25 (0.43) | .110 (.034) | 3.151* | .110 (.034) | 3.165* | .109 (.034) | 3.147* |
| Smoking | .045 (.037) | 1.225 | 0.16 (.037) | .045 (.037) | 1.223 | .046 (.037) | 1.231 | .045 (.037) | 1.218 |
| Occupational exposure | .012 | 1.272 | 1.51 | .012 | 1.274 | .012 | 1.288 | .012 | 1.287 |

Continued

TABLE 1. (Continued)

| Variable | Unlagged[a] Coefficient[b] | Unlagged[a] t-statistic | Unlagged[a] Mean[c] | Lagged 1 day[a] Coefficient[b] | Lagged 1 day[a] t-statistic | Lagged 2 days[a] Coefficient[b] | Lagged 2 days[a] t-statistic | Lagged 3 days[a] Coefficient[b] | Lagged 3 days[a] t-statistic |
|---|---|---|---|---|---|---|---|---|---|
| Number of disabilities | — | — | 0.16 (0.49) | — | — | .0004 (.0258) | 0.017 | — | — |
| Number of hospital visits | -.0265 (.0097) | -2.738* | 0.66 (1.30) | -.0265 (.0097) | -2.736* | -.0267 (.0097) | -2.735* | -.0266 (.0097) | -2.748* |
| Education | -.0015 (.0065) | -0.231 | 3.51 (2.18) | -.0014 (.0065) | -0.225 | -.0015 (.0065) | -0.231 | -.0015 (.0065) | -0.240 |
| Temperature-Humidity Index | .0804 (.0844) | 0.952 | 54.97 (7.91) | .0720 (.0834) | 0.863 | .1302 (.0819) | 1.589 | .1101 (.0817) | 1.236 |
| Air Pollution | .2006 (.0237) | 0.869 | 67.08 (34.07) | .0169 (.0240) | 0.707 | .0011 (.0242) | 0.047 | .00080 (.0243) | 0.033 |
| Medical Costs | | | 577.14 (586.14) | | | | | | |
| $R^2$ | .1292 | | | .1291 | | .1294 | | .1293 | |

* Signifies that the coefficient is statistically significant at 5 percent level (one-tailed test).

** Signifies that the coefficient is statistically significant at 10 percent level (one-tailed test).

a/ Refers to the respective lags in meteorological and air pollution variables.

b/ The standard error of the coefficient is in parenthesis

c/ Means of untransformed variables. The standard deviation is in parentheses.

TABLE 2. ESTIMATED REGRESSION EQUATIONS: ALL DISEASES

| Variable | Unlagged[a/] Coefficient[b/] | Unlagged[a/] t-statistic | Unlagged[a/] Mean[c/] | Lagged 1 day[a/] Coefficient[b/] | Lagged 1 day[a/] t-statistic | Lagged 2 days[a/] Coefficient[b/] | Lagged 2 days[a/] t-statistic | Lagged 3 days[a/] Coefficient[b/] | Lagged 3 days[a/] t-statistic |
|---|---|---|---|---|---|---|---|---|---|
| Sample size | 3,650 | | | | | | | | |
| Constant | 5.440 | | | 5.419 | | 5.277 | | | |
| Age | .0074<br>(.00058) | 12.734* | 40.43<br>(29.51) | .0074<br>(.00058) | 12.737* | .0074<br>(.00058) | 12.742* | .0074<br>(.00058) | 12.738 |
| Sex | .0297<br>(.0247) | 1.201 | 0.432<br>(0.495) | .0297<br>(.0247) | 1.201 | .0300<br>(.0247) | 1.212 | .0298<br>(.2047) | 1.207 |
| Race | .0678<br>(.0501) | 1.352 | 0.055<br>(0.229) | .0682<br>(.0501) | 1.359 | .0684<br>(.0501) | 1.364 | .0682 | 1.362 |
| Marital status | .0325<br>(.0289) | 1.124 | 0.349<br>(0.476) | .0327<br>(.0289) | 1.131 | .0331<br>(.0289) | 1.147 | .0336<br>(.0289) | 1.163 |
| Family income | .0000062<br>(.0000023) | 2.605* | 8,648<br>(5,171) | .0000062<br>(.0000023) | 2.596* | .0000062<br>(.0000023) | 2.592* | .00000619<br>(.00000239) | 2.588* |
| Number of people in household | .00249<br>(.00730) | .341 | 2.873<br>(2.068) | .00251<br>(.00730) | .344 | .00263<br>(.00730) | .361 | .00258<br>(.00730) | .354 |
| Drinking | .120<br>(.030) | 3.924* | 0.257<br>(0.437) | .120<br>(.030) | 3.927* | .120<br>(.030) | 3.941* | .120<br>(.030) | 3.925* |
| Smoking | .039<br>(.033) | 1.184 | 0.180<br>(0.384) | .039<br>(.033) | 1.179 | .039<br>(.033) | 1.178 | .039<br>(.033) | 1.176 |
| Occupational exposure | .0024<br>(.0087) | .280 | 1.483<br>(1.410) | .0024<br>(.0087) | .283 | .0026<br>(.0087) | .300 | .0025<br>(.0087) | .293 |

Continued

TABLE 2. (Continued)

| Variable | Unlagged[a] Coefficient[b] | t-statistic | Mean[c] | Lagged 1 day[a] Coefficient[b] | t-statistic | Lagged 2 days[a] Coefficient[b] | t-statistic | Lagged 3 days[a] Coefficient[b] | t-statistic |
|---|---|---|---|---|---|---|---|---|---|
| Number of disabilities | .020 (.021) | .927 | 0.199 (0.538) | .020 (.021) | .924 | .020 (.021) | .932 | .020 (.021) | .930 |
| Number of hospital visits | -.019* (.0088) | -2.154 | 0.749 (1.341) | -.019* (.0088) | -2.156 | -.019* (.0088) | -2.170 | -.019* (.0088) | -2.172* |
| Education | .0047 (.0060) | .778 | 3.240 (2.211) | .0047 (.0060) | .783 | .0047 (.0060) | .779 | .0046 (.0060) | .766 |
| Temperature-humidity index | .060 (.077) | .778 | 54.97 (7.91) | .064 (.075) | .848 | .111 (.074) | 1.489 | .106 (.741) | 1.438 |
| Air pollution | .0049 (.0220) | .224 | 67.08 (34.07) | .00589 (.0221) | .266 | -.0054 (.0221) | -.245 | -.0063 (.0221) | -.286 |
| Medical costs | | | 605.84 (587.88) | | | | | | |
| $R^2$ | .1061 | | | .1062 | | .1065 | | .1065 | |

* Signifies that the coefficient is statistically significant at 5 percent level (one-tailed test).

a/ Refers to the respective lags in meteorological and air pollution variables.

b/ The standard error of the coefficient is in parentheses.

c/ Mean of untransformed variables. The standard deviation is in parentheses.

## Age of the Patient

Age of the patient was the most important factor in explaining the variation in the consumption of inpatient medical services per hospital stay. The coefficient was positive as expected and it was statistically significant at 1 percent level for respiratory diseases only (model 1) and also for all diseases (model 2) analyzed in this study. The positive coefficient implies that as the patient grows older he consumes more medical services per hospital stay. The average age of the patient was about 33 years for the patients hospitalized for respiratory diseases and about 40 for the patients hospitalized for all diseases analyzed.

## Sex of the Patient

The coefficient of sex of the patients was positive and was statistically significant at the 5 and 10 percent levels, respectively, for model 1 and 2, implying that women consume more medical services when hospitalized than men. About 43 percent of the patients who were treated for all diseases analyzed here were women and the percentage of women in the respiratory disease category was 42.

Jaksch and Stoevener [12] found that 68 percent of women consume out-patient services for respiratory illnesses, but women consume fewer out-patient medical services than men per episode of illness. The results of this study indicate that the percentage of women admitted to the hospital is lower than that of men. Yet when they are admitted to the hospital they consume more services there than men. This may have some implications about differences in the rate of affliction with respiratory diseases between men and women, as well as about sex differences in the costs of work loss on the job and the availability of medical care in the home.

## Race of the Patient

Race of the patient was statistically significant at the 10 percent level for all diseases combined but was not significantly different from zero for respiratory diseases only. The positive coefficient on the race variable implies that blacks and other non-whites consume more in-patient medical services than whites. Of all patients who consumed inpatient medical services for the diseases analyzed in this study, only about 5 percent were nonwhite.

## Marital Status of the Patient

Marital status of the patient was statistically significant at the 10 percent level for respiratory illnesses but not significant for all diseases taken together. The positive coefficient indicates that married persons consume more in-patient medical services per hospital visit. About 35 percent and 31 percent of the patients admitted for all diseases combined and respiratory diseases only, respectively, were married persons. Jaksch and Stoevener [12] found that over 84 and 81 percent of the patients consuming out-patient medical services for respiratory and circulatory respiratory diseases, respectively, were married. Married persons may consume fewer inpatient medical services because of the availability of home care for the patient. Unless a married person is very sick, he may not go to the hospital but he may consume more medical services in the hospital once he is admitted.

## Family Income

The coefficient of family income has a positive sign and is statistically significant at the 1 percent level in both disease categories. As the household income of a patient rises he or she consumes more medical services per hospital stay. The average family income was over $9,000 for patients with respiratory illnesses and about $8,600 for patients in the all diseases category.

## Number of Persons in the Patient's Household

The coefficient was positive but not significantly different from zero in both models indicating that there is no relationship between the number of people in the patient's household and the consumption of inpatient medical services. This variable appears to have been a poor proxy for the effect of crowding in living conditions which it was supposed to measure.

## Drinking Habits of the Patient

The coefficient of the drinking variable is positive as expected and statistically significant at the one percent level. Though data on the amount of drinking the patients do were not available for this study, this result is consistent with the popular notion of association between drinking and bad health. About 25 percent of the patients analyzed in this study consumed alcoholic beverages occasionally or often.

## Smoking Habits of the Patient

The coefficient of this variable was positive but not statistically significant for any of the models. Similar results were obtained by Jaksch and Stoevener [12, p. 87] for out-patients consuming medical services for respiratory and circulatory-respiratory diseases.

This is a surprising result because it is known that in general smoking deteriorates the condition of health, especially for patients who have respiratory illnesses.

The results for smoking in this analysis may be attributed to poor data available for this variable. The inpatient questionnaire only contained data on whether a person smoked or not. As in the case of drinking, the amount of smoking and the number of years smoked by the patient were not known. Only 16 to 18 percent of the patients said that they smoked. As the percentage of smokers in the general population is much higher [22] the possibility of a measurement error suggests itself.

## Occupational Exposure to Pollution

The coefficient of occupational exposure to job related pollution was positive for both models. It was significantly different from zero at the 20 percent level in only the case of respiratory diseases with two- and three-day lags of the air pollution and meteorological variables. It was not significantly different from zero in the remaining cases. The positive coefficient implies that workers exposed to dust, dirt, etc., spend more on inpatient medical services than white collar workers in offices.

The exact occupation of the patient was not known and the categories of occupations were very broad. This may also have contributed to the non-significance of the coefficients.

Number of Disabilities of the Patient

The coefficient of the number of disabilities a patient had was not statistically significant from zero in any of the models. The nature of disabilities may be more important than the number of disabilities in explaining the expenditure on medical services. The nature of the disabilities was not known.

Number of Hospital Visits

The number of times in the preceding three years a patient was admitted to a hospital is negatively related to the medical expenses under consideration here. This variable had a coefficient which was statistically significant at the 5 percent level in all models. The negative coefficient of this variable indicates that the more frequently the patient had been to the hospital, the less will be his expenditure on medical services during the stay under consideration. The expected sign of the coefficient was positive. Perhaps the total length fo stay in the hospital during previous visits would be a more appropriate variable.

Education of the Patient

Education was not a significant variable in any of the models. This is not surprising given the difficulty of predicting the effect of this variable and its correlation with some other variables included in the analysis [Appendix Tables 2 and 3].

Temperature-Humidity Index

The coefficient of this variable was statistically significant at the 20 percent level for two- and three-day lags in both models. The sign of the coefficient was positive as expected in all cases.

Air Pollution

None of the coefficients in the eight submodels evaluated was statistically significant. This implies that there is no relationship between suspended particulates and the consumption of inpatient medical services in the Portland Metropolitan Area, given the specifications of these models.

One of the primary shortcomings explaining the nonsignificance of the regression coefficient of air pollution may be a time lag of greater than three days between the onset of illness and the patient's admission to a hospital. The aggravation of disease as an effect of deterioration in air quality may be slow to be noticed and the patient may not feel the necessity of seeking medical help immediately. A hospital bed or surgeon's time (in case of surgery) may also not be available on short notice. For all of these reasons the association of the decline in air quality which may have caused The hospitalization with the date of admission to the hospital, is very difficult to make.

## GENERAL COMMENTS

Only about 10 to 13 percent of the variation in total medical costs for inpatient services was explained by the deterioration in air quality, meteorological conditions, and socioeconomic and general characteristics of the patient.

As discussed by Jaksch and Stoevener [12] the low coefficient of multiple determination ($R^2$) may be attributed to the fact that the models used in this study are a simple representation of a much more complex medical phenomenon. In both models (and all submodels) age of the patient, family income, drinking habits of the patient, and the number of hospital visits by the patient in the last 3 years were the significant variables in explaining the variation in the consumption of inpatient medical services. The influence of unspecified factors on inpatient medical costs is greater than the explanation offered by these few variables.

There are several limitations to this study which indicate that its results should be used with caution. First, there were a number of inadequacies in the data used. The specific laboratory tests and radiological procedures were not known for a patient, instead only broad categories of these tests and procedures were known. Thus, the estimates were made on the basis of categories of these tests and procedures. The number of drugs consumed per day were not known for each patient separately. The pharmacy staff at the hospital reported that, in general, the expenditure on drugs is the same per day for each patient and if this amount varies it does not vary a great deal. Only approximation could be used in calculating the time involved in surgery. There was also no indication whether the consultations a patient had with a physician were of limited or extensive nature.

Second, occupational addresses for the hospital admitted patients were not recorded on the questionnaire forms, hence, the air pollution and meteorological values at the job were not taken into account. Thus, air pollution and meteorological values at only residential addresses were considered in this study.

Third, data on the socioeconomic characteristics of patients came from the questionnaire administered to patients at the hospital. The questionnaire was not designed for the purpose of this study. There may also have been important measurement errors with several variables.

Finally, and most importantly, the time lag between the onset of the illness and the patient's admission to the hospital may vary from illness to illness and according to the availability of medical services. The lags are likely to be much greater in some instances than could be considered in an analysis using the data studied here. It becomes apparent that much more specific data are required for the analysis of inpatient medical costs' relationship to air pollution. Such data would have to be collected at the time of the patient's admission to the hospital. The information would have to focus on the history of the patient's well-being during the time between the onset of the current disease episode and his admission to the hospital. Only if such information is available will it be possible to relate in a meaningful way changes in air pollution levels to medical services provided by hospitals. It is unlikely that such data will become available unless a considerable commitment is made to generate them as patients' hospital medical records develop. This would involve a long-run cooperative research project between the medical profession and social scientists.

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## SECTION VIII

## APPENDIX

APPENDIX TABLE 1. Classification of Diseases

I. Diseases of the respiratory system

- Upper respiratory infections
- Lower respiratory

II. Allergies affecting the respiratory system

- Asthma
- Hay Fever
- Specific diseases

III. Diseases of the circulatory system

- Heart
- Circulatory system

IV. Other allergies and skin diseases

- Eczema
- Other allergies
- Other skin diseases
- Specific diseases - allergies

V. Diseases of the eye

- Inflamatory disease of the eye
- Non-specific eye diseases

APPENDIX TABLE 2. Correlation Matrix of Variables - Respiratory Diseases

| Variables | Age | Sex | Race | Marital Status | Family Income | Persons in Household | Drinking | Smoking | Occupational Exposure | Number of Disabilities | Number Hospital Visits |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | 1.000 | -.045 | -.095 | .473 | -.246 | -.567 | -.309 | -.269 | -.032 | .202 | .182 |
| Sex | | 1.000 | -.008 | -.071 | -.029 | .024 | -.097 | -.106 | -.380 | -.019 | .013 |
| Race | | | 1.000 | -.077 | -.071 | .054 | -.048 | .017 | .005 | -.061 | .055 |
| Marital Status | | | | 1.000 | .022 | -.101 | -.481 | .344 | .057 | .096 | .149 |
| Family Income | | | | | 1.000 | .236 | .055 | -.027 | -.002 | -.107 | -.127 |
| Persons in Household | | | | | | 1.000 | -.111 | -.109 | .033 | -.061 | -.028 |
| Drinking | | | | | | | 1.000 | .450 | .119 | .066 | .089 |
| Smoking | | | | | | | | 1.000 | .137 | .039 | .093 |
| Occupational Exposure | | | | | | | | | 1.000 | -.025 | -.037 |
| Number of Disabilities | | | | | | | | | | 1.000 | .153 |
| Number of Hospital visits | | | | | | | | | | | 1.000 |
| Education | | | | | | | | | | | |
| THI unlagged | | | | | | | | | | | |
| THI lagged 1 day | | | | | | | | | | | |
| THI lagged 2 days | | | | | | | | | | | |
| THI lagged 3 days | | | | | | | | | | | |
| Air Pollution Unlagged | | | | | | | | | | | |
| Air pollution Lagged 1 day | | | | | | | | | | | |
| Air pollution Lagged 2 days | | | | | | | | | | | |
| Air pollution Lagged 3 days | | | | | | | | | | | |
| Medical Costs | | | | | | | | | | | |

Continued

APPENDIX TABLE 2. (continued)

| Variables | Education | THI unlagged | THI lagged 1 day | THI lagged 2 days | THI lagged 3 days | Air pollution unlagged | Air pollution lagged 1 day | Air pollution lagged 2 days | Air pollution lagged 3 days | Medical Costs |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | -.347 | .002 | .009 | .005 | -.002 | -.030 | -.022 | -.014 | -.009 | .332 |
| Sex | .032 | .002 | -.001 | .011 | .011 | .023 | .027 | .017 | .002 | -.002 |
| Race | -.040 | -.015 | -.019 | -.010 | -.015 | .007 | .001 | -.003 | -.008 | -.027 |
| Marital Status | .016 | -.004 | -.004 | -.017 | -.023 | .007 | -.002 | -.011 | -.014 | .224 |
| Family Income | .309 | .017 | .024 | .019 | .018 | .020 | .018 | .014 | .007 | -.011 |
| Persons in Household | .418 | .010 | -.022 | -.002 | .010 | .035 | .043 | .042 | .035 | -.156 |
| Drinking | .066 | -.037 | -.034 | -.031 | -.023 | .004 | 0 | -.003 | -.004 | .193 |
| Smoking | -.008 | .004 | .003 | -.004 | .007 | .004 | .010 | .014 | .020 | .148 |
| Occupational Exposure | 0 | -.018 | -.023 | -.018 | .016 | .011 | .015 | .021 | .027 | .016 |
| Number of Disabilities | .034 | .003 | .006 | 0 | .009 | -.003 | .003 | .007 | .012 | .057 |
| Number of Hospital visits | -.002 | .023 | .022 | .016 | .019 | -.007 | -.007 | -.101 | -.010 | .016 |
| Education | 1.000 | .018 | .011 | .011 | .025 | .028 | .027 | .027 | .027 | -.082 |
| THI unlagged | | 1.000 | .925 | .845 | .802 | .198 | .215 | .220 | .212 | .017 |
| THI lagged 1 day | | | 1.000 | .927 | .849 | .165 | .189 | .210 | .214 | .017 |
| THI lagged 2 days | | | | 1.000 | .931 | .125 | .151 | .180 | .200 | .027 |
| THI lagged 3 days | | | | | 1.000 | .114 | .128 | .156 | .185 | .021 |
| Air pollution Unlagged | | | | | | 1.000 | .924 | .729 | .504 | .013 |
| Air pollution Lagged 1 day | | | | | | | 1.000 | .910 | .716 | .012 |
| Air pollution Lagged 2 days | | | | | | | | 1.000 | .916 | .004 |
| Air pollution Lagged 3 days | | | | | | | | | 1.000 | .004 |
| Medical Costs | | | | | | | | | | 1.000 |

*APPENDIX TABLE 3. Correlation Matrix of Variables - All Diseases*

| Variables | Age | Sex | Race | Marital Status | Family Income | Persons in household | Drinking | Smoking | Occupational exposure | Number of disabilities | Number of hospital visits |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | 1.000 | -.012 | -.108 | .391 | -.301 | -.600 | .218 | .184 | -.067 | .201 | .192 |
| Sex | | 1.000 | -.006 | -.118 | -.044 | -.006 | -.116 | -.125 | -.376 | -.031 | -.019 |
| Race | | | 1.000 | -.065 | -.062 | .087 | -.022 | .029 | .013 | -.058 | .077 |
| Marital Status | | | | 1.000 | .021 | -.042 | .404 | .295 | .070 | .100 | .168 |
| Family income | | | | | 1.000 | .250 | .064 | -.013 | .023 | -.096 | -.147 |
| Persons in household | | | | | | 1.000 | -.063 | -.063 | .061 | -.053 | -.025 |
| Drinking | | | | | | | 1.000 | .436 | .109 | .064 | .096 |
| Smoking | | | | | | | | 1.000 | .152 | .026 | .097 |
| Occupational exposure | | | | | | | | | 1.000 | 0 | -.024 |
| Number of disabilities | | | | | | | | | | 1.000 | .185 |
| Number of hospital visits | | | | | | | | | | | 1.000 |
| Education | | | | | | | | | | | |
| THI unlagged | | | | | | | | | | | |
| THI lagged 1 day | | | | | | | | | | | |
| THI lagged 2 days | | | | | | | | | | | |
| THI lagged 3 days | | | | | | | | | | | |
| Air pollution Unlagged | | | | | | | | | | | |
| Air pollution Lagged 1 day | | | | | | | | | | | |
| Air pollution Lagged 2 days | | | | | | | | | | | |
| Air pollution Lagged 3 days | | | | | | | | | | | |
| Medical Costs | | | | | | | | | | | |

Continued

APPENDIX TABLE 3. (continued)

| Variables | Education | THI unlagged | THI lagged 1 day | THI lagged 2 days | THI lagged 3 days | Air pollution unlagged | Air pollution lagged 1 day | Air pollution lagged 2 days | Air pollution lagged 3 days | Medical Costs |
|---|---|---|---|---|---|---|---|---|---|---|
| Age | -.389 | -.002 | -.003 | -.007 | -.015 | -.018 | -.014 | -.008 | -.005 | .303 |
| Sex | .017 | .004 | 0 | .012 | .014 | .029 | .038 | .034 | .023 | 0 |
| Race | .017 | -.017 | -.022 | -.015 | -.014 | .008 | .001 | -.005 | -.009 | -.020 |
| Marital Status | .032 | .001 | -.004 | -.016 | -.023 | .023 | .011 | 0 | -.003 | .170 |
| Family Income | .306 | .008 | .014 | .012 | .019 | .009 | .012 | .011 | .011 | -.034 |
| Persons in Household | .441 | .010 | .029 | 0 | .010 | .024 | .027 | .025 | .020 | -.163 |
| Drinking | .095 | -.034 | -.032 | -.032 | -.025 | .016 | .006 | -.008 | -.016 | .156 |
| Smoking | .029 | .010 | .011 | .006 | .010 | .023 | .019 | .015 | .016 | .111 |
| Occupational Exposure | .026 | -.018 | -.021 | -.017 | -.012 | .018 | .018 | .019 | .023 | -.007 |
| Number of Disabilities | .051 | -.006 | -.005 | -.009 | -.008 | -.013 | -.006 | -.003 | 0 | .071 |
| Number of Hospital visits | .002 | .003 | .004 | .001 | .001 | -.015 | -.018 | -.019 | -.019 | .033 |
| Education | 1.000 | .014 | .007 | .009 | .024 | .022 | .022 | .023 | .023 | -.078 |
| THI unlagged | | 1.000 | .026 | .851 | .806 | .190 | .204 | .208 | .202 | .010 |
| THI lagged 1 day | | | 1.000 | .931 | .851 | .155 | .177 | .198 | .205 | .010 |
| THI lagged 2 days | | | | 1.000 | .931 | .115 | .140 | .170 | .192 | .018 |
| THI lagged 3 days | | | | | 1.000 | .109 | .120 | .147 | .178 | .016 |
| Air pollution Unlagged | | | | | | 1.000 | .024 | .731 | .509 | .004 |
| Air pollution Lagged 1 day | | | | | | | 1.000 | .912 | .723 | .005 |
| Air pollution Lagged 2 days | | | | | | | | 1.000 | .918 | 0 |
| Air pollution Lagged 3 days | | | | | | | | | 1.000 | .001 |
| Medical Costs | | | | | | | | | | 1.000 |

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16. ABSTRACT


This study was undertaken to ascertain the possibility of measuring from available data the impact of air pollution on the consumption of inpatient services which patients consume per hospital stay.

The study area was the Portland, Oregon metropolitan area, and the period of study was 1970-72. The diseases which were thought to be associated with air pollution were first identified. A sample of the patients was taken from a hospital population and the medical costs incurred by them were calculated. Suspended particulates as a measure of air pollution, temperature-humidity index as a measure of meteorological conditions of the area, and socio-economic characteristics of patients were used in a regression model to explain variations in medical costs.

The analysis did not indicate a quantitative relationship between air pollution in the Portland area and the consumption of inpatient medical services per hospital stay. Age, family income, and drinking habits of a patient do significantly affect inpatient medical costs, but the variables included in the analysis accounted for less than 15 percent of the statistical variation in the dependent variable.


17. KEY WORDS AND DOCUMENT ANALYSIS

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