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OXIDANT AIR POLLUTION AND WORK PERFORMANCE OF CITRUS HARVEST LABOR

Health Effects Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
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by

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FOREWORD

The many benefits of our modern, developing, industrial society are accompanied by certain hazards. Careful assessment of the relative risk of existing and new man-made environmental hazards is necessary for the establishment of sound regulatory policy. These regulations serve to enhance the quality of our environment in order to promote the public health and welfare and the productive capacity of our Nation's population.

The Health Effects Research Laboratory, Research Triangle Park, conducts a coordinated environmental health research program in toxicology, epidemiology, and clinical studies using human volunteer subjects. These studies address problems in air pollution, non-ionizing radiation, environmental carcinogenesis and the toxicology of pesticides as well as other chemical pollutants. The Laboratory develops and revises air quality criteria documents on pollutants for which national ambient air quality standards exist or are proposed, provides the data for registration of new pesticides or proposed suspension of those already in use, conducts research on hazardous and toxic materials, and is preparing the health basis for non-ionizing radiation standards. Direct support to the regulatory function of the Agency is provided in the form of expert testimony and preparation of affidavits as well as expert advice to the Administrator to assure the adequacy of health care and surveillance of persons having suffered imminent and substantial endangerment of their health.

The economic impact on individuals from exposure to high oxidant concentrations may be reflected in many forms. This study attempts to measure in economic terms one of these forms - the effect on worker productivity. The results of this study indicated that the average income citrus workers in Southern California was reduced by approximately two percent when working in areas where oxidant concentrations were high. Considerable differences in performance levels of workers were noted when exposed to similar environmental conditions. This report represents the first attempt to document the economic cost of reduced productivity, a very important and frequently neglected social cost of air pollution.

John H. Knelson, M.D.
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PREFACE

This project was initiated in the summer of 1975 while the authors were at the University of California, Riverside. Dr. Donald Gillette of the Health Effects Research Laboratory of the U.S. Environmental Protection Agency originally suggested the research. Professor Lester Lave of Carnegie-Mellon University, Professor Jon Nelson of The Pennsylvania State University, Professor Wallace Oates of Princeton University, the Resource Economics Group at the University of New Mexico, and Professors Ralph d'Arge, Robert Rowe, and Todd Sandler of the University of Wyoming have all provided helpful comments. Personnel of the Statewide Air Pollution Research Center of the University of California, particularly Dr. C. Ray Thompson, have under rather trying circumstances, greatly expedited administrative details of the project. Computational assistance has been provided by the University of Wyoming Computer Center.

ABSTRACT

This project assesses the effect of photochemical oxidants on the work performance of twelve individual citrus pickers in the South Coast Air Basin of southern California. A model of the picker's decision problem is constructed in which oxidants influence the individual's picking earnings and leisure-time via a short-term and reversible morbidity effect. Circumstances are specified under which this effect can be interpreted as the additional earnings the individual would have to receive in the presence of oxidants in order to make him indifferent to the presence of oxidants. This Hicksian compensating surplus is estimated separately for each of twelve individuals. In terms of absolute dollar magnitudes, compensating surpluses appear to range from less than twenty dollars to nearly two hundred dollars over an entire calendar year, given the piece-work wage rate scales and the levels of air pollution prevailing in the South Coast Air Basin during 1973 and 1974. As a percentage of what individual earnings would have been in the absence of air pollution, the dollar magnitudes range from three-tenths of one percent to nine percent. The average is about two percent. All estimates of the compensating surplus are conditional upon the individual not adjusting the hours he picks in response to air pollution.

Estimates give fairly strong support to the hypothesis that air pollution impact, measured in terms of the compensating surplus, tends to increase with increasing numbers of hours worked.

No tendency was found for the individual to substitute leisure-time for work-effort as ambient oxidant levels increased. However, the procedures employed to estimate this relationship could have biased the results.

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Chapter 1
INTRODUCTION

Upon having acquired some familiarity with the epidemiological literature reviews attempting to document the covariation of health effects and air pollution, one is struck by the frequent inability of these reviews to discover a substantial number of consistent findings for the effects thought to be caused by any one pollutant. Various reasons are typically advanced for this lack of consistency: inadequate characterization of the pollutants; the use of noncomparable, and sometimes questionable, estimating techniques; failure to account for other environmental influences and self-induced health stresses; failure to distinguish between pollution levels at work and at home; lack of attention to the difference between indoor and outdoor pollution; and other factors.[1] Nowhere in this refrain is it pointed out that epidemiology lacks an analytical framework in which the objects of study, human beings, are viewed as being capable of choice. In particular, the health effects of air pollution are usually treated as being absolute, even though all epidemiological findings are statistical inferences drawn from a sample of individuals with minds of their own. Basically, a set of inputs, including air pollution is posited to exist and these inputs are considered to be combined, on grounds of some _a priori_ investigator knowledge about exogenously determined physical and biological associations, to produce an output, an observed health effect. The epidemiological literature generally fails to recognize that to the extent health effects are subject to fixed economic and non-economic constraints, these effects have to be measured on norms endogenous to the individual human being. Attempts to explain the etiology of observed health effects must recognize that these individuals use different input mixes and magnitudes because: (1) they face different sets of relative prices for various combinations of preventive and ameliorative health care; (2) they have different biological endowments, measured and nonmeasured; and (3) they succeed to varying degrees, in the presence of uncertainty, in maximizing utility. Most epidemiological effort accounts for only the second of these considerations, even though remedial measures to combat pollution-induced health effects may differ, depending on whether the etiology of the health effects depends on economic or biological factors. One purpose of this study is to provide an example, albeit an incomplete example, of how microeconomic analysis permits the introduction of the first consideration into an empirical study fundamentally epidemiological in emphasis. No serious attempt is made, however, to show how the analytical framework of the study might be generalized to encompass a broad variety of epidemiological problems. Nevertheless, although no effort will be made to do so here, it will be fairly apparent that the analytical framework is easily generalized to account for the third consideration. The typical epidemiological study of the health effects of air pollution might capture the health effects that lie in people's stars; it fails to capture the health effects that lie in people themselves.[2]

A second and perhaps less controversial motivation for this study is to provide and apply an analytical framework for assessing the economic effects of environmental pollution upon the performance of inputs, particularly labor inputs, in production processes. Nearly all studies of the economic effects of environmental pollution view changes in relative market prices as being demand-induced.[3] Constant relative unit supply prices as between and among outputs are assumed. However, any change in process productivity necessarily alters the price the producer must receive in order to be willing to supply a given quantity of an output good. These productivity changes therefore also constitute a source of change in output market prices. Failure to consider the impact of pollution upon supply means that an important facet of the total economic effect of environmental pollution is being neglected. Although the present study is limited to estimating the effect of air pollution upon worker performance, it does provide an example of a necessary step in any attempt to ascertain the ultimate economic impact upon the market price of the outputs the workers cooperate in producing.

Those studies of the economic effects of environmental pollution upon inputs that have been performed are known as materials damage studies.[4] They have two distinguishing common characteristics. First, they focus entirely upon specific inputs without devoting attention to the manner in which the inputs are involved in a production process. This study appears to be the first dealing with a particular input that explicitly accounts for the producer's decision problem.

A second distinguishing characteristic of the materials damage studies is their fixation on nonhuman inputs. Except for a few rather rough efforts employing highly aggregated data, the economics of the effects of environmental pollution upon worker performance has been left undone. Perhaps the reason is that data drawn from the performances of individual workers doing jobs requiring substantial physical exertion in an occasionally highly polluted environment have been lacking. Data of this sort were available for this study.

Finally, there currently is virtually no evidence bearing upon the economic effects of photochemical smog.[5] In spite of this, quite stringent ambient air quality standards have been adopted for the various chemical precursors of smog as well as for the mixture that results from atmospheric transformation processes. Although it cannot be expected that the effects established in these pages constitute a large portion of the total negative economic effects of photochemical smog, the results provide defensible evidence that these effects do in fact exist.

In succeeding chapters, the effect of photochemical smog upon the work performance of citrus workers is investigated. The next chapter describes the analytically relevant features of the market setting for the empirical efforts reported in the fifth and the sixth chapters. A third chapter is both a summary of the data base available for the study and a commentary on the deficiencies of this data base with respect to the analytical model presented in the fourth chapter. A final chapter summarizes the study, points out its limitations, and suggests how more information might be gleaned from the same data base.

Footnotes: Chapter 1

1. For an extension of this list, see Commission on Natural Resources (1975) 58-169.

2. A recent paper by Smith (1975) tends to support the argument of this paragraph. In applying the Ramsey tests for specification error to some thirty-six epidemiological studies on air pollution and mortality, Smith found that not a single one of the studies met the Ramsey tests for the absence of this error!

3. The studies used by Waddell (1974) are almost entirely of this sort.

4. Waddell (1974) lists several such studies.

5. The only really careful study available appears to be Nelson (1975).

Chapter 2
THE EMPIRICAL SETTING

The Setting. This study deals with the men and women whose primary occupation is the harvesting of citrus fruit in the South Coast Air Basin of southern California. The object of the study is to ascertain whether their work performance is influenced by the presence of photochemical smog. The occupation of citrus harvesting has the ease of entry and exit, the geographical and numerical scope, and the absence of idiosyncratic (i.e., heterogeneous, highly differentiated, task-specific skills enabling the current occupant to possess a degree of monopolistic advantage) characteristics that Doeringer and Piore (1971) term the secondary labor market. Harvesting operations in citrus groves are highly labor-intensive activities for which there at present exist no economic substitutes for hand-labor. A substantial number of workers choose to be employed on a year-round basis and are thus exposed to varying air pollution levels over the year. Since the citrus harvest occurs in both high and low smog months, many individuals work during periods of relatively low and relatively high smog levels.

Except for backyard citrus trees, citrus is a crop which even in the smallest commercial groves has harvest labor requirements well in excess of any labor supply the family of the owner is likely to be able to provide.[1] Rosedale and Mamer (1974, p. 11), in a study of harvest operations in Ventura County, the center of California's lemon industry, indicate that from 1966 through 1972 eighty-five to ninety percent of harvest costs were direct labor costs. In an earlier study of the Ventura County lemon industry Smith, et. al. (1965, p. 4) state that "...all labor and material costs for lemon production on the tree averaged eighty-five cents per field box." Forty-five cents of this sum was picking cost.

There appears to have been very little change in citrus harvest labor productivity over the years. Our data indicate that the representative worker picks about 1900 pounds of lemons and 3000 pounds of oranges per eight-hour work day. Fellows (1929, p. 71) indicates that in 1929 these rates corresponded to 1750 pounds of lemons and 3000 pounds of oranges. Although mechanical harvesting aids and systems do exist, the U.S. Census of Agriculture (1973, pp. 6, 29) shows that, in the 1968-69 season, of 764 reporting California lemon growers who harvested nearly 700 million pounds of lemons, only six growers, harvesting a total of less than five million pounds of lemons, used harvesting machines. Similarly, of 1969 California orange growers reporting slightly more than two billion pounds of oranges harvested, only sixteen growers, whose aggregate harvest was 11.7 million pounds of oranges, employed machines for picking. For both technological and economic reasons, it would appear that picking labor is an integral and necessary part of the California citrus industry.

Harvest operations in the California citrus industry are typically organized around large packing-houses that are either privately owned and usually specialize solely in harvesting, packing, and marketing, or are grower cooperatives (e.g., Sunkist Growers) who participate in all facets of citrus production. Many growers turn their harvest operations almost entirely over to the packing-houses, permitting picking policies and the sequence of picks across different owners' groves to be established by the packing-house management. This management is said to have a general idea at any particular time of the sequence in which groves are to be picked, but the initially selected sequence is subject to alteration according to weather conditions, the rate at which fruit in particular groves is ripening and growing, and other factors. Orange picking activities are said to be somewhat less subject to plan alterations of this sort than are lemons. This perhaps is due to the fact that at least some lemons are normally picked every week of the year, while the picking times for orange varieties are more limited in the choice of harvest dates. The marketing of oranges appears to be similarly concentrated in time. Table 2.1 below gives the relevant picking and marketing calendar time intervals for southern California lemons and oranges. The geographical area to which the table refers roughly corresponds to the climates prevailing over the South Coast Air Basin.

Table 2.1

Annual Harvesting and Marketing Cycles for Southern California Citrus

	Lemons	Oranges: Early, Midseason, Navels	Oranges: Valencias
Full bloom dates	March 5-Dec. 30	March 5-March 30	March 5-March 30
Begin harvest	Aug. 1	Nov. 20	March 10
Most active harvest	Jan. 15-July 15	Dec. 15-May 15	May 10-Oct. 25
Begin marketing	Aug. 1	Nov. 25	March 15
Most active marketing	March-July 15	Dec. 20-May 20	May 15-Nov. 1
End marketing	July 31	June 15	Dec. 20

Source: Statistical Report Service (1975, pp. 40-44).

Within the range of prices that have prevailed since World War II, the consumer demand for fresh citrus fruit as well as processed citrus fruit is thought to be relatively price inelastic.[2] However, given that citrus fruit is often stored for as long as six months with only moderate spoilage, an individual grower is unlikely to exercise meaningful influence upon market price via his harvesting and marketing decisions. A further implication is that the size of the crop and factors such as weather, rather than market price, will be the primary influences upon the quantity and temporal distribution of harvest labor requirements, assuming, of course, that the price and availability of labor does not exhibit substantial seasonal fluctuations. Interviews with packinghouse managers have confirmed that market prices expected during the next one to six months in a particular harvest year have little or no influence upon the choice of harvest dates although, in exceptional circumstances, expected prices may determine whether the season's fruit in a particular grove will be harvested at all.[3] In effect, therefore, over a fairly wide range of piece-work wage rates for harvest labor during a particular growing season, there will be near-zero covariation between this wage rate and the number of harvest labor man-hours expended in a particular grove. The man-hours expended will primarily be a function of the amount of fruit in the grove.

The individual picker is part of a picking crew that, according to the stage in the picking cycle, may be as small as ten people and as high as forty people. A typical size appears to be about thirty people. The crew is supervised by a foreman who is paid in proportion to the amount of fruit his crew picks. This foreman is responsible for getting the pickers and equipment to the grove to be picked and for maintaining his crew at the desired size. Once in the grove, the foreman tries to assure that the fruit is picked in accordance with the specified conditions. He also maintains a record of the amount of fruit picked by each picker.

Over each crew foreman is a salaried field superintendent. This superintendent answers to the general manager of the packing-house or growers' cooperative and is responsible for the over-all operation and coordination of harvesting and grove maintenance activities within and among groves and growers. In the great preponderance of situations where the piece-work wage rate for pickers varies with the relative difficulty of picking conditions, it is he, prior to the entrance of pickers into the grove, who estimates the relative difficulty of the picking opportunity and thereby establishes the piece-work rate to apply to the particular grove. In the words of one packing-house manager, the base rate that is adjusted according to the degree of picking difficulty is established in accordance with "prevailing market conditions."

Frequently, the responsibility for securing a suitable labor supply for harvesting purposes is transferred from the packing-house or cooperative to a labor contractor, a specialist in the recruitment and supervision of citrus workers. Crew foremen are then employees of the contractor rather than the packing-house or cooperative, although the actual performance of crews will continue to be monitored by a field superintendent. Pickers are paid for their production performance by the contractor and it is he who sets the piece-work wage rate for each grove. The contractor, in effect, assumes the functions and associated risks of picker recruitment, supervision, payment, and provision of whatever picker life support facilities are standard. In return, the contractor is guaranteed a certain rate of compensation. The labor contractors involved in the present study all appear to have had long experience in their business and to have rather large operations. They have made the flow of their business regular and routine and depend upon established customers and a large number of workers who have been previously employed by them and to whom they can offer fairly regular employment.

The Mechanics of Picking Citrus Fruit. Actual picking procedures for lemons and for oranges have many common features but they also differ in several important respects. The differences tend to be due mainly to the fact that during any one season the fruit in a lemon grove does not mature for picking purposes at the same time but instead is distributed over much of the year. This means that any single grove might be picked as many as four times in a given season. During the first three picks, only the fruit that is "up to size" is picked. In order to ascertain whether a given piece of fruit is of picking size, the picker must manipulate a measuring device. In addition, as he must also do when picking oranges, he must avoid damaging the fruit quality by leaving long stems, cutting the point at which the stem is attached to the fruit, or pulling the fruit off the tree. Only during the terminal or "strip" pick does the picker take all lemons from the grove. In contrast, all orange picking activities are "strip" picks. Further intensifying the difficulties of picking lemons relative to oranges is the fact that lemon trees have thorns and are generally bushier than orange trees. In fact, lemon pickers typically wear rather heavy clothing and shoulder-length, rather awkward looking gloves in order to protect their persons from the thorns. Many individuals specialize in lemon-picking and will pick oranges only when there are no lemons available; whereas relatively few people who primarily pick oranges will pick lemons in the absence of oranges.[4]

Apart from the degree of difficulty of the picking operation, the actual mechanics of picking of the two types of fruit appear to be identical. Citrus groves in southern California are universally planted in long, straight rows so as to facilitate irrigation, maintenance, and harvesting activities. Upon the arrival of pickers in the grove, the grove is divided according to "drive" rows down which a collection device (e.g., a truck) periodically makes an appearance. Individual pickers are then assigned row sets of three trees on both sides of the drive row. Each picker is usually initially assigned the same six rows with which to initiate his picking activities at each new grove. The ease of the pick for the first row set thus varies randomly from grove to grove for each picker. Only this first row set is assigned. After the initial assignment, the pickers leapfrog, although unless there are only a small number of rows remaining, once a picker starts a row it is his to complete. In cases where the number of remaining rows is inadequate for a one-to-one correspondence between pickers and rows, everyone picks what remains.[5] These procedures appear to vary not at all among groves.

Citrus pickers are paid on a piece-rate basis; that is, each picker is paid a unit price for the quantity of fruit he picks rather than the number of time units he expends. The relative ease of picking therefore helps to explain the quantity of fruit he picks and the amount of money he earns for any given time interval during which he picks. Seamount and Opitz (1974) disaggregate the picking activity into three facets: net picking time; time moving within and between trees while picking; and time moving to and from field containers and dumping fruit into these containers. The proportion of time passed in each of these three facets will vary according to whether the picker is engaged in skirt or ladder picking. Ladders are used with trees the fruit of which cannot be reached with both feet on the ground. Ladder picking is thought to slow the picker's rate of pick by forty to sixty percent relative to skirt picking.[6]

Net picking time is the picking act of searching, reaching, clipping, and placing the fruit in the bag the picker has hanging diagonally across his shoulders and carries on his hip. For ladder strip picks, it accounts for sixty percent or more of the picker's time and more than five minutes per standard 3115 cubic inch field box.[7] Seamount and Opitz (1974, p. 165) list the following nonpicker factors as probably influencing net picking time: fruit density; distance of the fruit from the picker; fruit size; fruit stem characteristics; tree leafiness; picker orientation; platform stability; freedom of various picker body members; portion of the tree being picked; and tree height, diameter, and surface characteristics.

Frequency of movement within and between trees is though to be related to fruit density, fruit clustering, and ease of reaching the fruit.[8] The trees in most citrus groves are planted sufficiently close together so that movement between trees is thought to have little or no influence on rate of pick. The speed with which others in the picker's crew pick could have some influence on the individual picker's rate of pick since it can influence the distance he has to move among row sets. However, movement from one row set to another by a single picker is sufficiently infrequent to make it implausible that the factor has other than trivial importance to the rate of pick. For strip picking with ladders and for an extremely small sample of pickers' time, moving within and between trees an average of about one and one-half minutes per 3115 cubic inches in box of fruit is required.[9]

Transporting the picked fruit from the row sets to field receptacles placed in the drive rows and dumping the fruit into these receptacles consumes an average of about forty seconds per 3115 field box for most pickers.[10] Little other than the roughness of the terrain is thought to influence this facet of picking activity. Movement from one grove to another is thought by Seamount and Opitz (1974, p. 169) to be a greater influence.

In most respects, the citrus picking endeavor is ideally suited to application of the piece-work wage rate. Output is readily defined, measured, and monitored, the results of each picker's efforts are separable from those of other pickers, and the difficulty of the worker differentiating his task from the tasks of other pickers (thus making it hard for him to argue that his task is in some sense "more difficult") all serve to make it easy to assign the entire responsibility for perfunctory work performance solely to the individual picker himself.

Grove factors are, of course, likely to be the major influence upon differences in the individual picker's rate-of-pick from one time period to another. However, it should be noted that the responses of individual pickers to these factors can differ greatly from one picker to another. Thus, one must be extremely cautious, in trying to generalize from the responses of a few pickers to the entire picker population. This caution is well supported by some of the findings of Smith, et. al. (1965), with respect to lemon pickers. While studying an "example" crew, they noted that the fastest worker picked an average of 3.375 field boxes per hour while the slowest picked only 1.750 field boxes per hour. The crew mean was 2.570 boxes per hour with a standard deviation of $\pm$ 0.389 boxes per hour.[11] In a separate sample of 2500 pickers only 24 percent of the total variance in rate of pick could be accounted for by grove factors, while 64 percent was accounted for by variations in pickers.[12] They also note that variations in rate-of-pick appear to be much greater among U.S. citizens than among the Mexican nationals working in identical groves.[13]

The Wage System. As earlier noted, citrus pickers are paid by the quantity of fruit they pick rather than by the number of hours they work. Pickers having two or three months of experience who are unable to earn the minimum wage regularly are simply terminated.[14] Three different classes of means of determining the piece-work wage rate for a particular grove on a given day appear to prevail. Two of the three are, in effect, sequential spot contract systems in which the picker and his employer are continually renegotiating on terms that must be satisfactory to picker and to grower. The three classes may be distinguished according to the extent to which and the manner in which the factors that contribute to the difficulty of picking are taken into account.

The most sophisticated means of determining piece-work wage rates per box of fruit picked is employed for lemons. This means is simply a component of a labor management system designed to reduce rates of picker turnover and absenteeism and thereby lower grower screening and recruiting costs for pickers as well as reducing the likelihood of having to reallocate inputs because of the unexpected absence of a picker. Unless the grower has available a perfect substitute at equivalent cost, each picker who quits or each day a picker is absent means that the grower must, at a cost, attempt to adjust either by juggling the distribution of tasks among the remaining workers or by initially hiring more workers than the picking process requires in order to ensure duplication of the services of absent or terminated pickers. The motivation is to do away with the historically casual nature of the supply of pickers to lemon growers. In order to enhance the likelihood of assuring themselves a reasonably stable labor supply of more-or-less known quality, the lemon growers have tacitly shifted part of the risk of the picker's uncertain income stream and living conditions to themselves; that is, by providing health, disability, unemployment, and life insurance, retirement plans, explicitly stated promotional tracks, paid vacations, and other accoutrements of the modern industrial blue or white collar worker, the growers have to some degree transferred many risks that historically have accrued to the picker to the income streams of the growers and their creditors.[15]

One major means California lemon growers have adopted to unburden the picker of variability in his income stream is to adjust piece-work wage rates in accordance with the degree of difficulty in picking conditions.

The more difficult the picking chance, the higher the piece-work wage rate. For lemon pickers, the wage per box of fruit picked associated with each combination of three key grove variables that supposedly influence the rate of pick are published and are applicable for several weeks or perhaps an entire season. Table 2.2 presents a pay schedule used in Ventura County during the middle 1960's. The pay schedules relevant to lemon picking in the current study are identical in structure, although the piece-work wage rates have been altered over time.

As Table 2.2 indicates, the supposedly influential variables are the number of fruit on the tree that meet the specified conditions (e.g., color), size of fruit, and tree height. The values of these variables are recorded at the time of picking for each grove in which the picker's crew works.

Since all fruit meeting prespecified conditions is to be picked, a picker's earnings in any particular grove are then the number of boxes of fruit he picks multiplied by the per box wage rate as determined by the fruit density, fruit size and tree height in the grove. It should be noted, however, that these three grove variables do not always completely determine the per box wage rate, for they do not capture all grove attributes thought to contribute to the relative difficulty of picking. For example, as mentioned elsewhere, the slope of the ground in the grove and the bushiness of the tree are also influential. In groves where variables in addition to the three variables mentioned above are thought to be relevant, the foreman of the picker crew apparently announces the adjustment before the picking performance. Moreover, since all fruit meeting prespecified conditions is to be picked, pickers have little, if any, incentive on a particular day to urge each other to slow the rate of pick, given that all pickers are at least earning the minimum wage. To do so would reduce the earnings of the better pickers without enhancing the earnings or reducing the required work effort of the slower pickers. Of course, the schedule of the per box wage rates with respect to a particular grove variable might be adjusted over time if it became particularly noticeable that certain pickers were receiving earnings greatly in excess of what might normally be expected. This adjustment might redound to the disadvantage of those pickers whose performance was not so responsive to variations in the variable in question. It is then conceivable that the latter pickers might urge the former

Table 2.2

Rates of Pay in Cents per Box for Lemon Picking, by Tree Classes, Yields, and Fruit Size, Ventura County, 1964.

Yield	Class I*			Class II			Class III			Class IV		
	Fruit size (number per box)											
	Under 240	240-300	Over 300	Under 240	240-300	Over 300	Under 240	240-300	Over 300	Under 240	240-300	Over 300
bxs/tree**	cents											
0-1/4	47	56	70	57	64	75	66	72	79	78	86	95
1/4-1/2	41	46	53	48	54	59	55	60	66	67	73	81
1/2-3/4	36	40	45	42	46	51	47	51	56	58	63	70
3/4-1	33	37	41	38	42	45	42	46	50	52	56	62
1-1 1/2	31	33	36	35	38	41	38	41	44	47	51	54
1 1/2-2	29	31	33	32	35	37	34	37	41	43	46	50
2-3				30	32	35	31	34	38	38	42	46
3+							28	32	36	35	39	43

*Tree classification:
Class I - Picked without a ladder.
Class II - Ladder-picked trees less than 9 1/2 feet tall.
Class III - Ladder-picked trees 9 1/2 to 12 feet tall.
Class IV - Ladder-picked trees over 12 feet tall.
**Field box capacity: 2,926 cubic inches.

Source: Smith, <u>et. al.</u> (1965, p. 6).

pickers to reduce their performances. Nevertheless, since there are several thousand pickers employed in any one crop season,[16] it does not seem far-fetched to view the picker as a wage-taker; that is, he acts as if his picking performance does not influence the per box wage rate he will receive and, furthermore, other pickers act as if he does not influence the per box wage rate they receive.

The second class of means of determining the piece-work wage rate is considerably less formal. It is what is in effect a sequential spot contracting system found in orange harvest efforts where the grove variables likely to influence picking performance differ from one grove to another. Even for those crews who, when picking lemons, work under a published fee schedule that matches wage rates to combinations of picking conditions, the per box wage rate applicable to a particular orange grove is only determined shortly before the entrance of the crew into the grove. Upon the discovery that the prior determination of the wage rate does not accurately reflect picking conditions, this wage rate may be adjusted. However, at least for the crews for whom we collected data, the wage-rate was never reduced after entrance to the grove. It was only increased and then only infrequently.

Finally, for sets of groves that are extremely uniform in quality and for which pickers will therefore be picking for extended periods of time under more-or-less uniform conditions, piece-work wage rates are established only in accordance with the labor supply and demand conditions prevailing at the beginning of the season or picking period. This, of course, raises the possibility that faster workers may be urged by their slower fellows to reduce their picking rates so as to reduce the possibility of management demands to raise average performance levels. Management is undoubtedly aware of these group pressures but, to judge from the pay system they have adopted, it apparently feels that the cost of the loss in picker productivity is outweighed by the cost reductions due to not having to keep detailed picker performance and grove attribute records when groves do have uniform attributes. In any case, for the data we possess, it is only in the Irvine area where this could constitute an analytical problem.

<u>A Review of the Salient Features</u>. Since the purpose of this study is to estimate the response of the citrus picker's work performance to variations in air pollution, an analytical model of the picker's decision problem is

required in order to generate testable hypotheses. Most important, the model must be a reasonable representation of reality. From the discussion of the preceeding pages, the following salient features of the market for citrus picking labor can be culled. It is desirable to account for these features in any model of the picker's decision problem.

1) At least on the supply side, the market for citrus pickers embodies the major feature of a competitive labor market, i.e., the individual picker is a wage-taker.

2) The picker is paid entirely on a piece-work basis.

3) Entry into the market is easy. Exit appears to be even easier.

4) The market has substantial geographical and numerical scope.

5) Citrus picking, at least for any single variety, is a homogeneous activity for which individual pickers cannot differentiate their particular tasks from those of other pickers.

6) The citrus harvest is a highly labor-intensive activity. Except for ladders, cutting shears, and bags into which to deposit picked fruit, complementary capital inputs exercise little, if any, influence on the individual picker's output. Moreover, there are no good economic or even technical substitutes for the individual picker.

7) Market price of citrus fruit is not a primary influence on the quantity and temporal distribution of harvest labor requirements within a single harvest season.

8) The picker's output is readily defined, measured, and monitored.

9) Picking procedures are standardized from one grove to another.

10) While picking a particular grove, picking procedures do not require the picker to take involuntary leisure.

11) Each picker's efforts are separable from those of other pickers.

12) A learning curve of two or three months duration exists for picking citrus fruit.

13) Substantial differences are known to exist among pickers in the responses of their picking rates to certain grove attributes.

14) The citrus picker's immediate supervisor, the picking crew foreman, is typically paid on the basis of the quantity of fruit his crew picks per unit time.

15) A salaried field superintendent from a growers' cooperative or a packing-house oversees the crew foreman.

16) For given labor market conditions, piece-work wage rates vary with the degree of picking difficulty in a particular grove.

17) The piece-work wage rate is set by the crew foreman or field superintendent before initiation of picking activity in a particular grove. However, this wage rate may later be modified if initial expectations about picking conditions are not fulfilled.

18) During a particular harvest season, the individual grower is a price-taker for both his fruit crop and his use of harvest labor.

Footnotes: Chapter 2

1. In a study of family and hired labor on U.S. farms, Sellers (1966, p. 35) states, in effect, that all commercial citrus growers employ hired labor.

2. See Bell (1965, p. 4).

3. Interview of the first author with Mr. Robert Lamberson and Mr. Edward Ruiz of Upland Lemon Growers, March 11, 1976.

4. Interview of the first author on March 12, 1976, with Mr. Xavier Piedra, Manager of the San Gabriel Valley Labor Association.

5. The description in this paragraph is a synthesis of conversations of the first author with Mssrs. Lamberson, Ruiz, and Piedra, as well as Mr. Mack Garcia of the River Growers Association in East Highlands, California.

6. Seamount and Opitz (1974, p. 165).

7. Ibid.

8. Ibid., p. 167.

9. Ibid.

10. Ibid.

11. Smith, et. al. (1965, p. 20).

12. Ibid., p. 36.

13. Ibid., p. 23.

14. Smith, et. al. (1965, pp. 46-51) state that this occurs. Interviews of one of the authors with labor camp managers confirmed the Smith, et. al. statement.

15. See Manpower Administration (1969) and Rosedale and Mamer (1974) for detailed descriptions of the features of the system. The description offered in the latter source which, among other things, refers to special leaves, birthday greetings and cake, counseling, and legal aid, Christmas greetings, adult education, and entertainment, is reminiscent of newspaper accounts of the Japanese firm or perhaps an academic environment. Mr. Jack Lloyd of the Coastal Growers Association in Ventura County is widely credited with developing the system. Insights into the motivations for developing the system are available in Smith, et. al. (1965, pp. 14-19). A study of the variability of the degree of risk-shifting

from pickers to growers with respect to such factors as the productivity and dependability of the picker, the market for lemons, societally provided benefits, labor supply, and other factors would be most interesting. At the abstract level, a framework for approaching these questions is to be found in Alchian and Demsetz (1972) and Crocker (1973). A much more thorough development is presented in Azariadis (1975).

16. Rosedale and Mamer (1974, p. 19) state that in 1973, 3335 pickers were employed by the Coastal Growers Association of Ventura County alone.

Chapter 3

THE DATA BASE

Description. Two classes of data make up the empirical basis of this study: (1) observations on indicators of picker work performance such as boxes of fruit picked and hours worked; and (2) observations on the conditions under which the picker worked such as the piece-work wage rate and grove and environmental conditions. These two data classes are available on no less than a day-to-day basis for each individual picker studied. Air pollution and temperature data are usually available on an hour-by-hour basis. Since no systematic effort was made to collect data on individual picker characteristics such as age and state of health, no comparisons across individuals of the reasons for variations in work performance are possible.

Except for the air pollution and temperature observations, all data were acquired from records maintained by citrus packing-houses and labor camps in southern California. These packing-houses and labor camps were selected from a list supplied by Sunkist Growers Cooperative. Every packing-house and labor camp on the list was sent a copy of the original research proposal along with a letter explaining the type of data in which we were interested. The various packing-houses and labor camps were then contacted by telephone in order to ascertain their willingness to cooperate in the study and the nature of the data they possessed. The following criteria were developed for the collection of data from the packing-houses and labor camps during the summer of 1975. It should be recognized that the application of these criteria resulted in a nonrandom sampling of the citrus picker population.

1) The study is a panel study in which the objects of interest are the daily work performances of individual citrus pickers. Data files containing detailed information on the day-to-day work performances and conditions of individual pickers are therefore to be sought.

This perspective of the central objective of the study avoided the necessity of collecting possibly sensitive data on individual picker socioeconomic attributes such as age, state of health, etc. Each individual worker selected for study can then be treated as a separate and distinct study.

2) Most of the individual pickers for whom work performance and conditions data are acquired must have worked at times and locations where ambient concentrations of photochemical smog were substantially above background levels. Given that the central objective of the study is to ascertain the covariation of picker work performance and photochemical smog the rationale for this criterion is obvious.

3) Pickers are to be selected having near continuous records of employment as citrus harvesters during 1973 and 1974. The years 1973 and 1974 were selected because citrus growing conditions, according to packing-house managers, exhibited substantial differences between the years. Moreover, the most detailed ambient smog data was available for these years. Pickers with long employment histories during the two-year period were desired in order to maximize available degrees of freedom for hypothesis testing.

4) Pickers are to be selected having at least one year of experience in citrus harvesting. It is hoped that the application of this criterion negated any of the learning effects to which Smith, et. al. (1965, pp. 41-46), refer.

5) Pickers having relatively high, moderate, and low records of average daily earnings are to be selected. Although there was no intent in the study to make detailed explanatory comparisons of work performance among pickers, it was thought desirable that a set of pickers having a fair distribution of apparent potential productivities be selected. The reason was an intuition that the influence of air pollution upon picker performance might vary with the potential productivity of the picker.

In Table 3.1 is provided a listing of all picker performance and grove condition data obtained for 237 individuals, with 103 individuals from Upland (U) and Riverside (R), 60 individuals from Ventura (V), 32 individuals from Irvine (I), and 42 individuals from San Bernardino-Redlands (S).[1]

Temperature and air pollution data consist of records of a number of monitoring stations throughout southern California. These records are maintained on computer tape by the Statewide Air Pollution Research Center of the University of California, Riverside. Table 3.2 provides those temperature and air pollution monitoring stations by name that were used

Table 3.1

Individual Picker Performance and Grove Condition Data

A. Data Organized by Crew to which Individual Picker Belongs.

Data Description	Unit of Measure	Location
Calendar date	Day	U,V,S,I,R
Grove location	1/4 Section	U,V,S,I,R
Camp departure	Military time	U,S,R
Camp return	Military time	U,S,R
Picking initiated	Military time	U,S,I,R
Picking terminated	Military time	U,S,I,R
Wage rate	Cents per 3115 $in.^3$ box	U,V,S,I,R
Fruit type	Lemons, navels, valencias	U,V,S,I,R
Fruit size	Fruit per 3115 $in.^3$ box	U,V,I
Tree class	Height in feet	U,V
Average boxes picked per tree by crew	3115 $in.^3$ boxes	U,V,S,I,R
Total trees picked by crew	Trees	U,V,I
Tree age	Years	S

B. Data Organized by Individual Picker.

Data Description	Unit of Measure	Location
Work time	Hours	U,V,S,I,R
Boxes picked	3115 $in.^3$ boxes	U,V,S,I,R
Refused to work	(0,1)	U
Sick, did not work	(0,1)	U
No reason, did not work	(0,1)	U
Nonpicking work activity	Hours	U,V,S,I,R
Weekly gross income	Cents	U,V,S,I,R
Weekly net income	Cents	U,V,S,I,R
Lives in labor-camp	(0,1)	U,V,S,I,R

Table 3.2

Temperature and Pollution Stations

Grove Locations	Temperature Station Name	Pollution Station Name
Upland	Upland	Upland Civic Center
Ventura	Santa Paula (1973) Summit Fire Lookout (1974)	Santa Paula
San Bernardino-Redlands	San Bernardino	San Bernardino
Irvine	El Toro Air Station	El Toro
Riverside	UC, Riverside	Norco

for each of the general grove locations. All temperatures used in this study are maximum hourly arithmetic average dry-bulb temperatures in F^{o} on each work-day of interest. Air pollution measures are hour-by-hour arithmetic averages of ambient concentrations of ozone or oxidants in parts per million by volume.

Possible Sources of Measurement Error. Known as well as suspected measurement errors lurk throughout the data set used for this study. Some are perhaps sufficiently severe to intrcduce serious possibilities of bias into empirical estimates of relationships developed from the analytical framework of the next chapter.

Given the objective of this study, by far the most unkind source of measurement error is the air pollution data. The following quote, in a December 18, 1975, memorandum entitled Errors in Ozone/Oxidant Monitoring Systems from Mr. Roger Strelow, Assistant Administrator for Air and Waste Management, USEPA, to all USEPA regional administrators, succinctly states the most dismaying facet of the problem with the air pollution data,

> "Based upon results to date, we suspect that the existing data could possibly contain some positive and some negative errors... Therefore, I do not believe we should attempt to make any modifications to the existing data; we simply do not know what adjustments to make, or even if the data is generally too high or too low." (p. 3)

Earlier in the memorandum, Mr. Strelow notes that certain combinations of instrumentation, calibration procedure, and operator performance appear to result in a variable negative bias.

The above does not exhaust the sources of error in the air pollution data. With the exception of the air pollution and temperature monitoring stations relevant to the fruit harvesting sites in Irvine and Ventura, all monitoring stations are generally located five to eight miles from the groves. In both Irvine and Ventura, the monitoring stations are central to and only a short distance from all picking sites. However, in Upland, San Bernardino-Redlands, and Riverside the stations are in downtown areas and are typically at somewhat lower elevations than in the groves. The locations of these stations relative to the groves made it impossible, by triangulating among stations, to arrive at a weighted mean of harvest site air pollution concentrations and temperatures. Instead, the temperature and the concentration at the monitoring stations closest to the harvest site have in all cases been used as a measure of the temperature and air pollution at the harvest site. We have absolutely no basis for judging discrepancies in measures realized at the stations and the actual measures at the harvest site. If a guess is required we would assert, on no basis other than casual observation, that readings at the Upland, San Bernardino-Redlands, and Riverside stations were slightly higher for some hours on some days more frequently than they were slightly lower than the actual state of affairs in the groves. This assertion is made on the basis of the downtown locations and lower elevations of the monitoring stations; it is not an assertion we are anxious to defend.

Relative to the measurement errors in the environmental conditions data, sources of this error in the grove conditions and work performance data seem innocuous and limited indeed. Perhaps the most serious is the rounding-off of the number of hours a picker has worked to the nearest half-hour. In circumstances where the work-day has been rather short, this could lead to some bias in estimates, although it seems likely that there is no systematic bias with respect to the sign of the error.

It is possible that error exists in the size-of-fruit variable, when observations on this variable are available. Typically, the daily value for this variable is determined by having the foreman of the picking crew select five boxes of fruit harvested that day from the grove being picked. The total number of fruit in the boxes divided by five then represents the "size-of-fruit" recorded for determining the piece-work rate of pay. Although an effort is apparently made to select individual boxes from a number of locations within a particular grove, a sample of five boxes from the daily population of several hundred boxes a crew is likely to pick is at best a "small" sample; that is, it will probably be biased. We possess no information, however, permitting us to evaluate the direction or the magnitude of this possible bias.

Other than the instances referred to in this section we are unaware of any other possible sources of measurement error in the data we have used.

Footnotes: Chapter 3

1. Worker performance data were obtained from the San Gabriel Valley Labor Association of Cucumonga, the Lemoneira Ranch of Santa Paula, the River Growers Association of East Highlands, and Irvine Valencia Growers of Irvine. Grove condition data were provided from Upland Lemon Growers of Upland, Lemoneira Ranch of Santa Paula, Western Fruit Growers Packing Company of Mentone, Irvine Valencia Growers of Irvine, and Corona College Heights Citrus Company of Riverside.

Chapter 4
A MODEL OF THE HARVEST OPERATION

Our fundamental purpose is to explain the influence, if any, that photochemical smog has upon the work performance of the individual citrus worker. It is obvious that any attempt to establish empirical values for this influence requires that the expressions to be estimated be explicitly derived from an analytical statement of the picker's decision problem. It is perhaps not so obvious that a complete analytical statement of the picker's work performance requires some attention to the grower's decision problem. The reason is that the picker's work performance is influenced by certain of the choices the grower makes. In turn, these grower choices are plausibly influenced in part by the grower's past observations on picker work performance. Thus, at least initially, one must recognize the interdependent nature of the two sets of parties' decision problems. Only then can one legitimately consider making a set of assumptions that will form the basis of the analytical model to be estimated. Sound judgment of the value of what is ultimately retained relative to what has been cast aside requires knowledge of the scope of this initial problem framework.

As noted in Chapter 2, with or without the intermediation of a labor contractor or a grower cooperative, the picker-grower relationship can be described as a sequence of spot contracts. The individual citrus picker is an independent contractor who daily sells his labor services in response to various combinations of piece-work wage offers, expected picking and environmental conditions, and prospective hours of work. The product the picker is selling is the number of boxes of fruit he picks within a given time interval. His realized daily earnings are determined by his wage per box of fruit picked, the relative ease of picking the fruit, and the number of hours he is able to work. The relative ease of picking the fruit may plausibly influence his innate productivity as well as the number of hours he chooses to work. In either case, his realized earnings will be affected.

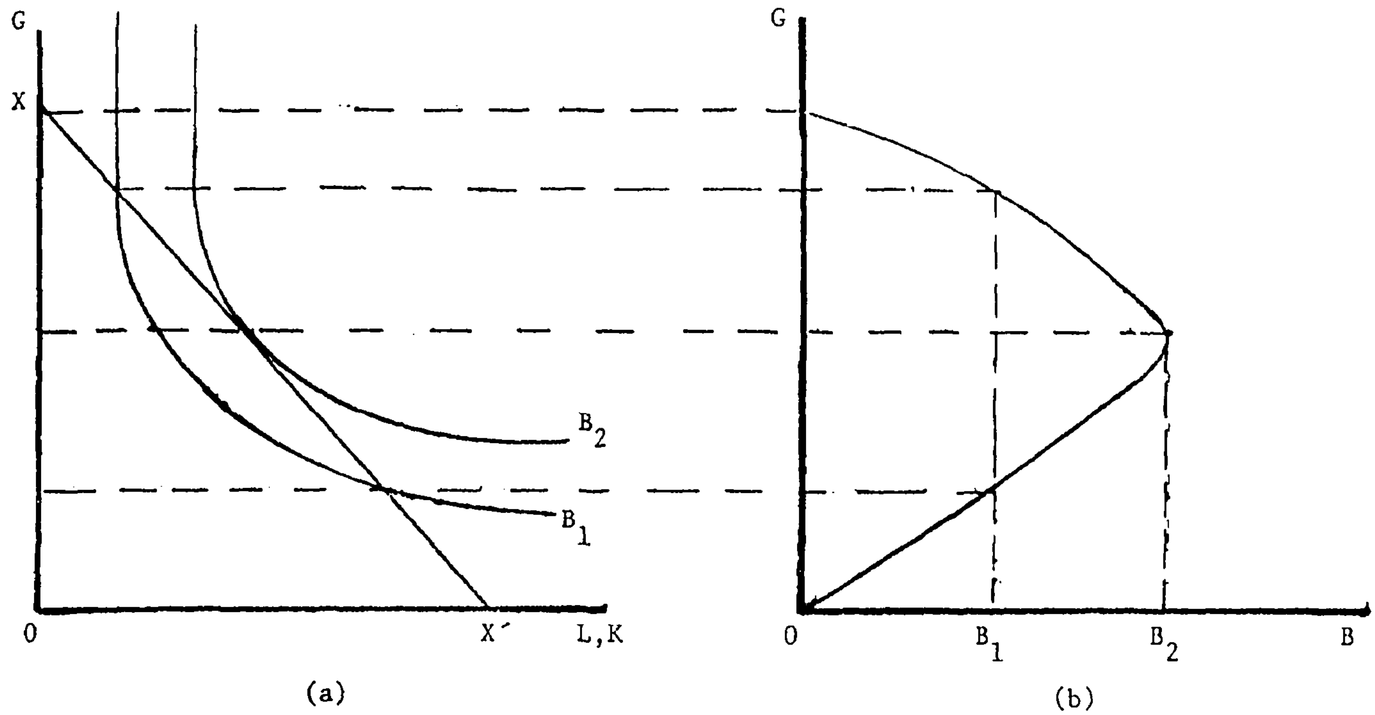
Just as pickers can trade-off reduced effort and gains in income, so can growers substitute between fruit output and those grove conditions that enhance the ease of picking. Of course, fruit output and certain grove conditions (e.g., fruit density) that enhance picking are highly complementary. However, other grower investment activities increase grower costs without contributing anything to and perhaps even detracting from the amount of fruit grown. For example, growers can reduce the height of their trees or clear the ground of large stones so as to aid picking ease. In the extreme, a grower might remove any tree from his grove once it reaches a height requiring a ladder to pick its fruit. Younger and shorter trees yield less fruit, however. If the grower reduces his fruit output in order to make life easier for the pickers, he often reduces his gross revenues; but if he increases his fruit output in order to increase his gross revenues, he sometimes makes life harder for pickers. Making life harder for pickers requires, if they are to be willing to accept the harder life, that the grower increase his costs by increasing the piece-work wage rate for picking.

Figures 1a and 1b below present the non-pecuniary essence of the grower's long-term problem. In Figure 1a, the B-isoquants represent output levels embodied in the citrus fruit production function. The citrus fruit that will be hanging on the trees is influenced by the non-harvest labor and capital, L and K applied to the grove, and the composite grove conditions, G. G is an output as well as an input; that is, it is a product the grower sells to the picker in exchange for reduced piece-work wage rates as well as being a determinant of fruit yields. Now, viewing G as an output rather than an input, the line XX′ shows, for a given stock of fully employed L and K, the relation between composite grove conditions developed solely to ease picking and non-harvest labor and capital devoted to improving fruit yields. Alternatively, the X′-intercept can be taken as the origin. The labor and capital devoted to producing grove conditions rather than fruit yields increases as one moves to the left from the X′-intercept. Thus, when the X′-intercept is taken as the origin, the XX′ line simply indicates the ratio of G to the amount of L, K committed to the production of G.

Figure 1b is derived, as indicated by the dotted lines, from the intersections of the isoquants in Figure 1a with XX′. Over the OB_2 interval on the B-axis of Figure 1b, an improvement in grove conditions

Figure 4.1

Relationship Between Grove Conditions and Fruit Yields



occurs jointly with an increase in fruit yields. For example, the careful pruning of trees will both increase hanging fruit and make the harvesting of fruit easier. The OB_2 interval of Figure 1b corresponds to a movement from X′ to the tangency of B_2 with XX′ in Figure 1a. If, from the grower's perspective, both fruit output and grove conditions command positive prices (the first by increasing gross revenues and the second by reducing the harvest costs), the grower will never intentionally select a combination of fruit output and grove conditions in the increasing portion of the production possibility frontier in Figure 1b. He will instead select a portion in the declining portion of this boundary because it is only in this portion that the grower, in order to increase his revenues by producing more fruit, must at the same time increase his harvest costs by making picking more difficult.

The implications of Figure 4.1 are unnecessarily complex for this study. Little, if any, violence is done to the nature of the grower's decision problem if the harvest problem is treated as being entirely separable from decisions about investing in grove conditions and fruit yields. From the perspective of the current harvest, all prior investments are predetermined. Moreover, except for extreme circumstances where one decides to harvest the fruit by bulldozing the trees, current harvest decisions have little or no effect upon future fruit yields or grove conditions. Assuming all growers to be net revenue maximizers, the representative grower's harvest (i.e., short-run) decision problem can therefore be represented as:

(1) Max: $\pi = pB - bK - vL - C,$

where:

(2) $B = B(C)$, a concave function, and $B_c \geq 0$,

and

(3) $C = C(w, K, L, \bar{G}, \bar{E})$, C_K, $C_L \geq 0$; $C_w \gtrless 0$.

A subscript indicates a derivative taken with respect to the subscript, and

π is the grower's net revenue from the harvest.

p is the constant daily selling price of a box of fruit.

B is the number of boxes of fruit actually picked by a picking crew.

b is the unit rental price of composite capital.

K is the number of units of composite capital the grower employs.

v is the hourly wage rate of nonpicking labor.

L is the man-hours of nonpicking labor.

w is the wage the individual picker receives for each box of fruit he picks.

C is the grower's expected total wage bill for pickers. It is thus the piece-work wage rate multiplied by the number of boxes of fruit the grower expects to have picked. Consistent with the static statement of the nature of the grower's harvest decision problem, the speed with which picking occurs and thus the number of workers he hires are presumed to be matters of indifference.

$\bar{G}$ is an invariant composite variable representing existing grove conditions that influence the ease of picking. In a longer-run setting, it would be a function of nonpicking labor, capital, and environment, and their respective prices. It includes the quantity of fruit hanging on the grower's trees.

$\bar{E}$ is a composite variable representing environmental conditions such as air temperature and photochemical smog concentrations that may influence the ease of picking. It is exogenous to the grower.

Expression (2) states that the number of boxes of mature fruit the grower will have picked is a function of the total picker wage bill the grower expects to have to pay. As (3) indicates, this total picker wage bill depends upon the piece-work wage rate, grove and environmental conditions, and the quantity of nonpicking labor and capital provided that it is complementary to picking labor. It appears in practice, however, that the provision of non-harvest labor and capital differs only trivally from one grove to another. We therefore disregard it in subsequent discussion.

Upon substituting (2) and then (3) into (1), and partially differentiating the result with respect to w, K, and L, one obtains the usual first-order conditions. These conditions determine the net revenue maximizing values w,* K,* and L* for the grower in terms of p, b, and v as well as the parameters of B(.) and C(.). One of the conditions:

(4) $\pi_w = pB_c C_w - C_w = 0,$

or

(4a) $p = B_c^{-1} = C_B$

is a standard result. This expression states that short-run grower net revenue maximization requires the marginal cost of fruit picking, C_B, to be set equal to the selling price of a box of picked fruit.

The value of w the grower chooses constitutes part of the picker's decision problem. The daily decision problem the picker faces may be stated as:

(5) Max: $U(I_t, H)$ $\quad U_{I_t} > 0,\ U_H < 0$

subject to:

(6) $I_t - w(G) \cdot B\ (E, G, H^+ - Z) + M = 0$

(7) $H(E, G, I_{t-1}) + Z = H^+$

where U(.) is concave, all partial derivatives are continuous, and where:

- I_t is the picker's daily consumption expenditures and savings. For notational simplicity, it is assumed the picker works in only one grove a day.
- H is the daily number of hours the picker harvests fruit in a particular grove.
- H^+ is the length of the picking crew's work-day in a particular grove. The individual picker is unable to influence the length of this work-day.
- I_{t-1} is the picker's earnings in the previous pay period.
- Z is the leisure time the picker voluntarily takes when he otherwise could have been working.
- M is all nonpicking income accruing to the picker.

All other variables are defined as they were for the grower.

This formulation of the picker's short-run decision problem states that he obtains utility, U, from income (or the physical goods and services that income can buy) and that he receives disutility from work. Utility for each day directly depends only on the level of earnings and the hours of work during that day, although the hours of work may be influenced by earnings in the previous pay period. The incentive effects, if any, of income and social security taxes and minimum wages are disregarded.[1]

The first constraint, (6), implies that the picker's daily consumption expenditures and savings are exactly equal to his daily earnings from harvesting citrus plus whatever outside income he is able to obtain. Outside income, M, is fixed for the day in question. The second constraint implies that the daily number of hours the worker is able to pick cannot exceed the number of hours that the crew to which he belongs picks. Time during which his crew picks but the worker does not pick is used by the worker to pursue leisure activities from which he obtains positive utility.

Since the picker is unable to influence the length of the crew's work-day, the above decision problem may be written as:

(8) $L = U\ (I_t, H) - \lambda \left[I_t - w(G) \cdot B\ [E, G, H(.)] + M \right] = 0$

and the necessary conditions for an interior utility maximum are:

(9) $L_{I_t} = U_{I_t} - \lambda = 0$

(10) $L_H = U_H - \lambda w B_H = 0$

(11) $L_\lambda = I_t - w(.) \cdot B\ [E, G, H(.)] + M = 0$

Expressions (9) and (10) above represent, respectively, the marginal utility of earnings and the marginal disutility of work presuming that the opportunity to acquire earnings by working exists. Taken together, (9) and (10) imply

(12) $U_H / U_{I_t} = \frac{\lambda w B_H}{\lambda} \equiv w B_H$,

which is the value of work to the picker and the rate at which in equilibrium he is willing to substitute leisure for earnings. From (4) and (12), simultaneous individual grower net revenue and individual picker utility maximization thus requires that:

(13) $C_B = w B_H$;

that is, the rate at which the grower's expected total wage bill changes in response to changes in boxes picked must be equal to the value of work to the picker.

From the individual picker's perspective, the left-hand side of (13) is predetermined. Although this picker may have some trivial influence upon C_B, the thousands of citrus pickers available to growers in southern California make it worthwhile for the individual picker to behave as if he had no influence whatsoever. Each day the picker is considering whether or not to work therefore, the picking opportunities available to him are composed of a set of discrete points, one point for each grower, where the coordinates of a point indicate the total earnings a picker can expect to be paid by a grower in exchange for picking fruit over a work-day of given length.

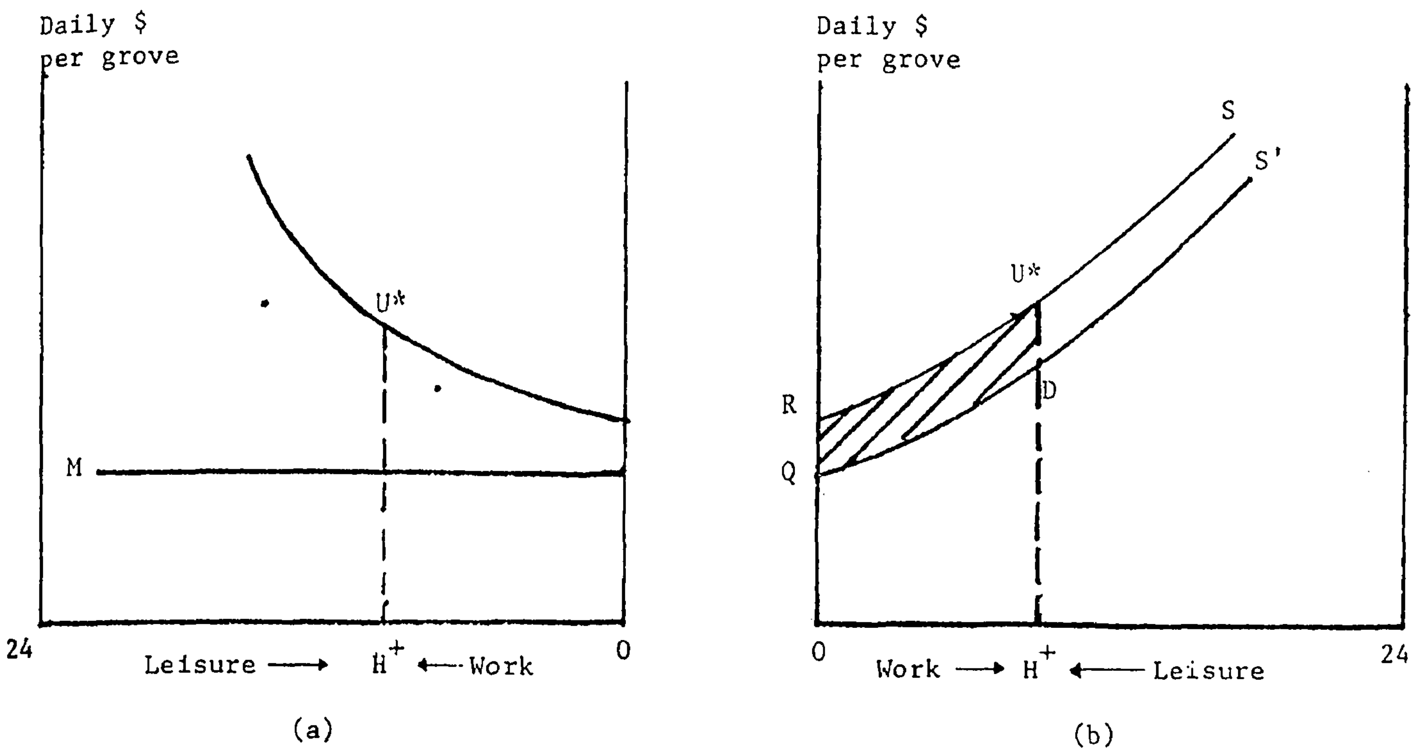
Temporarily assume that all growers are identical in terms of their grove attributes, except that their groves differ in size and therefore require a greater expenditure of hours from a given number of men in order to be picked. This implies that the piece-work wage rate will be constant across groves and that the individual picker's earnings opportunities will differ only according to the number of hours it will take his crew to pick each grove. One can therefore construct an indifference function for the individual picker showing the change in leisure necessary to compensate him for a marginal change in perceived earnings opportunities from picking while maintaining a constant level of utility.

At the beginning of any given day, the individual picker faces the situation depicted in Figure 4.2(a). Each point in the figure represents a picking or nonpicking earnings opportunity, one point to an opportunity. Only the points on the indifference function represent picking opportunities. All others represent other types of jobs such as fruit loading, truck driving, pruning, box repair, etc. In the situation depicted, U*, which lies on the picking opportunity indifference function, is on the highest indifference function passing through any of these points, and this point will be the earnings opportunity the individual will choose for that day. If earnings opportunities other than picking always lie below the picking opportunity indifference function, the individual will choose to pick each and every day, given that picking opportunities are available. However, if on some days, nonpicking earnings opportunities become available that lie above the picking opportunity indifference function, the individual will take the alternative job rather than picking fruit. As for the picking opportunities, they will change from day to day as the sizes of the groves ripe for picking change. Over time therefore, one will observe the individual picking at various points on his picking opportunity indifference function.

The above reasoning is not altered by the fact that grove attributes are dissimilar across groves. This is because growers adjust piece-work wage rates so that for any particular expenditure of his hours over the picking day, the individual picker is led to expect his earnings will be (nearly) equal from one grove to another. This means that as crew hours

Figure 4.2

The Individual Picker's Choice of Earnings Opportunities



increase and if the picker works as long as his crew, he expects to be sliding along the same indifference function as he moves from grove to grove. Thus, for example, all groves having the attributes associated with U* in Figure 4.2(a) are expected by the picker to provide the same level of earnings for the expenditure of H^+ hours of his time.

After subtracting nonpicking income, the S curve in Figure 4.2(b) is the mirror image of the picking opportunity indifference function in Figure 4.2(a). Since the indifference function has a negative slope throughout, the slope of the S function is the negative of the individual picker's marginal rate of substitution between earnings and leisure. It thus provides a constant real income supply function which, because of the convexity of the picking opportunity indifference function, has a positive slope. Since the S function is a compensated supply function, it has no backward bending portion as do ordinary labor supply functions. Once the individual has actually selected a grove in which to pick, the S function also represents the number of hours the picker is willing to supply the grower at different levels of earnings.

The above commentary has almost entirely concentrated upon the individual picker's decision problem at the start of each work day. However, once he has made his choice of a grove in which to pick, he may discover that his initial perceptions were mistaken. For example, assuming that his first-stage decision of whether or not to pick is not influenced by his expectations about levels of air pollution, he may find, once he has started picking, that his earnings are distressingly low because air pollution levels are reducing his physical picking prowess.[2] Similarly, he may find that the piece-work wage rate being paid is imperfectly adjusted to grove attributes so that his earnings for a given time expenditure are less than he had been led to expect. These disappointments are reflected in the shift of the supply function in Figure 4.2(b) from S to S´. If in spite of his disappointments the picker continues to work as long as his crew, the cross-hatched area RQDU* represents the additional income required to return the individual to his former indifference function. It is thus a measure of the compensating surplus and is representative of the social loss caused by air pollution that attaches to this picker. However, since the picker is, by assumption, constrained to work the same number of hours as his crew, the area overstates the compensation required if he were allowed to adjust his hours downward. Upward adjustments of hours are infeasible because the picker is institutionally constrained from working longer hours than does his crew.

Without further information, economic theory does not permit prediction of the combination of hours and earnings the picker will choose for his adjustment. Nevertheless, assuming that leisure is not an inferior good for the picker, the substitution and income effects of earnings changes possess the same sign in our compensated supply function: we should observe nonincreasing hours of work as the earnings of a picker are reduced.

Footnotes: Chapter 4

1. Pickers whose earnings after a two or three month training period frequently fail to meet the minimum wage are no longer permitted to work. In the empirical work of the next chapter only pickers who have continued to pick long after the training period are analyzed.

2. The assumption that the worker's choice among groves on any particular day is independent of air pollution levels is fairly innocuous, given the more-or-less constant distribution of expected air pollution concentrations over the locale in which the picker is likely to have picking opportunities. For example, air pollution magnitudes and magnitude durations are unlikely to differ perceptibly in those areas of Upland in which citrus is grown. Expected air pollution levels might influence the picker's decision whether or not to pick at all; however, our empirical efforts do not attempt to deal with this issue.

Chapter 5

AIR POLLUTION AND EARNINGS: EMPIRICAL RESULTS

Standard least-squares estimating techniques are readily applied to the second stage (the stage in which the individual has decided to do at least some picking during a day) of the representation in the last chapter of the picker's decision problem. Empirical implementation of this representation requires information on earnings, the piece-work wage rate, boxes of fruit picked, picker and crew hours worked, and grove and environmental attributes. The objective is to estimate, with respect to changes in air pollution, the changes in the individual picker's earnings when he is picking fruit and the changes in the leisure he voluntarily takes when he could have been picking fruit. The maintained hypothesis is that picker earnings vary negatively, and voluntarily taken hours of leisure vary positively, with respect to increases in air pollution. This chapter deals with the impact of air pollution upon earnings. The next chapter presents results for absenteeism.

Throughout the empirical investigation described in this and the succeeding chapter, the overriding criterion has been to arrive at estimated expressions yielding unbiased, or at least consistent, coefficients for a particular explanatory variable, the air pollution variable. Consistent estimates of these coefficients allow us to make inferences about the compensation in terms of earnings the picker requires to make him indifferent to an increase in the level of air pollution. They can also enable us to infer the change in the picker's equilibrium hours worked with respect to changes in air pollution.

One common source of bias in estimated coefficients is "data-grubbing." In the words of Selvin and Stuart (1966, p. 21):

> " . . . any preliminary search of data for a model, even when the alternatives are predesignated, affects the probability levels of all subsequent tests based on that model on the same data, and in no very simple way, and also affects the characteristics of subsequent estimation procedures. The only valid course is to use different data for testing the model dredged from the first set of data."

In order to assure that the data used to test the hypotheses generated from the analytical framework of the previous chapter are unsullied by any prior efforts to put together an empirical model from a combination of analytical and empirical investigations, the picking histories of four experienced pickers who worked more-or-less continuously picking lemons over an entire year were used for preliminary estimation. All "data-grubbing" for the empirical results presented in this report was limited entirely to these four pickers; that is, the estimates for all pickers other than the four issue from virgin data.

Estimates of the Inverse Supply Function. The analytical framework surrounding Figure 4.2 makes it convenient to estimate the inverse supply function, the function in which earnings are determined by hours worked. The coefficient attached to the air pollution variable in an empirical counterpart:

$I_t = f$ (H, air pollution, other factors that shift S in Figure 4.2(b))

to the S function of Figure 4.2(b) will, for the sample observations on the picker's work performance, then measure the shift of S averaged over all the hours the individual picker worked.

For estimation purposes, several assumptions, in addition to those embodied in the analytical framework, were imposed upon the stochastic form of the above earnings expression. First, in the absence of unique directions about functional form from the picker's decision model, all estimated expressions have been specified in double-logarithmic form. Although no formal comparisons were made, exploratory manipulations with the four preliminary test pickers made it appear that the double-log form fit each picker's data equally as well as arithmetic or semi-log forms. The double-log form was ultimately selected because of its greater flexibility. In particular, it permits the marginal effect of air pollution upon individual picker earnings to be constant, decreasing, or increasing; it makes the coefficients of the explanatory variables easily interpretable as constant elasticities; it restricts the dependent variables to positive values; it reduces the influence of extreme data values; and, finally, it may reduce heteroskedasticity.

Second, the picker was always assumed to work the same number of hours as his crew. Thus only those observations in which the picker's work-day was the same length as that of his crew were used for estimation purposes. This implies that the picker does not view his hours-worked as a decision variable, but rather accepts H as exogenously determined by the crew foreman through the foreman's choice of H^+. This is equivalent to assuming that $Z = 0$ in (12). The assumption was adopted for two reasons: (1) to provide an estimate of the response of earnings to air pollution independent of states in which nonzero combinations of earnings and leisure could be chosen; and most importantly, (2) to reduce possibilities of introducing bias into the estimated air pollution coefficients because of failure to include a variable relevant to explanation of the variations in the picker's earnings. As will be shown in a later chapter dealing with absenteeism, our data does not permit us to account for very much of the variation in the hours the picker chooses to work. Since hours-worked is an integral element of the earnings expression, an inability to explain very much of the variation in hours-worked substantially increases the risk that a relevant variable, nonorthogonal to the air pollution variable, is being neglected. The assumption that hours-worked is exogenous rather than endogenous to the picker's problem neatly avoids this.

Third, the variable representing hours-worked could, because of the common practice in the packinghouse crew records of rounding to the nearest half hour, contain a relatively high degree of measurement error when the picker worked for only a short time in a given grove. In order to correct for this possible source of error, we assumed for the earnings expression that the picker always worked at least two hours when he worked at all. The adoption of this assumption required that all observations in which the picker worked less than two hours be excised from the data used for estimation purposes.

Finally, an examination of the residual pattern of some ordinary-least-squares regressions for the four preliminary test lemon pickers revealed a definite drift of the residuals across time, even though each of these four individuals were known to have been picking lemons for years. An obvious means of ameliorating this is to introduce a calendar date variable into the regression specification. This additional variable might capture the work performance effects of selective picking as opposed to clean picking of lemon groves. Workers engaged in lemon picking are required to use rings and pick by color during most of the multiple harvests in a lemon grove during a calendar year. Inclusion of a variable representing calendar date may capture the effect of prior picking that has occurred in a grove or it may register factors not explicitly recorded that do influence picking ease. Since all orange picking is clean picking, calendar date did not seem relevant. Inspection of the residuals for ordinary-least-squares estimates of an orange picker's earnings expression seemed to confirm this irrelevancy.

Table 5.1 below presents the acronyms of the variables used to estimate the earnings expression. The initial ordinary-least-squares estimates of the earnings expression for the four preliminary test pickers revealed several additional statistical problems. As has been stressed in previous pages, our primary concern was to obtain consistent estimates of the coefficient for the air pollution variable. However, if it is not statistically confirmed that the air pollution variable is significantly different from zero at the usual test levels, then any claims as to the effect of air pollution upon the performance of citrus pickers is unfounded. As is well known, collinearity inflates the standard errors of the set of explanatory variables. In turn, this implies a reduction in the t-statistics and an unnecessarily conservative test of significance. Different equation specifications for the four preliminary test pickers verified that TM and DE were relevant explanatory variables and consequently must be included in the empirical specification. Additionally, both were collinear with the air pollution variables and thus rendered difficult an interpretation of the levels of statistical significance of these variables.

Tables 5.2 and 5.3 provide detail on the extent of collinearity between the air pollution variables and temperature. Each picker is identified by the general locale in which he picked fruit as well as by a number immediately following the locale. The parenthetic numbers indicate the years to which data for the picker refer. Thus Upland 1 (1973) refers to the same individual as Upland 1 (1974), but the year from which the data is drawn is different. Those to whom we refer to as pickers are thus on occasion the same individual distinguished by year and/or crop. A distinction was made between crop years for the picking activities of the same individual because the time pattern of the fruit harvest is said by growers and packinghouses to have differed fairly substantially between 1973 and 1974.[1]

Table 5.1

Glossary of Variable Names

B - The number of 3115 cubic inch field boxes picked by the picker during the work-day in a particular grove.

BT - The average number of 3115 cubic inch field boxes picked per tree during the work-day by the picker's crew in a specific grove.

DE - The calendar date of the work day: Jan. 1 = 1; Dec. 31 = 365.

I_t - The picker's daily gross earnings in dollars from picking activities for each grove worked.

I_{t-1} - The picker's gross earnings in dollars from picking activities in the previous pay period.

H - The number of hours the picker spent in picking activities in each grove.

FR - The number of fruit from the grove required to fill a 3115 cubic inch field box.

ØZ - The arithmetic average 24-hour ambient concentration on the work day of O_3 in parts per million by volume as measured by the CHEMILUM method at the monitoring station closest to the grove site.

ØZH - The arithmetic average of the hourly ambient concentrations of O_3 occurring during the time interval the worker was actually engaged in citrus picking. This variable is also measured by the CHEMILUM method at the monitoring station closest to the grove site.

TM - The maximum hourly arithmetic average dry-bulb temperature in F^o on the work-day at the monitoring station closest to the grove site.

TR - An index indicating the height of the trees picked by the worker's crew during the work day.
1 = tree can be picked without a ladder.
2 = ladder picked trees up to 9 1/2 feet tall.
3 = ladder picked trees 9 1/2 to 12 feet tall.
4 = ladder picked trees in excess of 12 feet tall.

w - The rate-of-pay (in dollars x 10) the picker receives for each 3115 cubic inch field box of citrus he picks.

Table 5.2

Simple Correlation Coefficients Between ØZ, ØZH, and TM for Various Lemon Pickers.

Worker $\underline{r}$:	ØZ.ØZH	ØZ.TM	ØZH.TM
Upland 1 (1973)	.735	.744	.588
Upland 1 (1974)	.643	.753	.555
Upland 2 (1973)	.737	.749	.590
Upland 2 (1974)	.658	.747	.557
Upland 3 (1973)	.711	.749	.593
Upland 4 (1973)	.752	.835	.653
Upland 22 (1974)	.558	.753	.554
Santa Paula 10 (1973)	N.A.	.478	N.A.
Santa Paula 10 (1974)	N.A.	.486	N.A.
Santa Paula 11 (1973)	N.A.	.472	N.A.
Santa Paula 11 (1974)	N.A.	.453	N.A.

N.A. - Not Available.

Table 5.3

Simple Correlation Coefficients Between ØZ, ØZH, and TM for Various Orange Pickers

Worker $\underline{r}$:	ØZ.ØZH	ØZ.TM	ØZH.TM
Upland 2 (1973)	N.A.	.688	N.A.
Upland 4 (1973)	N.A.	.703	N.A.
San Bernardino 5 (1973)	.824	.763	.654
San Bernardino 7 (1973)	.747	.751	.585
Irvine 38 (1974)	N.A.	.223	N.A.
Irvine 39 (1974)	N.A.	.205	N.A.
Irvine 40 (1974)	N.A.	.223	N.A.

N.A. - Not Available

For both lemon and orange pickers, the collinearity between air pollution and temperature is somewhat less for ØZH than for ØZ. Whenever available data allow it, the former measure of air pollution is used in the estimated expressions. Some collinearity between the temperature and air pollution variables was, of course, expected. The standard way to resolve this complication is to obtain an unbiased estimate of the temperature coefficient from an extended sample, or from a sample where the correlation between the collinear variables is less severe, and then to subtract the temperature term from the dependent variable, thus forming a new regression specification. Because air pollution and temperature in the Ventura region do not appear to be highly correlated, it would seem that data collected from that region would be ideal for this purpose. However, after considerable consternation, we decided not to follow this procedure. Our reasons were two. First, it was felt that the transformation of the dependent variable would alter the interpretation of the estimated coefficients. It is not clear to us, in terms of the analytical framework of Chapter 4, what the use is of a measure of the compensating surplus for air pollution where the picker has already received the compensation required to make him indifferent between existing temperatures and some hard-to-identify temperature he regards as ideal for his citrus fruit picking activities. Second, and perhaps more important, the temperature coefficient used to transform the earnings variable for one individual would, of necessity, be the coefficient estimated for another individual or set of individuals. It is generally acknowledged that responses to identical perturbations in meterological and environmental variables can differ greatly across individuals. The possibility of introducing bias into the other estimated coefficients, particularly the air pollution coefficients, therefore seemed, in our judgment, to be excessive. We thus instead chose to present regression results where the temperature variable is both included and excluded, leaving it to the reader to judge for himself where the "true" level of significance lies.

With respect to the calendar date variable, we attempted to mollify the collinearity problem by viewing the system as recursive. Specifically, we hypothesized the following pair of expressions:

(15a) $Lw = f(LBT, LFR, LTR, LDE)$,

(15b) $LI_t = g[L\hat{w}, LH, L \text{ (air pollution)}, LTM, L \text{ (grove attributes)}]$

where L denotes the natural logarithm of the original arithmetic value of the variable. (15a) is interpreted as the piece-work wage rate faced at the beginning of each day by the crew of the individual picker, and, given that the individual has chosen to pick during that day, (15b) is the picker's actual earnings expression. The expression of empirical interest, (15b), can be estimated by the two-stage-least-squares method. Assuming the usual classical conditions for the general linear model hold, consistent estimates of coefficient for the explanatory variables will be obtained.

The adoption for lemon pickers of the system represented by (15a) and (15b) introduced an additional collinearity problem. In particular, a linear combination of the grove attributes included as arguments in the earnings expression is highly collinear with the estimated rate-of-pay variable also appearing on the right-hand side of (15b). Theoretically, the inclusion of all these variables is required; but a specification of this sort reduces the rank of the data matrix below that required for satisfaction of the order condition for identification. Consequently, it was necessary to delete one of the grove attribute variables from (15b). The correlations of the various grove attribute variables with the air pollution variables served as our principal guide in determining the best variable to delete from the second structural equation. It can be shown that exclusion of a potentially relevant but orthogonal variable will not bias the air pollution coefficient, although it will increase the standard error. For the four preliminary test pickers, a review of the simple correlation coefficients revealed that the tree height variable, TR, was relatively uncorrelated (approximately -.06) with the air pollution variable for three of the pickers. For one picker the simple correlation between the two variables was high; however, it was also positive, even though the citrus industry universally expects, for given piece-work wage rates, that tree height and earnings per grove picked will vary inversely. These two facts for this single picker (the high simple correlation and its positive sign), imply that the bias imparted to the air pollution coefficient of this picker would be negative. All these considerations for the four preliminary test pickers led us to delete TR for all pickers in all two-stage-least-squares regression specifications.

Apart from the variables explicitly introduced through the theoretical model, conversations with various labor camp managers produced suggestions about potentially relevant factors. It appears to be a widely held notion that the performance of the typical citrus harvest worker will markedly decrease on Fridays and Mondays. Expectations of a wild weekend and supposed fulfillment of these expectations are offered as a rationale for this occurrence. For the four workers initially surveyed, however, estimated coefficients for dummy (0,1) variables for Friday and Monday did not yield estimates significantly different from zero at the usual levels. Consequently, these variables were not included in our final specification.[2]

A second common observation is that many pickers set an earnings goal and will not work as productively once this goal is achieved. Since pickers receive weekly paychecks, one way of ascertaining the validity of this hypothesis is to include a measure of the worker's total earnings in previous weeks. Inclusion of such a variable in the two-stage-least-squares formulation for the four preliminary test workers did not yield statistically significant estimates. Hence, this variable was also not included in the estimated expressions for other workers.

Finally, labor camp managers believe that multiple groves worked in a day seriously impairs the productivity of the worker. It is thought that moving three or four times a day causes the worker to go through three or four "warm up" periods, thus slowing down his picking output. Again, inclusion of a single explanatory variable representing number of groves picked did not yield a coefficient significantly different from zero.

It should be mentioned that although none of the three variables alluded to above proved to be statistically significant, the expected signs were in fact obtained.

We have referred several times to "the air pollution variables" in the preceding discussion without explicitly stating in each circumstance what measure we are postulating. Ideally, one would like the pollution monitoring stations to be located in each and every grove, with hourly readings having a one-to-one correspondence with hourly picking performance. Unfortunately, the picking data cannot be disaggregated to this extent. Moreover, we also must rely on the hourly readings from the closest recording station.

In some instances, we were unable to obtain the start and stop times for the picking crews for the various groves, and in these cases we employed the arithmetic average 24-hour ambient concentration of air pollution in parts per million by volume as measured by the CHEMILUM method. For the majority of workers for whom we were able to ascertain the actual time period of the day during which they picked fruit, we used the arithmetic mean of the hourly concentrations during this time span as our measure of air pollution.

Several alternative characterizations of the air pollution measure can be hypothesized. These might include higher moments (e.g., the variance) or perhaps some distributed lag structure. We have not attempted a distributed lag specification, but inclusion of the variance of the air pollution measure has not proven to be significant in various trial runs for the four preliminary test pickers.

The reader is by now no doubt aware that we are aware of the likely existence of measurement error in the air pollution variable. Since it does not appear possible to identify any systematic deviations in the values of this variable, it would seem that an instrumental variable would be our best recourse. The most likely candidate for an instrument, among those variables available to us, would be temperature, TM. However, this variable is already included in the regression specification. The next best alternative was posited to be TM lagged one period. A sample run for two of our trial pickers using the maximum temperature of the previous day as a proxy for the actual air pollution during the period of the next day in which the worker picked did not produce any interesting results. Given that the correlation between this lagged temperature and air pollution was only about 0.70, little gain from this reformulation could be expected. In the results to be presented below, the air pollution variable itself is utilized.

This completes the description of the basic model specifications used for estimation. The empirical specifications finally settled upon for the four preliminary test pickers were carefully checked for conformity with the classical linear model. An effort was, in fact, made to employ a program package for the formal Ramsey (1969) tests for specification error. Since time and available resources did not permit the correction of package programming errors, resort was had to less formal means. Heteroscedastic disturbances were searched for by evaluating scatter diagrams of residuals versus values of the dependent variable. No heteroscedasticity appears to be present in the final estimated expressions for the four preliminary test pickers. All variables for which data was available and which might plausibly be nonorthogonal to the air pollution variables were included at one time or another in specifications for the preliminary test workers. All those not found wanting in terms of statistical significance were included in all subsequent specifications. Autocorrelation was evaluated by means of the Durbin-Watson statistic. In the multiplicative form of the earnings expression finally selected, checks were made to assure that the disturbances were at least approximately log-normally distributed.

This completes the description of how we arrived at the basic specifications used for estimation of the earnings expression. Estimates for these expressions appear in Tables 5.4 and 5.5. Note that with one statistically insignificant exception for lemon pickers and two statistically insignificant exceptions for orange pickers, the coefficients for the air pollution variables are consistently of the expected sign. Moreover, even though a collinear temperature variable is included, the coefficients for almost half (seven of eighteen) the pickers are statistically significant at traditional levels for non-rejection of the maintained hypothesis that air pollution has a detrimental influence upon picker earnings. An indication of the impact that collinearity between the air pollution and temperature variables has upon the statistical significance of the former can be obtained from Table 5.5, where the temperature variable has been deleted from the empirical specification. In Table 5.5, all but two air pollution coefficients (both for orange pickers) have the expected negative sign and these negative coefficients are statistically significant for thirteen of the eighteen pickers. A further comparison of Table 5.5 with Table 5.4 makes it appear that the impact of the deletion of the temperature variable upon the statistical significance of the air pollution coefficients in Table 5.5 was greater for those pickers having nonsignificant air pollution

Table 5.4A

Earnings Estimates by Two-Stage-Least-Squares for Lemon Pickers. Dependent Variable = LI_t.

Picker: Variable	Upland 1[a] (1973)	Upland 1 (1974)	Upland 2[a] (1973)	Upland 2 (1974)	Upland 3 (1973)	Upland 4[b] (1973)	Upland 22 (1974)	Santa Paula 10[a] (1973)	Santa Paula 10 (1974)	Santa Paula 11[a] (1973)	Santa Paula 11 (1974)
Constant	1.326	1.270	3.180	4.713	0.831	-2.220	0.214	0.931	0.842	3.800	1.650
	(1.680)	(1.210)	(1.740)	(1.306)	(1.502)	(1.570)	(1.700)	(2.588)	(0.523)	(1.490)	(0.495)
Lw	-0.207	-0.780	-0.475	-0.509	-0.604	1.610	0.830	-0.270	-0.122	-0.473	-0.320
	(0.472)	(0.423)	(0.479)	(0.404)	(0.493)	(0.409)	(0.594)	(0.604)	(0.163)	(0.889)	(0.122)
LH	1.084	1.080	1.010	1.028	1.021	0.960	1.074	0.986	1.070	1.150	1.060
	(0.041)	(0.039)	(0.046)	(0.043)	(0.043)	(0.047)	(0.049)	(0.103)	(0.023)	(0.055)	(0.021)
LFR	0.073	0.268	-0.092	-0.129	0.255	0.107	-0.199	0.388	0.068	-0.002	0.120
	(0.297)	(0.219)	(0.342)	(0.221)	(0.359)	(0.329)	(0.349)	(0.354)	(0.129)	(0.289)	(0.103)
LBT	-0.018	-0.204	0.113	-0.067	-0.070	0.339	0.243	-0.314	-0.119	-0.155	-0.106
	(0.108)	(0.114)	0.108	(0.111)	(0.359)	(0.098)	(0.162)	(0.102)	(0.040)	(0.145)	(0.026)
LOZ								-0.242**	-0.034***	-0.029	0.002
								(0.128)	(0.016)	0.074	(0.019)
LOZH	-0.015	-0.023	-0.038**	-0.017	-0.029*	-0.012	-0.047*				
	(0.022)	(0.024)	(0.021)	(0.026)	(0.018)	(0.018)	(0.031)				
LTM	-0.173	0.028	-0.164	-0.414***	-0.085	-0.178	-0.037	-0.266	-0.042	-0.351	-0.142***
	(0.175)	(0.148)	(0.186)	(0.158)	(0.178)	(0.172)	(0.190)	(0.455)	(0.073)	(0.295)	(0.070)
$\bar{R}^2$	0.824	0.856	0.824	0.822	0.849	0.888	0.822	0.640	0.877	0.927	0.912
S.E.	0.246	0.209	0.287	0.206	0.217	0.176	0.257	0.304	0.169	0.174	0.155
D-W	1.88	2.09	1.79	1.86	1.92	1.70	1.82	1.68	1.94	1.72	1.57
F	131.46	153.18	143.24	120.52	127.87	124.86	104.74	15.11	381.42	99.92	456.11
Sample Size	168	162	189	156	136	101	143	58	293	54	264
Sample Period	March 17- Dec. 21	April 1- Nov. 2	March 19- Dec. 21	April 1- Nov. 2	March 17- Dec. 20	March 16- Dec. 21	April 17- Nov. 2	May 14- July 11	Jan. 3- Nov. 20	May 13- July 11	March 3- Dec. 4

Table 5.4A
(continued)

[a]The results reported for this picker have been derived from various empirical testing procedures and regression specifications.

[b]This picker is a woman.

Levels of significance are explicitly shown for only the air pollution and temperature variables.

*Coefficient is significantly different from zero at the 0.10 level of the one-tailed t-test.

**Coefficient is significantly different from zero at the 0.05 level of the one-tailed t-test.

***Coefficient is significantly different from zero at the 0.025 level of the one-tailed t-test.

(The numbers in parentheses are the standard errors of the estimated coefficients).

Table 5.4B

Earnings Estimates by Ordinary-Least-Squares for Orange Pickers.[b] Dependent Variable = LI_t

Picker: Variable	Upland 2 (1973)	Upland 4 (1973)	San Bern. 5 (1973)	San Bern. 7 (1973)	Irvine 38 (1974)	Irvine 39 (1974)	Irvine 40 (1974)
Constant	2.210	2.094	0.898	-0.786	3.583	1.279	2.387
	(2.062)	(1.325)	(1.285)	(1.363)	(1.190)	(1.282)	(1.175)
Lw	0.290	0.323	0.119	1.189	a	a	a
	(0.288)	(0.181)	(0.178)	(0.252)			
LH	1.371	1.114	0.884	1.029	1.001	1.146	1.172
	(0.109)	(0.686)	(0.077)	(0.090)	(0.067)	(0.062)	(0.066)
LTR			-0.162	0.082			
			(0.112)	(0.167)			
LBT			-0.043	0.150			
			(0.051)	(0.095)			
LØZ	0.065	-0.009			-0.081*	-0.027	0.065
	(0.075)	(0.047)			(0.059)	(0.062)	(0.057)
LØZH			-0.061***	-0.054			
			(0.030)	(0.053)			
LTM	-0.567	-0.468**	0.028	-0.226	-0.568*	-0.096	-0.366*
	(0.043)	(0.276)	(0.283)	(0.312)	(0.270)	(0.293)	(0.265)
$\bar{R}^2$	0.755	0.864	0.487	0.814	0.692	0.759	0.756
S.E.	0.181	0.110	0.410	0.397	0.308	0.332	0.303
D-W	1.276	2.043	1.800	1.502	1.328	1.557	1.111
F	44.094	77.782	24.724	127.562	82.392	116.543	113.519
Sample Size	57	54	163	152	114	115	114
Sample Period	June 18- Sept. 9	June 20- Sept. 8	Feb. 29- Dec. 31	Mar. 4- Oct. 18	Apr. 4- Aug. 28	Apr. 4- Aug. 28	Apr. 4- Aug. 28

Table 5.4B
(continued)

[a]Rate-of-pay in 1974 for Irvine is a constant 32 cents per box since grove conditions are very nearly uniform.

[b]For orange pickers, there is no *a priori* reason to think that grove attributes contributing to picking ease vary systematically by calendar date. Thus LDE is not a relevant explanatory variable and two-stage-least-squares estimating procedures were not necessary to avoid the collinearity problem between LDE and the environmental variables.

*Coefficient is significantly different from zero at the 0.10 level of the one-tailed t-test.

**Coefficient is significantly different from zero at the 0.05 level of the one-tailed t-test.

***Coefficient is significantly different from zero at the 0.025 level of the one-tailed t-test.

(The numbers in parentheses refer to the standard errors of the estimated coefficients).

Table 5.5A

Earnings Estimates by Two-Stage-Least-Squares for Lemon Pickers When LTM is Deleted. Dependent Variable = LI_t.

Picker: Variable	Upland 1 (1974)	Upland 1[a] (1973)	Upland 2 (1974)	Upland 2[a] (1973)	Upland 3 (1973)	Upland 4 (1973)	Upland 22 (1974)	Santa Paula 10[a] (1973)	Santa Paula 10 (1974)	Santa Paula 11 (1974)	Santa Paula 11[a] (1973)
Constant	1.410	1.177	2.731	2.620	0.662	-2.226	0.029	0.862	0.736	0.046	0.029
	(1.020)	(1.515)	(1.109)	(1.610)	(1.424)	(1.479)	(1.394)	(2.741)	(0.446)	(0.217)	(1.090)
LW	-0.772	-0.159	-0.640	-0.448	-0.517	1.606	0.816	-0.291	-0.112	-0.428	-0.850
	(0.411)	(0.458)	(0.404)	(0.472)	(0.469)	(0.409)	(0.586)	(0.610)	(0.162)	(0.160)	(0.881)
LH	1.080	1.088	1.035	1.020	1.247	0.963	1.074	0.987	1.070	1.124	1.140
	(0.039)	(0.041)	(0.044)	(0.045)	(0.041)	(0.047)	(0.049)	(0.103)	(0.023)	(0.020)	(0.057)
LFR	0.260	0.041	-0.035	-0.127	0.188	0.107	-0.189	0.426	0.053	0.130	0.095
	(0.214)	(0.291)	(0.221)	(0.335)	(0.329)	(0.329)	(0.342)	(0.352)	(0.129)	(0.110)	(0.295)
LBT	-0.201	-0.002	-0.109	0.124	-0.048	0.342	0.239	-0.325	-0.114	-0.158	-0.200
	(0.111)	(0.103)	(0.111)	(0.005)	(0.105)	(0.012)	(0.160)	(0.102)	(0.040)	(0.028)	(0.149)
LOZ								-0.256***	-0.038***	-0.088***	-0.072
								(0.110)	(0.015)	(0.034)	(0.069)
LOZH	-0.021	-0.026**	-0.058***	-0.046**	-0.032**	-0.031**	-0.050**				
	(0.020)	(0.018)	(0.021)	(0.019)	(0.017)	(0.013)	(0.026)				
$\bar{R}^2$	0.856	0.826	0.814	0.824	0.857	0.888	0.822	0.619	0.887	0.894	0.916
S.E.	0.208	0.244	0.210	0.286	0.211	0.301	0.256	0.304	0.169	0.163	0.186
D-W	2.090	1.89	1.81	1.470	1.901	1.704	1.827	1.67	1.930	1.42	1.470
F	185.190	159.69	136.84	171.860	162.63	137.842	126.644	14.14	327.020	484.79	104.390
Sample Size	162	168	156	189	136	101	143	58	293	264	54
Sample Period	Apr. 1- Nov. 2	Mar. 17- Dec. 21	Apr. 1- Nov. 2	Mar. 19- Dec. 21	Mar. 17- Dec. 20	Mar. 16- Dec. 21	Apr. 17- Nov. 2	May 14- July 11	Jan. 3- Nov. 20	Mar. 3- Dec. 4	May 13- July 11

Table 5.5A
(continued)

[a]The results reported for this picker have been derived from various empirical testing procedures and regression specifications.

*Coefficient is significantly different from zero at the 0.10 level of the one-tailed t-test.

**Coefficient is significantly different from zero at the 0.005 level of the one-tailed t-test.

***Coefficient is significantly different from zero at the 0.025 level of the one-tailed t-test.

(The numbers in parentheses are the standard errors of the estimated coefficients).

Table 5.5B

Earnings Estimates by Ordinary-Least-Squares for Orange Pickers When LTM is Deleted.[b] Dependent Variable = LI_t.

Picker: Variable	Upland 2 (1973)	Upland 4 (1973)	San Bern. 5 (1973)	San Bern. 7 (1973)	Irvine 38 (1974)	Irvine 39 (1974)	Irvine 40 (1974)
Constant	-0.401	-0.885	1.018	-1.859	1.092	0.861	0.777
	(0.520)	(0.331)	(0.441)	(0.868)	(0.131)	(0.139)	(0.139)
Lw	0.420	0.442	0.119	1.230	a	a	a
	(0.272)	(0.171)	(0.178)	(0.260)			
LH	1.386	1.132	0.884	1.022	1.027	1.148	1.186
	(0.110)	(0.069)	(0.076)	(0.094)	(0.067)	(0.061)	(0.065)
LTR			-0.164	0.082			
			(0.110)	(0.165)			
LBT			-0.043	0.150			
			(0.051)	(0.095)			
LØZ	0.001	-0.062**			-0.108**	-0.031	0.049
	(0.057)	(0.036)			(0.059)	(0.061)	(0.057)
LØZH			-0.059***	-0.071**			
			(0.028)	(0.045)			
$\bar{R}^2$	0.752	0.856	0.487	0.800	0.680	0.759	0.752
S.E.	0.183	0.112	0.409	0.411	0.313	0.331	0.304
D-W	1.160	1.942	1.794	1.497	1.283	1.553	1.091
F	57.540	99.016	29.855	146.035	117.723	176.164	167.960
Sample Size	57	54	163	152	114	115	114
Sample Period	June 18- Sept. 9	June 20- Sept. 8	Feb. 29- Dec. 31	Mar. 4- Oct. 18	Apr. 4- Aug. 28	Apr. 4- Aug. 28	Apr. 4- Aug. 28

Table 5.5B
(continued)

[a]Rate-of-pay in 1974 for Irvine is a constant 32 cents per box since grove conditions are very nearly uniform.

[b]For orange pickers, there is no *a priori* reason to think that grove attributes contributing to picking ease vary systematically by calendar date. Thus LDE is not a relevant explanatory variable and two-stage-least squares estimating procedures were not necessary to avoid the collinearity problem between LDE and the environmental variables.

*Coefficient is significantly different from zero at the 0.10 level of the one-tailed t-test.

**Coefficient is significantly different from zero at the 0.05 level of the one-tailed t-test.

***Coefficient is significantly different from zero at the 0.025 level of the one-tailed t-test.

(The numbers in parentheses refer to the standard errors of the estimated coefficients).

coefficients but relatively significant temperature coefficients in Table 5.4. Of course, since we have no reason to suppose that temperature is an irrelevant explanatory variable and since temperature is obviously nonorthogonal to air pollution, only the air pollution coefficients in Table 5.4 should be viewed as unbiased estimates. Nevertheless, since the air pollution coefficients of Table 5.5 generally do not exhibit major change from those in 5.4, one can tenatively and somewhat hesitantly conclude that, over the observed ranges of variation of the two variables, air pollution has greater relevance to picker earnings than does temperature.[3]

One must temper the generalizations of the above paragraph with the observation that the estimated equations for three orange pickers (Upland 2 (1973), Irvine 38 (1974), and Irvine 40 (1974)) have Durbin-Watson statistics probably indicative of negative autocorrelation of disturbances. It therefore seems likely that the estimated expressions for these individuals, as presented in Tables 5.4 and 5.5, are misspecified. More will be said shortly about the sources of this specification error.

Finally, when reviewing Tables 5.4 and 5.5, the careful reader will have noted that the three grove attributes (BT, FR, TR) used by the packinghouses to determine the piece-work wage rate are frequently statistically non-significant and often seemingly of the wrong sign. However, because the piece-work wage rate is adjusted in accordance with changes in the values of these grove attribute variables, one cannot interpret their coefficients in the customary manner. Instead of representing the response of the picker's earnings to changes in the grove attributes variables, the coefficients represent <u>the deviation</u> in the individual picker's adjustment to the change <u>from</u> the adjustment to the grove attribute reflected in the piece-work wage rate. If this rate were always adjusted perfectly for the individual picker, the coefficients attached to the grove attribute variables would each be zero; that is, any change in one or more of the three grove attributes would have no effect whatsoever upon the picker's earnings.

<u>Increases in Income Required to Compensate Pickers for Earnings Losses Due to Air Pollution</u>. For expressions in which the temperature variable has been included, Table 5.6 below presents the calculated effects of air pollution upon the daily earnings of those lemon and orange pickers for whom

Table 5.6

Required Picker Income Compensations[a]

Picker: Statistic	Lemons Upland 2 (1973)	Lemons Upland 22 (1974)	Lemons Upland 3 (1973)	Lemons Santa Paula 10 (1973)	Lemons Santa Paula 10 (1974)	Oranges San Bern. 5 (1973)	Oranges Irvine 38 (1974)
n	189	143	136	58	293	163	114
ΣI_t	2899.30	1645.93	1489.07	821.86	4063.85	1886.23	2063.40
$\Sigma \emptyset Z$				262.1			475.95
$\Sigma \emptyset ZH$	1291.30	1403.40	895.30			1064.06	
$\bar{I}_t$	15.34	11.51	10.95	14.17	13.87	11.57	18.1
$\overline{\emptyset Z}$				4.52	3.38		4.175
$\overline{\emptyset ZH}$	6.83	9.87	6.58			6.528	
$\hat{b}$	-0.038	-0.047	-0.029	-0.242	-0.034	-0.061	-0.081
$\bar{V}$ in dollars	-0.090	-0.055	-0.048	-0.760	-0.140	-0.108	-0.351
$\bar{\bar{V}}$ in dollars	-0.280	-0.105	-0.144	-0.900	-0.380	-1.138	-0.446
$n\bar{\bar{V}}$ in dollars	-52.92	-15.02	-19.58	-52.20	-111.34	-185.49	-50.84
$\left(\frac{n\bar{\bar{V}}}{I_t+n\bar{\bar{V}}}\right)100$	-1.8%	-0.9%	-1.3%	-6.0%	-2.7%	-9.0%	- 2.5%

[a] These calculations were made from estimated expressions in which it was assumed the picker's work-time was institutionally fixed.

statistically significant air pollution coefficients have been obtained. A table showing the same calculations when the temperature variable has been excluded is not presented because the air pollution coefficient in these expressions is thought to be biased; that is, since temperature is known to be nonorthogonal to air pollution and since we are unable to show that temperature is an irrelevant explanatory variable, calculations of required compensation using statistical results that do not account for temperature would be highly untrustworthy. The sole purpose of presenting estimates for expressions in which temperature is deleted has been to provide the reader a sense of the extent to which collinearity between temperature and air pollution affects the standard error and thus the statistical significance of the air pollution coefficient in estimated expressions including both variables.

Table 5.6 does not include pickers with statistically insignificant air pollution coefficients because we are able to reject, for these pickers only, and only within the context of the particular empirical specification, the hypothesis that air pollution influenced their earnings. For those pickers exhibiting statistically significant air pollution coefficients, the calculated losses represent, in accordance with the analytical construct presented in Chapter 4, the compensation the picker requires to make him indifferent between the presence or absence (except for "background" levels) of photochemical oxidants, given that he works as long as his picking crew. In Table 5.6, $n\bar{\bar{V}}$ represents this total required compensation for the picker during the period of observation and the bottom row of figures shows this required compensation as a percentage of what the picker's earnings would have been in the absence of air pollution. Thus, for example, in the 293 lemon groves in which Santa Paula 10 picked from January 3, 1974, to November 20, 1974, he required in compensation 38 cents per grove that he picked, $111.34 in total, and 2.7% of what his income would have been in the absence of air pollution.

Table 5.6 actually contains two calculations of picker's required compensations. Both assume that the response of the picker's earnings to variations in air pollution is a constant. The first calculation, $\bar{V}$, is

$$\bar{V} = \hat{b}\,\frac{\text{arithmetic mean of } I_t}{\text{arithmetic mean of } \emptyset Z \text{ or } \emptyset ZH} \equiv \hat{b}\,\frac{\bar{I}_t}{\overline{\emptyset Z} \text{ or } \overline{\emptyset ZH}},$$

where $\hat{b}$ is the estimated coefficient of the air pollution variable. This calculation gives the picker's required income compensation for the <u>average</u> grove he picks. The second calculation, $\bar{\bar{V}}$, is the picker's required income compensation per grove that he picked during the period of observation. It is:

$$\bar{\bar{V}} = \frac{\hat{b}}{n}\sum_{i=1}^{n} \frac{I_{t_i}}{\text{ith air pollution observation}},$$

where the i subscript indexes the groves in which the worker picked and n is the number of groves. Only the dollar magnitudes and percentages associated with $\bar{\bar{V}}$ are presented in Table 5.6 because $\bar{\bar{V}}$ takes greater account of the peculiarities of each grove in which the picker has worked. Calculations of required compensations that use $\bar{V}$ rather than $\bar{\bar{V}}$ will obviously give lower dollar and percentage magnitudes.

<u>Does Air Pollution Impact Vary with the Picker's Physical Condition?</u> The picking of citrus fruit is a physically strenuous activity, giving reason to speculate that over relatively long work-days the picker will become fatigued and therefore be more susceptible to the deleterious effects of air pollution.[4] However, the results reported in Tables 5.4 and 5.5 reflect the impact of air pollution on the earnings of various pickers for a wide range of work-day lengths. By including this entire range of work-day lengths in the sample used for each estimate in Tables 5.4 and 5.5, one obtains air pollution coefficients representing <u>weighted</u> averages of the picker's responses over all work-day lengths. In the absence of further analysis, it is impossible to disentangle the separate contribution to these weighted averages of assorted work-day lengths. Furthermore, it could be that the failure of the procedures used in Tables 5.4 and 5.5 to consider the differential effect of hours worked upon air pollution impact may, for certain pickers, have incorrectly resulted in statistical rejection of the hypothesis that air pollution influences picker earnings.

The results exhibited in Table 5.7 are the air pollution coefficients obtained by running the exact specifications of Tables 5.4 and 5.5 on partitionings by hours worked of the identical observations of picker performance used in Tables 5.4 and 5.5. No Irvine workers are included in Table 5.7. They will be discussed separately. The results included in Table 5.7A include temperature as an explanatory variable, while those in Table 5.7B do not. Although the covariance F-test for single coefficients developed by Tiao and Goldberger (1962) could be used to test for statistically significant differences in the air pollution coefficients across partitionings, time did not permit the completion of this task for this report. A glance at the differences in magnitude among many of the coefficients for single pickers nevertheless leaves little doubt that statistically significant differences are fairly common.

The speculation that picker responsiveness to air pollution increases directly with the length of the work-day receives some support from the results exhibited in Table 5.7A.[5] For ten of the fifteen pickers in the table, the air pollution coefficient, an elasticity coefficient, increases in negative magnitude with increases in the length of work-day. Indeed, given the near-universal lack of significance (Upland 4 (1973) in lemons is the sole exception) of the air pollution coefficients in the partitionings representing relatively short work-days, it is tempting to assert that air pollution has little, if any, impact unless the work-day is in excess of about six or seven hours. The results of Table 5.7A are at least consistent with this interpretation.

The apparent tendency of air pollution impact to increase with increased work-day length is associated with the most interesting and important feature of Table 5.7A: with the exceptions of Upland 2 (1973) in oranges and Upland 4 (1973) in oranges, all pickers for whom statistically non-significant air pollution coefficients were obtained in Table 5.4 now have significant air pollution coefficients for the work-day partitioning greater than or equal to seven hours. In fact, it is plausible that the failure of Upland 4 (1973) in oranges to be significant is due to collinearity between temperature and air pollution. Note that in Table 5.7B, where temperature

Table 5.7A

Air Pollution Coefficients (and Standard Errors) for H Partitionings. Dependent Variable = LI_t.

Picker	Fruit	Statistic	$2.0 \le H < 4.0$	$4.0 \le H < 7.0$	$2.0 \le H < 7.0$	$H \ge 7.0$
Upland 1 (1973)	Lemons	$\hat{b}_{LØZH}$	-0.001	-0.026		-0.096***
		s	(0.030)	(0.042)		(0.043)
		n	44	64		60
Upland 1 (1974)	Lemons	$\hat{b}_{LØZH}$	-0.008	0.019		-0.081***
		s	(0.050)	(0.039)		(0.036)
		n	37	63		62
Upland 2 (1973)	Lemons	$\hat{b}_{LØZH}$	-0.031	-0.065		-0.075
		s	(0.041)	(0.052)		(0.063)
		n	67	45		67
Upland 2 (1974)	Lemons	$\hat{b}_{LØZH}$	-0.043	0.080		-0.085**
		s	(0.053)	(0.044)		(0.044)
		n	31	63		62
Upland 2 (1973)	Oranges	$\hat{b}_{LØZ}$			0.181	0.030
		s			(0.188)	(0.087)
		n			14	43
Upland 3 (1973)	Lemons	$\hat{b}_{LØZH}$	-0.024	-0.048**		0.065
		s	(0.032)	(0.024)		(0.070)
		n	37	47		52
Upland 4 (1973)	Lemons	$\hat{b}_{LØZH}$	-0.035**	0.025		-0.137***
		s	0.022	(0.043)		(0.053)
		n	33	37		31
Upland 4 (1973)	Oranges	$\hat{b}_{LØZ}$			0.039	-0.005
		s			(0.066)	(0.065)
		n			14	40
Upland 22 (1974)	Lemons	$\hat{b}_{LØZH}$			-0.018	-0.061**
		s			(0.051)	(0.033)
		n			49	48

Table 5.7A
(continued)

Picker	Fruit	Statistic	$2.0 \leq H < 4.0$	$4.0 \leq H < 7.0$	$2.0 \leq H < 7.0$	$H \geq 7.0$
Santa Paula 10 (1973)	Lemons	$\hat{b}_{L\emptyset Z}$			-0.021	-0.299*
		s			(0.288)	(0.201)
		n			30	28
Santa Paula 10 (1974)	Lemons	$\hat{b}_{L\emptyset Z}$	-0.047	-0.024		-0.020
		s	0.045	0.021		(0.021)
		n	60	117		116
Santa Paula 11 (1973)	Lemons	$\hat{b}_{L\emptyset Z}$			-0.271	-0.108**
		s			(1.066)	(0.053)
		n			30	24
Santa Paula 11 (1974)	Lemons	$\hat{b}_{L\emptyset Z}$	0.075	-0.020		-0.055**
		s	(0.082)	(0.023)		(0.030)
		n	34	97		90
San Bern. 5 (1973)	Oranges	$\hat{b}_{L\emptyset ZH}$	-0.045	-0.118**		-0.027
		s	(0.049)	(0.068)		(0.081)
		n	38	46		79
San Bern. 7 (1973)	Oranges	$\hat{b}_{L\emptyset ZH}$			0.032	-0.062***
		s			0.069	0.030
		n			57	95

*Coefficient is significantly different from zero at the 0.10 level of the one-tailed t-test.

**Coefficient is significantly different from zero at the 0.05 level of the one-tailed t-test.

***Coefficient is significantly different from zero at the 0.025 level of the one-tailed t-test.

Table 5.7B

Air Pollution Coefficients (and Standard Errors) for H Partitionings When LTM is Deleted. Dependent Variable = LI_t.

Picker	Fruit	Statistic	$2.0 \leq H < 4.0$	$4.0 \leq H < 7.0$	$2.0 \leq H < 7.0$	$H \geq 7.0$
Upland 1 (1973)	Lemons	$\hat{b}_{LØZH}$	0.015	-0.047		-0.097***
		s	0.037	(0.037)		(0.044)
		n	44	64		60
Upland 1 (1974)	Lemons	$\hat{b}_{LØZH}$	0.006	-0.025		-0.054**
		s	(0.047)	(0.029)		(0.030)
		n	37	63		62
Upland 2 (1973)	Lemons	$\hat{b}_{LØZH}$	-0.046*	-0.099**		-0.052
		s	(0.035)	(0.052)		(0.045)
		n	67	45		67
Upland 2 (1974)	Lemons	$\hat{b}_{LØZH}$	-0.038	-0.038		-0.103***
		s	(0.046)	(0.037)		(0.045)
		n	31	63		62
Upland 2 (1973)	Oranges	$\hat{b}_{LØZ}$			0.011	0.037
		s			(0.140)	(0.068)
		n			14	43
Upland 3 (1973)	Lemons	$\hat{b}_{LØZH}$	-0.038	-0.034*		0.038
		s	-0.033	(0.025)		(0.041)
		n	37	47		52
Upland 4 (1973)	Lemons	$\hat{b}_{LØZH}$	-0.047***	-0.001		-0.055*
		s	(0.020)	(0.044)		(0.036)
		n	33	37		31
Upland 4 (1973)	Oranges	$\hat{b}_{LØZ}$			0.009	-0.067*
		s			(0.060)	(0.044)
		n			14	40
Upland 22 (1974)	Lemons	$\hat{b}_{LØZH}$			-0.010	-0.031
		s			(0.046)	(0.056)
		n			49	48

Table 5.7B
(continued)

Picker	Fruit	Statistic	$2.0 \le H < 4.0$	$4.0 \le H < 7.0$	$2.0 \le H < 7.0$	$H \ge 7.0$
Santa Paula 10 (1973)	Lemons	$\hat{b}_{LØZ}$			-0.074	-0.275*
		s			(0.224)	(0.180)
		n			30	28
Santa Paula 10 (1974)	Lemons	$\hat{b}_{LØZ}$	-0.052	-0.024		-0.022
		s	(0.045)	(0.021)		(0.021)
		n	60	117		116
Santa Paula 11 (1973)	Lemons	$\hat{b}_{LØZ}$	0.020	-0.016		-0.055**
		s	0.070	0.022		(0.030)
		n	34	97		90
Santa Paula 11 (1974)	Lemons	$\hat{b}_{LØZ}$			-0.045	-0.108***
		s			(0.125)	(0.054)
		n			30	24
San Bern. 5 (1973)	Oranges	$\hat{b}_{LØZH}$	-0.035	-0.131***		-0.038
		s	(0.040)	0.061		(0.061)
		n	38	46		79
San Bern. 7 (1973)	Oranges	$\hat{b}_{LØZH}$			0.036	-0.069***
		s			(0.065)	(0.030)
		n			57	95

*Coefficient is significantly different from zero at the 0.10 level of the one-tailed t-test.

**Coefficient is significantly different from zero at the 0.05 level of the one-tailed t-test.

***Coefficient is significantly different from zero at the 0.025 level of the one-tailed t-test.

has been deleted from the estimated expression, the air pollution coefficient is fairly significant for the longer work-day partitioning.

In Table 5.8 are presented the estimates obtained for work-day partitionings of the three Irvine orange pickers. The partitioning of work-day lengths for these pickers causes the air pollution coefficients for the shorter work-days to be statistically significant. This is diametrically opposed to the observed tendency for most other pickers of air pollution impacts to increase with increasing work-day lengths. In fact, the overall statistical results for the shorter work-day length estimates accord rather closely to those obtained for other pickers. The magnitudes and signs of the coefficients for each variable are similar to those obtained for other pickers, the Durbin-Watson statistic is very close to 2.00, and the F-values for the entire expression are highly significant. The estimates for these shorter work-days thus seem quite reliable. For the longer work-days, reliability must be sought elsewhere. The Durbin-Watson statistics imply negative autocorrelation and F-values for the entire expression are statistically nonsignificant. Plots of the residuals against the values of the dependent variable displayed a classic case of heteroscedasticity. Clearly, the statistical estimation procedure employed for this longer work-day length partitioning must be found wanting. With some consternation, we violated our data-grubbing ethic, and, now including a calendar date variable, we re-estimated the same expression for the longer work-days of these three Irvine pickers. The coefficient for this variable was nonsignificant; it added extremely little to the total explanation of the variations in the dependent variable; and neither the coefficients nor the standard errors of other variables were altered in any more than a minor way. Upon plotting the residuals of the estimates against time, however, a sine-curve pattern could be distinctly discerned. The period between each peak of the wave was consistently about two weeks long. We have no explanation for this phenomenon, nor do we understand why the apparent statistical quality of the estimates for the shorter and the longer work days should be so utterly different.

Table 5.8

Earnings Estimates by Ordinary Least Squares for H Partitionings of Irvine Orange Pickers. Dependent Variable = LI_t.

Picker:	Irvine 38 (1974)		Irvine 39 (1974)		Irvine 40 (1974)	
Variable	2.0≤H<7.0	H≥7.0	2.0≤H<7.0	H≥7.0	2.0≤H<7.0	H≥7.0
Constant	3.086	2.104	2.223	1.276	1.959	1.700
	(1.512)	(1.270)	(1.767)	(1.503)	(1.288)	(1.524)
Lw	a	a	a	a	a	a
LH	1.086	0.316	1.210	0.581	1.176	0.898
	(0.130)	(0.257)	(0.115)	(0.263)	(0.119)	(0.272)
LØZ	-0.143**	0.080	-0.100*	0.027	-0.171**	0.164
	(0.077)	(0.063)	(0.068)	(0.065)	(0.099)	(0.065)
LTM	-0.565	-0.038	-0.390	0.109	-0.266	-0.176
	(0.395)	(0.325)	(0.472)	0.367	(0.339)	(0.370)
$\bar{R}^2$	0.612	0.014	0.705	0.031	0.701	0.176
S.E.	0.325	0.249	0.382	0.280	0.272	0.293
D-W	1.95	1.04	1.92	1.27	1.91	1.43
F	40.563	1.44	83.915	2.480	55.714	1.76
Sample Size	53	61	51	63	47	66
Sample Period	Apr. 4-Aug. 28	Apr. 4-Aug. 28	Apr. 4-Aug. 28	Apr. 4-Aug. 28	Apr. 4-Aug. 28	Apr. 4-Aug. 28

[a]Rate-of-pay is a constant 32 cents per box since grove conditions are very nearly uniform.

*Coefficient is significantly different from zero at the 0.10 level of the one-tailed t-test.

**Coefficient is significantly different from zero at the 0.05 level of the one-tailed t-test.

***Coefficient is significantly different from zero at the 0.025 level of the one-tailed t-test.

(The numbers in parentheses refer to the standard errors of the estimated coefficients).

In spite of our puzzlement with respect to the longer work-day estimates for the Irvine orange pickers, the fact still remains that a partitioning by work-day lengths for these pickers did result in statistically significant air pollution coefficients for the shorter work-day partitioning for each picker. If the reader is willing to take one instance of a statistically significant air pollution coefficient for each picker in either Table 5.4A, 5.5A, 5.7A, and/or 5.8 as being acceptable evidence of a deleterious air pollution impact upon a picker, then the proposition that sixteen of eighteen, or eighty-nine percent, of the pickers studied appear to have been significantly and negatively impacted cannot be rejected. Only Upland 2 (1973) and Upland 4 (1973), both in oranges, refuse to yield negative and statistically significant air pollution coefficients. Remembering, however, that those whom we have called different pickers are often the same pickers picking a different crop or in a different year, twelve of twelve, or one hundred percent, of the pickers studied appear to have had their work performance damaged by air pollution for at least one of the two crops in both the years studied. It would place some strain upon one's credulity to insist that this observed frequency of deleterious air pollution impacts across individuals is simply due to chance, particularly when it is recognized that the collinearity between temperature and air pollution in Tables 5.4A, 5.5A, 5.7A, and 5.8 increases the standard error of the air pollution coefficient and thus reduces its statistical significance, without, of course, biasing the coefficient itself.

The calculations in Table 5.9 are performed in a manner identical to those in Table 5.6. Unless the longest work-day length partitioning for a picker did not yield a statistically significant air pollution coefficient, only the air pollution coefficients, the earnings observations, and the air pollution observations falling within the longest partitioning are used to calculate $\bar{V}$ and $\bar{\bar{V}}$. Otherwise the coefficients and observations for a lesser work-day length partitioning that did have a statistically significant air pollution coefficient are used. ΣI_t, however, refers to all work-day lengths. The percentage in the last column of the table is therefore defined in exactly the same manner as the last row in Table 5.6: it is the compensation, in terms of a percentage of what his <u>total</u> earnings would be in

Table 5.9

Required Picker Income Compensations Calculated Using Results of H Partitionings

Picker	Partitioning	$\hat{b}_{LØZ}$ or $LØZH$	ΣI_t	$\bar{V}$	$\bar{\bar{V}}$	$n\bar{\bar{V}}$	$\left(\frac{n\bar{\bar{V}}}{I_t + n\bar{\bar{V}}}\right)100$
Upland 1 (1973)	H≥7.0	-0.096	$3163.33	$-0.429	$-0.667	-$40.44	-1.3%
Upland 1 (1974)	H≥7.0	-0.081	3468.22	-0.240	-0.036	-24.75	-0.7%
Upland 2 (1973)[a,b]	H≥7.0	-0.075	2899.30	-0.287	-0.500	-33.72	-1.2%
Upland 2 (1974)	H≥7.0	-0.085	2899.37	-0.206	-0.339	-21.13	-0.7%
Upland 3 (1973)[b]	4.0≤H<7.0	-0.043	1489.07	-0.078	-.236	-10.86	-0.7%
Upland 4 (1973)[a]	H≥7.0	-0.137	1213.50	-0.365	-0.719	-22.22	-1.8%
Upland 22 (1974)[b]	H≥7.0	-0.061	1645.93	-0.038	-0.088	-4.51	-0.3%
Santa Paula 10 (1973)[b]	H≥7.0	-0.299	821.86	-0.667	-1.086	-30.44	-3.5%
Santa Paula 10 (1974)[b]	H≥7.0	-0.020	4063.85	-0.098	-0.159	-18.91	-0.5%
Santa Paula 11 (1973)	H≥7.0	-0.108	1020.63	-0.647	-0.765	-18.59	-1.8%
Santa Paula 11 (1974)	H≥7.0	-0.055	4331.51	-0.325	-0.406	-37.29	-0.9%
San Bern. 5 (1973)[b]	4.0≤H<7.0	-0.118	1886.23	-0.049	-0.077	-6.14	-0.3%
San Bern. 7 (1973)	H≥7.0	-0.062	3529.50	-0.097	-0.166	-16.20	-0.5%
Irvine 38 (1974)[b]	2.0≤H<7.0	-0.143	2063.40	-0.529	-0.685	-36.31	-1.8%
Irvine 39 (1974)	2.0≤H<7.0	-0.100	2313.10	-0.316	-0.418	-21.32	-0.9%
Irvine 40 (1974)	2.0≤H<7.0	-0.171	2650.36	-0.697	-0.877	-41.22	-1.6%

[a]Lemons only.

[b]This picker had a statistically significant air pollution coefficient for the impartitioned estimates. See Table 5.6.

the absence of air pollution during the entire period of observation, the picker requires to make him indifferent to the presence of air pollution.

Upon taking the percentage required compensations for the pickers in Table 5.6, as well as the same compensations for those pickers in Table 5.9 who do not appear in Table 5.6, and then calculating an unweighted arithmetic mean over all eighteen pickers, one obtains a figure of 2.0 percent. Calculating this same mean for all twelve individuals yields a lesser required compensation of 1.3%, where each crop and/or year for each individual is weighted by n.

The partitionings in Tables 5.7A, 5.7B, and 5.8 lack an analytical basis. They were selected to provide similar numbers of degrees of freedom across partitionings for most pickers. Moreover, as the careful reader will have already noted from Table 5.1, they do not refer to actual work-day lengths but rather to work-day lengths in a particular grove. Thus a picker could conceivably have worked three hours in one grove and six hours in another on a given day, yet not have his actual work-day length appear as nine hours in our data. Instead, the three hours would be counted as an observation in the less than four hours partitioning, while the six hours would appear in the middle partitioning. This means, then, that the air pollution coefficients for the lower and middle ranges in Table 5.7 are not representative of the interaction between hours worked and air pollution impact since H does not represent actual work-day length. However, this problem is trivial for the upper partitioning because, with only an extremely few exceptions involving no more than an hour, all observations in this upper partitioning have a one-to-one correspondence between hours worked in a particular grove and the length of the actual work-day. Of course, since it is likely the lower and middle partitionings for at least some pickers include hours toward the end of long actual work-days, the calculations of required picker compensations in Table 5.7A are biased downward, i.e., actual required compensations are higher. Some idea of the magnitude of this downward bias is provided by comparing the calculated required compensations for pickers in Table 5.6 with the calculated required compensations for these same pickers in Table 5.9. For the pickers appearing in both tables, the percentage required compensations in Table 5.6 exceed those appearing in Table 5.9 by factors of as little as one-half (Upland 22 (1973)) and as great as thirty (San Bernardino (1973)).

Given the downward biases in the absolute magnitudes of the percentage required compensations of Table 5.9, it seems reasonable to conclude that the representative individual in this study would have had to receive two to three percent of what his income would be in the absence of air pollution to make him indifferent to the presence of the air pollution levels to which he was subjected. This statement applies only to circumstances in which the picker chose to work each day as many hours as he was institutionally allowed.

Footnotes: Chapter 5

1. These differences among crop years could have been accounted for by a dummy variable. However, this would have presumed that the difference was explained solely by a shift in the intercept of the earnings expression. The responsiveness of earnings to air pollution would have implicitly been assumed to have remained the same in the two years. Because of the large number of observations we had available on each picker's performance, the course we adopted appeared less restrictive.

2. In retrospect, a dummy variable approach might not have been the best way to handle this problem. The labor camp managers may be saying that Fridays and Mondays are separable and distinct blocks of time; that is, they cannot be embodied in the time constraint (7) of the picker's decision problem, but must be treated as additional time constraints. This would imply that separate earnings expressions should be estimated for each of these two days.

3. Although it could easily be a coincidence, it is worth noting that the negative magnitudes of the air pollution coefficients for the three Irvine workers vary directly with the worker's ages. Irvine 38 is in his early forties, Irvine 39 is in his late twenties, and Irvine 40 is only eighteen years old.

4. There exists sound empirical evidence in the economics literature to support this notion of declining marginal productivity with respect to increases in the number of hours worked. Feldstein (1967), for example, in a study using British data finds that the elasticity of output with respect to hours substantially exceeds that with respect to men.

5. There exists an alternative explanation for the association between picker responsiveness to air pollution and long work-days: high air pollution levels and long work-days may themselves be associated. For example, long work-days may occur primarily in the summer months when high air pollution levels also occur. Although no attempt was made to calculate a simple correlation coefficient between crew work-day lengths and air pollution levels, a scanning of the data files for several workers made it appear that long work-days are distributed more-or-less rectangularly over the entire calendar year.

6. One interesting alternative strategy, which involves using first differences in the dependent variable, is presented in Ashenfelter and Heckman (1974).

Chapter 6

AIR POLLUTION AND ABSENTEEISM: EMPIRICAL RESULTS

Absenteeism. One must remember that the calculated required compensations in Chapter 5 refer solely to situations in which the picker chose to work as long as he was permitted: he did not choose to adjust to the presence of air pollution by taking more leisure. Does he sometimes take more leisure when air pollution is high? If so, the required compensations presented in Tables 5.6 and 5.9 will be excessive if extrapolated to circumstances in which pickers do occasionally voluntarily choose leisure as a mode of adaptation. As (12) of Chapter 4 implies, for leisure to be chosen, its marginal utility must exceed the marginal utility of the earnings the picker could have obtained by continuing to work. Although the picker suffers disutility from the loss of earnings consequent upon his decision not to work, he also acquires some positive utility by having more leisure available. The compensation he requires to return to his original utility level in the presence of air pollution is therefore less than if he were to suffer a similar loss in earnings but still work the same number of hours he would without air pollution.

The model presented in Chapter 4 readily captures the additional dimension of the picker's voluntary taking of leisure as an adaptation to the presence of air pollution. Remembering that $H \equiv H^+ - Z$, upon rewriting (14) in the standard form for a labor supply function one obtains

$$(15) \quad Z = H^+ - H(I_t, \text{ air pollution, other factors that shift S in Figure 4.2(b)})$$

Given that environmental conditions help to determine the hours the picker chooses to work, a regression specification of Z on crew-hours and the factors determining the hours the picker works yields an estimate of the covariation between the hours the picker chooses not to work when he could have worked and the level of air pollution. Note that in (15), if air pollution actually influences the picker's decision, the dependent variable Z, the hours the picker chooses not to work, and the level of air pollution are expected to vary directly with one another.

Because of the myriad of factors which may enter into the picker's decision not to pick and which are unrepresented in (15), we cannot hope to achieve a particularly high degree of explanatory power. Of course, to the extent air pollution is a relevant explanatory variable and is uncorrelated with excluded but relevant explanatory variables, explanatory power is of no importance. The air pollution coefficient will still be unbiased and that is all that matters for our purposes.

In order possibly to reduce the extent to which relevant variables that are nonorthogonal to the air pollution variable are excluded from attempts to estimate (15), the estimates appearing in Table 6.1 include observations during which the picker worked less than two hours. They do not, however, include observations in which the picker chose not to appear for work at all. Thus the results should be interpreted as showing the picker's propensity to work a lesser number of hours than his crew worked on a particular day, given that the picker chose to work for at least some time during that day. Regressions run with observations included in which the picker chose not to work at all gave results in which much less than one percent of the variation in Z was explained (for two pickers the $\bar{R}^2$'s were negative) and the F-tests for the entire expression were always less than unity. Air pollution coefficients were never statistically significant. The somewhat better robustness of the estimates appearing in Table 6.1 can plausibly be attributed to the greater number of factors (family illness, vacation plans, etc.) influencing the decision not to appear for work at all as opposed to the factors influencing the decision to quit picking and undertake leisure after having already expended picking effort on a particular day. Available data limited the absenteeism estimates to Upland lemon pickers.

The estimates appearing in Table 6.1 are certainly not encouraging if one initially suspected that pickers adapt to air pollution by substituting leisure for picking effort. Any discouragement can, however, be tempered by at least three factors that might have influenced the character of the estimates. First, the pickers whose work performances are reported in this study were all deliberately selected because of their long and more-or-less continuous work records. In short, these pickers tend on a day-to-day basis to persevere

Table 6.1

Absenteeism Estimates by Ordinary-Least-Squares for Upland Lemon Pickers.[a] Dependent Variable = Z.

Picker: Variable	Upland 1 (1973)	Upland 1 (1974)	Upland 2 (1973)	Upland 2 (1974)	Upland 3 (1973)	Upland 4[b] (1973)	Upland 22 (1974)
Constant	-0.409	-0.183	-0.650	-0.616	1.149	1.854	-2.942
	(1.124)	(0.678)	(0.566)	(0.999)	(0.927)	(1.706)	(1.215)
w	0.052	-0.041	0.114	-0.124	0.108	0.027	0.030
	(0.047)	(0.060)	(0.023)	(0.105)	(0.043)	(0.081)	(0.145)
H^+	0.073	0.054	0.076	0.067	0.110	0.091	0.224
	(0.024)	(0.013)	(0.013)	(0.022)	(0.022)	(0.042)	(0.026)
FR	-0.002		-0.003	0.003	-0.010	-0.008	0.002
	(0.003)	(0.001)	(0.004)	(0.002)	(0.003)	(0.005)	(0.003)
BT	-0.008	-0.034	0.0001	-0.221	-0.016	-0.199	-0.427
	(0.047)	(0.116)	(0.0001)	(0.185)	(0.038)	(0.098)	(0.240)
ØZH	-0.012	0.003	0.006	0.004	0.009	0.018	0.007
	(0.012)	(0.005)	(0.006)	(0.008)	(0.011)	(0.019)	(0.009)
TM	0.003	-0.001	0.004	0.003	0.002	0.011	0.007
	(0.008)	(0.005)	(0.004)	(0.005)	(0.006)	(0.012)	(0.006)
TR	0.181	0.125	0.070	0.283	0.147	-0.048	0.403
	(0.121)	(0.125)	(0.066)	(0.197)	(0.106)	(0.172)	(0.264)
I_{t-1}	0.006	0.008	0.008	-0.018	-0.019	-0.063	0.048
	(0.018)	(0.010)	(0.008)	(0.016)	(0.021)	(0.032)	(0.025)
$\bar{R}^2$	0.042	0.105	0.213	0.057	0.218	0.148	0.372
S.E.	0.818	0.428	0.470	0.619	0.653	0.989	0.737
F	2.01	3.54	7.91	2.25	6.54	3.82	12.56
D-W	1.95	2.18	2.18	2.14	2.13	1.70	1.90
Sample Size	186	174	205	168	160	131	157
Sample Period	Mar. 17- Dec. 21	Apr. 1- Nov. 2	Mar. 19- Dec. 21	Apr. 1- Nov. 2	Mar. 17- Dec. 20	Mar. 16- Dec. 21	Apr. 17- Nov. 2

Table 6.1
(continued)

[a]These estimates include observations in which the picker worked less than two hours.

[b]This picker is a woman.

(The numbers in parentheses refer to the standard errors of the estimated coefficients).

in citrus harvesting. Perhaps pickers who, relative to the population of pickers, exhibit greater perseverance in their day-to-day picking activities will exhibit similar tenacity within any single day.

Second, the values of the air pollution and temperature variables used in Table 6.1 are those employed in all earlier tables; that is, they are the arithmetic mean ambient pollution concentrations and temperatures over the crew's work-day rather than the picker's work-day. Thus, on those occasions where Z is positive, pollution concentrations and temperatures occurring when the picker was taking leisure are included in the observed values of the pollution and temperature variables. The use of the latter values would be justified if and only if the picker's expectations about future pollution and temperature concentrations during the rest of the crew's work-day were always realized. This seems unlikely. It is therefore preferable to presume that the picker formulates his expectations about air pollution and temperatures for the rest of the work-day on the basis of the pollution and temperature levels he has already experienced. The values employed for estimation purposes should therefore have been some combination of pollution and temperature levels occurring while the picker was actually working. The failure to do so in the estimates of Table 6.1 means that the air pollution and temperature variables include measurement error and that their coefficients are therefore biased. The direction of bias for either coefficient is not immediately evident, particularly since the errors for these two somewhat collinear variables probably interact in a complex way.[1]

Third, in contrast to the earnings estimates of Chapter 5, no attempt was made for the absenteeism estimates to experiment with the empirical specifications for one or two pickers. That is, no effort was expended to gain insight into the absenteeism relationship by learning from the empirical results for "test" pickers. The estimates appearing in Table 6.1 are the first absentee estimates attempted for each picker.

In summary, the results presented in Table 6.1 make it easy to reject the maintained hypothesis that air pollution influences picker absenteeism. This rejection must, however, be highly conditional because of the character of the pickers for whom estimates were made, because of the inclusion of air pollution levels occurring after the picker had chosen leisure, and because no experimentation on "test" pickers was performed.

Simultaneous Adjustments of Work-Effort and Leisure. The model of the picker's decision problem presented in the fourth chapter implies that the picker, when faced with actual or expected air pollution, may adjust his work-effort, his leisure-time, or both. In the section immediately preceding this one and in Chapter 5, empirical tests of the model were undertaken, but no effort was made to estimate expressions in which the picker was permitted to adjust simultaneously his work-effort and his leisure. Thus no account has been taken of circumstances in which the picker suffered reduced but still positive productivity during part of his work-day, and, perhaps in response to this reduced productivity, then decided to substitute leisure for additional expenditure of picking effort. Nevertheless, the model of the picker's decision problem would seem to lend itself readily to simultaneous treatment of the influence of work-effort and voluntarily taken leisure-time upon earnings, or the influence of earnings and work-time upon voluntarily taken leisure-time. All one need do is replace Z on the left-hand side of (15) with $H^+ - H$, substitute the H(.) of (15) into the H of (14), and state the resulting expression in stochastic form. The resulting or "reduced-form" expression is overidentified, however, meaning that one cannot allocate the estimated coefficients of the reduced form between (14) and (15), the original structural expressions. The air pollution coefficient should nevertheless provide an estimate of the combined effect upon earnings of work-effort and voluntarily taken leisure-time.

Following the procedures outlined in the above paragraph, we have estimated reduced-form expressions by two-stage-least-squares for two pickers, Upland 2 (1974), and Upland 22 (1974). In both cases, earnings, I_t, was the dependent variable, i.e., expression (15) was substituted into expression (14). Without further analysis, the results cannot be considered enlightening. The highly statistically significant but positive air pollution coefficients obtained with the reduced form have thus far defied interpretation. Time has not permitted a detailed investigation of what may be causing these positive coefficients.

Footnotes: Chapter 6

1. Additional remarks on the nature of the bias introduced are available in Anderson and Crocker (1971, p. 174).

Chapter 7

CONCLUSIONS AND FEASIBLE EXTENSIONS

Conclusions. Whenever one constructs a formal model of a real situation, one is attempting to express in an internally consistent manner a conviction as to which of the elements of the situation are trivial and which are essential. A bounded rationality requires that one pick and choose. It is a commonplace of statistical inference that one's convictions about the essential elements can, by comparing their implications with observations on real situations, be rejected but never completely accepted. The best one can do is fail to reject the convictions. It is worth noting, however, that even a rejection must rest upon some self-convincing interpretation of one's observations. The pressures of uncertainty operate symmetrically.

In order to secure the reality of citrus picking in the presence of air pollution somewhat more closely, a model of the picker's decision at the beginning of each day of whether or not to pick citrus and his supply of work-effort once he has decided to pick has been constructed. In the model, the response of work-effort to air pollution was viewed strictly as a biological relation: that is, air pollution entered the picker's production function for citrus fruit but it did not enter his utility function. The response was, in essence, viewed as a short-term and reversible morbidity effect. No attempt was made to capture any long-term and irreversible effects. Certainly neither the model nor its empirical implementation captures all features that may influence the individual picker's work performance each and every day. For example, in addition to disliking the loss in earnings that the presence of air pollution causes, he may also dislike air pollution in and of itself. Nevertheless, the essential features of the determinants of the individual's day-to-day earnings from the picking of citrus fruit, appear, for the most part, to have been captured, both analytically and empirically.

The decision agent of the model, the individual citrus picker, corresponds exactly to the decision agent in each of the empirical analyses. It should be recognized that the study does not consist of a single empirical analysis of a collection of decision agents, but rather of a series of analyses, one analysis to each of eighteen pickers distinguished by individual, crop, or year. This series of analyses involved the consistent application of the identical analytical model to each picker. Although data did not permit explicit investigations of the reasons for differences among pickers in their responses to the presence of air pollution, these responses were consistently of the same order of magnitude.

With the exception of four "preliminary test" pickers, the basic model was empirically applied only once to each picker, thus avoiding the often difficult-to-interpret effects upon subsequent tests and estimation procedures of the "data-grubbing" or "massaging" techniques so frequently employed in similar studies.[1] Given the resources and time available to the study, this procedure was not without its costs, however. For a few pickers (in particular, all three of the Irvine orange pickers and the two Upland orange pickers), the stochastic statement of the model was clearly misspecified. The obvious way to repair this is to respecify in a correct fashion the expressions to be estimated for these pickers, and then apply these expressions to the data for new pickers drawn from the same crews. We possess the requisite data, but it has not been put in a form susceptible to computer treatment. Moreover, if we had investigated in detail the sources of the misspecifications for the Irvine and Upland orange pickers, we would have drawn available resources away from applying the estimated expression for the four preliminary test pickers to additional pickers in locales and for crops where the expression appeared to be robust. In our judgment, the application of the expression for the four preliminary test pickers to more pickers appeared more valuable to the study than correction of the misspecifications for the Irvine and Upland orange pickers.

The analytical model developed in Chapter 4 explains both the picker's decision whether or not to pick each day as well as his decision about how much effort to put forth once he has decided to pick. Only the latter aspect of the model has been subjected to empirical test, and this aspect is considered to be separable from the daily decision of whether or not to pick at all. Fortunately, the available data for each picker permitted us to distinguish days in which the picker worked for as many hours as he was institutionally allowed from days in which he started working but voluntarily substituted leisure part way through the work-day. In the model, it was shown that in circumstances where the picker did not substitute leisure for earnings, the loss, if any, in earnings due to air pollution could be interpreted as a measure of the Hicksian compensating surplus, i.e. the social loss caused by air pollution that attaches to the picker. This measure of social loss is simply the additional earnings the picker requires in the presence of air pollution to make him indifferent to its presence. This compensating surplus was estimated from an inverse constant real income supply function. Disregarding the specification problems for the Irvine and Upland orange pickers, this surplus was positive for all twelve individuals and sixteen of the eighteen pickers studied. (Again, two pickers may be the same individual distinguished by crop and/or year). For ten of the eighteen pickers and six of the twelve individuals, however, the surplus did not become apparent until account was taken of the possibility that the impact of air pollution might differ according to the length of time a picker has worked on a given day. In fact, estimates give fairly strong support to the hypothesis that air pollution impact, measured in terms of the compensating surplus, tends to increase with increasing numbers of hours worked. For pickers, the surplus amounts to an average of about 2.0 percent of the picking earnings they would have had in the absence of air pollution, while for individuals the same percentage is 1.3 percent. If one removes from these calculations the pickers whose estimated expressions appear to be misspecified, one is left with positive compensating surpluses for thirteen of the thirteen pickers and nine of the nine individuals studied. The average compensating surplus as a percentage of picking earnings in the absence of air pollution is then 2.3 percent for the pickers and 1.3 percent for the individuals. Percentage compensating surpluses differ between pickers and individuals because the former surplus is an unweighted arithmetic mean, while the latter arithmetic mean is established by weighting each picker by the number of observations for him in a crop or year. In terms of absolute dollar magnitudes, these compensating surpluses appear to range from less than twenty dollars to nearly two hundred dollars over an entire calendar year, given the piece-work wage rate scales and the levels of air pollution prevailing in the South Coast Air Basin during 1973 and 1974.

In addition to estimates of the compensating surplus for a number of pickers, two attempts were made to estimate the effect of air pollution upon the picker's substitution of leisure time for picking effort. One set of estimates presumed that while still picking, the picker did not adjust his picking effort. No statistically significant impact of air pollution upon the substitution of leisure time (absenteeism) for picking effort was discovered. It is possible this lack of significance is due to the fact that all the pickers tested had stable work histories, that the measure of air pollution employed covered the crew's work-day rather than just the period during which the picker in question was working, or that the statistical procedures employed were unsuited to the problem. No attempt has been made to ascertain whether any of these factors have influenced the estimates for absenteeism.

A second set of estimates tried to treat simultaneously the picker's reduction of picking effort during a single work-day and his outright substitution of leisure time for picking effort. Few research resources were devoted to this treatment, and the results obtained were not susceptible to immediate interpretation.

In summary, the results of the study provide quite strong evidence that citrus pickers would have had to be compensated by about two percent of what their incomes would have been in the absence of air pollution in order to be indifferent to the air pollution levels prevailing in the South Coast Air Basin in 1973 and 1974. This presumes that pickers did not reduce the hours they spent picking citrus fruit in response to these air pollution levels. Although much more tentative than the preceding estimates of required compensations, estimates of the responsiveness of absenteeism to air pollution during the same period were statistically insignificant. Thus, for the pickers studied, required income compensations averaging about two percent of picking earnings are quite accurate, given that air pollution did not influence absenteeism.

Feasible Extensions of this Research. The research possibilities residing in this data set are by no means exhausted. One might, in fact, map out a lengthy research program consuming several man-years of effort. No attempt is made in this section to do so; nevertheless, as embodied in this report, the study is somewhat incomplete. In this section, work that can quite readily be done with the existing data set and analytical framework is briefly discussed. The section and the report conclude with an even briefer discussion of extensions requiring the acquisition of additional data and/or the development of an analytical framework capable of encompassing a greater range of phenomena.

Currently in our possession is the same information used for the pickers and individuals studied in this report for approximately an additional 350 pickers comprising about 220 distinct individuals. As this report is being written, the information for six of these pickers has been tabulated and keypunched but has not yet been submitted to the ministrations of the computer. In spite of the consistency of the results generally obtained across pickers, the small number of pickers and individuals studied (note, however, that a large number of observations were available for each picker), make one a bit hesitant to testify resoundingly that it has been definitively established that photochemical oxidants are detrimental to the work performance of citrus pickers. After all, fifteen or so replications of an experiement do constitute a small sample. Running the experiment for additional pickers would be a time-consuming task, but, given what has thus far been accomplished, mostly a mechanical one. In a letter to the project officer dated November 21, 1975, we stated that an analysis of about sixty pickers would be an adequate sample size. Clearly, this has not been accomplished.

Perhaps the most troublesome problem in discovering the statistical significance of the air pollution coefficients has been the collinearity between the air pollution and temperature variables. This collinearity is reflected in the considerable reductions in standard errors of the air pollution coefficients that frequently occur when the temperature variable is deleted from the expressions to be estimated. One obvious but as yet untried way possibly to reduce this collinearity is to partition each picker's data set by temperature intervals so as to lessen the variability of temperature.

This, of course, does not guarantee that the variability of air pollution might not be reduced as much or even more. The partitioning would have the additional advantage of providing a partial test of the hypothesis that air pollution impacts vary with temperature levels.

A partitioning of the air pollution variable itself can provide information on whether the assumption used in this study of a constant elasticity of air pollution impact with respect to earnings is reasonable. The partitioning can also provide insight into the form of the relationship between earnings and air pollution, including whether there is some positive level of air pollution at which a negative impact of air pollution upon earnings begins. Some preliminary efforts along these lines for six pickers show no tendency whatsoever for the air pollution elasticity of earnings to increase with increasing air pollution levels. Some imagination and perhaps a bit of wishful thinking enables one to discern a slight tendency for the elasticity to decline with increasing air pollution.[2]

Only the arithmetic mean of the concentration air pollution during the crew's work-day or over a twenty-four hour period are used in this report as a measure of air pollution, although the variance of the air pollution distribution over the crew's work-day was introduced and found to be statistically insignificant for the four preliminary test pickers. Of course, the arithmetic mean and variance are not the only characterizations of the air pollution measure that might be relevant. For example, given the intuition of many familiar with the health impacts of air pollution that peak concentrations account for a disproportionate share of impact, a measure of skewness could also be relevant. In addition, it is plausible that within any given work-day the effect of air pollution is cumulative, requiring that one account for prior air pollution levels during the day via a distributed lag structure.

The speculations of the preceding paragraph suggest that characterizations of the air pollution variable in addition to its arithmetic mean might be relevant. No suggestion is made in analytical terms, however, as to why they might be relevant. An analytical framework for their relevance is readily provided in terms of the economics of uncertainty. By using the arithmetic mean of air pollution, we have implicitly and strongly assumed that the picker makes his picking decisions solely on the basis of the expected value of air pollution concentration. In short, certainty equivalence, with its implication that the concentrations the picker expects are always realized, has been assumed. The picker's behavior at any time is therefore viewed as invariant with respect to the probability of error in his forecast of expected air pollution dosages. It is readily shown that, independently of actual pollution dosages, the existence of the possibility of discrepancies between the picker's expected and realized air pollution dosages is costly in and of itself.[3] This study, as presently constituted, could therefore be neglecting a fairly important facet of the impact of air pollution upon citrus picker work performance. The air pollution measures of the previous paragraph would permit one to test for the existence and magnitude of this uncertainty effect without necessitating any fundamental changes in the analytical framework already employed in the study.

All expressions estimated in this study are based upon the assumption of an additive error term with the usual Gauss-Markov properties. Since the study is actually a series of analyses of the work histories of individuals, one analysis to an individual, this is not an altogether innocent assumption. It implies that the error for a picker during work-day t is independent of the error at t-1. Except for certain orange pickers, this assumption seems, in fact, innocent enough since Durbin-Watson statistics consistently hovered around 2.00. For these orange pickers, however, the Durbin-Watson statistics were consistent with the presence of rather severe negative autocorrelation. There exist several possible responses to this presence, none of which have been applied to the orange pickers in this study. For example, one might resort to maximum likelihood or two-stage-least-squares estimating procedures. Or there may be some neglected variable, such as lagged earnings, that has a systematic influence on the current earnings of orange pickers but has none upon the current earnings of lemon pickers. It would be a rather simple matter to designate as "preliminary test" workers a couple of the orange pickers for whom expressions have already been estimated, experiment with their stochastic specifications, and then apply the resulting improved specification to additional orange pickers.

The stochastic expressions of the inverse supply function that have been estimated in this study have not embodied all the *a priori* information the analytical framework is capable of generating. For example, given that air pollution does not enhance the ability of the picker to harvest fruit, a few simple manipulations of the compensating surplus model of Chapter 4 will generate the conclusion that air pollution must affect picker earnings either not at all or negatively. This is a result of the inability of the picker to work for longer hours than does his crew and it implies the coefficient for the air pollution variable can be restricted to zero or negative values. It is possible that this knowledge about the sign of the air pollution coefficient would, if a restricted estimation technique such as the mixed estimation method of Theil and Goldberger (1961) is used, would reduce the variance of the air pollution estimator and thereby increase the efficiency of estimation.

The empirical sections of this study that attempt to estimate the relationship between air pollution and absenteeism, as well as the simultaneous relationship between air pollution, earnings, and absenteeism, are incomplete. As was indicated in the main text, any investigation of the simultaneity between earnings and absenteeism was set aside as soon as difficulties of interpretation were faced. If only because a full description of the picker's response to air pollution requires that account be taken of the possibility that he adjusts both work effort and leisure time during a single day, more thorough investigation of this simultaneity would be useful. As for absenteeism, again as was indicated in the text, a measure of air pollution that measures cumulative work-day exposures occurring prior to the picker's termination of work effort would be preferred to the air pollution measure actually employed. The use of this preferred measure might show some effect of air pollution upon absenteeism.

The discussion to this point in this last section of the report has dealt solely with additional research that can be done within the confines of the existing data set and analytical model. It was pointed out that opportunities are available to acquire greater confidence in the measured air pollution impacts reported here, to gain better understanding of the interactions between air pollution impact and factors such as temperature, and to delve further into the reasons why air pollution impacts for certain pickers and certain classes of relationships were not obtained. If one combines the existing data set with additional data and if one expands the analytical model, a number of further issues can be empirically investigated. For example, it would be most interesting to know why air pollution impacts appear to differ among individuals. If differences in biological endowments are the source, these differences are easily built into a slightly expanded version of the analytical model of Chapter 4. It would be a relatively easy matter to acquire information on such obvious sources (or proxies for sources) of differences as age, weight and height, and sex. A much more ambitious effort might involve interviews to acquire data on medical histories, life styles, and occupational histories. Acquisition of data of this sort would allow a pooled time series-cross sectional analysis capable of explaining the relationship between the disturbances of a specific picker population at two or more different times.

The reader familiar with the biomedical literature will have long ago noted that no mention is made anywhere in the previous pages of biomedical evidence of the effects of photochemical oxidants upon the human organism. Although a cursory review of the biomedical literature did not yield any studies that could be employed as a priori information in this study, a more thorough review might provide such information. Biomedical information might, in fact, be particularly useful in specifying functions explaining the sources of differences in air pollution impacts among individuals. This information would be extremely valuable in a pooled time series-cross sectional study.

A final question perhaps of interest is the feasibility of extending the approach used here to other industries in order to study the effects of environmental pollutants upon labor performance. The data available to this study are certainly unusual to some degree because of their detail on the day-to-day pay scales, working conditions, and environmental conditions of individual workers. It is, in fact, difficult to think of another single industry for which similar detail would be available, in which the supply of worker effort is strongly separable from the efforts of other workers, and where complementary capital equipment is of no more than trivial import. In the absence of these conditions, the analytical model of the worker's supply of effort decision would be more complicated. This is not to say, however, that the model cannot be built, nor that the data is unlikely to be available with which to implement it empirically. For example, many firms in the construction industry and in agricultural industries monitor the output of individual workers and maintain records of the conditions under which they are working. Collection of the data is normal business practice. This is the only data required to implement some approximation of the approach taken in this study.

Footnotes: Chapter 7

1. It should be noted, nevertheless, that there exist orderly and rigorous techniques for inductive model-building that permit one to weigh the gains in improved specification against the losses in robustness of estimators. For an analysis of the properties of one of these techniques, see Wallace and Ashar (1972).

2. For more detail and a less cautious statement about these tendencies, see Crocker and Horst (1976).

3. For formal proofs and arguments showing this in pollution contexts, see Crocker (1971, pp. 21-26), and National Academy of Sciences (1974, pp. 427-470).

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16. ABSTRACT

This project assesses the effect of photochemical oxidants on the work performance of twelve individual citrus pickers in the South Coast Air Basin of southern California. A model of the picker's decision problem is constructed in which oxidants influence the individual's picking earnings and leisure-time via short-term and reversible morbidity effect. Circumstances are specified under which this effect can be interpreted as the additional earnings the individual would have to receive in the presence of oxidants in order to make him indifferent to the presence of oxidants. This Hicksian compensating surplus is estimated separately for each of twelve individuals. In terms of absolute dollar magnitudes, compensating surpluses appear to range from less than twenty dollars to nearly two hundred dollars over an entire calendar year, given the piece-work wage rate scales and the levels of air pollution prevailing in the South Coast Air Basin during 1973 and 1974. As a percentage of what individual earnings would have been in the absence of air pollution, the dollar magnitudes range from three-tenths of one percent to nine percent. The average is about two percent. All estimates of the compensating surplus are conditional upon the individual not adjusting the hours he picks in response to air pollution. Estimates give fairly strong support to the hypothesis that air pollution impact, measured in terms of the compensating surplus, tends to increase with increasing numbers of hours worked.

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