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PM_{10} POLLUTION AND THE CONSUMPTION OF PHYSICIAN SERVICES IN MISSOULA COUNTY, MONTANA

by

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PM_{10} Pollution and the Consumption of Physician Services in Missoula County, Montana (pp.79)

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Time-series analysis was used to assess the association between particulate air pollution (PM_{10}) and the consumption of physician services used to treat respiratory disease in Missoula County, Montana by Medicaid recipients. The intent was to quantify one component of the direct health costs of exposure to PM_{10}. The study period consisted of two three-month segments, January-March 1994 and October-December 1994. After controlling for meteorological factors and temporal factors, ordinary least squares regression analysis and generalized least squares regression analysis were used to isolate the impact of daily PM_{10} pollution levels on total daily Medicaid physician expenditures and total daily Medicaid physician visits for the treatment of respiratory disease. Based on the statistical results, this study found little evidence to suggest that increases in PM_{10} pollution contribute to increases in physician expenditures or increases in physician visits for respiratory disease in Missoula County, Montana by Medicaid recipients.

Table of Contents

Figures and Tables

Chapter 1. Introduction

Despite improvements in air quality since the passing of the Clean Air Act in 1970, air pollution still poses a threat to human health.[1] There is considerable evidence within the health, environmental, and economic literature which implicates air pollution as a contributing factor to premature mortality, illness, work and school absenteeism, and restricted activity. The direct and indirect health costs of air pollution, whether measured in terms of the medical costs incurred to treat the air pollution-related diseases, lost wages, or physical discomfort, are substantial.[2]

If the adverse health effects associated with air pollution are to be further reduced, continued efforts, in the form of more stringent federal, state, or local air quality standards or increased enforcement of current standards, may be required. However, air pollution regulation imposes immense costs on society. In addition to the expense required to administer and enforce pollution standards, air pollution control may cause costly modifications to existing firms, firm shutdowns, unemployment, and higher prices for consumers and producers.

Removal of all pollutants from the air is neither possible nor cost effective. The goal of air quality management is to achieve an optimal level of pollution where the costs of implementing air pollution controls are balanced against the benefits likely to result

[1] In 1970, Congress passed the Clean Air Act which led to the formation of the Environmental Protection Agency (EPA). The act authorized the EPA to set National Ambient Air Quality Standards (NAAQS) for six common pollutants: particulate matter, sulfur dioxide, nitrogen dioxide, lead, carbon monoxide, and ozone.

[2] It should be recognized that health costs are only a portion of the total economic effects that result from air pollution. Other economic effects of air pollution include reduced visibility, damage and soiling of property, and reduced agriculture and forest yields.

from the cleaner air. To achieve such an equilibrium, the policy-maker must have quantitative information regarding the costs and benefits associated with certain air pollution levels. The economist can help to translate the physical effects of air pollution into monetary terms which can than be compared to the costs associated with air pollution control.

Although it is not possible to derive a monetary value which represents all the direct and indirect health costs associated with air pollution, economists have made progress in valuing various components of air pollution-related health effects such as premature mortality, increased hospitalization, increased emergency room utilization, work loss, and restricted activity. However, within the economics literature, few studies have assessed the economic impact of air pollution on the consumption of physician services. This is an unfortunate deficiency given that physician services used to treat air pollution-related diseases may make up a sizable portion of the total health costs attributable to air pollution. Access to a large data base consisting of individual Montana Medicaid patient medical data provides this study with a unique opportunity to remedy that deficiency.

The objectives of this study are three-fold: 1) to develop an appropriate time-series model for empirically estimating the effect of particulate air pollution on morbidity as measured by the consumption of physician services in Missoula County, Montana, 2) to estimate the effect of particulate air pollution on the consumption of physician services, and 3) to quantify the effect of particulate air pollution on the consumption of physician services in monetary terms. The results of this study may prove useful to local or state air quality officials who are responsible for creating and implementing optimal air pollution control programs. If it can be demonstrated that particulate air pollution adversely affects health, the health benefits derived from a reduction in particulate air pollution are then comparable to the economic costs of pollution control.

The following chapter provides a summary of studies which have previously investigated the relationship between particulate air pollution and human health. Chapter 3 describes the assumptions and the general models used to isolate the impact of particulate air pollution on the consumption of physician services. A description of the study area, (Missoula County, Montana), and a description of the source of the medical data (The Montana Medicaid Program) are included in Chapter 4. Chapter 4 also discusses the compilation of the medical data, the particulate air pollution data, and the meteorological data. The statistical methods employed in the analysis, the empirical models, and the empirical results are presented in Chapter 5. Finally, in Chapter 6, limitations of the study and suggestions for further work are presented.

Chapter 2. Review of the Literature

Over the past four decades, numerous studies have investigated particulate air pollution-related health effects. Early research conducted in the 1950s and the 1960s was primarily concerned with documenting the health effects associated with severe episodes of air pollution in both US and European cities. Research conducted since the mid 1970s, however, has mainly investigated the health effects associated with levels of particulate air pollution common to many US cities.

Although early research was useful in documenting the substantial adverse health effects associated with severe pollution episodes, Pope et al (1995) maintain that recent studies are more relevant to understanding the subtle health effects associated with lower levels of particulate air pollution. Pope et al further contend that research conducted since the mid 1970s has generally had better air quality data, better health measurements, and more advanced econometric techniques than early studies. These improvements in both data measurement and statistical techniques have allowed the researcher to more accurately assess the impact of particulate air pollution on health.

This literature review is only concerned with the more recent studies of the adverse health effects of particulate air pollution. The studies reviewed in this chapter have used two approaches to quantify the effects of air pollution on human health. Cross-sectional studies have typically compared differences in mortality or morbidity (illness) rates across several cities or counties at a selected point in time. Time series studies have commonly examined daily changes in mortality or morbidity rates in a single location which experiences changing air quality over time. The reviewed studies are divided into categories based upon the type of analysis used, cross-sectional or time-series, and health endpoints, mortality or morbidity.

Cross-Sectional Analyses

The mortality and morbidity effects associated with long-term or chronic effects of exposure to air pollution have been examined using cross-sectional analysis.[3] An advantage of cross-sectional studies is that they allow the researcher to observe the long-term effects of air pollution on a large number of people across a wide array of geographic environments.

One common approach is to develop an aggregate cross-sectional data base, usually for cities or Standard Metropolitan Statistical Areas (SMSAs), on a number of variables which might be associated with mortality or morbidity rates. Regression analysis can then be used to determine if a statistically significant association exists. Ideally, a study of this nature would be able to relate various levels of air pollution to measures of health for homogenous individuals.

In practice, however, most cross-sectional studies suffer from data problems. Due to the characteristics of the available data, cross-sectional studies often aggregate data across geographical areas comprised of heterogeneous individuals. Consequently, measures of individual diversity, health habits, and health histories are often unavailable

[3] Comparisons of mortality/morbidity across communities with varying levels of air pollution at a selected point in time are often interpreted as evaluating the long-term or chronic effects of exposure to air pollution rather than the acute effects due to the cross-sectional design of the studies and the use of average pollution measures over a relatively long period of time, typically one year or more.

to the researcher or are at best crude measures. Further, it is virtually impossible to measure an individual's current and cumulative "true" exposure to air pollution.

Many cross-sectional studies also share two statistical problems: heteroscedasticity and multicollinearity. In the presence of heteroscedasticity, the ordinary least squares (OLS) estimates are unbiased but inefficient. Consequently, the standard errors of the estimated coefficients are incorrect, and this may lead the researcher to make erroneous statements about the significance of a coefficient. In the presence of multicollinearity it becomes difficult to separate the effects of one pollutant on mortality/morbidity rates from the effects of other pollutants and non-pollutant factors.

Mortality

One of the most in-depth and comprehensive cross-sectional studies of the effects of air pollution on human health was conducted by Lave and Seskin (1977). Lave and Seskin investigated the statistical association between ambient air pollution and mortality rates in the United States using cross-sectional data on over 100 SMSAs for the each of the years 1960, 1961, and 1969. Linear regression analysis was used to relate total mortality rates in SMSAs to eleven explanatory variables. The explanatory variables consisted of three different measures of both sulfates and total suspended particulates (TSP), four socioeconomic variables, and total population. Lave and Seskin found that TSP was consistently and significantly related to total mortality rates in a positive manner. Based on the parameter estimates of TSP and sulfates, they estimated that a 58% reduction in TSP and an 88% reduction in sulfur oxides, reductions corresponding to proposed EPA control levels, would be associated with a 7% decrease in total morbidity and mortality levels.[4] Accounting only for the benefits to human health alone, Lave and Seskin calculated that such a reduction in total mortality could result in a national annual benefit of $16.1 billion (1973 dollars) in health improvements.

Lave and Seskin's work has been reviewed, reanalyzed, and expanded by various researchers including Thibodeau et al (1980) and Ozkaynak and Thurston (1987). A recurring criticism of Lave and Seskin's work, and cross-sectional mortality studies in general, revolves around the omission of other explanatory variables which may have influenced the mortality rates. Additional variables cited as potentially influencing mortality rates include smoking habits, dietary factors, availability and quality of medical care, occupational exposure, length of residence in a geographical area, and pre-existing disease. The omission of such variables from Lave and Seskin's analysis has led researchers to question whether the observed association between air pollution and mortality was spurious (Gerking and Schulze 1981).

Subsequent cross-sectional studies, which used data sets similar to those of Lave and Seskin, found contrary results when additional explanatory variables were included in the model specification. In particular, Crocker et al (1979) analyzed 1970 mortality rates for 60 US cities while attempting to control for cigarette smoking, diet, and medical care. Two stage least square (2SLS) analysis was used to estimate a two equation model which had mortality rates and doctors per capita as the endogenous variables. Crocker et al argued that a single equation model was not appropriate because medical care may influence an individual's health while the amount of illness in a given area may influence

[4] Lave and Seskin assumed that air pollution in the form of suspended particulates and sulfur oxides would have the same effect on morbidity as mortality.

the supply of medical care. An ordinary least squares model would be unable to capture simultaneity of these effects. Crocker et al reported that no significant association between TSP and mortality was found.

Using the same data set as Crocker et al (1979), Gerking and Schulze (1981) observed a significant negative association between TSP and mortality when smoking, diet, exposure to cold, and doctors per capita were included as explanatory variables. Similar to Crocker et al (1979), Gerking and Schulze used 2SLS analysis to estimate a two equation model treating medical care and mortality as endogenous.[5]

Analyses by Chappie and Lave (1982) did not indicate a statistically significant association between TSP and mortality using a 1974 SMSA data set which included variables such as smoking, alcohol consumption, and nutrition. Chappie and Lave also investigated the influence of medical care as measured by doctors per capita on mortality using a simultaneous equation framework. The nonsignificance of the particulate variables was not altered by adding the medical care variable or going to a simultaneous equation framework.

Lipfert (1984) re-examined the 1969 Lave and Seskin data set after including several additional explanatory variables. Although Lipfert maintained that it was not possible to conclude whether TSP had a significant effect on mortality, he did find that the air pollution regression results were sensitive to the inclusion of such variables as smoking and diet.

[5] Chappie and Lave (1982) argue that the alleged negative significance of the estimated coefficients arises from a technical error in the computation of the sampling variances of the 2SLS coefficients. Although Gerking and Schulze's 2SLS coefficients are correct, the variances and t-statistics are not correct.

The form of the relationship between mortality and exposure to air pollution is an important issue. Although Lave and Seskin (1977) considered logarithmic, quadratic, linear spline, and dummy variable models in addition to the linear model, they chose to focus on the linear specification despite some of the alternative functional forms having greater explanatory power. They argued for the use of the linear model because it was simple and easy to interpret.

Lave and Seskin's choice of the linear model specification was questioned by later researchers (Thibodeau et al 1980, Evans et al 1984). In his reanalysis of Lave and Seskin's 1969 data , Lipfert (1984) maintained that it was unlikely for the pollution variables or other continuous explanatory variables to have a linear response on mortality rates. To test for nonlinearities, Lipfert investigated specifications employing quadratics, linear splines, and dummy variables. Based on numerous regressions, Lipfert was unable to conclude whether the response of TSP was linear or nonlinear.

Mendelsohn and Orcutt (1979) also questioned the linear specification when they considered 1970 mortality and air pollution data for US county groups. However, after examining the residuals from regressions and investigating quadratic terms for the pollutants, they concluded that the linear specification of the model seemed appropriate.

Controversy over the cross-sectional approach made popular by Lave and Seskin has also focused on the selection of the geographic unit of analysis. In particular, Lipfert (1984) has argued that use of SMSAs or even larger groupings can result in a geographical bias due to east-west differences in urban characteristics. This geographical bias has the potential of leading to spurious regression results. In addition, the estimated air quality is likely to be more accurate for smaller areas because as the area served by the monitoring site increases, the representativeness of the air quality sampling decreases. Therefore, the use of large geographical areas makes it difficult for the researcher to obtain accurate information on an individual's "true" exposure to air pollution.

To test whether the choice of geographic unit was important, Chappie and Lave (1982) estimated models using OLS for three types of areas: cities, counties, and SMSAs. In the presence of sulfates, TSP was not found to make a significant contribution to any of the regressions. However, when no sulfate variables were included in the model, TSP did make a significant contribution to the city, county, and SMSA regressions. Chappie and Lave concluded that based on their results, the choice of the geographic unit was unimportant. The association between TSP and mortality was changed little by using city or county data instead of SMSA data.

Mendelsohn and Orcutt (1979) chose to use county groups as their unit of analysis. In addition, they attempted to remove variations of mortality rates across county groups which were not caused by air pollution by controlling for age, race, and sex. They did not find evidence that TSP was associated with mortality.

As a group, the reviewed cross-sectional mortality studies did not find strong evidence to support the hypothesis that increases in particulate air pollution are significantly associated with increases in mortality. Although Lave and Seskin (1977) reported that TSP was significantly associated with mortality in a positive manner, subsequent cross-sectional studies found that Lave and Seskin's results were sensitive to the inclusion of additional explanatory variables and the choice of the estimation technique.

Morbidity

Morbidity has also been compared across cities and counties with differing levels of air pollution. Ostro (1983) has argued that morbidity studies have four advantages over mortality studies: morbidity may be a more sensitive indicator of air pollution-related health effects because of the relative quickness of impact; air pollution may cause a lot of illnesses which never result in death; the researcher is able to use a smaller sample size because illness occurs more frequently than death; and certain indicators of morbidity, such as increased medical visits or work loss, may help to quantify the economic benefits of a reduction in air pollution. Similar to cross-sectional mortality studies, concerns have been expressed over the proper specification of the relationship between air pollution and morbidity, omitted variables, heteroscedasticity, and multicollinearity.

Several attempts have been made to estimate the health and economic effects of pollutants using the Health Interview Survey (HIS), a large cross-sectional database collected periodically by the National Center for Health Statistics. Unlike many of the previous cross-sectional databases used to investigate the health effects of air pollution, the HIS provides data on several health indicators in addition to socioeconomic and demographic characteristics at an individual level. Ostro (1983) initiated the use of the HIS for estimating the acute health effects of air pollution. Linear regression analysis indicated that TSP was significantly related to increases in days of work loss and days of restricted activity. Furthermore, using logit and Tobit models, Ostro found that TSP was significantly associated with increases in work loss days. A particular advantage of

Ostro's research was that the work loss regressions provided a health endpoint that could be measured in monetary terms.[6]

Ostro (1987) and Ostro and Rothschild (1989) subsequently used six separate years of the HIS, 1976-1981, and found a significant positive association between particulate matter and acute measures of morbidity. To more accurately assess the impact of particulate air pollution on health, four different features were incorporated into both follow-ups: 1) a Poisson distribution was used to model the health endpoints which consisted of a large number of zeros and small values, 2) a fixed effect model was employed to control for intercity differences, 3) data on fine particulate matter was used rather than TSP because fine particulate matter is more harmful to respiratory health than TSP, and 4) additional health indicators, measured as days of respiratory-related restricted activity and days of minor restricted activity, were used as dependent variables to capture the more subtle health effects of particulate air pollution.

Portney and Mullahy (1990) used the 1979 HIS to investigate the long-term effects of air pollution on chronic respiratory disease. Unique to their study was that the air pollution data was specific to the residential location of each individual in the sample. Previous cross-sectional studies had to rely on metropolitan wide pollutant averages that were applied to everyone in a city or SMSA and thus may not have given an accurate estimate of an individual's true exposure to the pollutant. Maximum likelihood probit methods were utilized to estimate several models which controlled for smoking , and

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[6] Health endpoints typically have been measured in terms of premature mortality, health care visits, work/ school absenteeism resulting from illness, or restricted activity resulting from illness.

migration. TSP was not found to be a significant predictor of chronic respiratory disease in any of those models.

The increased costs of hospitalization resulting from exposure to TSP were investigated by Carpenter et al (1979) who used data on 1972 hospital admissions in Allegheny County, PA. After controlling for such factors as age, sex, and race, linear regression results indicated a statistically significant association between TSP and respiratory hospital admission rates. A subsequent analysis of lengths of hospital stay which controlled for smoking, age, sex, and race indicated a significant association between levels of TSP, sulfur dioxide and respiratory disease. For the 1.6 million people residing in Allegheny County in 1972, Carpenter et al (1979) reported a conservative estimate for the costs of increased rates of hospitalization ($9.1 million) and the costs of increased length of stay ($0.7 million) for a total cost of $9.8 million.

Unlike cross-sectional mortality studies which did not find any consistent, statistically significant relationship between particulate air pollution and mortality, cross-sectional morbidity studies observed significant associations between particulate air pollution and various measures of morbidity. As a group, results of both the cross-sectional mortality and morbidity studies suggest that particulate air pollution may be more of a contributing factor to subtle health effects like restricted activity or work loss, rather than death.

Time-Series Analyses

The health effects of air pollution have also been investigated by examining the changes in daily mortality or morbidity rates associated with short term changes in air pollution. The advantage of time-series studies over cross-sectional studies is that a given set of individuals is studied over a period of time during which many factors such as smoking, diet, location, and occupational exposure to air pollution are relatively constant. Consequently, problems associated with omitted or poorly measured variables are greatly reduced or even eliminated. Other factors, however, such as climate, day of the week effects, seasonal effects, and annual effects need to be controlled for within the analysis. Potential statistical problems arising with time-series studies include autocorrelation, multicollinearity, the existence of long-term trends, and time lag effects.

Mortality

Increased daily mortality has been associated with various daily measures of particulate air pollution in numerous US cities. Coefficient of haze (COH) was found to be a significant predictor of increases in daily mortality in Santa Clara, California (Fairley 1990). KM, a measure of light transmittance that is sensitive to smaller particles, was positively associated with daily deaths in Los Angeles, California (Kinney and Ozkaynak 1991). Studies have also demonstrated positive associations with TSP and daily mortality in Detroit, Michigan (Schwartz 1991) and Steubenville, Ohio (Schwartz and Dockery 1992). In addition, particulate air pollution less than or equal to 10 micrometers in aerodynamic diameter (PM_{10}) has been linked to increases in daily deaths in Utah Valley, Utah (Pope et al 1992), St. Louis, Missouri (Dockery et al 1992), and Birmingham, Alabama (Schwartz 1993). Several of these studies also divided mortality by cause of death. Statistically significant positive relationships between particulate air pollution and respiratory-related deaths were observed in the Utah Valley and Santa Clara studies.

To account for the preponderance of zeros and small values in the daily death counts, a Poisson regression model was used in all of the studies except for the Los Angeles study, which used linear regression analysis. Climatic variables were included in all of the studies to control for the influence of weather on mortality. The possibility of nonlinearities in the weather were also addressed in the studies. To capture weekly patterns in the data, day of the week dummy variables were included in the Santa Clara, Los Angeles, and Birmingham studies.

A concern with time-series studies is the failure to control for seasonal or annual fluctuations in daily mortality or morbidity and daily air pollution. Inadequate control for long-term fluctuations can lead to accidental or spurious correlation between the two variables (Schwartz 1994b). Common seasonal factors that are of concern include infectious disease epidemics such as the flu (Schwartz 1994b). Infectious disease epidemics often occur in the same season as the air pollutant under study. With the exception of the Los Angeles study, annual dummy variables and a continuous time trend were included in all of the time-series analyses to account for year to year variations and changes over time. Seasonal fluctuations were addressed with the use of dummy variables in the Santa Clara, Detroit, Steubenville, St. Louis, and Utah Valley studies.

Filtering methods were used to reduce the influence of seasonal cycles in the Los Angeles and Birmingham studies.

An important issue in time-series studies is the possibility of time lag effects. It may be reasonable to expect a time delay between exposure to air pollution and death. The previous day's particulate level was reported to be a significant predictor of daily mortality in St. Louis, Steubenville, and Detroit. In Birmingham, the mean of PM_{10} concentrations on the three previous days was significantly associated with daily deaths. Pope et al (1992) reported that the five day moving average of PM_{10} levels gave the best model fit for Utah Valley. Fairley (1990), in his study of COH in Santa Clara, also reported that the effects of COH on daily mortality appeared to be delayed by one or two days.

In contrast to cross-sectional mortality studies, results of time-series mortality studies strongly support the hypothesis that an increase in particulate air pollution is associated with an increase in mortality. It is unlikely that the observed positive association between particulate air pollution and death was spurious given that all of the studies controlled for seasonal and annual fluctuations in the data. Further, the positive association was observed across a variety of US cities at different periods in time.

Morbidity

Time-series analysis methods, similar to those used for mortality, have been used to investigate associations between particulate air pollution and morbidity. Particulate air pollution has been implicated as contributing to increased incidence of respiratory disease (Pope et al 1991) and decreased lung function (Johnson et al 1990). Particulate air pollution has also been found to be associated with increases in respiratory morbidity as measured by school absenteeism (Ransom and Pope 1992).

Time-series studies have also evaluated the health and the economic effects of particulate air pollution by examining associations between particulate concentrations and health care visits for respiratory illness. Time lag effects become a strong possibility when health care visits are used as the dependent variable in an analysis because it is unlikely that an individual will seek medical care on the day of exposure except in the most severe cases. A time delay may occur between exposure to the air pollutant and the appearance of a symptom. A delay may also occur between the development of a symptom and the reporting of the symptom to a physician or a hospital. Furthermore, the length of the time lag between the development of the illness and the individual's visit to a physician or admittance to a hospital may vary due to the availability of medical services and the type or the severity of the illness (Lipfert 1993).

Using Medicare records, Schwarz (1994a) observed a statistically significant positive relationship between the current day's PM_{10} level and hospital admissions for pneumonia and chronic obstructive pulmonary disease for the elderly in Minneapolis-St. Paul, Minnesota. Chronic obstructive pulmonary disease was also found to be significantly associated with the previous day's PM_{10} level. Poisson regression analysis was used to control for weather, seasonal fluctuations, and time trends. Schwartz did not indicate whether day of the week effects were controlled for in the model.

A series of studies found a strong positive association between the operation of a steel mill, PM_{10}, and hospital admissions for respiratory disease in Utah Valley, Utah (Pope 1989, Pope 1991, Ransom and Pope 1995). During the time periods analyzed in the studies, the mill shut down and then reopened. When the steel mill was in operation, PM_{10} levels in Utah Valley were approximately twice as high as when the mill was closed. To control for the coincidence of high winter PM_{10} levels with epidemics of respiratory disease, Pope (1989, 1991) and Ransom and Pope (1995) included control population groups consisting of non-respiratory hospital admissions and/or neighboring communities unaffected by the air pollution of the steel mill.

Pope (1989) used ordinary least squares to regress mean monthly PM_{10} levels, lagged mean monthly PM_{10} levels, and temperature on monthly admissions for pneumonia, pleurisy, bronchitis, and asthma. Statistical results indicated that PM_{10} was a significant predictor of increases in all respiratory admissions, respiratory admissions for children, and bronchitis and asthma admissions for adults. Statistically significant associations were observed between admissions and particulate air pollution levels up to a month or more before the hospital visits. Pope (1991) expanded his 1989 investigation by extending the study period, including two additional study areas, one of which served as a control area, and including a time trend. Autoregressive regression models, using maximum likelihood estimation, were used in lieu of ordinary least squares to account for autocorrelation. Results of the expanded analysis were generally consistent with those of the first paper. PM_{10} was found to be a significant predictor of respiratory hospital admissions. Pope did not include seasonal indicators in either model.

Ransom and Pope (1995) expanded Pope's (1989, 1991) work by comparing hospital admission rates for respiratory and cardiovascular disease across periods of time when the Utah Valley steel mill was open and closed. Further, they estimated the external health costs associated with the particulate air pollution produced by the steel mill. A negative binomial regression model, similar to a Poisson regression model, was used to analyze the data on monthly hospital admissions. A dummy variable indicating whether the steel mill was in operation was included in the model in addition to seasonal indicators and a time trend. A statistically significant positive effect was observed between the operation of the steel mill and hospital admissions for respiratory disease. No significant association was found between the operation of the mill and cardiovascular disease. Summing across all respiratory and cardiovascular disease groups, Ransom and Pope estimated that the excess hospitalization costs brought about by the operation of the steel mill and its production of particulate air pollution were approximately $2 million per year.

Two related studies explored the relationship between TSP and the consumption of medical services in the Portland, Oregon Metropolitan area in the late 1960s and the early 1970s. Using patient records from the Oregon Kaiser Foundation Health Plan, Jaksch and Stoevener (1974) measured the impact of TSP on the consumption of out-patient medical services and Bhagia and Stoevener (1978) focused on the association between TSP and in-patient medical services. For both studies, the TSP data was geographically interpolated to assign an air pollution value to each patient's residential address. Jaksch and Stoevener were also able to account for occupational exposure. Unlike most time-series analyses, smoking, socioeconomic, and demographic factors were used as explanatory variables in the models. Climatic data consisted of a temperature-relative humidity index. Neither study controlled for day of the week and seasonal influences.

Jaksch and Stoevener assigned a dollar value to each clinic visit, medical procedure, or treatment based on a system used by Kaiser to quantify medical services performed. The dependent variables used in the analyses were the cost per visit and the frequency of visits. OLS was used to relate the effects of TSP on medical costs for respiratory and circulatory-respiratory disease. The model considered time lags from zero to three days. TSP was significantly related to the cost of respiratory disease visits for lags of zero and one day. Jaksch and Stoevener estimated that a 20 ug/m^3 increase in TSP was associated with a 3.5 cent increase in medical costs per patient per visit. Air pollution was not found to be significantly related to the number of visits or circulatory-respiratory disease.

Bhagia and Stoevener (1978) used the consumption of medical services by a patient per hospital stay as the dependent variable in their analysis. The consumption of medical services was represented by the total dollar value for all services rendered to the patient. These services included: hospital room rent, surgical procedures, lab and radiology exams, operating and recovery room rent, anesthesia, physician's time, medication, and consultations. Medical costs, air pollution, and climate variables were transformed into natural logs. Time lags from zero to three days were considered in the model. Bhagia and Stoevener concluded that given their model specifications, OLS results indicated that there was no relationship between TSP and the consumption of in-patient medical services for respiratory disease.

Student health center visits were studied by Durham (1974) who used 1970-1971 records from seven California universities located in the Los Angeles Basin and the San Francisco Bay Area. Although correlation and factor analysis did not indicate an association between particulate matter and respiratory illness, three aspects of the study are notable. One, the use of university health centers resulted in no added expense for students which should have encouraged students to report even minor complaints to the health center. Two, Durham included only data from patients residing within five miles of each university to control for the degree and duration of a student's exposure to air pollution. Three, the use of two different regions allowed for temporal and spatial control.

A period of heavy smog conditions in the Salt Lake Valley was studied by Lutz (1983) to determine if a relationship existed between several air pollutants and patient visits to a family practice center for respiratory diseases. The investigation was based on 13 weekly totals of patients diagnosed with respiratory disease expressed as a percentage of the total number of patients seen for the week. Consequently, the study was not compromised by day of the week or lag effects (Lipfert 1993). The climate variables considered by Lutz were the percentage of sky cover and days with smoke and/or fog. Bivariate correlations indicated that particulate matter was highly correlated with the percentage of patients seen with respiratory disease.[7] A potential drawback of the analysis was Lutz's failure to consider the effect of temperature on respiratory disease.

[7] Lutz (1983) did not specify what type of particulate matter was used in the analysis.

Overall, the reviewed time-series morbidity studies demonstrate a significant positive relationship between particulate air pollution and morbidity. The studies observed the significant impact of particulate air pollution on several measures of morbidity including hospital admissions, outpatient medical costs, and physician visits. As with time-series mortality studies, it is unlikely that the results were spurious since the positive relationship between particulate air pollution and morbidity was observed across several US cities, different health endpoints, and different time periods.

Conclusion and Limitations of Air Pollution-Health Studies

It is difficult to make comparisons among the reviewed studies because the studies differ in study design, statistical techniques, health definitions, pollution definitions, and the inclusion or omission of additional variables that influence the health endpoints. Taken as a group, however, both the cross-sectional and time-series studies seem to indicate a relationship between particulate air pollution and morbidity. In addition, this association was observed across a wide variety of geographical locations, climates, years, and health endpoints suggesting that the particulate air pollution-related health effects are not a result of some factor omitted from the analyses. Although the time-series studies found a significant association between increases in particulate air pollution and increases in mortality, the cross-sectional studies were unable to demonstrate a consistent and significant association between the two.

The first of two flaws common in the majority of these studies is the absence of detailed estimates of an individual's exposure to particulate air pollution. In almost all of the studies the community air pollution levels were used as proxies for an individual's exposure. Ideally, the researcher would like to adjust the particulate pollution variables for time spent outdoors and indoors and for occupational exposure. If such adjustments could be made, the effects of particulate air pollution on health would likely be altered, thus presenting a more accurate estimate of the health effects of air pollution. Obtaining such detailed exposure information, however, would be a costly undertaking.

The second common flaw is that few studies quantified in monetary terms the impact of particulate air pollution on health. The lack of economic assessment of these studies is unfortunate since the goal of policies aimed at reducing air pollution is to obtain levels of pollutants at which society's marginal costs and marginal benefits are equal. To analyze the economic costs associated with air pollution, the health effects of particulates, such as shortened life span or increased hospital admissions, need to be translated into monetary terms.

The intent of this study is to help remedy the lack of economic assessment of the health effects of particulate air pollution. A model is developed in the following chapter which will allow for the estimation of the impact of particulate air pollution on morbidity as measured by the consumption of physician services used for the treatment of respiratory disease. If particulate air pollution is found to significantly increase the incidence of respiratory disease in Missoula County, Montana, the health effects of exposure to particulate air pollution can then be quantified in monetary terms.

Chapter 3. The Model

This section builds a model to investigate the short term impacts of changes in particulate air pollution on morbidity as measured by the consumption of medical services for respiratory disease. The model is a time-series analysis incorporating many of the same assumptions used by Jaksch and Stoevener (1974), Lave and Seskin (1977), Bhagia and Stoevener (1978), and Seskin (1979).

General Framework

To begin, six general assumptions must be made. One, assume that there is an individual who has become ill with a respiratory disease caused by or worsened by particulate air pollution. Two, assume that many of the other factors that affect the individual's health such as socioeconomic, demographic, and personal characteristics, change very little within a given area from day to day. Three, assume that medical care is a necessity of life for the individual. The individual is aware that if the respiratory disease is left untreated, the disease could cause discomfort, or in the most extreme case, death. Four, given the choice between pain and suffering or medical treatment, it is assumed that the individual will seek medical attention to improve his or her health and/or to prevent further deterioration of the health state.[8] Five, assume that medical treatment for diseases caused by air pollution are not close substitutes for non-medical treatment. Most medical needs are very specific and hence alternative goods will not

[8] It is recognized that some individuals will not seek medical care for the treatment of respiratory disease. However, even though the respiratory disease may impose costs on the individual and/or society in terms of lost worker productivity or restricted activity, no demand for medical services occurs (Jaksch and Stoevener 1974).

provide the same amount of satisfaction to the ill individual.[9] Finally, assume that the consumption of medical services used in the treatment of respiratory disease is not affected by the price of the medical service or the individual's income. This is reasonable given the set-up of the Medicaid system which will be discussed in Chapter 4. For a Medicaid recipient, the price of medical services (excluding time costs) and the recipient's income play a very small role in his or her consumption of medical services.[10]

It must be recognized that in addition to income, other socioeconomic and demographic characteristics may affect the overall level of the consumption of medical services within a given area. However, the constancy of such factors over short periods of time minimizes their importance in a time-series study of this nature.

Hypotheses and Statistical Models

Following Jaksch and Stoevener (1974), the effect of particulate air pollution on health and the subsequent hypothesized increase in the demand for medical care can manifest itself in two ways, both of which allow for the establishment of two testable hypotheses:

> **Hypothesis One**: An increase in particulate air pollution will increase the severity of the respiratory disease thus requiring more intensive or additional medical care than what would have normally been necessary. This will result in an increase in the consumption of medical services per day.

> **Hypothesis Two**: An increase in particulate air pollution will increase the number of contacts with the medical system, resulting in a greater utilization of medical services per day.

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[9] It is recognized that an individual may choose to treat his or her respiratory illness with over-the-counter drugs. This type of treatment and its corresponding costs are not accounted for in this analysis.

[10] In Montana, the majority of medical services rendered to a Medicaid recipient require only a small co-payment ranging between $0.50 and $2. The amount of the co-payment or the availability of medical care does not vary with a Medicaid recipient's income.

Hypothesis One

To test the null hypothesis that an increase in particulate air pollution is not associated with an increase in the consumption of medical services used to treat respiratory disease, equation (1) will be used:

(1) $C_i = f(AP_i, M_i, D)$

where

C_i = medical services consumed for the treatment of respiratory disease resulting from exposure to pollution on the i th day.

AP_i = a measure of air quality on day i.

M_i = a measure of meteorological conditions on day i.

D = temporal patterns in the data.

Specification of Variables

Medical Services

Several alternative measures can be used to measure the quantity of medical services consumed. For example, studies have used patient days, the number of cases treated, and the number of visits as a proxy for the quantity of medical services consumed. Many researchers, however, measure the quantity of medical services consumed in terms of dollar expenditures (Folland et al 1993). Unfortunately, using dollar expenditures as a proxy for the consumption of medical services has an inherent disadvantage; expenditures are unable to separate out the price, quantity, and quality components of health care. Further, expenditures do not accurately reflect the "true" cost to the consumer for the medical services because of the prevalence of health insurance and the availability of free care to some individuals. (Folland et al 1993). Due to the characteristics of the available Medicaid data, the present study will use expenditures to measure the consumption of medical services.

Air Quality

The impact of particulate air pollution on respiratory health is significant. Studies have found particulate air pollution exposure to be associated with increased incidence of respiratory symptoms (Pope et al 1991, Krupnick et al 1990, Ostro and Rothschild 1989, Dockery et al 1989) and decreased lung function (Johnson et al 1990). In addition, through its effect on respiratory health, particulate air pollution has also been linked to increases in the consumption of outpatient medical services (Jaksch and Stoevener 1974) and increased hospitalization and other health care visits for respiratory disease (Pope 1989, Pope 1991, Ransom and Pope 1995, Schwartz 1994, Lutz 1983).

Particulate matter is a complex and varying mixture of substances which may exist as smoke, droplets, dirt, or dust (Neher and Koenig 1994). Sources of particulate matter include motor vehicle emissions, wood burning, factory and utility smokestacks, mining, and construction activity.

The health risks associated with exposure to particulate air pollution depend on the size and concentration of the particle. The size of the particles determines how deeply they will penetrate into the respiratory tract where they can remain and cause damage to the respiratory system. Particles less than or equal to 10 micrometers in size are of particular concern because they are easily inhaled into the lungs (American Lung

Association 1994). Therefore, PM_{10} levels will be used in the present study as a measure of air quality.

Meteorological Conditions

Independently, or in conjunction with air pollution, meteorological conditions can affect an individual's respiratory health and consequently the consumption of medical services for respiratory disease (Jaksch and Stoevener 1974, Krumm and Graves 1982). Although a variety of meteorological factors may affect one's respiratory health, previous research has largely limited attention to temperature, humidity, and precipitation.

Temperature has been frequently hypothesized to be a contributing factor to respiratory disease. However, the effects of temperature on respiratory disease are mixed. Temperature may affect an individual's health differently depending upon the season of study and/or the study area. For example, increasing temperature acts as a stress factor on the human body during the summer months whereas decreasing temperature can cause stress in the winter (Styer et al 1995).

Studies have observed a significant negative association between temperature and hospital admissions for respiratory disease in Utah (Pope 1991) and increased respiratory symptoms in children in the Los Angeles area (Krupnick et al 1990). On the other hand, Bates and Sitzo (1987) observed that warmer temperatures were associated with increased emergency room admissions for asthma in southern Ontario. Temperature was not found to be a significant predictor of children's visits to pediatricians and hospitals for croup and obstructive bronchitis in five German cities (Schwartz et al 1991) or of respiratory visits to emergency rooms in Vancouver, British Columbia (Bates et al 1990).

Humidity and precipitation have also been hypothesized to affect respiratory health. As with temperature, no consistent results have been observed with either humidity or precipitation. A temperature-humidity index was significantly related to increases in the consumption of outpatient medical services for respiratory disease in the Portland, Oregon area (Jaksch and Stoevener 1974), but unrelated to the consumption of inpatient medical services for respiratory disease in the same area (Bhagia and Stoevener 1978). Relative humidity was not found to be related to respiratory disease in Vancouver, British Columbia (Bates and Sitzo 1987). Precipitation was found to be significantly associated with a higher probability of an individual experiencing respiratory symptoms in the Los Angeles area (Krupnick et al 1990) but unrelated to hospital admissions for respiratory disease in Utah (Pope 1989).

Interactions between meteorological conditions and air pollution may also adversely affect respiratory health. Both Jaksch and Stoevener (1974) and Krumm and Graves (1982) have maintained that it is important for the researcher to be aware of the possible interdependence between air pollution and weather. By themselves, meteorological conditions and air pollution may not have a harmful effect on health. However, in conjunction with each other, they may adversely affect an individual's state of health. Consequently, sole reliance on single measurements of meteorological conditions and air pollution will fail to capture the possible combined effect on health. In the present study, only temperature is hypothesized to affect the respiratory health of Missoula County Medicaid recipients.

Temporal Effects

In daily time-series studies it is necessary to account for seasonal, day-of-the-week, and holiday effects in the data. Seasonality needs to be addressed because respiratory disease often exhibits seasonal variations due to factors other than air pollution (Schwartz 1994a). For example, respiratory illness is often higher in the winter due to increased outbreaks of viral infections (Lipfert 1993). Several methods can be used to correct for seasonality in the data: 1) analyze the data by season, 2) prefilter to reduce patterns in the data, and 3) correct the model for possible autocorrelation (Ostro 1993). In the present study, data are analyzed separately by two three-month periods to reduce the seasonality effects.

Day-of-the week and holiday effects can also affect air quality and the consumption of medical services. Air pollution levels may be associated with weekly cycles in traffic flow and factory schedules (Durham 1974). In general, physicians are not readily available on weekends or holidays. Consequently, hospital and emergency room usage tends to be higher on weekends and holidays due to the reduced availability of physicians (Lipfert 1993). In the present study, a dummy variable representing Saturday or Sunday will be included in the statistical models presented in Chapter 5 to control for the reduced availability of physicians on weekends.

Hypothesis Two

An equation similar to equation (1) will be used to determine if an increase in particulate air pollution leads to a greater utilization of medical services in terms of increasing the number of contacts made with the medical system. To test the null hypothesis that an increase in particulate air is not associated with an increase in health care visits for the treatment of respiratory disease equation (2) will be used.

(2) $V_i = f(AP_i, M_i, D)$
where

V_i = the number of health care visits for the treatment of respiratory disease resulting from exposure to pollution on the i th day.

AP_i = a measure of air quality on day i.

M_i = a measure of meteorological conditions on day i.

D = temporal patterns in the data.

Specification of Variables

Health Care Visits

An alternative way of measuring the quantity of medical services consumed in the treatment of respiratory disease is to examine units of health care such as physician visits, hospital admissions or emergency room admissions. Although health care visits are a good measure of utilization, they do not reflect the intensity of the medical care (Folland et al 1993).

The use of health care visits as a measure of utilization has been widespread within the air pollution-health literature. Studies have found increases in particulate air pollution to be associated with increases in the utilization of medical services as measured by physician visits (Lutz 1983), hospital admissions (Pope 1989, Pope 1991) and emergency room admissions (Krumm and Graves 1982).

The arguments given for the inclusion of the explanatory variables AP_t, M_t, and D are the same as those given for equation (1).

Chapter 4. The Data

Description of the Study Areas

The experimental study area is Missoula County, located in western Montana (Figure 4-1). Missoula County is of particular interest due to its history of air quality problems. Cascade County, located in central Montana, serves well as the control study area (Figure 4-1).[10] Cascade County has relatively clean air, and its Medicaid population and annual Medicaid payments are comparable to those of Missoula County.[11]

In 1994, Missoula County's population was approximately 85,700 making it the second most populous county in the state of Montana (Montana Department of Commerce 1994). Missoula, with a population of 44,500 in 1992, is the largest city in Missoula County (US Bureau of Census 1994). Geographically, Missoula sits in a fertile valley at the confluence of three rivers, the Clark Fork, the Bitterroot, and the Blackfoot. Missoula enjoys a temperate climate. In 1994, the average temperature in July was 70° F and 34° F in January. The 1994 average annual precipitation was approximately 12 inches (NOAA 1994).

Due to its valley setting, it is not uncommon for Missoula to experience frequent and prolonged temperature inversions in the winter months. During an inversion, the

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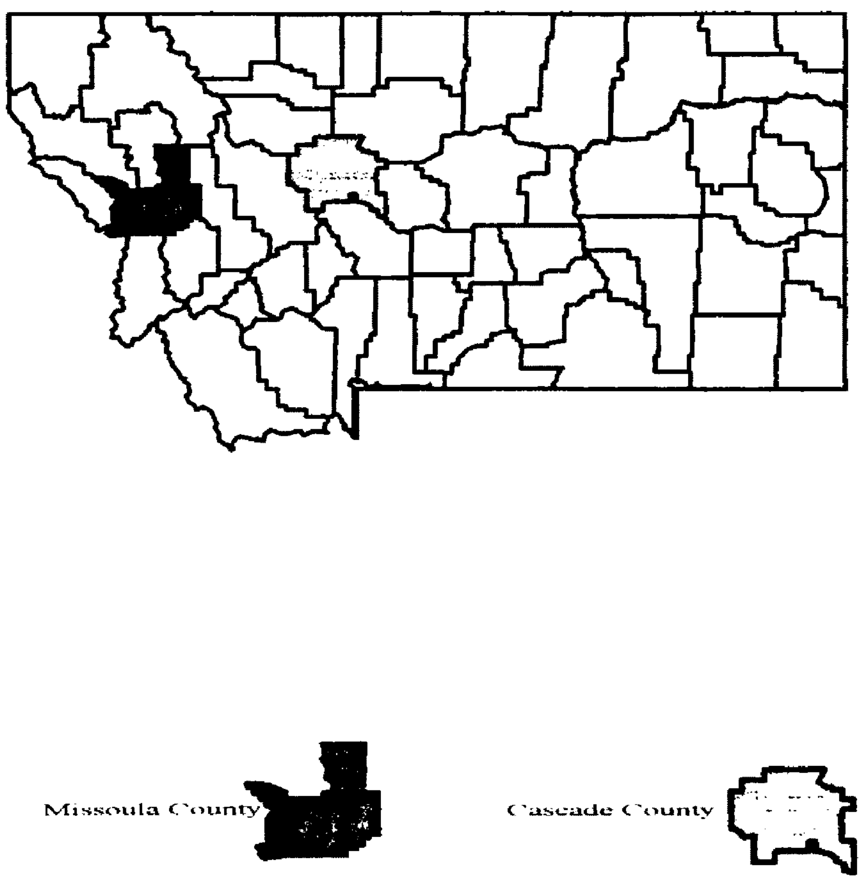
[10] A control population is used to test for statistically derived associations between mortality/ morbidity and air pollution that are physiologically implausible. In time-series studies, populations that are known to be unexposed to the pollutant under study or illnesses that are unlikely to respond to air pollution are often considered as control candidates (Lipfert 1993). In a time-series study it is important to control for the possibility of high winter air pollution levels coinciding with epidemics of respiratory disease. In addition, a control population can also be used to control for the possible effect of unusually severe weather conditions on the incidence of respiratory disease.

[11] 1992 statistics obtained from Montana's Department of Social and Rehabilitation Services indicate that the average monthly caseload for Medicaid recipients in Missoula County and Cascade County were 3890 and 3900, respectively. In 1992, Medicaid payments in Missoula County and Cascade County were approximately $21.7 million and $22.3 million, respectively.

valley air becomes stagnant and traps particulate air pollution near the valley floor. The principal source of particulate air pollution in the Missoula valley during the winter months is wood burning stoves. Ken Anderson (1996), air quality specialist at the Missoula County Health Department, estimates that over 40% of the particulate air pollution in Missoula County during the winter is caused by wood stoves. Anderson also maintains that during certain times in the winter, excessive road sanding can be responsible for upwards of 80% of the particulate air pollution in Missoula County.

Figure 4-1. Map of the state of Montana with Missoula and Cascade Counties



In 1994, Cascade County had a population approaching 81,200 (Montana Department of Commerce 1995). Great Falls, with a 1992 population of 56,600, is the largest city in Cascade County (US Bureau of Census 1994). Due to its location on a windy open plain, Great Falls is not prone to the buildup of particulate air pollution. Similar to Missoula, Great Falls also enjoys a relatively moderate climate. In 1994 the average temperature was 69° F in July and 27° F in January. Total precipitation in 1994 was 10.5 inches (NOAA 1994).

Characteristics of the Montana Medicaid Program

Medicaid is a jointly funded federal and state program which provides medical assistance for low income individuals who are aged, blind, disabled, or receive Aid to Families with Dependent Children. Medicaid is the largest source of funds for medical and health-related services for the poorest people in the United States. States are primarily responsible for the design and operation of their own Medicaid program, subject to federal government guidelines. Montana's Medicaid program is administered by the Medicaid Services Division of the Department of Public Health and Human Services (US Department of Health and Human Services 1995).

Not all Montana health care providers accept Medicaid patients. If a Montana provider does accept Medicaid, s/he agrees to bill Medicaid for the services rendered to the patient. Although it is not permissible for the provider to bill the patient directly, the provider may bill the patient for a small co-payment.

In Montana, a co-payment is required for most medical and health related services. Exceptions are made if the patient is under the age of 21, pregnant, a resident of a nursing home, a member of an HMO under Medicaid, or has already paid $200 in co-payments for the fiscal year. The amount of the co-payment varies with the type of service. Most physician, nurse practitioner, and clinic services have a co-payment of $1 or $2. Brand-name drugs require a co-payment of $2 whereas generic drugs cost the patient $1. Medical supplies and equipment are billed to the patient at a charge of $0.50 per item. Patients who are hospitalized are required to pay $100 per discharge (Department of Public Health and Human Services 1995).

In both Missoula County and Cascade County during 1994, Medicaid recipients were required to enroll in a managed care program called "Passport to Health". Under the Passport to Health program, the Medicaid recipient must choose a primary care provider, physician, nurse practitioner, nurse midwife, physician assistant, or clinic. The primary care provider is who the Medicaid recipient would see if s/he were ill or in need of a checkup. Further, the primary care provider must approve most hospital admissions, visits to other physicians, and emergency room services that are not life-threatening or urgent, before Medicaid will pay for these services (Department of Public Health and Human Services 1995).

There were several advantages to using the Montana Medicaid system for this research: 1) the number of Medicaid enrollees was large enough to provide a sufficient data base; 2) excluding time costs, the price of medical services was virtually free for Medicaid recipients which may have encouraged individuals to report even minor complaints to a health care provider; and 3) Medicaid covers a wide range of medical services including ambulatory care, outpatient and inpatient care, prescriptions, and home based care.

There are two potential limitations regarding the use of the Medicaid data that need to be mentioned. It is possible that the socioeconomic and demographic characteristics of the Medicaid population are not representative of the socioeconomic and demographic characteristics of either the Missoula County or the Cascade County populations. For example, the health status of the Missoula County Medicaid population may be different from the health status of the entire population of Missoula County. In addition, the utilization of medical services by Medicaid recipients may be different from the utilization of the entire Missoula County or Cascade County populations.[12]

Compilation of the Data

The data used in the statistical analyses are comprised of three types: Medicaid data, particulate air pollution data, and meteorological data. The data are described in this section. Descriptive statistics are included in appendices B, C, and D.

Medicaid Data

The Montana Medicaid Program funds a variety of medical services including inpatient and outpatient care at hospitals, physician and nurse specialist care, emergency room care, nursing home care, home based care, and psychiatric care. This study was only concerned with physician care, nurse specialist care, and lab and x-ray, hereafter referred to as physician care. The main reason for this choice is that the subtle health

[12] For example, Kasper (1987) found that Medicaid coverage resulted in a greater likelihood of seeing a physician for children under 18 years than for privately insured children.

effects of exposure to particulate air pollution are more likely to be apparent in a time series study of physician data rather than inpatient data. For example, hospital and emergency room admissions may reflect the more serious cases of exposure to air pollution or deal with individuals who have existing respiratory conditions.

Medicaid data were obtained from the Montana-Wyoming Foundation for Medical Care in Helena, Montana for the year 1994. The data came in the form of individual records on two computer tapes. For each contact, both patient and service information was available. Patient information consisted of four items: the identification number of the patient, the birth date of the patient, the patient's race, and the patient's sex. The service information included the provider identification number, the date of service available, the county of service, the provider reimbursement rate, the diagnosis(es),and the type of service or visit. The diagnoses were coded according to the International Classification of Diseases, ninth revision (ICD-9) codes.

After converting the Medicaid tapes into two Statistical Package for the Social Science Version 6.1 (SPSS) data files, a search of the data files was made to prepare a data base consisting of contacts made in Missoula County which had a primary diagnosis of respiratory disease (ICD-9 codes 460-519), and which corresponded to a physician service type: physician, nurse specialist, or lab and x-ray. A description of ICD-9 codes used in this study can be found in appendix A.

A deficiency with the Medicaid data base was that drugs consumed for the treatment of respiratory disease did not have an associated diagnosis code. As a result, it was necessary to conduct a second search of the two SPSS Medicaid data files for all drugs consumed in Missoula County. This drug data base was then merged with the physician data on respiratory disease. Next, patient identification numbers and dates of service for drugs were matched to patient identification numbers and dates of service for physician care. Drugs that did not correspond with a patient identification number and date of service for physician care were deleted from the data file.[13] This physician care data base for all respiratory disease was subsequently used to generate two additional data bases consisting of Medicaid sub-populations believed to be more susceptible to the harmful health effects of air pollution.

It is well known that air pollution does not affect the respiratory health of exposed persons with equal severity (American Lung Association 1994, Neher and Koenig 1994). Children and persons with asthma or Chronic Obstructive Pulmonary Disease (COPD), such as emphysema, are believed to be more susceptible to the adverse health effects of particulate air pollution than the general population (American Lung Association 1994, Vigliarolo et al 1994). Furthermore, studies have typically found associations between particulate air pollution and pneumonia, bronchitis, asthma, and COPD rather than the extremely broad category of all respiratory disease.[14]

To examine whether particulate air pollution has a different effect on different populations, the main data base consisting of physician services for all respiratory disease diagnoses was used to construct two smaller data bases: 1) children (less than or equal to 13 years of age) diagnosed with respiratory disease, and 2) persons diagnosed with

[13] It was assumed that every drug prescribed for a particular patient on the same day as a physician visit was for the respiratory ailment.

[14] See Pope (1989), Pope (1991), or Schwartz (1994a).

pneumonia (ICD-9 codes 480-486), bronchitis (ICD-codes 466.0-466.1), asthma (ICD-9 code 493), and COPD (ICD-9 codes 490-492, 494-496).[15] Along with the total respiratory disease data base, these two sub-groups are the primary focus of the statistical analysis.

The major flaw of the Medicaid data was that the patient's county of residence was not stated. The Medicaid data identified only the county in which the medical care was received. It is conceivable that patients receiving treatment for respiratory disease in Missoula County were not Missoula County residents and were not exposed to Missoula County particulate air pollution.[16] It is also possible that individuals exposed to particulate air pollution in Missoula County received treatment for a respiratory disease in a county other than Missoula County.[17]

Derivation of Dependent Variables

Since this analysis was interested in the day-to-day relationship between the consumption of physician services used in the treatment of respiratory disease and both daily particulate air pollution levels and meteorological conditions, physician data had to be aggregated on a daily basis. Further, the data had to be aggregated in a manner that

[15] It was not possible to examine each of the four diseases separately due to a limited number of observations for each of the disease categories. Grouping the diseases together may have helped to minimize potential problems of cross-over diagnosis coding.

[16] Since Missoula is the most urban city in western Montana, this situation is likely.

[17] It is unlikely that Missoula County residents were treated for respiratory illness in a county other than Missoula County due to the Passport to Health program. Further, since 82% of Missoula County residents reside within the Missoula Valley it may be safe to assume that most recipients treated for respiratory disease in Missoula County have been exposed to the particulate air pollution in the Missoula Valley.

would produce a measure of the consumption of physician services and a measure of physician utilization.

To express the effect of particulate air pollution on health as an economic cost, this study used two methods of quantifying the dependent variable. The first method used the summation of reimbursement values for all physician services rendered to Medicaid patients in the treatment of respiratory disease per day as a proxy measure for the total daily consumption of physician services. The second method used the total daily number of visits to a physician for the treatment of respiratory disease as a measure of utilization.

For each day in the study period, the following six different dependent variables were quantified and subsequently used in the statistical models presented in Chapter 5:

1. Total daily expenditures for physician care used in the treatment of respiratory disease.

2. Total daily number of visits to a physician for the treatment of respiratory disease.

3. Total daily children's expenditures for physician care used in the treatment of respiratory disease.

4. Total daily number of children's visits to a physician for the treatment of respiratory disease.

5. Total daily expenditures for physician care used in the treatment of pneumonia, bronchitis, asthma, or COPD.

6. Total daily number of visits to a physician for the treatment of pneumonia, bronchitis, asthma, or COPD.

Particulate Air Pollution Data

Although the air quality in Missoula County has improved since the 1970s, the county still suffers from a particulate air pollution problem.[18] During the winter months, small inhalable particles often become trapped near the valley floor due to temperature inversions. Due to the health risks associated with these small particles, the Environmental Protection Agency has set National Ambient Air Quality Standards (NAAQS) directed at particles with an aerodynamic diameter less than or equal to 10 micrometers (PM_{10}).[19] For particulate matter, there are both 24-hr and annual ambient air quality standards. The current 24-hr NAAQS standards for PM_{10} is 150 micrograms per cubic meter (ug / m^3) with no more than one expected exceedance per year. The annual PM_{10} standard is an annual arithmetic mean of 50 ug / m^3 (EPA 1987). Individual states are primarily responsible for ensuring the attainment and maintenance of the national standards. In 1994, Missoula County did not exceed the EPA's 24-hr standard of 150 ug / m^3 or the annual standard of 50 ug / m^3.[20]

For Missoula County, the particulate data came from one of several monitoring stations reported in the EPA Aerometric Information Retrieval System (AIRS) for 1994.

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[18] Anderson (1996) maintains that the air quality in Missoula County has improved since the 1970s due to a reduction in wood stove use, better monitoring of air pollution levels, and the use of liquid de-icer on roads.

[19] Before July 1987, the existing ambient air standards dealt with total suspended particulates (TSP) rather than PM_{10}.

[20] During 1994, however, stage one air alerts were issued in Missoula County by the Missoula City-County Health Department. For the period November 1993-March 1994, Missoula County had 7 stage one alerts. A stage one alert went into effect when the particulate count exceeded 100 micrograms per cubic meter during an eight hour average. For the period November 1994-March 1995, Missoula County had eight stage one alerts with an alert going into effect when the particulate count exceeded 80 micrograms per cubic meter during an eight hour average.

The data were obtained from the Department of Environmental Quality located in Helena, Montana. During 1994, monitoring of PM_{10} levels was conducted at four sites in Missoula County. Three of the monitoring stations were located within the city of Missoula: 3100 Washburn (Boyd Park); 301 W Alder; and Moccasin Lane. The fourth monitoring station was located at Stone Container near Frenchtown. The Boyd Park monitoring station collected PM_{10} samples on both an hourly basis and a 24-hr basis for two three-month periods, January through March and October through December. For the other six month period, April through September, sampling at the Boyd Park location was conducted only every sixth day. Monitoring at the other three stations was conducted periodically. The W Alder site collected samples every sixth day. The Moccassin Lane and Frenchtown sites conducted sampling either every third day or every sixth day.

Only observations from the Boyd Park site were used in this analysis for the two three-month periods, January through March 1994 and October through December 1994. The Boyd Park site, located in the most densely populated part of the county, was considered to provide a more reliable measure of the general exposure levels than a monitor situated in a more remote part of the county. In addition, the Boyd Park site provided daily readings which were necessary in order to have consistency with daily Medicaid and meteorological data.

The choice of the study period, January through March and October through December, was largely dictated by the availability of daily PM_{10} observations. No monitoring site in Missoula County conducted daily sampling for April through

September 1994. In addition, particulate air pollution tends to be a more serious problem in Missoula County during winter months due to increased wood stove burning and the sanding of icy roads. An advantage of analyzing each of the three month periods separately is that the seasonality effects are reduced.

Three different daily measurements of particulate air pollution were available from the Boyd Park monitoring station: the daily average of the hourly PM_{10} levels, the average 24-hr level, and the maximum hourly level. Two factors influenced the decision to use the average of the hourly PM_{10} readings in this analysis. First, the maximum hourly PM_{10} levels were not considered to be representative of Missoula County as a whole because they may apply only to a localized area around the monitoring site. On the other hand, the average readings have the advantage of being more smooth spatially and hence tend to be more representative of average community levels. Secondly, the average 24-hr observations were often missing during the study period--there were daily observations for only 83% of the days. On the other hand, the daily average of the hourly PM_{10} levels was available for 94% of the days. To fill in the missing daily average of the hourly PM_{10} levels, the daily 24-hr readings from the Boyd Park site were used.

During the entire study period, PM_{10} levels ranged from $5\, ug/m^3$ to $105\, ug/m^3$ with an average of $32\, ug/m^3$. Figure 4-2 shows the distribution of the daily average of the hourly PM_{10} values at the Boyd Park monitoring site for each of the six months. The distribution indicates that mean levels of PM_{10} were well below the EPA standard of $150\, ug/m^3$ during the six month study period.[21]

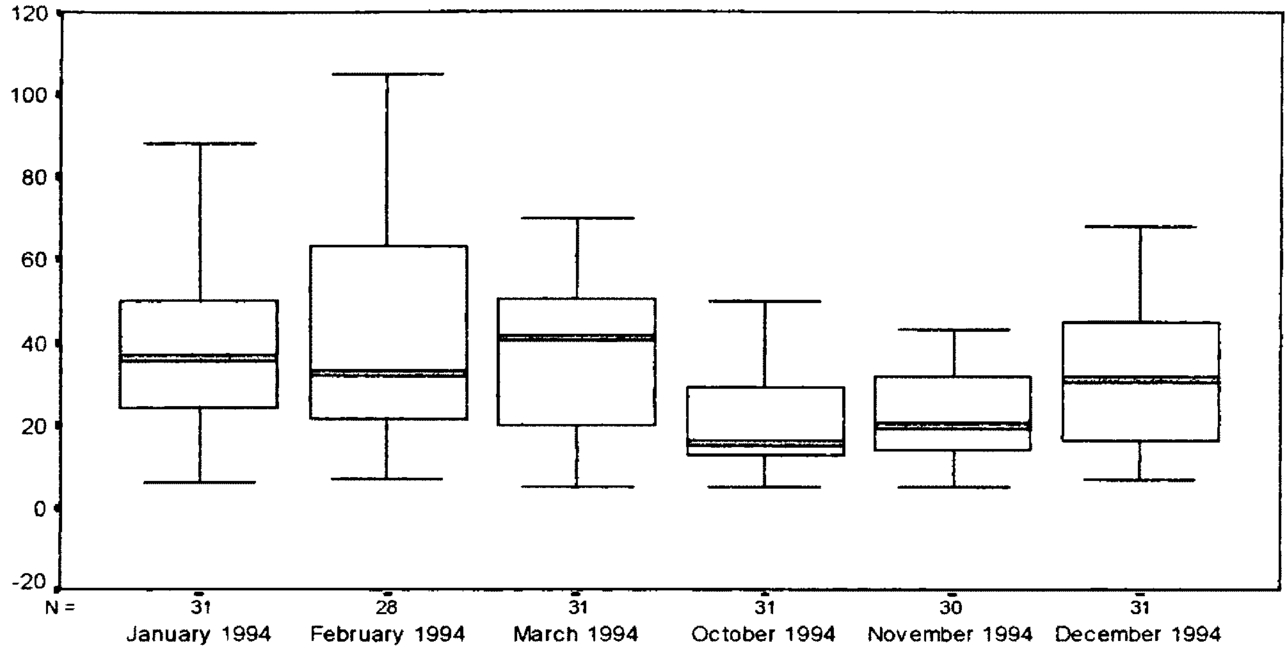

Figure 4-2. Boxplots by month to show distribution of daily PM_{10} levels in Missoula County, MT.

In Cascade County, PM_{10} monitoring in 1994 was conducted at the Great Falls fire station located on 9th Street and 1st Avenue South. The monitoring site only collected 24-hr PM_{10} samples every fourth day; neither hourly levels nor maximum daily levels were collected. For the six month study period, 7% of the 24-hr observations were missing. In order to examine daily changes in the consumption of physician services with daily changes of air quality, it was necessary to formulate a procedure to estimate PM_{10} levels on days when air quality measurements were not available. Linear

[21] A boxplot shows both the median and the interquartile range. The line inside the box represents the median. The vertical length of the box extends from the 25th to the 75th percentile. Fifty percent of all the observations lie within the range of the box. The "whiskers" on the box extend to the largest and the smallest observed values within 1.5 box lengths.

interpolation was used to obtain daily PM_{10} values. This method replaces missing data in a series by a linear interpolation of the numeric values before and after the missing points.

Figure 4-3 shows the distribution of the daily average of the hourly PM_{10} values in Cascade County for each of the six months. PM_{10} levels ranged from $4\,ug/m^3$ to $42\,ug/m^3$ with an average of $19\,ug/m^3$. The average PM_{10} levels in Cascade County are lower than those in Missoula County. Further, it is evident that the variability in daily PM_{10} levels in Cascade County is less than the variability in daily PM_{10} levels in Missoula County. During 1994, Cascade County did not violate either of the two NAAQS standards for particulate air pollution.

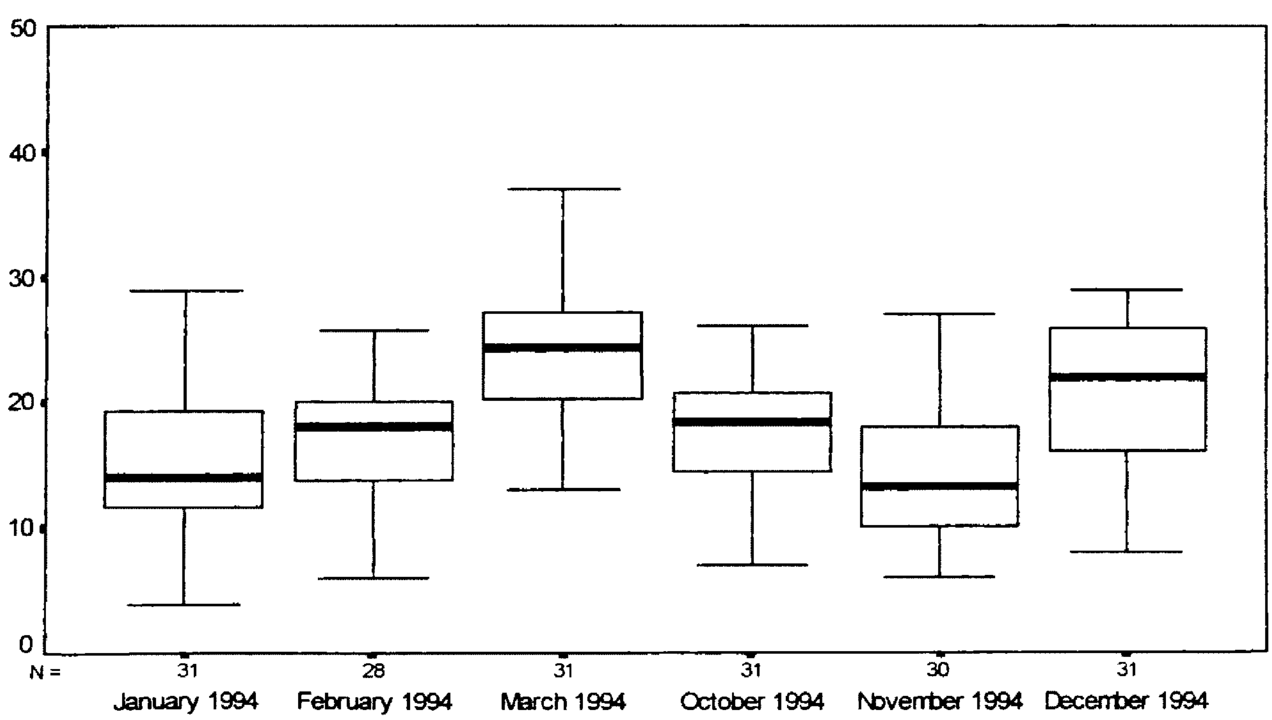

Figure 4-3. Boxplots by month to show distribution of daily PM_{10} levels in Cascade County, MT.

Meteorological Data

The meteorological data used in this study are based on daily observations taken at the Missoula County International Airport and the Great Falls Airport (Cascade County). The data was taken from the National Oceanic and Atmospheric Administration (NOAA) Climatological Data for Montana for 1994. Since similar studies have focused on temperature, it was felt that this analysis should also primarily concentrate on temperature so that results would be comparable to like studies. Although three different measures of daily temperature are considered in the analysis: the average daily temperature, the daily minimum, and the daily maximum, the analysis mainly focuses on the average daily temperature. Figures 4-4 and 4-5 show the distribution of average daily temperature by month for Missoula and Cascade Counties.

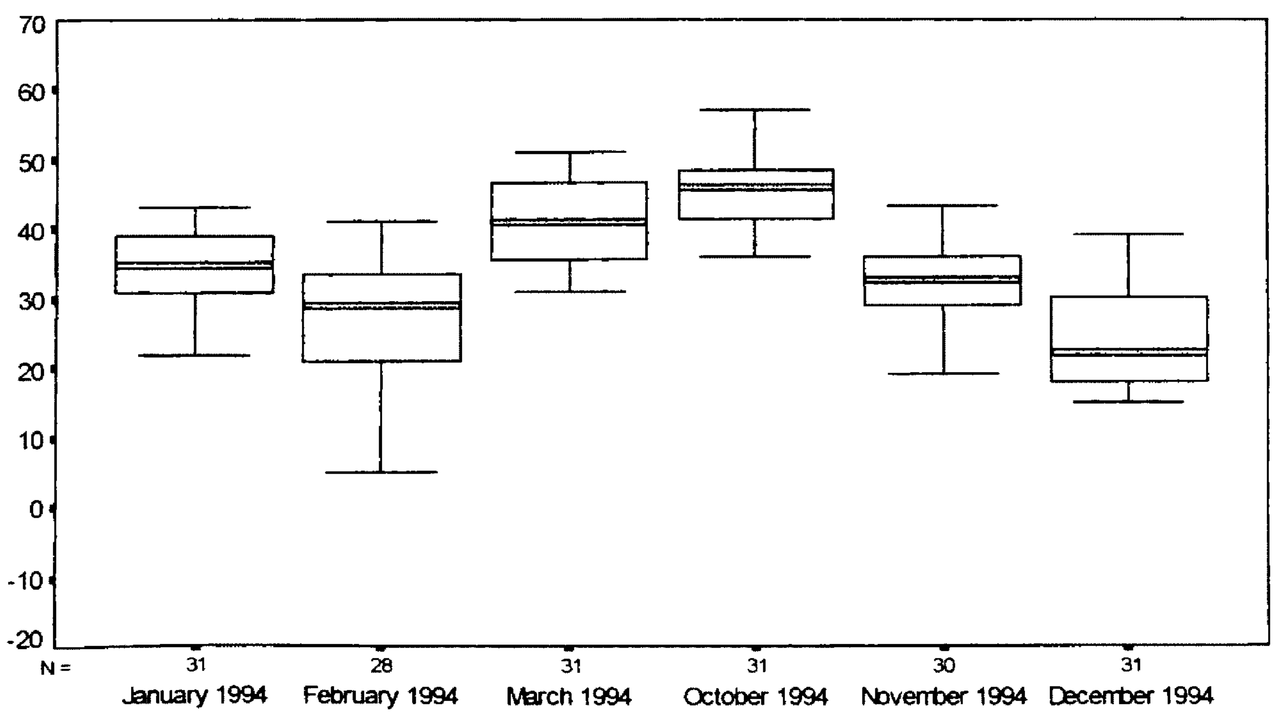

Figure 4-4. Boxplots by month to show distribution of average daily temperature in Missoula County, MT.

During the entire study period, average daily temperature in Missoula County ranged from a minimum of 1° F to a maximum of 57° F with an average of 34° F. For Cascade County, average daily temperature ranged from minus 18° F to 61° F with an average of 32 ° F.

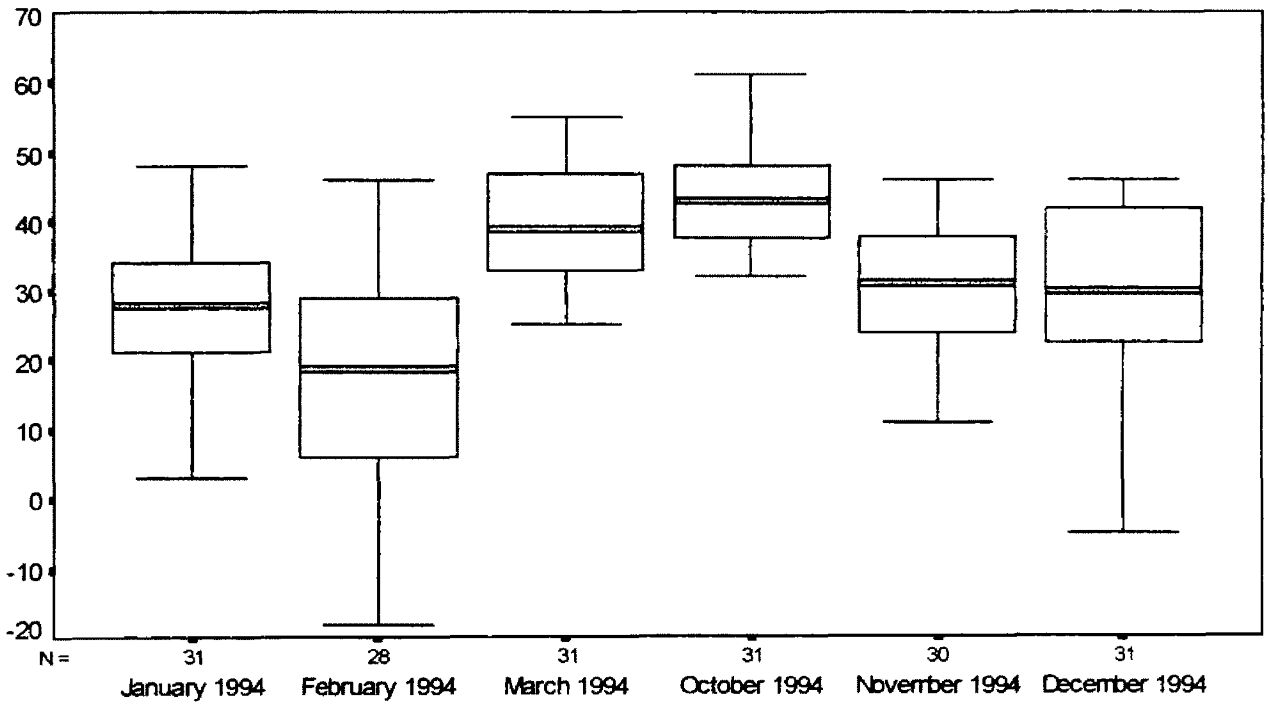

Figure 4-5. Boxplots by month to show distribution of average daily temperature in Cascade County, MT.

Chapter 5. Statistical Methods, Model, and Results

Initially, limited knowledge of the relationship between the consumption of physician services and PM_{10} levels and meteorological conditions led to both a linear and natural logarithmic specification of the physician expenditure model and the physician visit model. The PE test was subsequently performed to determine whether the appropriate model was linear or logarithmic.[22] Unfortunately, the results of the PE test were generally inconclusive.[23] However, scatterplots between the dependent variables and the independent variables suggested that a linear relationship might be appropriate for both the expenditure model and the visit model. Consequently, a linear specification of the models is used in the following analyses.

Due to the particulate air pollution data limitations discussed in Chapter 4, the data were split into two three-month periods, January-March and October-December. Separate linear models for physician expenditures and physician visits were estimated for each of the time periods. To investigate whether the effects of PM_{10} on respiratory health were consistent for different populations, the models were estimated separately for each of the three Medicaid populations discussed in Chapter 4.

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[22] The PE test can be used to determine whether the appropriate model specification is linear or logarithmic. For more information regarding the PE test, see Greene (1990) or Maddala (1992).

[23] PE test results for physician expenditures for total respiratory disease for January-March and October-December did not allow for the rejection of the null hypothesis of a linear specification ($t_{85} = -0.28 < t$ crit $= 2.0$ and $t_{87} = 1.2 < t$ crit $= 2.0$) or rejection of the null hypothesis of a logarithmic specification ($t_{85} = 1.5 < t$ crit $= 2.0$ and $t_{87} = 0.15 < t$ crit $= 2.0$) at a 0.05 error level. PE test results for physician visits for total respiratory disease for October-December did not allow for the rejection of the null hypothesis of a linear specification ($t_{87} = 0.51 < t$ crit $= 2.0$) or the rejection of the null hypothesis of a logarithmic specification ($t_{87} = 0.60 < t$ crit $= 2.0$) at a 0.05 error level. PE test results for physician visits for January-March did not allow for the rejection of the null hypothesis of a linear specification ($t_{85} = -0.44 < t$ crit $= 2.0$) at a 0.05 error level. however the null hypothesis of a logarithmic specification was rejected ($t_{85} = 2.99 > t$ crit $= 2.0$) at a 0.05 error level.

To test the hypothesis that an increase in PM_{10} pollution results in an increase in the consumption of medical services as measured by physician expenditures for respiratory disease the following model was used:

$$(1)\ \mathbf{EXP} = \alpha + B_1\mathbf{PM} + B_2\mathbf{TEMP} + B_3\mathbf{WEEKEND} + e$$

where **EXP** represents the total expenditures for physician services used in the treatment of respiratory disease on a given day, **PM** is the average of the hourly PM_{10} readings on a given day, and **TEMP** is the average temperature for the day. **WEEKEND** is a dummy variable representing Saturday and Sunday.[24]

Several sets of regression results for physician expenditures in Missoula County are presented in Table 5-1. The results are separated by population group and study period. The results indicate that increases in PM_{10} are not significantly associated with increases in physician expenditures for either of the two periods, January-March or October-December. The regression results, however, strongly support the inclusion of the weekend dummy variable to account for the reduced availability of physicians on Saturday and Sunday.[25] Moreover, it is obvious that the explanatory power of the regressions is largely derived from the influence of the weekend dummy variable.[26]

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[24] The inclusion of a dummy variable for the holidays in the study period was initially considered. Since both New Years Day and Christmas fell on the weekend in 1994, however, it was felt that the probable holiday effect would be accounted for by the inclusion of the weekend dummy variable.

[25] It is possible that the weekend dummy variable could be picking up the effect of unmeasured factors that might also influence physician expenditures for respiratory disease.

[26] Regressions were also run omitting the dummy variables for the weekend. The adjusted R^2 decreased significantly for both study periods. The signs of the coefficients were not altered for either period.

Although statistically insignificant, the coefficient associated with average daily temperature has the hypothesized negative sign in each of the regressions.

Table 5-1. Estimates of Effect of PM_{10} on Physician Expenditures in Missoula County, MT [a]

Model	Dependent Variable Physician Expenditures	Constant	PM_{10}	Temp	Weekend	R^2 Adj.	Estimation Method
1.1	Total Respiratory January-March 1994	981.97 (0.00)	0.045 (0.98)	-8.71 (0.08)	-539.9 (0.00)	0.25	OLS
1.2	Total Respiratory October-December 1994	1716.01 (0.00)	-6.70 (0.04)	-6.95 (0.16)	-1122.9 (0.00)	0.52	OLS
1.3	Total Respiratory Child January-March 1994	422.4 (0.00)	1.09 (0.38)	-3.07 (0.32)	-308.1 (0.00)	0.26	GLS
1.4	Total Respiratory Child October-December 1994	929.2 (0.00)	-2.60 (0.25)	-5.28 (0.14)	-565.3 (0.00)	0.46	GLS
1.5	Pn/Br/As/COPD January-March 1994	343.3 (0.00)	-1.13 (0.15)	-3.14 (0.11)	-129.1 (0.00)	0.17	GLS
1.6	Pn/Br/As/COPD October-December 1994	465.3 (0.00)	-1.16 (0.48)	-2.21 (0.36)	-292.8 (0.00)	0.28	GLS

Pn/Br/As/COPD=Pneumonia, bronchitis, asthma, and chronic obstructive pulmonary disease
Models 1.3-1.6 have been corrected for first order autocorrelation
[a] The p-values are in parentheses

The Durbin-Watson statistic suggested that the classic Ordinary Least Squares assumption of independent residual errors was violated in models 1.3-1.6. In addition, diagnostic plots of the residuals confirmed that there was a pattern to the error terms. Models 1.3-1.6 have been corrected for first order autocorrelation with the Generalized Least Squares (GLS) AUTO procedure available in the econometric software program, Shazam Econometrics Version 7.0 (White 1993). Collinearity among the explanatory variables is low in both regressions. Simple correlations between the independent variables are all less than 0.3.

A linear model similar to (1) was used to test the hypothesis that an increase in PM_{10} leads to an increase in physician visits for respiratory disease. Specifically, the model estimated was:

$$(2)\quad \mathbf{VIS} = \alpha + B_1\mathbf{PM} + B_2\mathbf{TEMP} + B_3\mathbf{WEEKEND} + e$$

where **VIS** represents the total number of visits to a physician for respiratory disease on a given day. The remaining independent variables are as previously defined.

Estimates of the parameters in (2) are found in Table 5-2. All of the models, except for model 2.6, have been corrected for first order autocorrelation. The results obtained for the visit model are similar to those found for the expenditure model. Overall, the regression results fail to indicate that PM_{10} is signficantly associated with increased physician visits for respiratory disease.

For January-March, average daily temperature appears to exert a strong negative influence on children's visits for respiratory disease and visits for pneumonia, bronchitis, asthma, and COPD. As hypothesized, physician utilization is negatively associated with Saturdays and Sundays. Again, the explanatory power of the regressions is derived from the inclusion of the weekend dummy variable.

Table 5-2. Estimates of Effect of PM_{10} on Physician Visits in Missoula County, MT [a]

Model	Dependent Variable Physician Visits	Constant	PM_{10}	Temp	Weekend	R^2 Adj.	Estimation Method
2.1	Total Respiratory January-March 1994	16.9 (0.00)	0.029 (0.36)	-0.16 (0.07)	-9.62 (0.00)	0.51	GLS
2.2	Total Respiratory October-December	28.5 (0.00)	-0.076 (0.12)	-0.021 (0.78)	-21.3 (0.00)	0.68	GLS
2.3	Total Respiratory Child January-March 1994	9.98 (0.00)	0.021 (0.29)	-0.10 (0.04)	-6.27 (0.00)	0.47	GLS
2.4	Total Respiratory Child October-December 1994	18.9 (0.00)	-0.058 (0.10)	-0.078 (0.17)	-12.36 (0.00)	0.63	GLS
2.5	Pn/Br/As/COPD January-March 1994	6.6 (0.00)	-0.006 (0.59)	-0.08 (0.01)	-2.08 (0.00)	0.28	GLS
2.6	Pn/Br/As/COPD October-December 1994	7.3 (0.00)	-0.02 (0.35)	-0.012 (0.70)	-5.66 (0.00)	0.39	OLS

Pn/Br/As/COPD=Pneumonia, bronchitis, asthma, and chronic obstructive pulmonary disease
Models 2.1-2.5 have been corrected for first order autocorrelation
[a] The p-values are in parentheses

Lag Effects

It may be reasonable to expect that physician expenditures and physician visits for respiratory disease on a given day would be affected by levels of particulate air pollution on preceding days.[27] A lag may occur between exposure to PM_{10} and the appearance of a respiratory symptom. A delay may also occur between the development of the respiratory illness and the reporting of the illness to a physician. To account for potential

[27] Physician expenditures and physician visits may also be affected by meteorological conditions on preceding days. Lagged values for average temperature up to three days were included as explanatory variables. The results did not indicate any statistically signficant association between expenditures or visits and temperature on preceding days.

lag effects, particulate air pollution lags of up to three days were examined for both the expenditure model (1) and the visit model (2).[28]

Selected results of the effects of lagged PM_{10} variables on physician expenditures are found in Table 5-3. The remaining results are not reported because the lagged PM_{10} variables were not statistically significant. Model 1.7 has been corrected for first order autocorrelation.

Table 5-3. Estimates of Effect of Lagged PM_{10} on Physician Expenditures in Missoula County, MT [a]

Model	Dependent Variable Physician Expenditures	Constant	PM_{10} lagged 1 day	PM_{10} lagged 2 days	Temp	Weekend	R^2 Adj.	Estimation Method
1.7	Pn/Br/As/COPD January-March 1994	225.3 (0.00)		1.8 (0.02)	-3.05 (0.10)	-117.9 (0.00)	0.19	GLS
1.8	Total Respiratory October-December 1994	1687.0 (0.00)	-7.04 (0.03)		-5.74 (0.24)	-1147.1 (0.00)	0.52	OLS
1.9	Total Respiratory October-December 1994	1678.9 (0.00)		-7.42 (0.02)	-5.24 (0.30)	-1142.4 (0.00)	0.52	OLS

Pn/Br/As/COPD=Pneumonia, bronchitis, asthma, and chronic obstructive pulmonary disease
Model 1.7 has been corrected for first order autocorrelation
[a] The p-values are in parentheses

The regression results obtained for January-March demonstrate that only PM_{10} lagged two days is significantly associated with increases in total daily physician expenditures for pneumonia, bronchitis, asthma, and COPD (see Table 5-3, model 1.7). A possible interpretation of the size of this result is that an increase of 10 ug/m^3 of

[28] The choice of the lag period was based on previous studies which used lags from one to three days.

PM_{10} lagged two days corresponds to an approximately $18 increase in total daily physician expenditures for pneumonia, bronchitis, asthma, and COPD, given constant levels of the other explanatory variables.

Selected results of the effects of lagged PM_{10} levels on physician visits for respiratory disease are shown in Table 5-4. The models have all been corrected for first order autocorrelation.

Table 5-4. Estimates of Effect of Lagged PM_{10} on Physician Visits in Missoula County, MT [a]

Model	Dependent Variable Physician Visits	Constant	PM_{10} lagged 1 day	PM_{10} lagged 2 days	Temp	Weekend	R^2 Adj.	Estimation Method
2.7	Total Respiratory-Children January-March 1994	10.27 (0.00)	0.019 (0.35)		-0.11 (0.03)	-6.28 (0.00)	0.46	GLS
2.8	Pn/Br/As/COPD January-March 1994	5.58 (0.00)		0.021 (0.07)	-0.08 (0.01)	-2.03 (0.00)	0.30	GLS
2.9	Total Respiratory October-December 1994	30.03 (0.00)	-0.15 (0.00)		-0.003 (0.97)	-21.7 (0.00)	0.71	GLS
2.10	Total Respiratory-Children October-December 1994	19.9 (0.00)	-0.12 (0.00)		-0.062 (0.26)	-12.7 (0.00)	0.67	GLS

Pn/Br/As/COPD=Pneumonia, bronchitis, asthma, and chronic obstructive pulmonary disease
Models 2.7-2.10 has been corrected for first order autocorrelation
[a] The p-values are in parentheses

Taken as a whole, the regression results reported in Table 5-4 suggest that lagged levels of PM_{10} are not signficantly associated with increased physician visits. Even with the inclusion of lagged PM_{10} values, average daily temperature remains strongly associated with children's physician visits for respiratory disease and physician visits for pneumonia, bronchitis, asthma, and COPD. The same negative relationship between temperature and visits was observed in models 2.3 and 2.5.

Additional Analyses

Numerous other regression models were estimated for both physician expenditures and physician visits for respiratory disease in Missoula County. The additional regressions included: separate analyses of individual and paired months; examination of time lags greater than three days; and investigation of additional meteorological factors. In addition, the models were tested for synergistic effects and nonlinearities.

Similar results to those just reported were found when regressions were run on individual months and paired months. The results indicated that PM_{10} was not significantly associated with increases in physician expenditures or increases in physician visits. In general, for the months October, November, and December, the coefficients associated with the PM_{10} variables were negative.

The possibility of the existence of time lags greater than three days between exposure to particulate air pollution and a visit to a physician was investigated. The lag effects of PM_{10} on expenditures and visits were further explored with regressions that used PM_{10} levels lagged up to 14 days, cumulative lags up to 5 days, and moving averages. The results did not demonstrate that various lagged measures of PM_{10} were significantly associated with increased physician expenditures or visits.

Regression models were also estimated with daily 24-hour high and low temperatures. In general, the 24-hour high and low temperatures were not consistently associated with physician expenditures or visits in a significant manner.

An attempt was made to investigate the data for a synergistic effect between PM_{10} and average daily temperature. The interaction variable, defined as the product of PM_{10} and average daily temperature, was included in both the expenditure and visit models separately from, and in addition to, the PM_{10} and temperature variables. The interaction term was not found to be statistically significant, thus indicating little or no evidence of a synergistic effect.

The possibility of nonlinearities in particulate air pollution and average daily temperature was also investigated. To test for nonlinearities, model specifications employing quadratic terms for PM_{10} and temperature were tried. Based on the results of several regressions which indicated that the quadratic terms were not significantly different from zero, it was concluded that the linear specification of both the expenditure and visits models seemed appropriate.

Cascade County Results

Regression results for Cascade County, Table 5-5 and Table 5-6, do not reveal any significant associations between PM_{10} and increased physician expenditures or increased physician visits for respiratory disease. Similar to the regression results obtained for Missoula County, the explanatory power of the regressions is mainly derived from the inclusion of the dummy variable for the weekend.

Table 5-5. Estimates of Effect of PM_{10} on Physician Expenditures in Cascade County, MT [a]

Model	Dependent Variable Physician Expenditures	Constant	PM_{10}	Temp	Weekend	R^2 Adj.	Estimation Method
3.1	Total Respiratory January-March 1994	1067.0 (0.00)	-4.58 (0.67)	-2.03 (0.68)	-619.4 (0.00)	0.41	GLS
3.2	Total Respiratory October-December 1994	1697.1 (0.00)	-13.11 (0.12)	-4.34 (0.24)	-947.55 (0.00)	0.47	OLS
3.3	Total Respiratory Child January-March 1994	518.21 (0.00)	-1.19 (0.85)	-3.29 (0.30)	-261.4 (0.00)	0.20	GLS
3.4	Total Respiratory Child October-December 1994	870.23 (0.00)	-7.94 (0.08)	-2.17 (0.27)	-480.05 (0.00)	0.44	OLS
3.5	Pn/Br/As/COPD January-March 1994	425.29 (0.00)	0.23 (0.96)	-2.19 (0.30)	-244.15 (0.00)	0.33	GLS
3.6	Pn/Br/As/COPD October-December 1994	480.57 (0.00)	-2.79 (0.52)	1.04 (0.58)	-332.20 (0.00)	0.29	OLS

Pn/Br/As/COPD=Pneumonia, bronchitis, asthma, and chronic obstructive pulmonary disease
Models 3.1, 3.3, and 3.5 have been corrected for first order autocorrelation
[a] The p-values are in parentheses

Table 5-6. Estimates of Effect of PM_{10} on Physician Visits in Cascade County, MT [a]

Model	Dependent Variable Physician Visits	Constant	PM_{10}	Temp	Weekend	R^2 Adj.	Estimation Method
4.1	Total Respiratory January-March 1994	18.25 (0.00)	-0.021 (0.92)	0.026 (0.75)	-10.84 (0.00)	0.56	GLS
4.2	Total Respiratory October-December 1994	35.63 (0.00)	-0.29 (0.03)	-0.04 (0.45)	-19.93 (0.00)	0.61	OLS
4.3	Total Respiratory Child January-March 1994	9.91 (0.00)	-0.09 (0.53)	0.02 (0.73)	-5.11 (0.00)	44	GLS
4.4	Total Respiratory Child October-December 1994	20.69 (0.00)	-0.19 (0.02)	-0.05 (0.19)	-11.18 (0.00)	0.55	OLS
4.5	Pn/Br/As/COPD January-March 1994	6.83 (0.00)	0.05 (0.51)	-0.03 (0.44)	-4.65 (0.00)	0.40	GLS
4.6	Pn/Br/As/COPD October-December 1994	8.81 (0.00)	-0.05 (0.35)	0.02 (0.47)	-5.69 (0.00)	0.40	OLS

Pn/Br/As/COPD=Pneumonia, bronchitis, asthma, and chronic obstructive pulmonary disease
Models 4.1, 4.3, and 4.5 have been corrected for first order autocorrelation
[a] The p-values are in parentheses

Selected regressions results of the effects of lagged PM_{10} variables on physician expenditures and physician visits in Cascade County are reported in Table 5-7 and Table 5-8. Overall, the results do not indicate that lagged values of PM_{10} are correlated with increased physician expenditures or increased physician visits. Unlike the results obtained for Missoula County, PM_{10} lagged two days is not significantly associated with increases in total daily physician expenditures for pneumonia, bronchitis, asthma, and COPD in Cascade County.

Table 5-7. Estimates of Effect of Lagged PM_{10} on Physician Expenditures in Cascade County, MT [a]

Model	Dependent Variable Physician Expenditures	Constant	PM_{10} lagged 1 day	PM_{10} lagged 2 days	Temp	Weekend	R^2 Adj.	Estimation Method
3.7	Pn/Br/As/COPD January-March 1994	411.70 (0.00)		0.91 (0.83)	-2.19 (0.28)	-250.05 (0.00)	0.33	GLS
3.8	Total Respiratory October-December 1994	1674.8 (0.00)	-13.36 (0.12)		-3.84 (0.30)	-921.18 (0.00)	0.46	OLS
3.9	Total Respiratory October-December 1994	1515.8 (0.00)		-5.14 (0.56)	-3.35 (0.38)	-916.82 (0.00)	0.44	OLS

Pn/Br/As/COPD=Pneumonia, bronchitis, asthma, and chronic obstructive pulmonary disease
Model 3.7 has been corrected for first order autocorrelation
[a] The p-values are in parentheses

Table 5-8. Estimates of Effect of Lagged PM_{10} on Physician Visits in Cascade County, MT [a]

Model	Dependent Variable Physician Visits	Constant	PM_{10} lagged 1 day	PM_{10} lagged 2 days	Temp	Weekend	R^2 Adj.	Estimation Method
4.7	Pn/Br/As/COPD January-March 1994	6.28 (0.00)		0.07 (0.95)	-0.02 (0.55)	-4.97 (0.00)	0.40	GLS
4.8	Total Respiratory October-December 1994	34.94 (0.00)	-0.28 (0.04)		-0.03 (0.55)	-19.44 (0.00)	0.60	OLS
4.9	Total Respiratory-Children October-December 1994	20.05 (0.00)	-0.18 (0.05)		-0.04 (0.26)	-10.89 (0.00)	0.54	OLS

Pn/Br/As/COPD=Pneumonia, bronchitis, asthma, and chronic obstructive pulmonary disease
Model 4.7 has been corrected for first order autocorrelation
[a] The p-values are in parentheses

Summary of Results

In summary, data from Missoula County and Cascade County were analyzed to investigate the association among physician expenditures/visits for respiratory disease, particulate air pollution (PM_{10}), and average daily temperature. Little evidence was found that would allow one to reject the null hypothesis that PM_{10} pollution, on the concurrent or preceding days, is associated with increased physician expenditures or increased physician visits for respiratory disease.

Chapter 6. Conclusion

This study has shown that increases in PM_{10} pollution are not significantly associated with the consumption of physician services or the utilization of physician services used for the treatment of respiratory disease in Missoula County by Medicaid recipients. Although an isolated statistically significant positive relationship was found between PM_{10} lagged two days and physician expenditures for pneumonia, bronchitis, asthma, and COPD during the period January-March, it is unclear whether the relationship was genuine or spurious.

The findings of this analysis are not consistent with the results of a number of time-series studies which have found significant associations between particulate air pollution and various measures of respiratory morbidity. Moreover, comparison of the results to those obtained in other studies is made difficult due to the fact that few studies have focused on the relationship between particulate air pollution and physician services.

Although this study did not find a significant positive relationship between PM_{10} and the consumption of physician services, it should not be concluded that PM_{10} does not have a significant effect on the respiratory health of Missoula County residents. Moreover, it should not be concluded that there are no health costs associated with PM_{10} pollution in Missoula County.[29] The shortcomings of the study, discussed below, may have seriously hindered the attempt to derive a significant PM_{10}-morbidity relationship.

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[29] The process that would have been used to go from the regression results to a monetary value of the health costs of particulate air pollution is described in appendix F.

Several observations suggest that the results of this study should be used with caution. First, there were two inadequacies with the Medicaid data. The Medicaid data did not contain information on the patient's county of residence. Consequently, the Medicaid population assumed to be exposed to PM_{10} pollution for the purposes of this study was subject to error. In addition, the date of service recorded for a patient may, in actuality, be the date of billing rather than the date of the physician visit. If the billing date for various physicians is not consistently related to the date of service, an attempt to relate daily changes in the consumption of physician services to short term changes in PM_{10} pollution will prove to be futile.

A second reason which suggests that the results should be interpreted with caution is the absence of information on exposure. Outdoor air pollution levels are poor proxies of an individual's exposure. A potential consequence of having large measurement error in the explanatory variables is that the OLS estimates are biased and inconsistent (Greene 1990).

In this study, it was not possible to address the problem of measurement error in the particulate air pollution variables. The absence of detailed information of an individual's exposure to PM_{10}, and the lack of daily PM_{10} levels from more than one site in Missoula County, necessitated the assumption that the PM_{10} levels observed at one monitoring site in the city of Missoula were adequate proxies for an individual's true exposure. It is recognized that this assumption may not be an accurate representation of the particulate air pollution situation in Missoula County.

The final observation which suggests that the results of this study should be used with caution is the possibility that 1994 was a relatively "good" year for particulate air pollution in Missoula County. As mentioned in Chapter 4, during 1994 Missoula County did not exceed the EPA's 24-hour standard of 150 ug/m^3 or the annual standard of 50 ug/m^3 for PM_{10}. For the two three-month periods analyzed in this study, the average daily PM_{10} level was only 32 ug/m^3. In Missoula County, a particulate count of zero to 40 ug/m^3 is considered good. Hence, 1994 may not have been a representative year for particulate air pollution in Missoula County.

In spite of the limitations of this study, several possibilities exist for further improvement of this work. One, an attempt could be made to obtain better particulate air pollution data. Rather than relying on the values from a single monitoring site to represent the average level of PM_{10} pollution in Missoula County, PM_{10} exposure could be estimated on the basis of the four monitoring sites located in the county. Two, an effort could also be made to obtain more detailed information on an individual's actual exposure to PM_{10} pollution. Refinements to the air pollution exposure data, both in terms of the PM_{10} data and an individual's exposure, would allow the researcher to obtain a more accurate estimate of the health effects of particulate air pollution.

Three, depending on access to medical and air pollution data, the time period of analysis could be extended to include several years of winter months or several years in entirety. To capture the effect of PM_{10} on the consumption of physician services, it may be necessary to investigate a longer period of time. Finally, other measures of respiratory morbidity such as hospital admissions, emergency room admissions, or absences from work or school could be analyzed using the general framework employed in this study. It is possible that the effects of PM_{10} on respiratory health vary, depending on the choice of the response variable.

Appendix A: Description of ICD-9 Codes

Definition of ICD-9 Group	ICD-9 Code
Acute Respiratory Infections	
Acute nasopharyngitis (common cold)	460
Acute sinusitis	461
Acute pharyngitis	462
Acute tonsillitis	463
Acute laryngitis and tracheitis	464
Acute upper respiratory infections of multiple or unspecified sites	465
Acute bronchitis and bronchiolitis	466
Other Diseases of the Upper Respiratory Tract	
Deflected nasal septum	470
Nasal polyps	471
Chronic pharyngitis and nasopharyngitis	472
Chronic sinusitis	473
Chronic disease of tonsils and adenoids	474
Peritonsillar abscess	475
Chronic laryngitis and laryngotracheitis	476
Allergic rhinitis	477
Other diseases of the upper respiratory tract	478
Pneumonia and Influenza	
Viral pneumonia	480
Pneumococcal pneumonia	481
Other bacterial pneumonia	482
Pneumonia due to other specified organism	483
Pneumonia in infectious diseases classified elsewhere	484
Bronchopneumonia, organism unspecified	485
Pneumonia, organism unspecified	486
Influenza	487

Appendix A: (continued)

Chronic Obstructive Pulmonary Disease and Allied Conditions	
Bronchitis, not specified as acute or chronic	490
Chronic bronchitis	491
Emphysema	492
Asthma	493
Bronchiectasis	494
Extrinsic allergic alveolitis	495
Chronic airway obstruction, not elsewhere classified	496
Pneumoconioses and other Lung Diseases due to External Agents	
Coal workers' pneumoconiosis	500
Asbestosis	501
Pneumoconiosis due to other silica or silicates	502
Pneumoconiosis due to other inorganic dust	503
Pneumonopathy due to inhalation of other dust	504
Pneumoconiosis, unspecified	505
Respiratory conditions due to chemical fumes and vapors	506
Pneumonitis due to solids and liquids	507
Respiratory conditions due to other and unspecified external agents	508
Other Diseases of Respiratory System	
Emphysema	510
Pleurisy	511
Pneumothorax	512
Abscess of lung and mediastinum	513
Pulmonary congestion and hypostasis	514
Postinflammatory pulmonary fibrosis	515
Other alveolar and parietoalveolar pneumonopathy	516
Lung involvement in conditions classified elsewhere	517
Other diseases of the lung	518
Other diseases of respiratory system	519

Appendix B: Definition of Variables

Variable	Definition
PM_{10}	Daily average of the hourly PM_{10} levels
Avg. Temp	Average daily temperature
Min. Temp	Minimum daily temperature
Max. Temp	Maximum daily temperature
Weekend	Dummy variable for Saturday and Sunday 1 = Sat and Sun, 0= Mon-Fri
Total Resp Exp	Total daily physician expenditures for all respiratory diseases (ICD-9 codes 460-519)
Total Resp Exp-Child	Total daily children's ($\leq$ 13 years) physician expenditures for all respiratory diseases
Pn/Br/As/COPD Exp	Total daily physician expenditures for pneumonia, bronchitis, asthma, and COPD
Total Resp Visit	Total daily number of physician visits for all respiratory diseases
Total Resp Visit-Child	Total daily number of children's ($\leq$ 13 years) physician visits for all respiratory diseases
Pn/Br/As/COPD Visit	Total daily number of physician visits for pneumonia, bronchitis, asthma, and COPD

Note: All physician expenditure and physician visit variables are aggregated by day.

Appendix C: Descriptive Statistics For Missoula County

January-March 1994 (n = 90)

Variable	Mean	Std. Dev.	Minimum	Maximum
PM_{10}	39	22.4	5	105
Avg. Temp	33.9	9.2	1	51
Min. Temp	22.8	9.1	-12	36
Max. Temp	44.5	11.4	11	71
Total Resp Exp	531.87	486.99	0.00	2679.60
Total Resp Exp-Child	271.49	274.10	0	1518.30
Pn/Br/As/COPD Exp	155.73	150.92	0	638.99
Total Resp Visit	9.91	7.21	0	28
Total Resp Visit-Child	5.36	4.55	0	15
Pn/Br/As/COPD Visit	3.16	2.30	0	9.0

October-December 1994 (n = 92)

Variable	Mean	Std. Dev.	Minimum	Maximum
PM_{10}	26	16.25	5	81
Avg. Temp	33.8	11	15	57
Min. Temp	24.8	10.2	3	46
Max. Temp	42.5	12.9	20	74
Total Resp Exp	978.68	715.11	28.00	3252.13
Total Resp Exp-Child	517.36	392.54	0	1722.5
Pn/Br/As/COPD Exp	274.94	253.39	0	1287.1
Total Resp Visit	19.6	11.8	1.0	48
Total Resp Visit-Child	11.13	7.28	0	32
Pn/Br/As/COPD Visit	5.51	4.08	0	21

****Note: All physician expenditure and physician visit variables are aggregated by day.**

Appendix D: Descriptive Statistics For Cascade County

January-March 1994 (n = 90)

Variable	Mean	Std. Dev.	Minimum	Maximum
PM_{10}	20	8.19	4.0	42
Avg. Temp	28.5	15.7	-18	55
Min. Temp	16	15.5	-34	44
Max. Temp	40.4	17.1	-12	72
Total Resp Exp	730.76	627.97	0.00	2433.94
Total Resp Exp-Child	323.59	373.63	0.00	1756.29
Pn/Br/As/COPD Exp	294.15	262.69	0.00	1129.30
Total Resp Visit	14.92	12.01	0	51
Total Resp Visit-Child	7.18	7.50	0	31
Pn/Br/As/COPD Visit	5.66	4.55	0	19

October-December 1994 (n = 92)

Variable	Mean	Std. Dev.	Minimum	Maximum
PM_{10}	17.5	5.77	6.0	29.0
Avg. Temp	34.6	13.3	-5	61
Min. Temp	24.5	13.2	-16	46
Max. Temp	44.3	13.9	3	77
Total Resp Exp	1038.7	621.29	84.09	2799.65
Total Resp Exp-Child	515.12	325.43	37.96	1453.67
Pn/Br/As/COPD Exp	370.28	274.91	0.00	1058.71
Total Resp Visit	23.08	11.59	2	53
Total Resp Visit-Child	12.29	6.85	1	30
Pn/Br/As/COPD Visit	6.82	4.08	0	17

****Note: All physician expenditure and physician visit variables are aggregated by day.**

Appendix E: Sample Shazam Program for Physician Expenditures for Respiratory Disease in Missoula County

```
read(allamb.dat)obs date day holiday exp pm maxpm &
temp mintemp maxtemp precip/skiplines=1
if(day.gt.5)weekend=1
if(day.lt.6)weekend=0
stat/all
*Generating logs of variables and lagged values for pm10
gen logexp=log(exp)
gen logpm=log(pm)
gen logtemp=log(temp)
gen lpm=lag(pm)
gen l2pm=lag(lpm)
gen l3pm=lag(l2pm)
*January-March
sample 1 90
*PE test to determine if model is linear or logarithmic
*step one
ols logexp logpm logtemp weekend/predict=lhat
ols exp pm temp weekend/predict=hat
gen loghat=log(hat)
gen lambda=lhat-loghat
ols exp pm temp weekend lambda
*step two
gen explhat=exp(lhat)
gen delta=hat-explhat
ols logexp logpm logtemp weekend delta
*Linear expenditure model for January-March
stat exp pm temp weekend
stat pm temp weekend/pcor
ols exp pm temp weekend/rstat anova
sample 2 90
ols exp lpm temp weekend/rstat anova
sample 3 90
ols exp l2pm temp weekend/rstat anova
sample 4 90
ols exp l3pm temp weekend/rstat anova
sample 1 182
*October-December
sample 91 182
*PE test
*PE test to determine if model is linear or logarithmic
*step one
ols logexp logpm logtemp weekend/predict=lhat
```

Appendix E: (continued)

```
ols exp pm temp weekend/predict=hat
gen loghat=log(hat)
gen lambda=lhat-loghat
ols exp pm temp weekend lambda
*step two
gen explhat=exp(lhat)
gen delta=hat-explhat
ols logexp logpm logtemp weekend delta
*Linear expenditure model for October-December
stat exp pm temp weekend
stat pm temp weekend/pcor
ols exp pm temp weekend/rstat anova
sample 92 182
ols exp lpm temp weekend/rstat anova
sample 93 182
ols exp l2pm temp weekend/rstat anova
sample 94 182
ols exp l3pm temp weekend/rstat anova
stop
```

Appendix F: Estimation of the Health Costs of PM_{10}

This appendix provides a brief description of the process that would have been used to go from the regression results to an estimate of the health costs of PM_{10} pollution in Missoula County had a significant positive relationship between PM_{10} and the consumption of physician services been observed.

Step one: Establish the relationship between physician expenditures or physician visits for the treatment of respiratory disease and PM_{10} based on the linear coefficient associated with PM_{10}. The linear coefficient would be obtained from the regression results. The linear coefficient measures the unit change in total daily physician expenditures (dollars) or total daily physician visits (visits) per one ug/m^3 change in PM_{10}.

Step two: Determine a reduction in PM_{10} levels that would result from compliance with a given pollution standard. Since Missoula County did not violate either of the NAAQS standards in 1994, an arbitrary reduction, such as a 10 ug/m^3 decrease in daily PM_{10} levels, could have be used.

Step three: Estimate the direct medical costs associated with a reduction in PM_{10}. Based on the reduction of daily PM_{10} levels determined in step two, calculate the corresponding total reduction in physician expenditures or physician visits using the linear coefficient described in step one for the periods, January-March 1994 and/or October-December 1994. (In order to determine the direct medical costs associated with a reduction in physician visits, it would be necessary to first assign a monetary value to the visits.)

It should be recognized that the direct medical costs calculated in step three only represent one component of the benefits that would be derived from a 10 ug/m^3 decrease in daily PM_{10} levels. Additional direct medical costs associated with exposure to PM_{10} pollution may include increased hospital admissions or increased emergency room admissions. Further, indirect costs associated with exposure to PM_{10} pollution, such as restricted activity, work loss, or discomfort, are not accounted for in step three. Consequently, the health cost estimates obtained in step three are low estimates.

Step Four: Extrapolate the estimates obtained in step three to the entire Missoula County population. In order to do this, it would be necessary to assume that the Missoula County Medicaid population is representative of the entire Missoula County population. This assumption is not likely, and hence, the estimates will be biased. Moreover, it is difficult to say in which direction the bias will occur. For illustrative purposes, however, this step would have been carried out.

References:

American Lung Association. 1994. The Perils of Particulates: An Estimation of Populations-At-Risk of Adverse Health Consequences from Particulate Matter in Areas with Particulate Matter Levels Above the National Ambient Air Quality Standards (NAAQS) of the Clean Air Act and the State of California's Air Quality Standard. New York: American Lung Association.

Anderson, Ken. 1996. Air Quality Specialist, Missoula County Department of Public Health. Phone Interview. February 1996.

Bates, D.V., and R. Sitzo. 1987. "Air Pollution and Hospital Admissions in Southern Ontario: The Acid Summer Haze Effect," Environmental Research **43**: 317-331.

Bates, D.V., M. Baker-Anderson, and R. Sitzo. 1990. "Asthma Attack Periodicity: A Study of Hospital Emergency Visits in Vancouver," Environmental Research **51**: 51-70.

Bhagia, G.S., and H.H. Stoevener. 1978. Impact of Air Pollution on the Consumption of Medical Services: Costs of Hospitalization in the Portland Metropolitan Area. Corvallis, OR: United States Environmental Protection Agency.

Carpenter, B.H., J.R. Chromy, W.D. Bach, D.A. LeSourd, and D.G. Gillette. 1979. "Health Costs of Air Pollution: A Study of Hospitalization Costs," American Journal of Public Health **69**(12): 1232-1241.

Chappie, Mike, and Lester Lave. 1982. "The Health Effects of Air Pollution: A Reanalysis," Journal of Urban Economics **12**: 346-376.

Cannon, James S. 1990. The Health Costs of Air Pollution: A Survey of Studies Published 1984-1989. New York: American Lung Association.

Crocker, T.D., W. Schulze, B. Shaul, and A.V. Kneese. 1979. Methods Development for Assessing Air Pollution Control Benefits Vol I. Experiments in the Economics of Air Pollution Epidemiology. Washington D.C.: US Environmental Protection Agency.

Department of Public Health and Human Services. 1995. Montana Medicaid, Meeting The Health Care Needs of Eligible Low Income Montanans. Helena, MT.

Department of Social and Rehabilitation Services. 1995. "Montana's Medicaid Program," Bulletin to Montana State Legislators, January 3, 1995.

Dockery, D.W., J. Schwartz, and J.D. Spengler. 1992. "Air Pollution and Daily Mortality: Associations with Particulates and Acid Aerosols," Environmental Research **59**: 362-373.

Dockery, D.W., F.E. Speizer, D.O. Stram, J.H. Ware, J.D. Spengler, and B.G. Ferris, Jr. 1989. "Effects of Inhalable Particles on Respiratory Health of Children," American Review of Respiratory Disease **139**(3): 587-594.

Durham, William H. 1974. "Air Pollution and Student Health," Archives of Environmental Health **28**: 241-255.

Environmental Protection Agency. 1987. "Revisions to the National Ambient Air Quality Standards for Particulate Matter," Federal Register **52**:(126): 24634-24669, (July 1, 1987).

Evans, J.S., T. Tosteson, and P.L. Kinney. 1984. "Cross-sectional Mortality Studies and Air Pollution Risk Assessment," Environment International **10**: 55-83.

Fairley, David. 1990. "The Relationship of Daily Mortality to Suspended Particulates in Santa Clara County, 1980-1986," Environmental Health Perspectives **89**: 159-168.

Folland, S., A.C. Goodman, and M. Stano. 1993. The Economics of Health and Health Care. New York: Macmillan Publishing Company

Gerking, Shelby, and William Schulze. 1981. "What Do We Know about Benefits of Reduced Mortality from Air Pollution Control?," American Economic Review **71**(2): 229-234.

Greene, William H. 1990. Econometric Analysis. Second Edition. Englewood Cliffs, NJ: Prentice Hall, Inc.

Jaksch, J.A., and H.H. Stoevener. 1974. Outpatient Medical Costs Related to Air Pollution in the Portland, Oregon Area. Washington D.C.: United States Environmental Protection Agency.

Johnson, K.G., R.A. Gideon, and D.O. Loftsgaarden. 1990. "Montana Air Pollution Study: Children's Health Effects," Journal of Official Statistics **5**(4): 391-408.

Kasper, Judith D., 1987. "The Importance of Type of Usual Source of Care for Children's Physician Access and Expenditures," Medical Care **25**(5): 386-398.

Kinney, Patrick L., and Haluk Ozkaynak. 1991. "Associations of Daily Mortality and Air Pollution in Los Angeles County," Environmental Research **54**: 99-120.

Krumm, Ronald J., and Philip E. Graves. 1982. "Morbidity and Pollution: Model Specification Analysis for Time-Series Data on Hospital Admissions," Journal of Environmental Economics and Management **9**: 311-327.

Krupnick, A. J., W.Harrington and B.D. Ostro. 1990. "Ambient Ozone and Acute Health Effects: Evidence from Daily Data," Journal of Environmental Economics and Management **18**: 1-18.

Lave, Lester B., and Eugene P. Seskin. 1977. Air Pollution and Human Health. Baltimore: Johns Hopkins University Press.

Lipfert, Frederick W. 1984. "Air Pollution and Mortality: Specification Searches Using SMSA-Based Data," Journal of Environmental Economics and Management **11**: 208-243.

Lipfert, Frederick W. 1993. "A Critical Review of Studies of the Association between Demands for Hospital Services and Air Pollution," Environmental Health Perspectives Supplements **101**(Suppl. 2): 229-268.

Lutz, Lawrence J. 1983. "Health Effects of Air Pollution Measured by Outpatient Visits," The Journal of Family Practice **16**(2): 307-313.

Maddala, G.S. 1992. Introduction to Econometrics. New York: Macmillan, Inc.

McRae, W.C., and J. Jewell. 1992. Montana Handbook. Chico, CA: Moon Publications, Inc.

Mendelsohn, Robert, and Guy Orcutt. 1979. "An Empirical Analysis of Air Pollution Dose-Response Curves," Journal of Environmental Economics and Management **6**: 85-106.

Montana Department of Commerce. 1995. Estimates of Montana's Resident Population: Counties. Helena, MT.

Montana Medicaid Program. 1995. Montana Medicaid, Meeting the Health Care Needs of Eligible Low Income Montanans. Helena, MT: Department of Public Health and Human Services.

Neher, Jon O., and Jane Q. Koenig. 1994. "Health Effects of Outdoor Air Pollution," American Family Physician **49**(6): 1397-1407.

National Oceanic and Atmospheric Administration (NOAA). 1994. Climatological Data Montana 1994 **97**(1, 2, 3, 10, 11, 12).

National Oceanic and Atmospheric Administration (NOAA). 1994. Climatological Data Annual Summary Montana 1994 **97**(13).

Ostro, Bart D. 1983. "The Effects of Air Pollution on Work Loss and Morbidity," Journal of Environmental Economics and Management **10**: 371-382.

Ostro, Bart D. 1987. "Air Pollution and Morbidity Revisited: A Specification Test," Journal of Environmental Economics and Management **18**: 87-98.

Ostro, Bart D. 1993. "The Association of Air Pollution and Mortality: Examining the Case for Inference," Archives of Environmental Health **48**(5): 336-342.

Ostro, Bart D., and Susy Rothschild. 1989. "Air Pollution and Acute Respiratory Morbidity: An Observational Study of Multiple Pollutants," Environmental Research **50**: 238-247.

Ozkaynak, Haluk, and George D. Thurston. 1987. "Associations between 1980 Mortality Rates and Alternative Measures of Airborne Particle Concentration," Risk Analysis **7**(4): 449-461.

Pope, C. A. III. 1989. "Respiratory Disease Associated with Community Air Pollution and a Steel Mill, Utah Valley," American Journal of Public Health **79**(5): 623-628.

Pope, C. A. III. 1991. "Respiratory Hospital Admissions Associated with PM_{10} Pollution in Utah, Salt Lake, and Cache Valleys," Archives of Environmental Health **46**(2): 90-97.

Pope, C. A. III., D.W. Dockery, J.D. Spengler, and M.E. Raizenne. 1991. "Respiratory Health and PM_{10} Pollution," American Review of Respiratory Disease **144**(3): 668-674.

Pope, C. A. III., Joel Schwartz, and Michael R. Ransom. 1992. "Daily Mortality and PM_{10} Pollution in Utah Valley," Archives of Environmental Health **47**(3): 211-217.

Pope, C. A. III., D.V. Bates, and M.E. Raizenne. 1995. "Health Effects of Particulate Air Pollution: Time for Reassessment?," Environmental Health Perspectives **103**(5): 472-480.

Portney, Paul R. and John Mullahy. 1990. "Urban Air Quality and Chronic Respiratory Disease," Regional Science and Urban Economics **20**: 407-418.

Ranson, Michael R., and C. A. Pope III. 1992. "Elementary School Absences and PM_{10} Pollution in Utah Valley," Environmental Research **58**: 204-219.

Ransom, Michael R., and C. A. Pope III. 1995. "External Health Costs of a Steel Mill," Contemporary Economic Policy **13**: 86-97.

Schwartz, Joel. 1991. "Particulate Air Pollution and Daily Mortality in Detroit," Environmental Research **56**: 204-213.

Schwartz, Joel. 1993. "Air Pollution and Daily Mortality in Birmingham, Alabama," American Journal of Epidemiology **137**(10): 1136-1147.

Schwartz, Joel. 1994a. "PM_{10}, Ozone, and Hospital Admissions for the Elderly in Minneapolis-St. Paul, Minnesota," Archives of Environmental Health **49**(51): 366-373.

Schwartz, Joel. 1994b. "Air Pollution and Daily Mortality: A Review and Meta Analysis," Environmental Research **64**: 36-52.

Schwartz, J., C. Spix, H.E. Wichmann, and E. Malin. 1991. "Air Pollution and Acute Respiratory Illness in Five German Communities," Environmental Research **56**: 1-14.

Schwartz, Joel, and Douglas W. Dockery. 1992. "Particulate Air Pollution and Daily Mortality in Steubenville, Ohio," American Journal of Epidemiology **135**(1): 12-19.

Seskin, Eugene P. 1979. "An Analysis of Some Short-Term Health Effects of Air Pollution in the Washington, D.C. Metropolitan Area," Journal of Urban Economics **6**: 275-291.

Styer, P., N. McMillan, F. Gao, J. Davis, and J. Sacks. 1995. "Effects of Outdoor Airborne Particulate Matter on Daily Death Counts," Environmental Health Perspectives **103**(5): 490-497.

Thibodeau, L.A., R.B. Reed, Y.M.M Bishop, and L.A. Kammerman. 1980. "Air Pollution and Human Health: A Review and Reanalysis," Environmental Health Perspectives **34**: 165-183.

US Bureau of the Census. 1994. County and City Data. Washington D.C.: US Department of Commerce, Bureau of the Census.

US Department of Health and Human Services. 1991. The International Classification of Diseases, 9th Revision, Clinical Modification, Fourth Edition. Washington D.C.: US Government Printing Office.

US Department of Health and Human Services. 1995. Health Care Financing Review Statistical Supplement. Baltimore: Health Care Financing Adminstration, Office of Research and Demonstrations.

Vigliarolo, P., S. Rappaport, K. Leiber, A. Gorman, and R. White. 1994. "Populations at Risk from Particulate Air Pollution - United States, 1992," Morbidity and Mortality Weekly Report **43**(16): 290-293, (April 29, 1994).

White, Kenneth, J. 1993. Shazam User's Reference Manual Version 7.0. Canada: McGraw-Hill Book Company.