# HEALTH AND AMENITY EFFECTS OF GLOBAL WARMING

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*This study shows that climate change would probably reduce mortality in the United States by about 40,000 per year, assuming a 4.5° warmer climate—the IPCC best estimate of temperature change with a doubling of carbon dioxide Benefits would extend to lower medical costs nationwide. Measuring willingness to pay by wage rates shows that people prefer warm climates and would be willing to give up between $30 billion and $100 billion annually for a 4.5° increase in temperatures.* (*JEL* Q25, J17, J31)

## I INTRODUCTION

Many researchers, environmentalists, and politicians are forecasting that rising world temperatures in the next century will have devastating effects on humans.[1] Although the calamities are barely spelled out, some scholars and writers have pointed to a warmer climate's being less healthful. Referring to the world as a whole, Working Group II of the Intergovernmental Panel on Climate Change asserted [IPCC 1995, SPM-10]: "Climate change is likely to have wide-ranging and mostly adverse impacts on human health, with significant loss of life." The IPCC report feared that increases in heat waves would cause a rise in deaths from cardiorespiratory complications. It also foresaw a rise in vector-borne diseases, such as malaria and dengue and yellow fevers. The report did acknowledge briefly that in colder regions there would be fewer cold-related deaths.

The few studies that have examined the relation between warming and human health or mortality in depth have focused either on increases in the number of days of very hot weather and the resulting mortality or on the spread of infectious diseases by such vectors as mosquitoes, flies, and snails.[2] Several major studies of the implications of global warming for the United States have neglected or claimed a lack of data on the effects on health or human welfare.[3] This study examines the overall effect of climate and, in particular, temperatures on mortality in the United States and the value people put on a warmer environment.

Rarely has any research explored people's preferences for less chilly weather. Given the circumstantial evidence that people prefer warm climates over cold, it is somewhat surprising that the effects of warming on human well-being have essentially been ignored. We do know that many people upon retiring flee to southern and warmer locales. According to a survey of people turning 50 in 1996, almost 40% plan to move when they retire and the most important criterion in selecting their destination (40%) is a "more favorable climate."[4] Folklore alleges that physicians sometimes recommend that patients escape to a warmer climate, never to a colder one. Presumably retirees, at least, find that higher temperatures improve their welfare. As air-conditioning has mitigated the rigors of hot summers, the population of the United States has been moving South and West, towards climates that enjoy less extreme cold weather. Most Americans

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1 Committee on Science, Engineering, and Public Policy, et al [1991], Mitchell [1991], Cline [1992], Gore [1992], IPCC [1992].

2 Smith and Tirpak [1989], Kalkstein [1991], Stone [1995]

3 National Research Council [1978], Nordhaus [1991], Cline [1992]

4 *USA Today*, May 13, 1996, B1

**ABBREVIATIONS**

DOT Department of Transportation
IPCC Intergovernmental Panel on Climate Change
PSI Pollution Standard Index



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and Canadians taking vacations in the winter head to Florida, the Caribbean, Mexico, Hawaii, or southern California. Exceptions crowd the ski slopes, but they are a minority.

To my knowledge, Hoch and Drake [1974] conducted the only study—summarized in the U.S. Department of Transportation (DOT) research described below—that examined the preferences of people for various climates, an important measure of how weather affects human welfare. Many studies that have examined the quality of life in various urban areas, however, have found that warmer climates were correlated with a willingness to accept lower wages.[5] As a gauge of preferences, that research and this paper both use workers' willingness to pay for a better climate as measured by the differential in wages among cities.

## II HEALTH EFFECTS

### *Past Research*

In the early 1970s, the U.S. Department of Transportation sponsored a series of conferences on climate change that examined, among other things, the effect of climate on health care expenditures and on preferences of workers for various climates. At that time, the government and most observers were concerned about possible cooling of the globe. The department organized the meetings because it planned to subsidize the development and construction of a large fleet of supersonic aircraft that environmentalists contended would affect the world's climate.

The third gathering, held in February 1974, examined the implications of climate change for the economy and people's well-being and included a study of the costs to human health from cooling, especially any increased expenses for doctors' services, visits to hospitals, and additional medication.[6] For that meeting, the department asked the researchers to consider a cooling of 2° Celsius (3.6° Fahrenheit) and a warming of 0.5°C (0.9°F). Robert Anderson, Jr., the economist who calculated health care outlays, made no estimate of the costs or savings should the climate warm; but his numbers show that for every 5% reduction in the annual number of heating degree days, a measure of winter's chill, health care costs would fall by $0.6 billion (1971 dollars).[7] In his paper summarizing the various studies on economic costs and benefits of climate change, Ralph D'Arge [1974], the principal economist involved in the DOT project, indicated that a 10% shift in degree days would be equivalent to a 1.8° change in temperature. Thus the gain in reduced health costs from a warming of 4.5° would be on the order of $3.0 billion in 1971 dollars or $21.7 billion in 1994 dollars, adjusting for population growth and price changes (using the price index for medical care).

A more recent set of studies has focused on excessive mortality related to heat spells in major cities.[8] These studies have typically found a rise in deaths during periods of very hot weather for certain cities. The results have not, however, applied to all hot spells or to all cities. Work concerned with "killer" heat waves has generally ignored the reduction in mortality that warmer winter months would bring.

Interestingly cities with the highest average number of summer deaths are found in the Midwest or Northeast while those with the lowest number are in the South.[9] Typically researchers have failed to find any relationship between excess mortality and temperature in southern cities, which experience the most heat. Moreover, Kalkstein and Davis [1989] reported without explanation that the "threshold" between temperatures that lead to excess deaths and those that have no effect, varies significantly among the cities. Nor have they found a correlation between premature deaths and air pollution (Kalkstein and Davis [1989], Kalkstein [1991]). Little attention has been devoted to whether any excess deaths represented only premature mortality of a few days of the old or sick or whether the excess deaths shortened lives significantly.

5 For example see Hoch [1974, 1977], Cropper and Arriaga-Salinas [1980], Cropper [1981], Roback [1982, 1988], Gyourko and Tracy [1991]

6. Anderson [1974]

7 Each degree that the average temperature for a day falls below 65°F produces one heating degree day If the mean temperature on a particular day were 60°, for example, the number of degree days would be five If the high for a day were 60° and the low 40°, the average would be 50° and the number of degree days would be 15

8 Bridger and Helfand [1968]; Oechsli and Buechley [1970]; Ellis [1972], Ellis et al [1975], Weiner [1984], Kalkstein and Davis [1989], World Health Organization [1990], Kalkstein [1991]

9 Smith and Tirpak [1989, 224–5]

These studies have found that those most susceptible to heat related deaths are elderly.[10] Kalkstein [1992] has reported that researchers have attributed the absence of heat related deaths in southern cities to acclimatization and the prevalence of housing that shields residents from high temperatures. If temperatures rise slowly over the next century by 2° to 6.3°, as is currently predicted [IPCC WG II 1995, SPM-2], people can become acclimated and housing can and, in the normal cycle, will be replaced. After all, half the housing stock in the United States has been built in the last 25 years.[11]

Earlier work, on the other hand, had found a negative relationship between temperature and mortality and/or a correlation between season and death rates.[12] Bull and Morton [1978], for example reported that deaths from myocardial infarction, strokes and pneumonia fell the higher the temperature in England and Wales. In New York, however, they fell only until the temperature reached 68° and then rose with the heat. Momiyama [1963] found that deaths followed a seasonal path but that in the United States this pattern had been reduced in the period from 1920s to 1960s. Even though a pattern of increased deaths in the winter is apparent for all portions of the United States, England and Wales, and Japan, many subsequent researchers have emphasized summer deaths due to high temperatures.

Other studies of the influence of climate change on human health have examined a rather narrow set of potential medical areas. The underlying research has generally referred to Lyme disease, malaria, dengue and yellow fevers, and encephalitis, none of which is a major health problem in the United States. The IPCC [1995, SPM-10] has asserted that the "geographical zone of potential malaria transmission in response to world temperature increases at the upper part of the IPCC-projected range (5° to 9° by 2100) would increase from approximately 45% of the world population to approximately 60% by the latter half of the next century." On the other hand, the World Health Organization [1990, 21] notes that

> until recent times, endemic malaria was widespread in Europe and parts of North American and that yellow fever occasionally caused epidemics in Portugal, Spain and the USA. Stringent control measures ... and certain changes in life-style following economic progress, have led to the eradication of malaria and yellow fever in these areas.

Concern about tropical and insect-spread diseases seems overblown. Inhabitants of Singapore, which lies almost on the equator, and of Hong Kong and Hawaii, which are also in the tropics, enjoy life spans as long as or longer than those of people living in Western Europe, Japan, and North America. Both Singapore and Hong Kong are free of malaria, but that mosquito-spread disease ravages nearby regions. Modern sanitation in advanced countries prevents the spread of many scourges found in hot climates. Such low tech and relatively cheap devices as window screens can slow the spread of insect vectors.

Insect-spread diseases might or might not increase under the stimulus of a warmer climate. Many of the hosts or insects themselves flourish within a relatively small temperature or climatic range. Plague, for example, spreads when the temperature is between 66° and 79° with relatively high humidity but decreases during periods of high rainfall.[13] Conditions for an increase in encephalitis, however, improve with higher temperatures and more rainfall. Parasitic diseases can usually be controlled through technology, good sanitary practices, and educating the public. Malaria-bearing mosquitoes flourish under humid conditions with temperatures above 61° and below 95°. Relative humidity below 25% causes either death or dormancy.

Even without warming, it is certainly possible that dengue fever or malaria could invade North America. Unfortunately, some of the government's well meaning environmental policies may make the vector more likely. The preservation of wetlands, although useful in conserving species diversity, also provides prime breeding ground for mosquitoes that can carry these diseases. If the United States does in the future suffer from such insect-borne scourges, the infestation may have less

10 Kalkstein and Davis [1989, 54], Kalkstein [1991, 147]

11 *Statistical Abstract* [1995, table 1227]

12. Momiyama and Katayama [1967, 1972], Momiyama [1963], Bull and Morton [1978].

13 White [1985, 7.7 3]

to do with global warming than with the preservation of swampy areas.

*Seasonal Effects*

The climate models generally predict that nighttime and winter temperatures will increase the most while daytime and summer highs will rise the least.[14] Many observers have pointed out that this will lengthen the growing season. It should also be beneficial to human health. The IPCC reports that over this century the weather in much of the world has been consistent with such a pattern: winter and night temperatures have risen while summer temperatures have fallen.[15]

A warmer globe would likely result in the polar jet stream's retreating towards higher latitudes; in the Northern Hemisphere the climate belt would move North.[16] Thus an average annual 6.7° increase in temperature for New York City, for example, would give it the climate of Atlanta. NYC's summertime temperatures, however, would not go up commensurably: the average high temperature in Atlanta during June, July, and August is only 4° warmer than New York City's and the latter city has on record a higher summer temperature than does the capital of Georgia. Summer temperatures generally differ less than winter temperatures on roughly the same longitude and differ less than average temperatures

A sample of 45 metropolitan areas in the United States shows that for each increase of a degree in the average annual temperature, July's average temperatures go up by only 0.5° while January's average temperatures climb by 1.5°.[17] Since warming will likely exert the maximum effect during the coldest periods but have much less effect during the hottest months, the climate change should reduce deaths even more than any summer increase might boost them.

In addition, as Table I documents, even deaths traceable to parasitic and infectious diseases are somewhat higher in the winter than in the summer. Respiratory and heart diseases, which kill many more people annually and which the IPCC Working Group II Summary singled out [1995, SPM-10] as increasing under a warmer climate, peak during *winter* months, not summer months. The table shows that respiratory problems, such as pneumonia and influenza, are a particular problem in cold months (this is true in both the northern and southern hemisphere), but even the leading causes of death—diseases of the circulatory system—kill more people in the winter. Except for accidents, suicides, and homicides, which are slightly higher in the summer, death rates from virtually all other major causes rise in winter months; overall mortality in the three years 1985 to 1990 was 16% greater when it was cold than during the warm season. Other years show similar patterns. Rather than increasing mortality, these data suggest that warmer weather should reduce it; but this possibility is rarely discussed.

Earlier studies have reported the relationship between season and death rates. Professor F. Ellis of the Yale University School of Medicine reported that deaths in the United States between 1952 and 1967 were 13% higher on a daily basis in the winter than in the summer [1972, based on Table II, 15]. This difference is smaller than experienced during the 1985–1990 years, a period which included some of the hottest summers on record. Ellis's study covered a time during which recorded average temperatures in the United States were somewhat lower than during the 1985–1990 period tabulated in Table I. If hot weather were detrimental to life, the differential between summer and winter death rates should have been smaller, not larger, during the later period.

Before the early or middle part of this century, deaths during the summer months were much higher relative to winter than is currently the case [18] The increase in average temperatures during this century has apparently been accompanied by a decline in hot weather deaths relative to winter mortality. Perhaps the decline of physical labor, which is afflicted with a much higher rate of fatal accidents than office work, explains the change. Momiyama [1977], however, reports that for

14. Gates et al. [1992]

15. Folland et al [1992]

16. See Lamb [1972, 117–118], Giles [1990]

17 The data were collected from the Department of Commerce, National Climatic Data Center, 1979.

18 Momiyama [1977]

**TABLE I**
Cause of Death by Season
(1985–1990)

| Cause of Death | Percent of All Deaths (December–February) | Percent Winter Over June–August* |
|---|---|---|
| Diseases of the respiratory system | 10% | 153% |
| Mental disorders | 1% | 123% |
| Diseases of the nervous system and sense organs | 2% | 125% |
| Diseases of the circulatory system | 46% | 123% |
| Endocrine and metabolic diseases and immunity disorders | 3% | 123% |
| Diseases of the genitourinary system | 2% | 121% |
| Diseases of the digestive system | 3% | 113% |
| Infectious and parasitic diseases | 2% | 113% |
| Neoplasms | 21% | 103% |
| Homicides | 4% | 86% |
| Suicides | 1% | 94% |
| Accidents | 1% | 90% |
| All Causes | 100% | 116% |

*Adjusted for differences in the number of days in each month

*Source* The National Center for Health Statistics, *Vital Statistics of the United States*, various years

most advanced countries, such as the United States, Japan, United Kingdom, France, and Germany, mortality is now concentrated in the winter.

A number of recent studies, as indicated above, have examined death rates on a daily basis. This allows the authors to compare extreme temperatures with mortality. Although the research has shown that it is typically the elderly or the very sick that are affected by temperature extremes, the analysis ignores whether this shortens life by more than a few days or a few weeks. That cities in the south fail to show any relationship of deaths to high temperatures suggests that the correlation in the north may stem from deaths of the most vulnerable when the weather turns warm. One way to parse out whether climate extremes shorten lives by only a few days or whether they lead to more serious reductions in the life span, is to consider longer periods. Monthly data on deaths and temperatures, for example, should on average measure whether any shortening is longer than a couple of weeks. A reduction in life shorter than that should wash out in the monthly data. Annual data would be even better but temperature fluctuations from year to year are too small to produce significant variation in death rates. A cross section examination of cities with different annual temperatures, however, would show whether high heat leads to a significant reduction in life expectancies. Below I have employed both monthly data and annual data to measure the impact of climate on mortality.

To examine more closely the relationship of temperature to mortality on a monthly basis, I regressed various measures of warmth on deaths in Washington, D.C., from January 1987 through December 1989. The results support the proposition that climate influences mortality. Washington was chosen because the National Center for Health Statistics publishes monthly data on deaths only by state, but the Center treats the nation s capital as a state. Since temperatures are recorded for major urban areas only, it is impossible to compare these numbers with monthly state death rates, except for the District of Columbia.

Using a city has an advantage in that many demographic variables affecting the death rate, such as age, race, income, and religion, are held reasonably constant over a three-year

**TABLE II**
Regression of Monthly Death Rates on Monthly Temperatures in Washington, D.C.
(January 1987 through December 1989)

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Average Low Temperature | –0 032<br>(–5 56) | | | | | |
| Mean Monthly Temperature | | –0 032<br>(–5 64) | | | –0 029<br>(–2 46) | |
| Average High Temperature | | | –0 031<br>(–5 73) | | | –0.029<br>(–2 56) |
| Hours of Daylight | | | | –0 240<br>(–4 67) | –0 026<br>(–0 26) | –0 019<br>(–0 19) |
| $R^2$ | 0 476 | 0 484 | 0 491 | 0 390 | 0 485 | 0 492 |
| F-Statistic | 30 94 | 31 86 | 32 79 | 21 78 | 15 53 | 15 95 |

t-statistics in parentheses
Data Sources *Vital Statistics of the United States*, 1987–1989 and *Climatological Data Virginia*, 1987–1989

period. Moreover, it seems likely that many environmental factors also remain fixed during much of the same period. Seasonal changes, especially warm weather, do, of course, affect smog levels. Warm summers producing ozone could partially outweigh any beneficial effects of heat by itself. Since we are interested in the net effect of warming on human mortality, however, it is desirable to include any effect temperature had on creating high levels of ozone that might add to deaths.

I adjusted the reported monthly number of deaths for the number of days in the month and then divided by Washington's estimated population for that month to produce a death rate per day series Yearly population figures, which declined for the three years, were calculated on the basis that the population declined linearly between each June population estimate. Regressing the death rate in the nation's capital for each month from 1987 through 1989 on the average maximum, minimum or mean monthly temperatures measured at National Airport for those 36 months showed that mortality declined with rising temperatures. All three temperature measures, shown in Table II, give similar results; but the variable for the average high temperature gives a slightly better fit. Since 1987 and especially 1988 were very hot summers in Washington, with the average high temperature during July 1987 and 1988 being 4.3°F and 4.5°F above normal, if heat waves were real killers, those summers should have biased the coefficient towards zero. Moreover, ozone becomes a much greater problem in hotter weather, which should also have raised the coefficient of temperature towards the positive.

Although deaths peak in the winter, factors other than cold, such as less sunlight, could induce the higher mortality. The peaking itself does not prove that warming would lengthen lives; it could be that the length of the day affects mortality. The day's length is closely correlated with temperature, of course, but the latter variable varies from year to year. As regression (4) in Table II shows, the length of the day is correlated with the death rate but is less significant than temperature. Moreover, if temperature measures are combined with the length of the day—regressions (5) and (6)—the latter variable loses its statistical significance, although the sign of the coefficient is still negative. Temperature remains the most significant variable.

The relationship of deaths to temperature is probably underestimated since some elderly from the Capital winter in warm climates and die there. Nevertheless, using the coefficients for any one of the temperature measures implies that a 4.5°F rise—this is the IPCC's [1992, 16] "best estimate" under $CO_2$ doubling—would cut deaths for the country as a whole by about 37,000 annually.

*Climatic Effects*

If death rates were lower in warm climates, however, that would provide further support for the proposition that a rise in average temperature would reduce mortality. Moreover, as mentioned above, employing annual data shows whether the effect of temperature is simply to reduce life by a short period or whether the effect is more substantial Clearly many factors affect mortality. Within any population the proportion that is old affects death rates. Since African-Americans have lower life expectancies than whites, the proportion that is black affects mortality rates. Income and education are also closely related to life expectancy. As is well known, smoking shortens lives. Severe air pollution has pushed up mortality, at least for short periods.

Although ideally death rates should be age and race adjusted to examine the effect of climate, the data to do so are not readily available. In addition the data should be adjusted for income and/or schooling as these factors affect life expectancy. Moreover, simply including variables for the proportion over 65 and black in a regression adjusts for most of the variance related to the distribution of age and race. To examine further the relationship between climate and mortality, therefore, I regressed the death rate in 89 large counties—those with over 2,000 deaths in 1979 that made up all or a portion of the 50 largest metropolitan areas in 1979—on the percent of the population which was over 65 in 1980; the percent black in 1980; the percent with 16 years or more of schooling; the median household income in 1979; per capita income in 1979; various health inputs, such as hospital beds and physicians per 100,000; and various weather variables.[19] The weather variables were the actual average temperatures during 1979, the highest temperature in the summer, the lowest temperature during the winter, the number of heating degree days during 1979, and the number of cooling degree days.[20] To examine whether it was temperature or sunlight that reduced mortality, I used the latitude and the elevation of the counties as well as the proportion of the sky that was cloudy (82 counties).

The health inputs, the latitude, the elevation, and the cloudiness were not statistically different from zero, added nothing to the results, and are not shown here. It would be useful to include data on smoking rates, but there is no such data by counties or even metropolitan areas circa 1979. State data, however, exist for 1955 and 1985; they show that smoking rates are higher in the south.[21] Thus smoking should be positively correlated with temperature and bias the temperature variables towards zero.

Assuming that the smoking rates of people in each of the counties matched those of the state as a whole and that smoking in 1985 was a good measure of smoking rates in 1979, I included a smoking variable in the regression. The latter assumption would seem to be reasonably valid as smoking rates vary only slowly over time, despite the trend downward in male smoking. Since the territories included in this study consist of the counties with the largest populations in the 50 largest metropolitan areas, they represent in most cases a significant portion of the state's population Thus the smoking rate for the state as a whole may be a fair proxy for the county smoking rate. The results show that while the smoking rate is positively correlated with the death rate, statistically it is insignificantly different from zero. More important from the point of view of this study, inclusion of this measure of smoking leaves the size and significance of the other variables virtually unaffected.

Although data for all 89 counties on air pollution were unavailable, the *Statistical Abstract* [1982–1983, Table 352] has published data on the Pollutant Standard Index (PSI)—a measure of air pollutants that affect health—for a group of standard metropolitan statistical areas.[22] From this group I collected data on

19 The data are for 1979 or 1980 because the Stanford University Library had annual weather data for urban areas only for 1975 to 1979

20 Cooling degree days are similar to heating degree days For each day the average temperature differs from 65° the difference in number of degrees is equal to the heating or the cooling degree days for that day. The total for the year is the reported variable

21 Cohen and Colditz [1994]

22 This index is based on five pollutants CO, $SO_2$, total suspended particulates, $O_3$, and $NO_2$. The PSI index rises above 100 when any one of the pollutants at only one station reaches a level judged to have adverse effects on human health. A level of 200 to 300 is considered very unhealthful and above 300, hazardous

days in which PSI exceeded 200 for a sample of 22 of the counties[23] The results failed to show any significant effect of pollution on mortality, a result consistent with earlier studies.

As expected, Tables IIIa and IIIb show that the proportion over 65 and the proportion black are highly significant in explaining death rates across counties. Regression (1) and regression (2) are the same except that the first employs a measure of education while the second uses median household income. Median income gives the best fit and, as expected, higher incomes reduce deaths. It is interesting to note that, at the mean, the elasticity of death rates with respect to median income is –0.26; that is, a 10% rise in income would reduce death rates by 2.6%. On the other hand, the elasticity of death rates with respect to percent of the population with 16 years of education is only –0.06. Evidently it is better to be rich than well educated. In both these regressions the average temperature in 1979 is highly significant (more so in the income regression) and shows unambiguously that warmer weather leads to lower deaths. Regression (2) explains 95% of the variance in death rates.

Regression (3), which includes temperatures squared—variable highly correlated with temperature—is intended to test whether the rate at which deaths are reduced falls at higher temperatures. Given the multicollinearity, neither variable is significant at the 5% level and the signs are reversed Regression (4) simply substitutes per capita income for median household income. The result is less significant than the regression with household income. The remaining regressions use other measures of climate and demonstrate that warmer is healthier or at least extends life expectancies—once the age structure is held constant there is a well established direct relationship between death rates and life expectancies. Equation (5) substitutes heating degree days in 1979 for average temperature and finds that the *colder* the winter, the *higher* the death rate. Regression (6) employs cooling degree days and finds that the *hotter* the summer, the *lower* the death rate Regression (7) employs both variables together. While their significance goes down as a result of multicollinearity, the signs still indicate that warmer winters and warmer summers reduce deaths. Regressions (8), (9), and (10) use the extremes recorded during the year—the highest temperature and the lowest temperature—and find the same pattern evinced by the degree day data, that is, warmer temperatures reduce mortality in both the winter and the summer (note that the higher the lowest temperature, the lower the death rate)

Since the objective is to measure the effect of a warmer climate, it is simplest to use regression (2) because its measure of temperature is the mean during the year. (It is also the regression with the highest F-Statistic and the largest $R^2$.) The coefficient for average temperature implies that if the United States were enjoying temperatures 4.5° warmer than today, mortality would be 41,000 less. This savings in lives is quite close to the number estimated based on the Washington, D.C , data for the period 1987 through 1989.

In summary, the monthly figures for Washington, D.C., between 1987 and 1989, indicate that a climate warmer by about 4.5° would reduce deaths nationwide by about 37,000, the regressions on 89 counties for 1979 point towards a saving in lives of about 41,000. These data sets produce roughly the same conclusion a warmer climate would reduce mortality by about the magnitude of highway deaths, although the latter deaths are more costly in that they probably involve a much higher proportion of young men and women.

### *Morbidity*

Presumably, if a warmer climate reduced deaths, it would also cut disease. Unfortunately data on health care costs do not exist by county. However, the *County and City Data Book* publishes figures on physicians and hospital beds per 100,000. Since medical facilities tend to be concentrated, these numbers have a lot of random noise. Some counties in a region may have a considerable concentration of hospitals and attendant physicians while nearby counties may have only a few. Nevertheless, I regressed hospital beds per 100,000 and physicians per 100,000 on household income, percent black, percent

23. Any day that the PSI exceeded 300 counted as two days

**TABLE IIIa**
Death Rates for 89 Counties
(1979)

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Percent Over 65 years 1980 | 49 84<br>(28 47) | 45 27<br>(25 87) | 46 32<br>(25 55) | 50 00<br>(29 67) |
| Percent Black 1980 | 4 35<br>(9 55) | 2 92<br>(6 25) | 2 73<br>(5 80) | 4 05<br>(8 71) |
| Percent with 16 years of Schooling | −2 76<br>(−2 72) | | | |
| Median Household Income 1979 ($000) | | −0 119<br>(−6 12) | −0 119<br>(−6 24) | |
| Per capita Income 1979 ($000) | | | | −0 156<br>(−3 22) |
| Average Temperature in 1979 | −0 094<br>(−3 37) | −0 112<br>(−4 61) | 0 160<br>(1 09) | −0 099<br>(−3 59) |
| Average Annual Temperature Squared | | | −0 016<br>(−1 87) | |
| $R^2$ | 0 929 | 0 946 | 0 949 | 0 931 |
| F-Statistic | 274 41 | 371 44 | 306 67 | 284 08 |

*Source* *Vital Statistics of the United States*, 1979, Vol II-Mortality, Part A, Table 1-17, *Annual Climatological Data, National Summary*, Vol 30, No 13, NOAA 1979, metric units, Bureau of the Census, *County and City Data Book*, 1983

**TABLE IIIb**
Death Rates for 89 Counties
(1979)

| | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|
| Percent Over 65 years 1980 | 44 92<br>25 46 | 45 33<br>(25 07) | 45 37<br>(25 64) | 42 56<br>(24 13) | 44 76<br>(24 92) | 43 46<br>(24 13) |
| Percent Black 1980 | 2.89<br>6.10 | 2 85<br>(5 96) | 2 93<br>(6 23) | 2 91<br>(6 14) | 2 79<br>(5 80) | 2 92<br>(6 27) |
| Median Household Income 1979 ($000) | −0 117<br>(−5 96) | −0 118<br>(−5 91) | −0 119<br>(−6 10) | −0 114<br>(−5 80) | −0 116<br>(−5 79) | −0 117<br>(−6 03) |
| Highest Temperature Summer 1979 | | | | −0 178<br>(−4 30) | | −0 130<br>(−2 66) |
| Lowest Temperature Winter 1979 | | | | | −0 040<br>(−3 81) | −0 023<br>(−1 90) |
| Heating Degree Days 1979 (1000s) | | | 0 145<br>(2 17) | | | |
| Cooling Degree Days 1979 (1000s) | | −0 451<br>(−3 99) | −0 239<br>(−1 63) | | | |
| $R^2$ | 0 945 | 0 944 | 0 947 | 0 945 | 0 943 | 0 947 |
| F-Statistic | 360 50 | 351.52 | 294 59 | 361 02 | 346 41 | 298 52 |

t-statistics in parentheses.

**TABLE IV**
Hospital and Physicians per 100,000
(89 counties in 1980)

| | Hospital Beds per 100,000 | Hospital Beds per 100,000 | Physicians per 100,000 |
|---|---|---|---|
| Median Household Income ($000) | –28 99<br>(–2 77) | –32 52<br>(–3 80) | –2 10<br>(–0 42) |
| Percent Black | 636 95<br>(2 53) | 583 15<br>(2 49) | 337 68<br>(2 82) |
| Percent over 65 | 557.24<br>(0 59) | | 541 86<br>(1.21) |
| Average Annual Temperature | –35 69<br>(–2 71) | –34 22<br>(–2 66) | –10 71<br>(–1 71) |
| $R^2$ | 0 303 | 0 300 | 0 158 |
| F-Statistic | 9 13 | 12 14 | 3 95 |

t-statistics in parentheses

over 65, and average annual temperature. The results are given in Table IV above.

Although these regressions do not have the statistical significance of the regressions on death rates, the hospital bed regressions and the coefficients for temperature in those regressions are significant at better than one in a thousand. The physicians regression is significant at the 99% level but the temperature variable is significant only at the 90% level. Nevertheless, all the temperature coefficients have a negative sign. The elasticity of hospital beds and physicians at the mean with average temperatures is –0.39 and –0.33. Assuming that the number of hospital beds and physicians reflected correctly the health care needs of their communities in 1979 and are an index of health care costs, the numbers suggest that private expenditures on health care would have been lower by $22 or $19 billion in 1994 had the climate been warmer. These numbers are remarkably close to the updated figures reported by Robert Anderson [1974] of $22 billion. They also understate the benefits of warming since they do not include gains from the reduction in suffering or from a reduction in working days lost from disease. Nor do they include any lowering of government expenditures on health care

## III HUMAN WELL-BEING

In *The Wealth of Nations*, Adam Smith [1937, 100–18] pointed out that workers must be paid more to work in an unpleasant place or to do nasty jobs. A casual examination of the job market illustrates the truth of that proposition. Oil companies must pay their workers premiums to cope with the climate on the North Slope of Alaska. Even in central and southern Alaska, labor commands higher wages than it does in the lower 48 states. These differentials reflect the desirability of jobs in one area over another. For example, those who have the least distaste for cold and darkness can be lured for the smallest premium to Prudhoe Bay, Alaska, to work in the oil fields. The differential in this case reflects the marginal valuation of the unpleasantness of work in that harsh environment of those with the least aversion to the conditions.

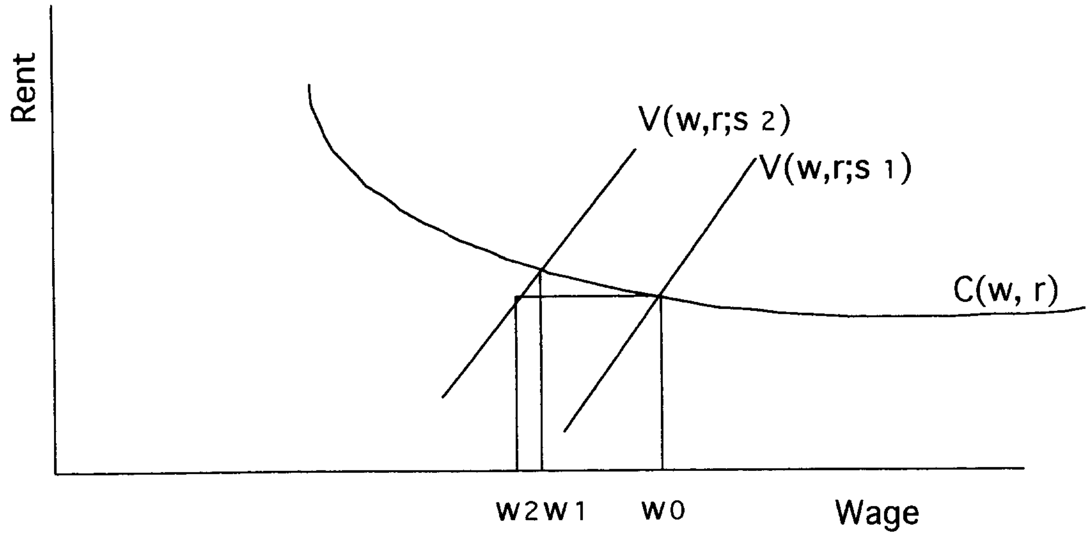
### *Theory of Amenity Values*

There is a large and growing economic literature on such amenity values.[24] Locational advantage can be reflected in the willingness of workers to accept lower wages or in the bidding up by business and home owners of land values.[25] If land values are raised enough, wages could even be forced higher to maintain real incomes. However, it is likely

24 See e g Hoch [1977], Rosen [1979], Cropper and Arriaga-Salinas [1980], Graves [1980], Cropper [1981], Roback [1982, 1988], Blomquist et al [1988], Graves and Waldman [1991], Gyourko and Tracy [1991]

25 See Roback [1982] for a full discussion

**FIGURE 1**




that if workers willingly work for less in a region with positive amenity values, this sum *understates* the benefits of the location. Some benefits have probably been capitalized into land values and are reflected in rents. Thus living costs are raised, making the reduction in wages that workers will accept smaller.

A simple algebraic model based on Roback's [1982] paper may clarify the relationship. Assume workers have identical tastes and skills and that their utility is a function of wages ($w$), rents ($r$), and amenity values ($S$), with $\delta U/\delta w > 0$, $\delta U/\delta r/0$, and $S_2 > S_1$. Assume also that firms are indifferent to the amenity but face the usual production function with land and labor. Their cost is a function of $w$ and $r$. Figure 1 shows a firm's constant cost as a function of wages and rents and the worker's equilibrium conditions for two cities with differing amenity values Wages and rents adjust so that workers and employers have no incentive to move. As can be seen, rents will be higher and wages lower for the city with the better amenity. The distance $W_0 - W_2$ measures the amount of wages the worker would be willing to give up to receive $S_2$ over $S_1$, while the measured wage reduction would be only $W_1 - W_0$, since the employee must also pay a higher rent. The lower value of the wages will, therefore, *underestimate* the value of the amenity.

The relationship of wages to amenity values becomes more complicated if the amenity value affects the costs of the firm either positively or negatively If $S_2$ raises the costs of the firm over $S_1$, wages will be lower in equilibrium but the effect on rents will be ambiguous In effect, workers must accept a lower wage to induce employers to locate in the city that imposes higher costs on them Alternatively, if the amenity lowers costs for the firm, rents will rise enough to discourage both employers and employees from locating in that favorable environment with an uncertain effect on equilibrium wages.

*Studies of the Effect on Rents*

Roback [1982, Table 3] found that none of the climate variables had any statistically significant relationship to land values, although heating degree days had a positive coefficient. Blomquist et al. [1988] reported that precipitation, humidity, heating degree days, and cooling degree days were negatively related to housing expenditures—a proxy for land values—while wind speed, sunshine, and being close to the coast were positively related. Even though statistically significant, both cooling and heating degree days had very small effects on housing expenditures. Taking into account the effects of heating and cooling days on both wages and housing costs, the full implicit price of these variables was trivial Gyourko and Tracy [1991] reported that the more precipitation, the greater the number of cooling degree days, the more heating degree days, and the higher the wind speed, the lower their measure of housing expenditures On the other side, they also found that the higher the relative humidity and the closer to the coast ($t = 1.94$), the higher the housing costs

In sum existing studies have reported mixed correlations between housing costs and weather-related amenity values. Gyourko and Tracy [1991, 784] conclude their analysis of amenities by finding that "for many city traits, the full price largely reflects capitalization in the labor rather than in the land market." The rest of this paper, therefore, will assume that climate amenities do not affect production costs and, as a result, any wage reduction underestimates the benefits from warming, although most of the amenity values do appear in the labor market.

*Studies of the Effect on Wages*

The DOT's third conference on global climate change, referred to above, used differences in occupational wages among urban areas to estimate the value of climate to humans. One of the tables, presented by D'Arge [1974, 569] in his overview of the economic research, drew on the work of Irving Hoch to supply estimates of the costs and benefits of a 0.5° Celsius (0.9°F) warming. Hoch's work [1974] implies that a rise in temperature would have bestowed on workers an implicit gain of $1 6 billion in 1971 dollars. In other words, adjusting for 1995's level of wages and salaries and assuming that the temperature/wage relationship is linear, workers in 1995 would have been willing to accept about $47 billion less in wages for working in a 4 5°F warmer climate.

Roback [1982] found that heating degree days, total snowfall, and the number of cloudy days were positively correlated with wages, suggesting these are disamenities. As expected, the number of clear days was negatively correlated with wages. In her 1988 paper, she also found that the colder the winter (heating degree days), the higher the wages.

Cropper [1981] found that July temperature was inversely correlated with wages for a variety of one-digit occupations. Not all of the regressions for the occupations found statistically significant temperature coefficients, but with the exception of Sales Workers, all had negative coefficients. Of the eight different occupations, four were significant at the 1% level and one was significant at the 5% level. The regression for all earners found a statistically significant correlation at the 1% level. In an earlier paper with Arriaga-Salinas [1980], they report that the coefficient for July temperature was also negatively related to wages.

Gyourko and Tracy [1991, Table 1] reported that heating degree days were positively correlated with weekly hedonic wages. The coefficient for cooling degree days was also positive but not significantly different from zero. Both precipitation and wind speed were significantly negatively correlated with the hedonic wage variable, a somewhat puzzling result Blomquist et al. [1988, Table 1], on the other hand, found that both heating degree days and cooling degree days were negatively correlated with their hourly wage equation, implying that workers prefer both cold and hot weather

All the studies show that hotter summers—more cooling degree days or higher July temperatures—are related to lower wages. On the one hand, all of the studies using heating degree days to measure winter cold, except Blomquist, found that the colder, the higher the wage. On the other hand, the warmer the January temperature, the higher the wage.

*Data*

To confirm and update Hoch's work [1977], I collected data for 1987 from the Bureau of Labor Statistics on wage rates for a handful of occupations in metropolitan areas. Except for Hoch, most of the other studies of amenity values have employed data on individuals and attempted to hold human capital constant. Hoch and this paper employ wage rates for a narrow group of occupations. Although there are advantages in utilizing the census data on individuals (sample size), measures to capture human capital are never perfect. In addition, hourly wages are typically estimated from annual earnings divided by estimates of hours worked during the year. In attempting to capture human capital, the hedonic wage regression typically involves a substantial number of variables. Not only do these equations include such poorly measured attributes of workers as education; but they employ a host of variables, such as occupation, industry, labor union affiliation, marital status, gender, and race, designed to eliminate all wage differentials except those related to amenity values. It is my opinion that reported wage rates for specific occupations from major urban areas, when the jobs are carefully defined and in general demand, measure compensating differentials more accurately.

The BLS reported data from 49 cities for secretaries, auto mechanics, and computer programmers; and on word processors (43 cities) and tool and die makers (36 cities). The Area Wage Survey published some of these earnings as weekly and others as hourly; moreover, some require more human capital and earn more annually. Consequently, I converted all earnings to percentage differences from the mean. In other words, for each occupation the percent earnings in each city was expressed as a percent of the mean earnings for that occupation in all cities. After eliminating areas without any published temperatures, there were 224 observations of earning differentials. Average annual temperatures existed for only 221 observations.[26]

*Empirical Results*

The equations that fit the data the best employed as independent variables one of the measures of annual temperature, together with the log of the population of the metropolitan area in 1990 and the difference between the average maximum temperature in July and the average minimum temperature in January (Seasonal Change). To measure differences in the rate of growth of demand by cities, I included the change in population from 1980 to 1990 but found that it added nothing to the results. In addition, a number of independent variables that might plausibly affect the desirability of various metropolitan regions were tried, including the crime rate, days that the city was in violation of EPA's ozone standard, heating days, cooling days, proportion of the population in the central city that was black, annual precipitation, plus a dummy variable for the south. None of these was significant. Table V gives the results for the various regressions.

To test whether it was appropriate to combine all the occupations into one regression, dummy values for each occupation were added to regression 1 for the normal annual temperature. The results, given in Appendix Table A1, are not significantly different from those in Table V.

These regressions indicate that workers prefer warm climates to cool and that they also prefer climates with substantial seasonal changes in temperatures Annual temperatures appear to be more significant than summer (cooling days) or winter (heating days), although regressions with those variables have slightly higher R squares The overall significance, as measured by the F-statistic, is higher with annual temperatures than with cooling days. Although not shown in Table V, these regressions were also run using average July temperatures and average January temperatures with similar but less significant results. Precipitation has a small and marginally significant effect in the cooling and heating equations. The last line in the table presents the gains from a warming of 4.5°, assuming that seasonal variation and precipitation remain unchanged. As may be seen, the gains might be as low as $30 billion or as high as $100 billion. Hoch's work, as reported above, implies a gain of about $50 billion, a figure well within the range predicted.

Should warming lead to a bigger boost in winter temperatures and a smaller rise in summer, as suggested above, the gain from higher temperatures would be offset in part by a de-

26 Atlanta, Baltimore, Boston, Charlotte, N C , Chicago, Cincinnati, Cleveland, Columbus, Ohio, Dallas-Ft Worth, Denver-Boulder, Detroit, Houston, Jackson, Mass , Kansas City, Los Angeles, Louisville, Memphis, Miami-Hialeah, Milwaukee, Minneapolis, New Orleans, New York, Philadelphia, Phoenix, Pittsburgh, Portland, Oreg , Richmond, Va , San Diego, Seattle, St Louis, Washington, D C , Wilmington, Del -Md., Corpus Christi, Tex , Fresno, Calif , Huntsville, Ky, Newark, N J., Rochester, N Y, South Bend, Tampa, Worcester, Mass -Conn , and San Francisco

**TABLE V**
Regression Results of Amenity Benefits
(Percent Wages of Average 1987)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Seasonal Variation (Avg July-Avg January) | –0.004<br>(–7 87) | –0 004<br>(–6 75) | –0.004<br>(–7 72) | | | | |
| Normal Annual Temperatures | –0 007<br>(–7 35) | –0 006<br>(–6 46) | | | | | |
| Elasticity | –0 378 | –0 343 | | | | | |
| Annual Precipitation | | –0 001<br>(–1 90) | | | | | |
| Log of Annual Temperatures | | | –0 868<br>(–7 11) | | | | |
| Elasticity | | | –0 363 | | | | |
| Log of Population | 0 110<br>(7.76) | 0 103<br>(7 09) | 0 111<br>(7 77) | 0 092<br>(6.59) | 0 092<br>(6 64) | 0 090<br>(6 48) | 0 094<br>(6 89) |
| Log of Cooling Days | | | | –0 113<br>(–7 28) | –0 066<br>(–1.53) | | |
| Elasticity | | | | –0 048 | –0.027 | | |
| Log of Heating Days | | | | | 0.085<br>(1.26) | 0.181<br>(7 55) | 0 190<br>(8 07) |
| Elasticity | | | | | 0 035 | 0 075 | 0 079 |
| Log of Precipitation | | | | –0 075<br>(–2 94) | –0.51<br>(–1 90) | –0 045<br>–1.69 | |
| Log Seasonal Variation (Avg July-Avg January) | | | | –0 157<br>(–3 43) | –0 242<br>(–2 35) | –0 383<br>(–8 27) | –0 417<br>(–9.87) |
| $R^2$ | 0.403 | 0.413 | 0.395 | 0 418 | 0 428 | 0 422 | 0.415 |
| Adjusted $R^2$ | 0 395 | 0 402 | 0 386 | 0 407 | 0 415 | 0 412 | 0 407 |
| F-Statistic | 46.60 | 36.30 | 45.09 | 39 33 | 32 66 | 39 98 | 51.92 |
| Number of Observations | 211 | 211 | 211 | 224 | 224 | 224 | 224 |
| 1994 Gains (Billions) | $96 90 | $88 49 | $93 70 | $29.08 | $39.12 | $46 97 | $49.22 |

t-statistics in parentheses

cline in seasonal variation, leading to a smaller dollar benefit. If all the rise in temperatures came in the nighttime (9°F), thus boosting winter lows with no rise in the day, seasonal variation would fall by 9° and average temperatures would rise by 4.5°. In that case, based on regression (1), workers would be worse off by around $10 billion. On the other hand, if the rise in temperatures reflected the current relationship of average temperature to average winter temperature (rises by 1.5° for every degree the annual mean goes up) and average summer temperature (rises by only 0.9°) as mentioned above, using regression (1) in Table V indicates a gain of $10 billion annually.

*Analysis of Results*

As the first part of this paper has demonstrated, a warmer climate would reduce deaths. At a minimum, these amenity values may simply reflect premiums workers are willing to pay to reduce their risks of premature mortality. If it were currently warmer by 4.5° with a resulting reduction in deaths of 40,000 annually, as predicted above, and if these amenity values reflect workers' valuation of reduced mortality, they would be valuing lives at between $750 thousand and $2.5 million, a somewhat lower figure than others have estimated. Since most of the weather-related deaths, however, are probably among the elderly or the very young, workers may not value the reduction in deaths greatly. Compare these values with the *Statistical Abstract of the United States* [1994, Table 138] report of an average value of life based on their future earnings for all people in the United States of only $113,487

Moreover, in all likelihood these estimates of the amenity value of climate substantially underestimate the tradeoff workers would make for warmer temperatures. If a warmer climate reduces costs to business, for example, by lowering transportation expenses, rents will have to be bid up to achieve equilibrium. People attempting to locate in preferred areas raise land values as well. These higher rents mean that workers must be paid more to compensate. Thus this estimate of the value of a less frigid climate may be much too low. In addition, well paid individuals prefer to live in pleasant climates, typically raising average incomes even of those less skilled in the area.

## IV. CONCLUDING REMARKS

Although it is impossible to measure the gains exactly, a moderately warmer climate would be likely to benefit Americans in many ways, especially in health and in satisfying people's preferences for more warm weather. Most people would enjoy higher temperatures, and the evidence supports the proposition that humans would live longer and avoid some sickness. Less cold weather would mean less snow shoveling, fewer days of driving on icy roads, lower heating bills, and reduced outlays for clothing

No doubt many drawbacks to global warming exist, the most notable being the possibility of a rising sea level In addition, the beneficial results described above apply strictly only to the United States, although it seems likely that advanced industrial countries in the middle latitudes would benefit as well. These regressions provide no information on the effect of warming on health or mortality in tropical or poor countries, which might suffer health impairment from warming It would be useful to extend this analysis to the entire globe, but that would be very difficult. Not only does the climate vary greatly and incomes, which are difficult to compare, differ hugely, but cultural traits, including diet, are significantly different. Hong Kong, for example, has the longest life expectancy in the world. Is that because it is tropical, because it is rich, or because of its diet?

Moreover, it should be stressed that the evidence presented here is for a *moderate* rise in temperatures. If warming were to continue well beyond 4.5°, the costs would mount and at some point the health and welfare effects would undoubtedly turn negative.[27] Contrary to many dire forecasts, however, the temperature increase predicted by the IPCC under a doubling of greenhouse gases would yield both health and welfare benefits for Americans.

27 Adding minimum temperature squared or average temperature squared to regressions produced coefficients that were not only negative but insignificantly different from zero.

**APPENDIX TABLE A1**

Regressions with Dummies for Occupations

| | Coefficient | Standard Error | t Stat |
|---|---|---|---|
| Intercept | 1 1885 | 0 0832 | 14.28 |
| Ann Temp-Secretaries | –0 0065 | 0 0009 | –7 15 |
| Ann Temp-Word Processors | –0 0066 | 0 0009 | –7 16 |
| Ann Temp-Comp Programer | –0 0065 | 0 0009 | –7 07 |
| Ann Temp-Tool & Die | –0 0067 | 0 0009 | –7 28 |
| Ann Temp-Vehicle Mechanic | –0 0066 | 0 0009 | –7 23 |
| Seasonal Variation | –0 0044 | 0 0006 | –7 80 |
| Log of Population | 0 1113 | 0 0144 | 7 75 |
| $R^2$ | 0 406 | | |
| Adjusted $R^2$ | 0 386 | | |
| F-Statistic | 19 82 | | |

## APPENDIX TABLE A2

1979 County Variables

| | Death Rates | Percent Over 65* | Percent Black* | Median Household Income | Mean Temperature |
|---|---|---|---|---|---|
| Mean | 8 65 | 11.2% | 15 3% | $18,966 | 55.5 |
| Standard Error | 0 22 | 0.4% | 1.4% | $405 | 0 79 |
| Median | 8 5 | 10.9% | 11 7% | $18,364 | 54 1 |
| Standard Deviation | 2.04 | 0 038 | 0 135 | 3819 7 | 7 41 |
| Minimum | 4.1 | 4 5% | 0 75% | $10947 | 43 3 |
| Maximum | 16.5 | 30.7% | 70 24% | $30011 | 75 7 |
| Standard Dev/Mean | 0.24 | 0 34 | 0 88 | 0.20 | 0 13 |
| Count | 89 | 89 | 89 | 89 | 89 |

| | Cooling Degree Days | Heating Degree Days | Percent with 16 Years of Schooling | Lowest Temp | Highest Temp |
|---|---|---|---|---|---|
| Mean | 698 | 2546 | 19 6% | 1 9 | 95 6 |
| Standard Error | 54 | 116 | 0 7% | 1 8 | 0 4 |
| Median | 583 | 2657 | 18 8% | −2 0 | 95 0 |
| Standard Deviation | 510 98 | 1093.9 | 0.062 | 17.37 | 4 22 |
| Minimum | 69 | 108 | 6 8% | −27 9 | 88 0 |
| Maximum | 2344 | 4679 | 42 8% | 42 1 | 117.0 |
| Standard Dev/Mean | 0 73 | 0 43 | 0 32 | 9 29 | 0 04 |
| Count | 89 | 89 | 89 | 89 | 89 |

## APPENDIX TABLE A3

Amenity Regression Data for 48 Cities

| | Percent of Mean Earnings | Normal Annual Temp | Cooling Degree Days | Heating Degree Days | Seasonal Change |
|---|---|---|---|---|---|
| Mean | 100% | 56 9 | 1325 | 4183 | 39.2 |
| Standard Error | 0 012 | 1.07 | 140 7 | 289 6 | 1 70 |
| Median | 99 4% | 54 77 | 1089 | 4686 | 43.9 |
| Standard Deviation | 0 085 | 7 42 | 975.1 | 2006 5 | 11 78 |
| Sample Variance | 0 007 | 55 09 | 950773 | 4025887 | 138 83 |
| Minimum | 85 6% | 44 06 | 115 | 199 | 13 5 |
| Maximum | 120.9% | 75 56 | 4095 | 8007 | 61 9 |
| Count | 48 | 48 | 48 | 48 | 48 |

## APPENDIX B

Data Resources

A. *Wage Data*

Bureau of Labor Statistics, *Area Wage Surveys*, Specific Metropolitan Areas, 1987 The data are for all industries.

B. *Weather and Climate Data*

James Ruffner and Frank E. Bair, eds. *Weather of U S. Cities*, Third Edition, Detroit: Gale Research Co 1987.

U.S. Department of Commerce, NOAA, National Climatic Data Center, *Climatological Data Virginia*. January 1987–December 1989, Vol 97, No 1–Vol 99, No 12, Washington National WSCMO AP, Average Maximum, Average Minimum, Average Temperatures; and *National Summary*, Annual Summary 1979, Vol. 30, No 13.

*Statistical Abstract of the United States*, 1991.

C *Death Rates*

The National Center for Health Statistics, *Vital Statistics of the United States*, 1979, 1987, 1988, and 1989

D. *Demographic Variables*

*Statistical Abstract of the United States*, 1983, 1984, 1987, 1991 and 1994

*County and City Data Book* 1983 and 1988

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