12-1996

Closing the loop : accounting for development's hidden environmental costs

Chad Matthew Hellwinckel

To the Graduate Council:

I am submitting herewith a thesis written by Chad Matthew Hellwinckel entitled "Closing the loop : accounting for development's hidden environmental costs." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.

Burton English, Major Professor

We have read this thesis and recommend its acceptance:

Bill Parks

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Alan Schlottman

Accepted for the Council:

Associate Vice Chancellor and
Dean of The Graduate School

CLOSING THE LOOP: ACCOUNTING FOR DEVELOPMENT'S HIDDEN ENVIRONMENTAL COSTS

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Chad Matthew Hellwinckel
December 1996

ACKNOWLEDGMENTS

I would like to thank the Department of Agricultural Economics and Rural Sociology for the opportunity to learn economic theory and agricultural research. Thanks goes to my committee members Burt English and Bill Parks for allowing me to develop my own research project and giving helpful advice at crucial times. Special thanks to Corey, for believing in most everything I do, and to Sally, for long walks chasing birds.

ABSTRACT

The existence of pollution externalities hinders the market from signaling the true costs of transactions within the economy. Several authors have theoretically modeled the flow of materials and value between the human economy and the environment, but to date empirical input-output models have failed to fully account for pollution externalities. Regional development organizations have not included environmental costs in their decision making process because information on emissions is hard to find and value.

This project develops and uses an input-output model of the East Tennessee economy in conjunction with sectoral pollution output data, a toxic risk index, and sectoral abatement costs to attempt to estimate the cost of four different development industry choices to East Tennessee. The target industries are auto part manufacturing, boat manufacturing , furniture manufacturing, and paper production. Multiple economic and environmental criteria are used to rank these industries. Paper production is found to be the least beneficial industry of the four to East Tennessee. Furniture is the next least beneficial. Boat and auto part manufacturing are ranked the most beneficial of the four for East Tennessee.

The existence of pervasive externalities, future discounting, and uncertainty makes accounting for the total cost of pollution externalities an impossible task. This should not detour development organizations from ranking alternative industries by collecting as much available information on pollution output and its effects.

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CHAPTER I

INTRODUCTION

Inexpensive labor and transportation in the Tennessee Valley are prompting many companies to place manufacturing facilities in East Tennessee. Four major groups of manufactured goods include metal auto parts, fiberglass boats, paper products, and furniture. These industries contribute jobs and income to East Tennessee. In addition, these industries contribute often overlooked pollution to the area. Pollution may be a cost and could reduce the total value of a manufacturing plant to the region. The amounts of pollution generated by potential development alternatives has been virtually impossible to collect in the past.

Development officials evaluating which industries to attract to the area have not had this information available to them. The East Tennessee Department of Economic and Community Development targets three main industries to attract to the area. The choice of these target industries depends upon growth potential and prior establishments in the region. Environmental indicators have been discussed but not incorporated into the decision process because of the ambiguity of available information (Philips, 1996).

How Can We Internalize Pollution Costs?

Leontief (1941) developed input-output analysis (I-O) as a means to account for the flow of goods of value within the human economy. Traditional input-output models are expressed in monetary units and only include those transactions that exchange money for goods. Traditional I-O models do not include flows of "free" goods from the environment and into the production process. Likewise, outflows from the production (and consumption) process and into the environment that are "external" to the market, are also not included.

A complete integrated economic-environmental input-output model has been slow to develop. There are many problems with compiling this model. The flow of all materials must be known. External materials are not exchanged and have no economic value, therefore industries have not, in the past, monitored their quantity and flow.

The pollutant's effects upon the environment must be determined. Emissions may only effect the local environment or they may add to damage on the global scale, or at many scales in-between. Pollution externalities may affect the present or the future. The effects may be nonlinear and indeterministic. An emission may be absorbed within the environment up to a certain amount, then cause an increasing amount of damage. At some unknown quantity of pollutant, the ecological unit may collapse.

After the effect in real terms is modeled, value must be assigned. Since the externalities impact non-market goods; contingent valuation, market observation, or other non-market valuation methods must be used. If such a model existed, external costs could be incorporated into the economic system through taxation or subsidization, thereby correcting any potential market failures.

Objectives of the Study

Four target industries economic and environmental impacts upon the East Tennessee area are evaluated using an input-output model of the East Tennessee economy, a matrix of pollution output for each manufacturing sector, a toxic substance index, and abatement cost estimates. The most common pollution analysis looks only at the single industry that may experience a final demand change, and therefore ignores the chain of input industries that will also be affected. The input-output model will allow both direct and indirect effects upon the region to be projected. The four target industries are ranked based upon this information. The final data will provide development organizations and government officials with a more complete picture of the projected impacts of alternative industries. Environmental, along with economic indicators can be incorporated into target industry decisions.

Figure 1 shows a complete circle within the larger environment. This circle represents the human economy, or in this project, the East Tennessee economy. There are free goods entering this loop from the environment. The free goods are affected by the pollution emitted from the human economy, thereby affecting the health and well-being of humans. This project's goal is to find a method to come as close as possible with available information to closing this loop. Can we put a price on economy wide pollution? Can we rank the relative risks of the various pollutants on human utility, or human health? What is the best we can do to approximate pollution costs with available data?

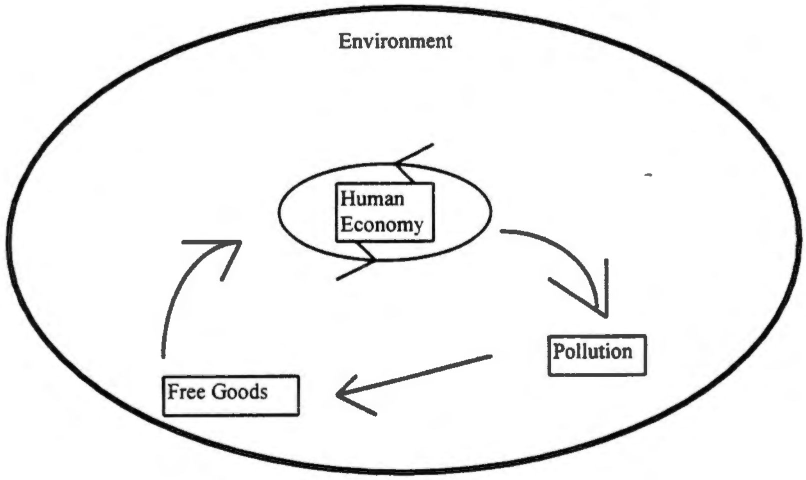

Figure 1. Relationship Between the Human Economy and the Environment

CHAPTER II

LITERATURE REVIEW

Past Community Development Appraisal

Several papers have appraised community development projects using input-output analysis (Seigel and Leuthold, 1993). Input-output analysis links all sectors in a study area with all other sectors by a matrix of coefficients which divide each industries total industrial output between all of its input industries. This enables researchers to study not only the effects of the particular development project, but the effects of the development project upon the entire community. Employment, final demand, value added and sometimes fiscal impacts have been accounted for by development studies. Studies choose a study area boundary such as a single county, a group of counties, or an entire state. The majority of studies examine at least one of three effects of a particular development project. Direct effects are the impacts upon the community of the development project by itself; The jobs, value added and taxes generated by the single development project under study. Indirect effects are the impacts upon the community caused by the input industries of the development project under study; The development project buys inputs from other businesses in the area which increases community jobs, value added and taxes collected. It is important to account for indirect effects in development appraisal, fore these are real impacts which are caused by the development project. Some studies also account for induced effects; Induced effects are the impacts upon the community from the increased spending at community businesses due to the increase in income brought about by the direct and indirect effects.

What about Externalities?

Development studies have failed to include externalities as impacts upon the community. Externalities are exchanges which occur between two parties but effect the utility of a third party not involved in the market transaction. The effects of externalities, by definition, fall outside of the market place. Because the value or cost of externalities is not directly observable, they have not been accounted for in past development appraisal studies. The next step in appraising the true costs and benefits of development is to account for externalities. Non-market effects of development may have a great impact upon the overall value of a particular project and need to be included in appraisal.

History of the Concept of Externalities

The beneficial workings of the free market system depend upon the assumption that all costs are included in production costs. Mention of externalities did not appear until around 1890, when Marshall referred to the positive externalities a firm gets from entering an industry that is already a certain scale (Marshall, 1890). The definition of externalities expanded quickly. Pigou stated that market imperfections could be corrected by charging the perpetrator with the difference between marginal cost and average cost. Pigou assumed that externalities are "market failures" which need to be corrected by internalizing these costs (Pigou, 1932).

Coase had a contrary view. He believed there may be no market failure. Where there is one agent affecting the utility of another agent, a market will be set up if property rights are assigned. Property rights assignment is the only role of government. If the costs of transaction are higher than the loss in utility , it is not efficient for a market to be formed. Net social benefit may be harmed by government intervention (Coase, 1960). The similarity of these two views is that they see non-market effects as costs that can be internalized into the market, and once this is done, the problem is solved. These are called 'market solutions'. The market would then create a pareto optimal reality.

Perrings (1987) believes that the market solution does not "internalize" all the costs of externalities. He names two problems which the market solution cannot help, future effects and uncertainty. Future costs are devalued in the present at the discount rate. This discount rate may be too high and excess costs will be pushed on to future generations. The rights of future humans are not adequately represented in the market discount rate. The existence of uncertainty means that even if future harm was not discounted, some costs may not be accounted for. For example, as the economy grows and more of the earth's resources and transformation processes fall under human control, the unpredictability of the rate and size of the environments negative influence on human utility (and prices) will increase. This uncertainty cannot be reduced to probabilistic risk assessments. Perrings, along with other modern economists, believe that there is no hope in attempting to 'internalize' all the external costs. It is seen as an impossible task which may in fact give harmful information to the market.

Pollution as an externality

Pollution is not an externality until a third party is harmed by the discharge. If a third party is harmed, the damage done by the polluting industry is a cost which is external to their production costs. This cost should be accounted for in community development appraisal. Of the many externalities, pollution is fairly approachable. There is a history of attempts to incorporate their cost into an input-output model and a few cost estimation methods already exist.

Theoretical Input-Output Economic-Environmental Models

Ayres and Kneese (1969) explain their theory of the "material balance" model of the economy. The laws of thermodynamics are at the foundation of their model. The law of Conservation of Energy states that matter and energy cannot be created or destroyed. In the economic process the weight of all materials coming from the environment will equal the weight of all materials dumped back into the environment. They view the production of material goods as a means to supply services to humans, and eventually all materials will be returned to the environment. The model's units are in pounds, and it does not attempt to tackle the problem of human valuation or ranking. The Kneese-Ayres model is a map of the flow of materials within the economy, but it is not helpful in value decision making. The model is important in that it shows that the human economy is not separate from the natural system (Ayres, 1972).

Cumberland (1966) includes environmental value within the standard input-output model. He treats the environment as a single industry in which other industries must buy inputs. The environmental inputs are accounted for in dollar terms. This would be an ideal model, and one which this paper will strive for, but he does not mention how value is to be assigned. Theoretically this was the first time environmental costs were acknowledged in an input output model of the economy, but the steps to arrive at valuation were ignored (Cumberland, 1966).

Herman Daly (1968) extends I-O from human-human and human-environment interaction to interactions which occur outside the human economy and entirely within the "environment". He places all human and non-human entities within a matrix which maps the flow of all 'goods' from all entities to other entities, whether these entities are human made (industries) or otherwise. This could include the flow of oxygen from a tree to a frog. The units within the human economy could be in monetary units, but outside the human boundary other real units would have to be used (Daly, 1968). Daly shows that there is really no absolute distinction between the economy and the environment. Everything involves transformations; taking in materials and emitting different materials.

Isard (1969) points out that there will be "more ecologic commodities than processes". The standard industry-industry model should be revised to a rectangular commodity by industry matrix. Otherwise his model is similar to Daly's by including all interactions and transformations (Isard, 1969).

Leontief (1972), the founder of input output analysis, also expanded his model. He ignored the materials balance approach of Kneese and Ayres, Daly and Isard. Instead, Leontief concentrated on the flows from the human economy into the environment. Pollution coefficients are linked to each industry to account for the total amount of real pollution. He also adds an anti-pollution industry to arrive at a value (or price) of pollution abatement spent by each sector of the economy. He can then analyze the effect of different abatement technology. This model only looks at the cost of pollution that society is already abating. It does not consider the pollution that is not handled by the anti-pollution industry. The Leontief expanded model theoretically improved the pollution accounting system by linking the pollution coefficients to final demand, but it did not make any headway in the valuation problem (Leontief, 1970).

Empirical Input-Output Economic-Environmental Models

Victor (1972) presented a model that includes ecological commodity inputs to the economy and outputs from the economy. In his empirical study of Canadian industry, he accounts for the input of water and the output of 25 materials. The economy is aggregated into 40 sectors and is based on data collected in 1961 (Victor, 1972).

There have been more recent empirical studies, Lave (1995) used the Toxic Release Inventory data from 1987 to compile a pollution matrix of 322 different substances that are known to be toxic. He did not include air emissions, such as carbon dioxide, carbon monoxide, and particulants, which may not be 'toxic' but are adding to environmental problems such as the 'greenhouse effect' and acid rain.

The theoretical input-output models have helped crystallize the concepts of conservation of energy, entropy, and the inseparability of the economy from the environment. Empirically, these models have not even come close to reality. The closest attempt so far was simply accounting for real pounds of toxic pollution (Lave, 1995).

Cost Estimation

Value Estimation

There are many studies which attempt to value the cost of pollution in dollar terms. Willingness to pay, contingent valuation, and market observation are used to do this. The willingness to pay method asks people how much they would pay for a pollutant's effects to be avoided. This gives a general figure on the value of a particular resource. The market observation method accounts for the market cost of a pollutant's effects upon other to estimate the cost of that pollutant. For example, the medical costs of black lung disease in coal miners can be directly attributed to the coal mining industry (Daly, 1989). These valuation methods typically focus on one resource or one pollutant and do not attempt to value economy wide externalities.

Pollution Output Estimation

Accounting for the real weight of extenalities is another way of estimating costs. If real weights of pollutants are known, they may be used in development appraisal. There are several sources which account for the real weight of pollutants from industry.

The US Environmental Protection Agency (EPA) has data on pollution discharge from most industrial sites within the US. The EPA's Toxic Release Inventory (TRI) accounts for all 322 toxic substances released from all large industrial sites. The EPA's Aerometric Information Retrieval System (AIRS) accounts for all releases into the air, toxic and non-toxic. The EPA's National Pollution Discharge Elimination System

(NPDES) accounts for all releases into the water, both toxic and non-toxic, of all large industrial sites.

The World Bank's International Development Group compiled the *Industrial Pollution Projection System (IPPS)* database, which accounts for fourteen aggregated pollutants discharged from aggregated industrial sectors. The World Bank used all the EPA databases described above to aggregate the pollutants into ten distinct categories released into three mediums (air, land, and water);

1) Toxic Pollution
   a) to air
   b) to land
   c) to water
2) Toxic Metal Pollution
   a) to air
   b) to land
   c) to water
3) SO2 to air
4) NO2 to air
5) CO to air
6) Volatile Organic Compounds to air
7) Fine particulates to air
8) Total Suspended Particulates to air
9) BOD to water
10) TSS to water

The IPPS aggregated the toxic pollutants and toxic metal pollutants to decrease the pollutant groups to a manageable level and because they have similar health effects. The other eight pollutants encompass the remaining pollutants which data is available (Hettige, 1996). The IPPS data lists pounds of each pollutant per million dollars output for each International Standard Industrial Code (ISIC) sector. The IPPS real weight pollution output data is listed in Table A-1. The effects of the fourteen pollutants are listed in Appendix B.

Human Health Risk Index

Risk indices can also help in cost estimation. They allow assessment of the relative danger of pollutants, which is more telling of the external costs than real quantities alone. The EPA's Human Health and Ecotoxicity Database (HHED) has indices of toxicological potency. Each of the 322 EPA classified toxic chemicals was assigned to one of four groups of toxicity. One, being the most dangerous to human health, and four being the least dangerous.

The IPPS used the HHED indices to develop a sectoral pollutant risk index. The IPPS's approach "was to multiply the quantity of each TRI chemical reported by a facility by its toxicological potency ranking, and then to sum the risk-weighted quantities for all chemicals released by the facility (Hettige, 1996)". All toxic substances are ranked in the HHED indices, so the IPPS's toxic pollutants and toxic metal pollutants to all three mediums are included within the risk weighted index. The IPPS database, reported in Table A-2, lists risk pounds of toxic waste released per million dollars output for each ISIC sector.

Abatement Costs

Although abatement cost estimates do not estimate the cost of pollution, it is an indicator of the cost that must be incurred if the industries were to abate further. There is a very real possibility that there will be tighter federal regulations in the future. Economic theories such as effluent charges and tradable permits are becoming more popular within the EPA, and one of the outcomes is that the industries which have cheap abatement costs will usually abate more than expensive abatement industries. Therefore cheap average abatement costs is a positive characteristic of an industry.

Hartman et.al. (1996) estimated average abatement costs of the eighty ISIC sectors by using the U.S. Department of Commerce and the U.S. Census Bureau's Annual survey of manufacture's costs. The abatement cost estimates are only average costs; Some industries will see the average cost increase with increasing abatement and others will see the average cost decrease. It is safe to assume that as abatement is increased drastically, eventually all industries will have increasing marginal costs. Therefore, in estimating the cost of total abatement, the estimates should be taken as a minimum. The abatement costs are reported in Table A-3.

CHAPTER III

METHODOLOGY

In order to address environmental and economic aspects of the four target industries, several steps must be followed.. Data is pulled from many sources and is manipulated to arrive at four main elements of the model; Direct and indirect final demand, employment and value added, fourteen different pollutant estimates for each target industry, risk weighted pounds of pollution for each target industry, and abatement costs per target industry. These model elements are used to rank the four industries by single and multiple criteria. The flow of the model's implementation is depicted in Figure 2.

Model Elements

Input-Output analysis

IMpact analysis for PLANning (IMPLAN, 1990) database and software is used in conjunction with a sectoral aggregation scheme and a defined study area to arrive at the direct and indirect effects of the four target industries on final demand, employment and value added.

IMPLAN is used to construct an input-output model of the East Tennessee study area. The aggregation of the economy follows the ISIC aggregation. There are eight scenario's corresponding to the four target industries under study. In each scenario, a particular target industry's final demand is increased by two different amounts;

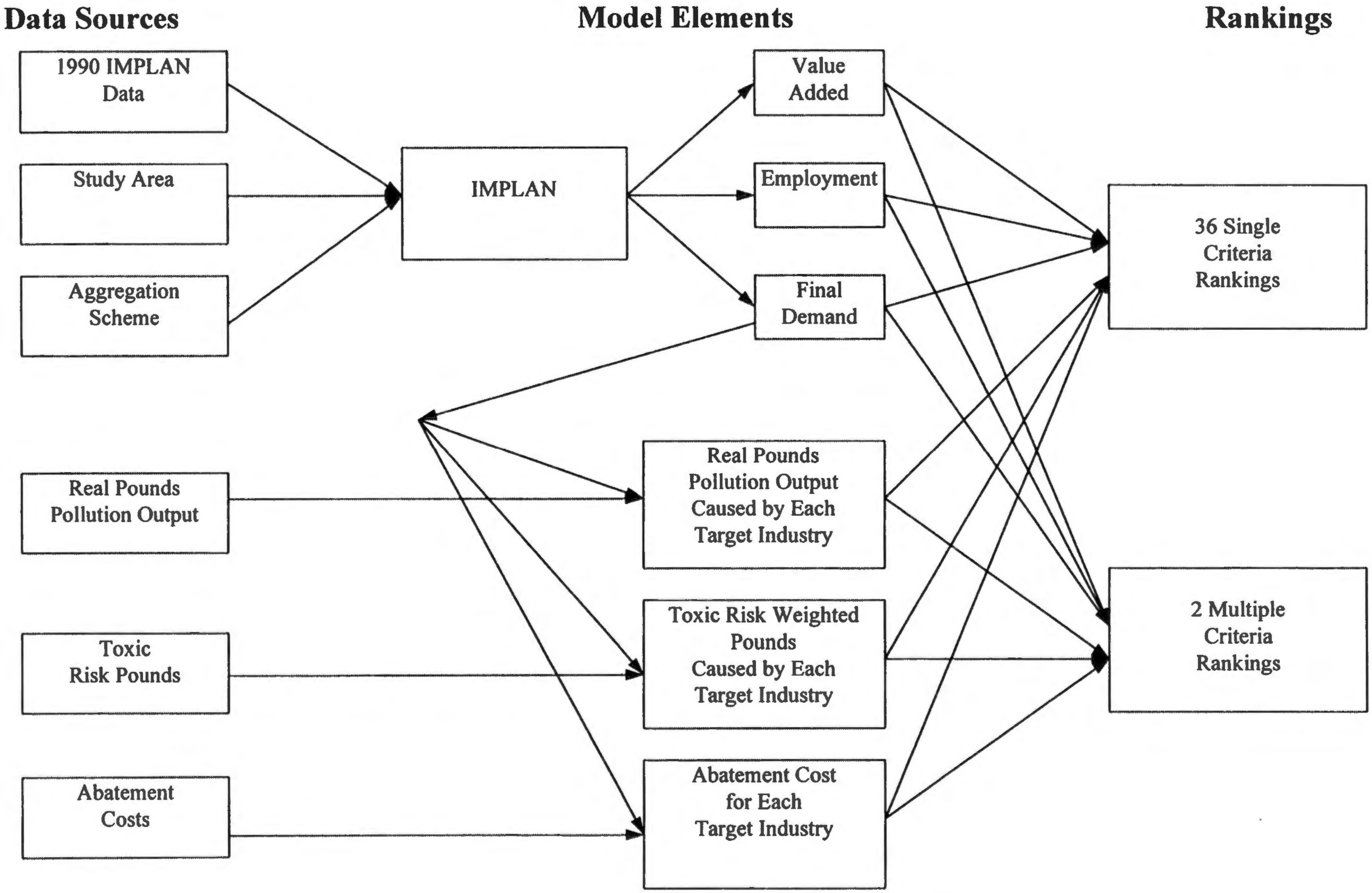

Figure 2. Flow Chart of Model Implementation.

1) one million dollars, and 2) the total final demand for the target industry in 1990. IMPLAN computes the direct and indirect effects upon final demand, employment and value added of each of the scenario's. This element of the model gives the combined direct and indirect impacts of each target industry's 1990 sales and the effects of a one million dollar increase in sales. Only backward linkages are incorporated into the model.

Real Weight of Pollutants

The World Bank's IPPS pollution matrix is used in conjunction with the economic data arrived at with IMPLAN (above) to find the direct and indirect real pounds of pollution per sector caused by each of the scenarios. For each scenario, the change in industry output of each economic sector in the aggregation scheme is multiplied by the IPPS pollution matrix. The quantities of the 14 pollutants released by each sector can be added together. The result is the direct and indirect quantities of the 14 pollutants caused by each of the eight scenarios.

Per job quantity estimates of the fourteen pollutants is also calculated. The four target industries' direct and indirect real pounds of pollution per million dollars final demand is divided by the number of employees per million dollars final demand to find the real pounds of pollution per job.

Risk Weighted Pounds of Pollutants

The World Bank's IPPS toxic substance risk weighted index is used in conjunction with the economic data arrived at with IMPLAN (above) to find the direct and indirect risk weighted pounds of pollution per sector caused by each of the scenarios. For each scenario, the change in industry output of each economic sector is multiplied by the risk weighted pounds per million dollars for that sector. The risk weighted pounds are added together to get the combined direct and indirect toxic risk weighted pounds of each of the eight scenarios.

Risk weighted pounds of toxic substances per job is also calculated. The four target industry's direct and indirect risk weighted pounds per million dollars final demand is divided by the number of employees per million dollars final demand to arrive at the risk weighted pounds of pollution per job.

Abatement Costs

Hartman's average abatement cost estimates for each sector are used in conjunction with the economic data arrived at with IMPLAN and the IPPS sectoral pollution data (above) to find the direct and indirect abatement costs of a million dollar increase in the final demand of the target industries. First the IPPS pollution data (Table A-1) and the IMPLAN final demand changes are used to find the amount of pollution generated by each sector, impacted either directly or indirectly of each scenario. Next, the resulting table and the table which lists the cost of abating each pollutant per pound per sector (Table A-3) are multiplied to find the abatement cost of each sector, impacted either directly or indirectly of each scenario. Finally, the resulting table can be summed to give the direct and indirect cost of abating each scenario's pollution output.

Abatement costs per job are also calculated. The four target industry's direct and indirect abatement costs per million dollars final demand is divided by the number of employees per million dollars final demand to find the abatement cost per job.

Ranking

The four model elements described above are used to rank the four industries including both economic benefits and environmental costs in the appraisal. The elements allow single and multiple criteria ranking to be done.

Single Criterion

The elements above allow the four industries to be ranked by 36 different criteria; 1) maximum value added, 2) maximum jobs, 3) minimum toxic risk pounds 4) minimum abatement costs and 5-18) minimum quantity of each of the fourteen pollutants per million dollars final demand; and 19) maximum value added, 20) minimum toxic risk pounds, 21) minimum abatement cost and 22-35) minimum quantity of each of the fourteen pollutants per job. By dividing value added per million dollars final demand by the risk weighted pounds per million dollars final demand, a 36th ranking criterion can be created; maximum value added per risk pound.

Multiple Criteria

Two separate multiple criteria ranking systems are undertaken. One will evaluate the rank of the four target industries based on per million dollars final demand comparisons. The second will evaluate ranks based on per job comparisons.

Since there is no 'price' available for the pollution output of production, a decisive objective method of ranking the four industries (overall) is not available. Ranking depends upon what indicator(s) are reasoned to be the most important to the ranker. It is a subjective process where there are a range of objectives the ranker may deem to be the most worthy. It must be realized that any overall ranking diminishes the scientific rigor of a ranking. Nonetheless, policy makers have to make decisions on the best industry based on all information that is considered either costs or benefits.

The first multiple criteria ranking system will be based on per million dollars final demand comparisons. Compared criteria include;

1) value added
2) jobs
3) risk weighted pounds of toxins
4) Value added per risk pound toxins
5) abatement cost
6) SO2
7) NO2
8) CO
9) VOC
10) fine particulates
11) total suspended solids
12) BOD
13) TSS

Value added and jobs are the economic benefits. Risk weighted pounds of toxins includes all toxic pollutants within its index, so the six toxic pollutants can be dropped from this comparison. Value added per risk pound toxins is also a positive criterion. The more value added received by the community for each risk pound of pollution, the better off the community is. Abatement costs are a negative indicator. Inexpensive abatement implies a greater possibility of future cleanup. The remaining eight air and water criteria are also included.

The second ranking system which compares the four target industries per job, has all the same criteria except 'number of jobs'. These two ranking systems include all the information arrived at in the model elements section to compare both the economic benefits and environmental costs together.

CHAPTER IV

DATA COLLECTION AND MODEL IMPLEMENTATION

Study Area Selection

Initially East Tennessee was picked because of its environmental boundaries. The Cumberland Plateau to the west and the smokies to the East lock air within the valley and funnel water into the Tennessee River. This makes it an excellent pollution study area, since the pollution which is created in the area tends to stay in the area. Economic considerations limited the study area to the Knoxville vicinity "Major Trading Area" defined in the Rand McNally Commercial Atlas (Rand McNally, 1993). This area includes the following eighteen counties:

Anderson	Grainer	Loundon	Scott
Blount	Hamblen	McMinn	Sevier
Campbell	Hancock	Monroe	Union
Cocke	Jefferson	Morgan	
Cumberland	Knox	Roane	

Although there is 'leakage' from this area (inputs are bought outside study area boundaries even if a supplier exists within), it is minimized by the large area and their economic connection making up a Major Trade Area. The study area is shown in Figure 3.

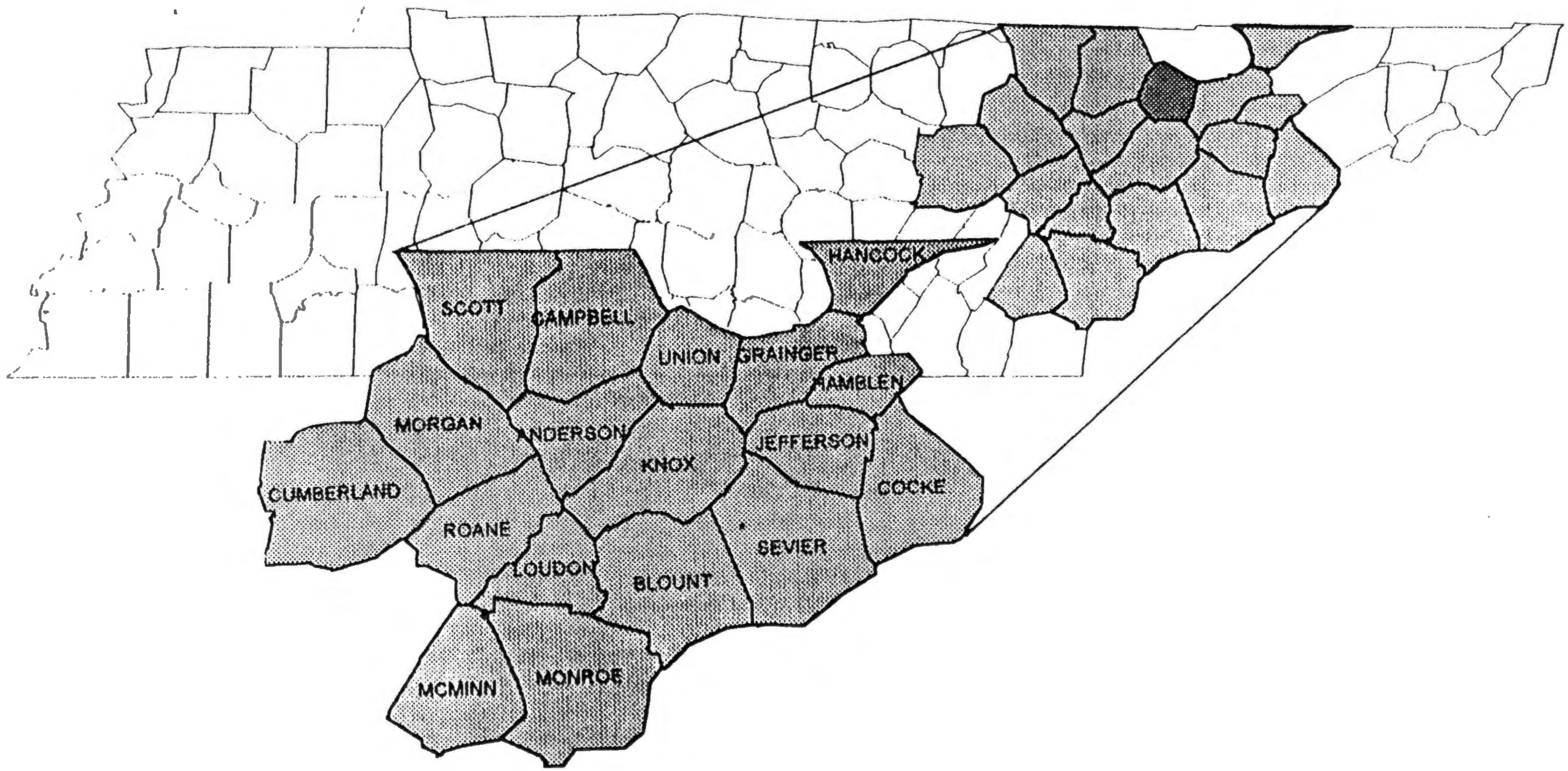

Figure 3. Map of Study Area

Target Industry Selection

The target industries were chosen after consulting with the East Tennessee Development District office in Knoxville, Tennessee. The industries of auto parts, boat, furniture and paper manufacturing are presently major industries in the area and are continuing to grow. Local auto part manufactures include Exide Corp., Eagle Bend, Dyka Mek Corp., Rockwell International and TRW Inc. Boat manufactures include Brunswick, Malibu Boats, Master Craft Boat Co., Bryant Boats Inc., and Sea Ray Boats Inc. Furniture manufactures include La-Z-Boy, Klote International, Bush-Line, and Kirby Manufacturing. Paper Mills include Rainbow Paper Products, Bowater Inc. and Mead Fine Paper.

Extraction of Economic Input-Output Data

Aggregation of the Economy

To study pollution effects at the 4 digit US Standard Industrial Code (SIC) level would be the most informative, unfortunately the IPPS pollution data is aggregated at the 4 digit International Standard Industrial Code (ISIC) level. IMPLAN data matches 4 digit US SIC sectors. A concordance translating US SIC sectors to ISIC sectors was obtained from the United Nations Industrial Development Organization (Fraser, 1996). It was used to aggregate the 374 four digit US SIC sectors into 80 four digit ISIC sectors. IMPLAN sectors were matched with their corresponding four digit US SIC codes. The rest of the IMPLAN sectors not aggregated into ISIC manufacturing sectors are aggregated in the main categories; Livestock, Crops, Forest and Fishing, Mining, Service, Education and Nonprofit, Utilities, Trade, Insurance and Banking, Sports and Rec., and Government. The aggregated sectors are listed in Table 1.

The use of four digit ISIC sectors causes some problems. The target sectors which undergo final demand changes are four digit US SIC sectors. The target sectors, which are bold italics in Table 1, are aggregated along with other US SIC sectors into a single ISIC sector. The number of sectors aggregated ranges from two (boat manufacturing) to eleven (furniture). Obviously there is variability of pollution output within these US SIC sectors that is simply aggregated to the four digit ISIC sector. The aggregation should be noted. This is the best data available and will be used with conservative caution

Economic Model Implementation

The aggregation scheme defined above is used to make a template which is applied to the East Tennessee study area. IMPLAN uses national data to determine what inputs each sector gets from other sectors. The four sectors of interest are single IMPLAN sectors (four digit US SIC sector), but they are within a larger aggregated ISIC sector because of the pollution data. Four different "scenarios" are made. Each scenario increases one of the four sector's final demand by one million dollars. IMPLAN is used to find the effects, both direct and indirect, of the final demand increase on the aggregated East Tennessee economy. IMPLAN gives the impacts upon final demand, total industry output (TIO), total value added, and number of employees.

Table 1. Aggregation Scheme of Sectors Under Study

U.S. SIC	IMPLAN	Description
		Motor Vehicles ISIC = 3843
3711	384	motor vehicles
3713	385	truck and bus bodies
3714	***386***	***motor veh. parts and accessories***
3715	387	truck trailers
3716	388	motor homes
3792	397	truck trailers and campers
3792	398	tanks and tank components
		Shipbuilding and Repairing ISIC = 3841
3731	392	shipbuilding and repairing
3732	***393***	***boatbuilding and repairing***
		Furniture and Fixtures, nonmetal ISIC = 3320
2434	138	wood kitchen cabinets
2451	143	mobile homes
2511	148	wood household furniture
2512	***149***	***upholstered household furniture***
2515	151	mattresses and bedsprings
2517	152	wood TV and radio cabinets
2519	153	household furniture
2521	154	wood office furniture
2531	156	public building furniture
2541	157	wood partitions and fixtures
2599	160	furniture and fixtures, N.E.C.
		Pulp, Paper and Paperboard ISIC = 3411
2610	161	pulp mills
2620	***162***	***paper mills, except building paper***
2630	163	paperboad mills

Note: sectors under study are in bold italics

Economic Results

Paper manufacturing (paper) had the largest direct total industrial output with 329 million dollars in business in 1990, followed closely by auto part manufacturing (auto parts) with 317 million dollars (Table 2). Furniture and boat manufacturing (furniture and boats) both totaled around 168 million in direct output. Paper also led in direct value added, with 127 million dollars. Auto parts followed with 106 million. Boats jumped ahead of furniture with 99 million to furniture's 70 million in value added.

Although paper had the most value added, it did not carry over into direct employment. Furniture employed 2346 persons, followed by auto parts, boats and the paper with 2213, 2068, and 1522 respectively.

Table 2. Economic Impacts in 1990

		Auto Parts	Boats	Furniture	Paper
Direct Totals	Industrial Output($mm)	317.28	167.69	167.94	328.81
	Value Added($mm)	106.13	99.41	69.94	126.77
	Employment(persons)	2,212.72	2,068.32	2,346.38	1,522.22
Indirect Totals	Industrial Output($mm)	96.24	33.96	52.26	101.92
	Value Added($mm)	49.25	17.58	28.61	60.87
	Employment(persons)	1,197.42	479.69	831.52	1,433.83
Direct and Indirect Totals	Industrial Output($mm)	413.53	201.66	220.20	430.73
	Value Added($mm)	155.38	116.99	98.55	187.64
	Employment(persons)	3,410.14	2,548.01	3,177.90	2,956.05

Source: IMPLAN Database and Software, University of Minnesota, St. Paul, MN,1990.

Paper spurred the most indirect value added with 61 million dollars. Auto parts, furniture and boats followed. Paper also spurred the most indirect employment of 1434 persons, followed by auto parts with 1197, furniture with 832 and boats with 480.

Adding the direct and indirect effects gives the total effect of the industries on all off East Tennessee. Paper contributed the most to value added, bringing in 188 million dollars. Auto Parts followed with 155 million. Boats manufacturing's larger direct effects made up for its small indirect effects and contributed 117 million dollars to value added, beating out furniture with 98 million dollars of value added. Auto parts employs the most people in East Tennessee with 3410. Furniture, paper and boats follow with 3178, 2956, and 2548 respectively

Boat manufacturing returns 593 thousand dollars value added for every million dollars final demand (Table 3). Furniture's value added equals 416 thousand, followed by paper and auto part with 386 thousand and 334 thousand respectively. Furniture employs the most workers per million final demand, with fourteen. Boat building employs twelve, auto parts employs seven, and paper employs five. The paper industry contributes the most to indirect value added, spurring 185 thousand dollars in value added. Furniture spurs 170 thousand indirectly, followed by auto parts and boats with 155 and 105 thousand respectively. Furniture contributes five jobs indirectly. Paper contributes 4.4 jobs, auto parts give 3.7 jobs, and boats contribute 2.9 jobs.

Table 3. Marginal Economic Impacts

		Auto Parts	Boats	Furniture	Paper
Direct Totals	Industrial Output($mm)	1.00	1.00	1.00	1.00
	Value Added($mm)	0.33	0.59	0.42	0.39
	Employment(persons)	6.97	12.33	13.97	4.63
Indirect Totals	Industrial Output($mm)	0.30	0.20	0.31	0.31
	Value Added($mm)	0.16	0.10	0.17	0.19
	Employment(persons)	3.77	2.86	4.95	4.36
Direct and Indirect Totals	Industrial Output($mm)	1.30	1.20	1.31	1.31
	Value Added($mm)	0.49	0.70	0.59	0.57
	Employment(persons)	10.75	15.19	18.92	8.99

Source: IMPLAN Database and Software, University of Minnesota, St. Paul, MN, 1990.

The total market effect shows boat manufacturing contributing the most value added to East Tennessee, followed by furniture, paper and the auto parts. Furniture contributes the most jobs per million dollars final demand with nineteen, followed by boats with fifteen, auto parts with eleven, and then paper with nine.

Extraction of Toxic Risk Weighted Pounds

No significant manipulation of IPPS's Toxic Risk index is needed. The index of risk weighted pounds per million dollars output value is simply multiplied by the vector of direct and indirect changes in final demand of each scenario derived from IMPLAN to get the toxic risk weighted direct and indirect pollution totals. The risk weighted totals only include the toxic pollutants and toxic metal pollutants to land, air, and water. They do not include the other air or water pollutants.

Extraction of Abatement Cost Estimates

The abatement costs provided by Hartman are converted from dollars per ton to dollars per pound. Some of the abatement cost categories do not match the fourteen IPPS pollutants. Seven of the fourteen match exactly; toxic air, toxic water toxic metal to water, SO2, NO2, and VOC. It is assumed in this study that 'lead air' approximates the cost of abating toxic metals to air. 'Other air' is assumed to approximate CO. 'Particulates' is assumed to approximate both fine particulates and total suspended solids. 'Conventional water' is assumed to approximate TSS. The cost of abating toxic and toxic metal pollution to land and BOD are not given.

The matrix of abatement costs per pound (Table A-3) is multiplied by the matrix of the amount of each pollutant, both direct and indirect, per sector, for each scenario (this matrix is found by multiplying the matrix of real lbs. pollutant of each sector (Table A-1) by the vector of sectoral final demand change caused by the IMPLAN scenario). The result is a matrix for each scenario which gives the cost of abating each sector's ten pollutant categories. Each scenario's matrix is summed, giving the abatement cost of each target industries total effluent, both direct and indirect. Hartman et. al. (1996) state that at the average abatement costs, some industries marginal costs are increasing and some are decreasing..

CHAPTER V

RESULTS

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Pollution Quantity Results

Paper is by far the most polluting industry of the four, and leads in all pollutants except two in 1990 (Table 4). In a general overall ranking, auto parts is the second most polluting industry, followed by boats and furniture. Paper emitted over one million pound of toxic pollution to East Tennessee air in 1990, only 4% of this was indirect. Boats, furniture and auto parts followed with 360, 255, and 190 thousand pounds respectively. Most of these industries' toxic effluent was indirect. Paper emitted 653 thousand pounds of toxic pollution to land and 410 thousand pounds to water. Auto parts emitted the second most to land and water, boats and furniture followed.

Boat manufacturing emitted 7, 706 pounds of toxic metal to the air, only 2% of which was indirect. Auto parts, paper and furniture followed. Auto Parts emitted the most toxic metal to land, over 27 thousand pounds. Fifty three percent of this was indirect. Paper, boats and furniture followed. Paper emitted 2,705 pounds of toxic metal pollution to water, followed by minimal amounts from auto parts, boats, and furniture.

Paper emitted the most effluent of every air pollutant. Eight and a half million pounds of SO2, 4.5 million pounds NO2, almost 10 million pounds CO, 1.4 million.

Table 4. Target Industries Output of Pollutants in 1990

	Toxic Pollution (lbs)			Toxic metal pollution (lbs)			Other Air pollution (lbs)						Other Water Pollution(lbs)	
	Air	Water	Land	Air	Water	Land	SO2	NO2	CO	VOC	FinePart	TotSusPart	BOD	TSS
Auto Part Pollution														
Direct	141,387	701	63,926	616	12	12,886	88,522	44,737	59,966	411,833	3,807	44,420	73	371
Indirect	48,839	3,117	48,615	545	79	14,572	99,130	81,483	117,461	95,845	9,457	20,871	4,489	328,056
Total	190,226	3,818	112,541	1,161	91	27,458	187,652	126,220	177,427	507,677	13,265	65,290	4,562	328,427
Boat Pollution														
Direct	330,400	47	47,625	7,552	24	5,087	56,177	25,154	3,354	208,443	56,345	17,608	25	80
Indirect	29,949	2,303	27,164	154	31	3,579	46,899	77,876	31,344	53,803	1,918	11,858	2,339	30,432
Total	360,348	2,350	74,788	7,706	55	8,666	103,077	103,030	34,698	262,246	58,263	29,465	2,364	30,512
Furniture Pollution														
Direct	233,541	168	21,040	147	-	310	40,809	28,886	30,565	925,350	26,870	91,863	-	5
Indirect	22,175	783	11,232	142	17	3,158	32,429	38,577	64,300	77,048	5,238	32,512	2,033	76,418
Total	255,716	951	32,271	289	17	3,468	73,238	67,463	94,865	1,002,398	32,108	124,375	2,033	76,423
Paper Pollution														
Direct	1,192,622	397,639	549,713	112	2,579	5,654	8,412,729	4,389,350	9,602,382	1,329,399	477,768	1,653,281	4,521,652	15,357,247
Indirect	52,223	12,240	103,158	436	126	14,423	133,773	106,140	153,696	88,857	6,741	42,654	20,427	102,277
Total	1,244,844	409,879	652,871	548	2,705	20,077	8,546,503	4,495,490	9,756,078	1,418,256	484,509	1,695,935	4,542,079	15,459,524

pounds volatile organic compounds (VOC), 484 thousand pounds fine particulates, and 1.7 million pounds of total suspended particles. Paper was rivaled only by furniture in VOC. Furniture produced a little over one million pounds of VOC. Auto parts emitted the second most in SO2, NO2, and CO. Boats emitted the second most in fine particulates, and furniture emitted the second most in VOC and total suspended particles.

Paper emitted the most BOC and TSS to water by far with 4.5 million and 15.5 million pounds respectively. Auto parts, furniture and boats emitted minimal quantities of BOD, almost all of which was indirect. Auto Parts emitted 328 thousand pounds of TSS, followed by furniture and boats.

Paper emits the most toxic pollution to air, land and water per million dollars final demand, emitting 3.7, 1.9, and 1.2 million pounds respectively (Table 5). Boats expel the second most toxic pollution to air, land and water. Auto Parts emits the least toxic pollution to air. Furniture emits the least to land and water. The boats industry ranks first in toxic metal to air pollution, emitting 46 pounds of toxic metal pollution to air. Boats is followed by auto parts, furniture and paper. Auto parts emits the most toxic metal to land, followed by paper, boats and furniture. Paper emits the most to water , followed by boats, auto parts and furniture.

Paper emits huge quantities of the other air pollutants. Paper produces 26 million pounds SO2, over 13.5 million pounds NO2, over 29.5 million pounds CO, 4.3 million pounds VOC, about 1.5 million pounds fine particulates, and over five million pound total suspended particles. Furniture edges out paper in total VOC, emitting almost six

Table 5. Target Industries Output of Pollutants per $MM Final Demand

	Toxic Pollution (lbs)			Toxic metal pollution (lbs)			Other Air pollution (lbs)						Water Pollution (lbs)	
	Air	Water	Land	Air	Water	Land	SO2	NO2	CO	VOC	FinePart	TotSusPart	BOD	TSS
Auto Part Pollution														
Direct	445.6	2.2	201.5	1.94	0.04	40.61	279.0	141.0	189.0	1,298.0	12.0	140.0	0.2	1.2
Indirect	153.9	9.9	154.0	1.72	0.25	45.92	311.5	257.0	369.1	302.1	29.3	65.6	13.6	1,038.8
Total	599.5	12.2	355.5	3.66	0.29	86.54	590.5	398.0	558.1	1,600.1	41.3	205.6	13.8	1,040.0
Boat Pollution														
Direct	1,970.3	0.3	284.0	45.04	0.15	30.34	335.0	150.0	20.0	1,243.0	336.0	105.0	0.2	0.5
Indirect	178.0	13.7	161.4	0.92	0.18	21.31	278.4	463.3	189.5	320.4	10.1	70.1	13.3	179.5
Total	2,148.3	14.0	445.4	45.95	0.33	51.64	613.4	613.3	209.5	1,563.4	346.1	175.1	13.4	179.9
Furniture Pollution														
Direct	1,390.6	1.0	125.3	0.87	-	1.84	243.0	172.0	182.0	5,510.0	160.0	547.0	-	0.0
Indirect	123.0	4.6	65.8	0.85	0.10	18.96	190.8	226.6	382.4	423.0	29.1	188.2	12.5	461.3
Total	1,513.6	5.6	191.1	1.72	0.10	20.80	433.8	398.6	564.4	5,933.0	189.1	735.2	12.5	461.3
Paper Pollution														
Direct	3,627.0	1,209.3	1,671.8	0.34	7.84	17.19	25,585.0	13,349.0	29,203.0	4,043.0	1,453.0	5,028.0	13,751.4	46,704.8
Indirect	158.3	37.1	312.9	1.32	0.38	43.72	403.2	320.8	465.0	269.2	19.1	128.2	61.5	311.0
Total	3,785.3	1,246.4	1,984.7	1.66	8.23	60.91	25,988.2	13,669.8	29,668.0	4,312.2	1,472.1	5,156.2	13,812.9	47,015.8

million pounds. Auto parts emits the least NO2 and fine particulates, furniture emits the least SO2, and boats emit the least CO, VOC, and total suspended particles. Paper also produces the most of the water pollutants, 13.8 million pounds BOD and 47 million pounds TSS. Furniture products the least BOD and boats causes the least TSS.

Toxic Risk Weighted Results

Paper is the most dangerous polluter to human health in 1990 (Table 6). Paper totaled over 38,000 toxic risk weighted pounds direct, six thousand pounds indirect and a total of over 44,000 toxic risk weighted pounds. This is over twice the risk pounds of the next polluter, furniture.

Furniture production had about 10,000 toxic risk weighted pounds from direct production and another 2700 risk pounds that were produced indirectly for a total of over 13 thousand toxic risk weighted pounds in 1990. Auto Parts ranked third in 1990 with five thousand toxic risk weighted pounds direct, 4.8 thousand pounds indirect and 9.8 thousand total risk pounds. Boats had the least risk pounds with three thousand

Table 6. Toxic Risk Weighted Pounds in 1990

	Auto Parts	Boats	Furniture	Paper
Direct	4,991	2,923	10,293	38,438
Indirect	4,828	2,969	2,723	6,176
Total	9,819	5,892	13,016	44,614

direct, about three thousand indirect and a total of around six thousand risk pounds. The boats industry was the least dangerous to human health in 1990. This only includes the toxic substances and does not include the other air or water pollutants.

Paper emits the most risk weighted pounds of toxic and toxic metal pollution per million dollars final demand (Table 7). Paper emits 120 pounds directly and causes 18.74 pounds indirectly to get a total of 138.6 risk pounds. Furniture emits 61 risk pounds directly and causes another 15.7 indirectly. Boats follow with 17.4 directly and 17.6 indirectly. Auto parts is the 'safest' industry, emitting 15.7 directly and 15.2 indirectly totaling to 31 risk pounds of toxic pollution. This index does not include the other air and water pollutants.

Abatement Cost Results

It should be pointed out once again that abatement costs are only estimates computed from the average cost of past abatement levels. Some industries marginal costs are increasing and some are decreasing at the average level. When increasing the amount abated significantly, the four industries marginal costs would likely increase at different rates. Due to this high chance of error in using average present abatement costs to estimate the cost of abating all of 1990's pollution, it will not be undertaken here. Yet, the average abatement costs can be used to compare the relative cost of small increases in amount abated. The cost of abating the pollution caused by a million dollar increase in final demand is compared.

Table 7: Toxic Risk Weighted Pounds per $MM Final Demand

	Auto Parts	Boats	Furniture	Paper
Direct	1,321.00	351.06	19,534.40	6,765.97
Indirect	390.92	987.48	57,037.13	16,022.92
Total	1,711.92	1,338.54	76,571.53	22,788.89

As mentioned in the literature review, the reason for calculating abatement costs is not to estimate the cost of present pollution to East Tennessee. Under possible tougher environmental laws in the future, one's which may use a market oriented approach to abatement, industries which have high abatement costs will more than likely be the last industries to clean up. Abatement costs are given to estimate which of the four are more likely to clean up under the assumption of tougher market oriented pollution laws.

Table 8 lists the cost of abating the four industries direct pollution per pound. Note the variance in abating the same pollutant from different industries. Furniture's toxic air pollution is extremely expensive to abate, costing over $13 per pound. Auto Part's toxic metal pollution to air is also very expensive to abate, costing over $21 per pound.

Table 9 lists the direct and indirect cost of abating all ten pollutants per million dollars final demand. Furniture is, by far, the most expensive industry to abate, costing $20,544 to abate the pollution caused by a one million dollar final demand increase. Nineteen thousand five hundred of this is direct, while about one thousand is indirect. Most the furniture's abatement costs are from cleaning toxic pollutants to air. It would

Table 8. Target Industries Direct Abatement Costs per Pound

	Toxic Air	Toxic Water	Toxic Metal Air	Toxic Metal Water	SO2	NO2	CO	VOC	Particulates	TSS
Auto Parts	$ 0.2721	$ 0.3367	$ 21.5301	$ 0.2986	$ 0.1354	$ 0.3454	$ 0.1937	$ 0.7670	$ 0.2525	$ 0.2039
Boats	$ 0.0352	$ 0.3367	$ 0.0352	$ 0.1398	$ 0.6158	$ 0.0352	$ 0.0352	$ 0.0352	$ 0.0538	$ 0.2186
Furniture	$ 13.0886	$ 0.1434	$ 0.1185	$ 0.5404	$ 1.5428	$ 0.0433	$ 0.1937	$ 0.1635	$ 0.0201	$ 0.0204
Paper	$ 0.2721	$ 0.1434	$ 0.1185	$ 0.3360	$ 0.0531	$ 0.0681	$ 0.0315	$ 0.0787	$ 0.0204	$ 0.0421

Source: Hartman, Rammond S. et.al. (1994, December), *The Cost of Air Pollution Abatement*, World Bank working paper,

Web site: http://www.worldbank.org/html/prdei/ipps/abcost/abate.htm.

Note: 1990 dollars

Table 9. Target Industries Abatement Costs per $MM Final Demand

	Auto Parts	Boats	Furniture	Paper
Direct	$ 1,321	$ 351	$ 19,534	$ 6,766
Indirect	$ 391	$ 243	$ 1,011	$ 243
Total	$ 1,712	$ 594	$ 20,545	$ 7,009

cost $7,009 to abate paper pollution, 6766 dollars of which is direct, leaving $243 of indirect costs. Auto parts follows with a direct cost of $1,321 and $390 indirect costs, totaling to $1,712. Boat manufacturing is the cheapest industry to abate. Only 351 dollars of direct cost and 243 dollars of indirect cost will abate the pollution caused by one million dollars of boat final demand.

Ranking

Single Criteria

Table 10 lists thirty six different objectives and the ranking of the four industries for each. A rank of 1 indicates the top industry of each criterion, and a rank of 4 indicates the last industry of each criterion.

Multiple Criteria

Of the 36 single criteria, 13 are used to compare the industries overall rank. Maximum value added per risk pound, minimum toxic risk pounds, maximum value added, maximum jobs, minimum abatement cost, and minimum quantities of the air and water pollutants will be used. Table 11 lists these criteria per one million dollar unit of final demand and the rank of the four target industries.

The paper industry has the second lowest value added (above only auto parts) and gives the least number of jobs, a mere 8.99. Paper out pollutes all the other industries except furniture in VOC. Paper's value added per unit of risk is the lowest of all the

Table 10. Single Criteria Rankings of Target Industries

Objectives	Auto Parts	Boats	Furniture	Paper
Maximize Value Added per $MM Final Demand	4	1	2	3
Max Jobs per $mm Final Demand	3	2	1	4
Minimize Toxic Risk Pounds per $mm Final Demand	1	2	3	4
Maximize Value Added per Risk Pound	2	1	3	4
Minimize Abatement Cost per $mm Final Demand	2	1	4	3
Mimimize a specific pollutant or pollutants per $mm Finad Demand:				
Toxic Pollution to Air	1	3	2	4
to water	2	3	1	4
to land	2	3	1	4
Toxic metal pollution to Air	3	4	2	1
to Land	4	2	1	3
to Water	2	3	1	4
SO2	2	3	1	4
NO2	1	3	2	4
CO	2	1	3	4
Vol Og Comp (VOC)	2	1	4	3
Fine Particulates	1	3	2	4
Tot Susp Part	2	1	3	4
BOD	3	2	1	4
TSS	3	1	2	4
Maximize Value Added per Job	2	3	4	1
Minimize Risk Pounds per Job	2	1	3	4
Minimize Abatement cost per Job	2	1	4	3
Minimize a Specific Pollutant or Pollutants per Job:				
Toxic Pollution to Air	1	3	2	4
to water	3	2	1	4
to land	3	2	1	4
Toxic metal pollution to Air	3	4	1	2
to Land	4	2	1	3
to Water	3	2	1	4
SO2	3	2	1	4
NO2	2	3	1	4
CO	3	1	2	4
Vol Og Comp (VOC)	2	1	3	4
Fine Particulates	1	3	2	4
Tot Susp Part	2	1	3	4
BOD	3	2	1	4
TSS	3	1	2	4

Note: ranking includes both direct and indirect pollution

Table 11. Multiple Ranking Criteria per $MM Final Demand

Rank	Industry	Value Added	Jobs	Toxic Risk Pounds	Value Added per Risk lbs.	Abatement Cost per lbs.	Air Pollutants (lbs) SO2	NO2	CO	VOC	FinePart	TotSusPart	Water Pollutants (lbs) BOD	TSS
1	Boats	$ 697,616	15	35	$ 19,877	$ 594	613	613	209	1,563	346	175	13	180
2	Auto Parts	$ 489,711	11	31	$ 15,827	$ 1,712	590	398	558	1,600	41	206	14	1,040
3	Furniture	$ 586,835	19	77	$ 7,618	$ 20,545	434	399	564	5,933	189	735	12	461
4	Paper	$ 570,660	9	139	$ 4,116	$ 7,009	25,988	13,670	29,668	4,312	1,472	5,156	13,813	47,016

Note: values include both direct and indirect effects sectors. This means that East Tennessee gets the least payment for every risk unit from the paper industry. Also, paper's abatement costs are the second highest behind furniture. Observing paper's low internal market returns and its high pollution levels, paper can be given the lowest rank of the four industries. Paper is the least desirable industry to attract.

Furniture returns the second highest value added behind boats and gives the most employment to East Tennessee, a huge 18.92 jobs per million dollars final demand. Yet environmentally furniture has the second highest toxic risk pounds and the second lowest value added per risk unit. Furniture costs the most of all the industries to abate; nearly three times more than the second highest, paper. This means that furniture wouldbe one of the last industries to abate. It has the highest VOC level and averages second most polluting behind paper in air pollutants. Furniture does have the lowest levels of SO_2 and BOD, although auto parts, boats and furniture all have minimal levels of BOD. Although furniture returns nearly a hundred thousand more than auto parts in value added and nearly three more jobs than boats, furniture can fairly confidently be given a rank of second least desirable industry to attract to East Tennessee. This decision is based heavily on its value added per risk unit return of $7,618, half of the next highest, auto parts. Furniture's extremely high abatement costs indicate it is not an industry to have in place under tougher environmental laws.

Ranking the remaining industries of boats and auto parts becomes a little more arbitrary. The boats industry returns nearly $200,000 more value added than auto part manufacturing, and over four more jobs. Auto parts gives about four units less of risk, but also returns less value added per risk unit than boats. Auto part and boats have fairly low abatement costs. Boats has the lowest cost of $594 and auto parts has a cost of about three times this. Air and water pollutant quantities are fairly similar except that boats produces a lot more fine particulates (than either boats or furniture) and auto parts produces a lot more TSS. Given boats higher value added and employment returns and its lower value added per risk unit, boats can be ranked as slightly more desirable than auto parts. Therefore boats is the most desirable industry of the four to attract to East Tennessee. Auto parts is the second most desirable. Graphical descriptions of some of the indicators are shown in Appendix D.

The data can be viewed in another pertinent way. Some people may believe that value added and pollution should be compared per unit of employment. Table 12 lists the same multiple criteria per employee, including both direct and indirect jobs. There are some noticeable changes by looking at the data in this way. Paper's value added per job is the greatest of all four. Furniture's rank in VOC drops from highest polluter to second highest behind paper. Furniture drops in value added ranking to below auto parts and paper. So even though furniture employs the most labor, it returns the least per worker. Boats risk unit ranking increases to become the least toxic risk industry, passing up auto parts. Auto parts gains ranking in value added by passing furniture but still does not catch boats. Observing the data in this representation does not change the ranking of the four industries; Boats is still most desirable, following by auto parts, furniture, and paper.

Table 12. Multiple Ranking Criteria per Job

Rank	Industry	Value Added	Risk lbs.	Value Added per Risk lb.	Abatement Cost	Air Pollutants (lbs) SO2	NO2	CO	VOC	FinePart	TotSusPar	Water Pollutants (lbs) BOD	TSS
1	Boats	$ 45,913	2	$ 19,877	$ 39	40	40	14	103	23	12	0.9	11.8
2	Auto Parts	$ 45,563	3	$ 15,827	$ 159	55	37	52	149	4	19	1.3	96.8
3	Furniture	$ 31,012	4	$ 7,618	$ 1,086	23	21	30	314	10	39	0.7	24.4
4	Paper	$ 63,477	15	$ 4,116	$ 780	2,891	1,521	3,300	480	164	574	1,536.5	5,229.8

Note: values include both direct and indirect effects

CHAPTER VI

LIMITATIONS AND CONCLUSIONS

Limitations

The analysis implemented in this study should only be done to appraise area wide target industries. The pollution data, risk weighted data, and abatement cost data are aggregated from several four digit US SIC sectors. There are two different ways of analyzing the industries costs and benefits on East Tennessee. Appraisal of general industrial categories can be done, or appraisal of a specific factory site can be done. The pollution data is too aggregated to undertake a specific factory analysis. The possibility of great over or under estimation of a proposed factory's pollution may cause more harm than good and lead to poor development decisions. Also, the health effects in a specific case depend on the location of the factory in relation to human populations. Such data has not been collected. A process by which more precise estimates of specific development alternatives is presented in Appendix C . This analysis determined the desirability of the broadly defined industries to the entire East Tennessee area.

The abatement cost estimates are average costs. They are calculated from the costs reported by individual industries which were needed to clean up to present levels of abatement. Marginal costs of specific industries may rise or fall at different rates when abating further. The estimates can be used to approximate the cost of cleaning up small increases in quantity abated. The average abatement costs should not be used to approximate cleaning up significant increases in quantity abated. Marginal costs could diverge too much to make this deduction.

Future Directions

What direction should be taken in the future? Can we even hope to correct the price system to "signal the true significance of the interdependence of human activities undertaken within a common environment (Perrings, 1987)?" Some economists believe that we can account for the actual cost of pollution and incorporate them into the market system through assignment of property rights. But for some externalities, this is a daunting task. Take global warming as an example. The first problem is, who owns the weather? Lets assume property rights can be assigned, does this solve our problem? What is the cost of a one part per million point rise in carbon dioxide of our air? Ecologists believe that the earth's temperature will not increase steadily up a smooth curve, but will change rapidly at an unpredictable point (Brown, 1995). The next CO2 point rise may not change anything, or it may change everything, costing lives and billions of dollars. Unpredictability and complexity of the environment must be realized and dealt with in some way. This is an example of what Daly (1989) calls a pervasive externality. There are not direct market effects. A cost could be estimated, but "such a calculation involves so many guesstimates, uncertainties, and arbitrary assumptions that it is a will-o-the-wisp, an ignis fatuus, a red herring (Daly, 1989)."

Some costs can be determined fairly easily. The medical costs of a disease directly related to working in a certain factory is easily internalized. Simply make the company pay all the medical costs. For the non-pervasive externalities, research should continue to estimate the cost to others, and these costs should be internalized. Yet, as long as there are pervasive externalities in accounting for an entire economy's pollution, complete costs cannot be estimated. Internalization of costs cannot be done in a way that takes all costs of the human economy's effluent into account. A much easier method is to decide that some things are to be avoided and set an absolute limit on effluents which lead to pervasive externalities.

What would this mean for pollution accounting in East Tennessee? The pervasive effluents, would have a quota for the entire region and industries could buy and sell the rights to pollute, much like some EPA permits already in use. The costs of the limit would be part of production costs. Yet even if externalities are limited, a region would still want to attract industries that pollute the least. Since total pollution costs cannot be estimated in total, the best method will continue to be a comparison of value added, employment and pounds of pollution. The development of other tools, such as risk indices and estimating the cost of non-pervasive externalities, will also be of use. The more analytical tools the better, as long as the tools are based on rigorous research methods. An estimate of an overall cost of pollution is not rigorous. The final decision should look at all the tools and a subjective decision based on the decision makers objectives should be made.

What has been accomplished?

How far did this project come to completing the goal of accounting for all the external costs of pollution and closing the economic loop? This study was able to estimate pollution output for 80 aggregated sectors by linking an input-output model with reported pollution output. The toxic pollutants were able to be weighted by risk to human health, and abatement costs could be estimated from average present abatement costs. This is where this project was stopped. If the loop were to be closed, the ecological effects of the real pounds of pollution would have to be estimated. To estimate the actual cost of pollution, ecological monitoring and research would need to account for the effect of pollution upon the many levels of the earth's environment, from individual molecules on up to the troposphere. Then this effect would have to be valued by other market observation or by contingent valuation or willingness to pay. This analysis was unable to make pollution cost estimates and was severely hindered in simply ranking the development alternatives.

Yet, given all the analytical problems, this project did bring to the surface the shadowy outline of the true pollution costs. The costs could not be estimated, but the real quantities, risk pounds, and abatement costs at least gave something tangible to compare to other alternatives. Viewed in this way, rankings of alternative development decisions can be made.

This project finds that complete costs of pollution externalities are not available, and because of the existence of pervasive externalities, such a figure should not even be attempted. Yet this project finds that there is enough information to rank the desirability of alternative industries based on available economic and environmental data.

Based on assessment of multiple economic and environmental criteria of the four target industries under study, paper manufacturing is the least desirable industry to East Tennessee. Furniture is the second least desirable. Auto parts and boat manufacturing are fairly similar in their costs and benefits. This analysis finds boat manufacturing to be slightly more beneficial than auto part manufacturing.

LITERATURE CITED

LITERATURE CITED

Ayres, R. U. (1972), *A Materials-Process-Product Model*, in A.V. Kneese and B.T. Bower (eds), **Environmental Quality Analysis**, Baltimore, Johns Hopkins Press, pp. 35-67.

Ayres, R.U. and Kneese, A.V. (1969, June), *Production , Consumption and Externalities*, **The American Economic Review**, LIX, pp. 282-97.

Brown, Lester R. (1995), *Nature's Limits*, **State of the World**, pp. 3-19, WW Norton and company, New York, , WorldWatch Institute.

Coase, R. H. (1960), *The Problem of Social Costs*, **Journal of Land and Economics**, Vol. 3, pp. 1-44.

Cumberland, J.H. (1966), *A Regional Inter-Industry Model for Analysis of Development Objectives*, Regional Science Association Papers, 17, pp. 65-94.

Daly, Herman E. (1968, May/June), *On Economics as a Life Science*, **The Journal of Political Economy**, Vol. 76, pp.392-406.

Daly, Herman E., and John B. Cobb (1989), Jr. **For the Common Good**, Beacon Press, Boston, Massachusetts,. Chapters 2 and 7.

Fraser, Jill (1996), Concordance of U.S. SIC and ISIC Codes, United Nations Industrial Development Organization. Geneva, Switzerland.

Hartman, Ranmond S. et. al. (1994, December), *The Cost of Air Pollution Abatement*, World Bank working paper, Web Site: **http://www.worldbank.org/html/prdei/ipps/abcost/abate.htm.**

Hettige, Hemamala, et. al. (1996), *Industrial Pollution Projection System*, World Bank PRDEI, **http://www.worldbank.org/html/prdei/ipps/ippshome.html**.

IMPLAN (Impact analysis for PLANning) software (1990), Version 91-F, University of Minnesota, St. Paul Minnesota.

Isard, Walter (1969, March 27), *Some Notes on the Linkage of the Ecologic and Economic Systems*, paper delivered to the Regional Science and Landscape Analysis Project, Department of Landscape Architecture, Harvard University and the Regional Science Research Institute.

Lave, Lester B. et al. (1995), *Using Input-Output Analysis to Estimate Economy-Wide Discharges*, **Environmental Science and Technology**, Vol. 29, No. 9, pp. 420-426.

Leontief, Wassily (1941), **The Structure of the American Economy, 1919-1929: An Empirical Application of Equilibrium Analysis**, Cambridge Mass., Harvard University Press.

Leontief, Wassily, and Daniel Ford (1972), *Air pollution and the economic structure: empirical results of input-output computations*, **Input-Output Techniques**, eds. A. Brody and A.P. Carter, North-Holland Publishing, pp. 9-30.

Leontief, Wassily (1970), *Environmental Repercussions and the Economic Structure: An Input-Output Approach,* **Review of Economics and Statistics**, Vol. 52, No. 3, August, pp. 262-271.

Marshall, A. (1890), **Principles of Economics** (1st edn., London: Macmillan).

Papandreou, Andreas A. (1994), **Externality and Institutions**, Clarendon Press, Oxford.

Perrings, Charles (1987), **Economy and Environment**, Cambridge University Press.

Phillips, Beth (1996, June 23), Department of Economic and Community Development, East Tennessee Regional Office, personal correspondence.

Pigou, A.C. (1932), **The Economics of Welfare**, London, Macmillan.

Prigogine, I. (1971), *Time, Structure and Entropy*, in J. Zeman (ed.), **Time in Science and Philosophy**, Amsterdan, in Perrings, pg. 159.

Rand McNally (1993), **Rand McNally Commercial Atlas**. 124th edition.

Siegel, Paul B., and Frank O. Leuthold (1993), *Economic and Fiscal Impacts of a retirement/recreation community: a study of Tellico Village, Tennessee.* **Journal of Agricultural and Applied Economic**, vol. 25. pp. 134-47.

Victor, A. Peter (1972), **Pollution: Economy and Environment**. University of Toronto Press.

APPENDICES

APPENDIX A

Table A-1. Direct Output of Fourteen Pollutants per $MM Final Demand

		Toxic Pollutants (lbs)			Toxic Metal Pollutants (lbs)			Other Air Pollutants (lbs)						Water Pollutants (lbs)	
Four Digit ISIC Description	ISIC Code	Air	Water	Land	Air	Land	Water	SO2	NO2	CO	VOC	FinePart.	TotSusPart	BOD	TSS
MEAT PRODUCTS	3111	47.47	7.11	44.34	0.00000	0.02556	0.37028	195	1997	499	10	6	56	31.52	39.09
DAIRY PRODUCTS	3112	31.03	22.35	254.19	0.02274	0.00000	0.00000	141	198	35	9	0	73	7948.66	1144.90
PRESERVED FRUITS & VEGETABLES	3113	64.61	18.17	225.98	0.00000	0.55934	0.13404	736	375	72	136	5	73	300.80	474.51
FISH PRODUCTS	3114	11.20	0.00	12.79				173	76	5	2	2	32	574.42	979.27
OILS AND FATS	3115	161.59	52.26	944.13	0.06090	19.33186	0.01218	9387	3360	750	2572	5901	9615	175.31	198.08
GRAIN MILL PRODUCTS	3116	5.73	0.00	2.42	0.05998	1.53291	0.00000	328	262	51	277	542	1616	0.01	0.12
BAKERY PRODUCTS	3117	4.79	0.00	5.83				16	36	5	179	0	16	0.12	0.14
SUGAR FACTORIES & REFINERIES	3118	55.35	1.54	264.45	0.00000	1.10158	0.00000	6428	6171	3306	1094	135	4258	2130.73	3054.97
CONFECTIONERY PRODUCTS	3119	29.55	0.00	36.81				97	20	3	2	0	10	18.26	8.77
FOOD PRODUCTS, N.E.C.	3121	49.02	3.49	87.30	0.00954	0.26873	0.36122	432	439	94	132	12	196	2.75	1.09
PREPARED ANIMAL FOODS	3122	20.31	1.72	26.68	0.41108	0.52223	0.00000	745	205	56	24	308	1341	1.16	1.68
DISTILLED SPIRITS	3131	1.43	48.94	14.92				3887	1351	253	13355	170	325	5451.00	9797.25
WINE INDUSTRIES	3132	61.06	0.00	154.87	0.00000	0.66892	0.00000	462	70	6	1	0	48	24.37	13.37
MALT LIQUORS AND MALT	3133	109.91	6.23	59.29	0.08337	26.77371	0.00831	2146	1690	105	176	3	118	28.92	66.84
TOBACCO MANUFACTURES	3140	271.80	1.85	26.93				1265	766	100	252	10	24	1.53	1.87
SPINNING, WEAVING, & FINISHING TEXTILES	3211	350.96	178.85	326.21	2.89184	58.52000	0.19503	2422	3342	448	917	65	433	98.18	152.47
MADE-UP TEXTILES EXCEPT APPAREL	3212	244.02	3.31	41.15	2.35680	6.80788	0.00000	18	11	3	126	0	26	0.00	0.00
KNITTING MILLS	3213	139.68	12.87	273.27	0.00000	1.28599	0.00000	217	90	37	73	13	136	1.82	3.67
CARPETS AND RUGS	3214	192.69	46.26	347.53				0	0	0	0	0	0	11.62	19.54
CORDAGE, ROPE & TWINE	3215	2123.56	0.00	5.82	8.72737	0.00000	0.00000	2075	648	904	1261	0	1094	0.00	0.00
TEXTILES, N.E.C.	3219	5253.30	0.47	1183.45	1.07688	22.18892	0.20319	748	309	56	5938	0	445	0.00	3.20
WEARING APPAREL	3220	12.70	0.00	4.79	0.01053	0.84288	0.00000	32	12	3	8	0	1	0.00	0.00
TANNERIES AND LEATHER FINISHING	3231	4733.22	220.02	12687.84	1.60835	854.35948	1.29751	1299	343	126	3819	41	157	607.39	1147.01
FUR DRESSING AND DYEING	3232	692.88	20.08	861.93	0.54372	528.66091	0.21543	932	219	52	584	21	788	213.45	652.40
LEATHER PRODUCTS	3233	81.70	0.00	4.84				0	16	3	285	0	10	0.00	1.08
FOOTWEAR	3240	472.39	0.06	13.96				16	2	0	134	0	1	100.62	98.67
SAWMILLS, PLANING & OTHER WOOD MILLS	3311	226.97	1.09	71.31	2.32071	30.82684	0.04813	1036	2342	5901	2509	92	3258	100.09	471.96
WOODEN & CANE CONTAINERS; SMALL CANE	3312	8.50	0.00	0.60	0.00000	0.59589	0.00000	1	2	8	41	18	268	4.49	8.05
WOOD & CORK PRODUCTS, N.E.C.	3319	1490.24	0.13	138.85	0.06433	0.66055	0.00000	2968	1923	4293	5818	1755	4373	0.00	0.00
FURNITURE & FIXTURES, NONMETAL	3320	1390.62	1.00	125.28	0.87297	1.84498	0.00000	243	172	182	5510	160	547	0.00	0.03
PULP, PAPER, & PAPERBOARD	3411	3627.03	1209.31	1671.80	0.34211	17.19422	7.84432	25585	13349	29203	4043	1453	5028	13751.36	46704.84
PAPER & PAPERBOARD CONTAINERS & BOXES	3412	435.38	6.61	79.59	0.00000	0.06958	0.00000	201	1472	341	446	8	46	83.55	143.45
PULP, PAPER & PAPERBOARD ARTICLES,	3419	1589.12	6.00	400.67	9.58268	12.29823	0.45615	417	128	39	700	0	10	237.85	234.61
PRINTING & PUBLISHING	3420	413.12	0.02	55.79	0.01947	1.37237	0.00137	26	34	129	862	0	14	4.06	2.23
INDUSTRIAL CHEMICALS EXCEPT FERTILIZER	3511	5923.99	2992.90	20577.03	29.31936	929.58358	27.23254	11656	8658	6687	6766	395	1873	3988.90	6165.59
FERTILIZERS & PESTICIDES	3512	2363.89	110.89	3204.00	3.95947	276.52764	0.68231	1106	1065	212	1008	47	307	44.88	8732.58
SYNTHETIC RESINS, PLASTICS MATERIALS, & M	3513	5692.07	416.18	4718.77	1.57900	245.85827	5.14196	5185	13477	1993	9862	4	792	211.78	684.35
PAINTS, VARNISHES, & LACQUERS	3521	1621.59	4.22	3891.10	13.76042	105.96734	0.08705	246	217	31	1819	74	146	0.26	1.08
DRUGS AND MEDICINES	3522	1451.39	56.08	2172.40	0.24837	28.16052	0.14217	1825	775	91	908	13	345	61.09	15314.74
SOAP, CLEANING PREPS., PERFUMES, & TOILET	3523	363.94	5.23	616.05	0.34034	25.82124	0.22907	476	567	196	184	193	255	110.23	155.69
CHEMICAL PRODUCTS, N.E.C.	3529	2042.06	61.18	927.63	1.04873	16.39385	3.39966	5291	1652	53782	4098	1361	1847	13.04	18.81
PETROLEUM REFINERIES	3530	607.86	45.84	2574.07	4.94960	45.75797	1.96357	12664	7285	6579	6705	128	1117	158.28	794.37
MISC. PETROLEUM & COAL PRODUCTS	3540	398.09	11.66	117.18	0.71620	23.07535	0.23495	20866	12982	9828	3259	641	8004	21.96	26.96
TIRES AND TUBES	3551	137.76	2.85	237.89	5.35410	208.28418	0.26784	3797	1312	161	3844	54	420	0.02	9.43
RUBBER PRODUCTS, N.E.C.	3559	1757.17	0.43	671.38	3.32245	310.72353	0.28078	1	5	1	384	1	2	0.70	3277.07
PLASTICS PRODUCTS, N.E.C.	3560	1896.01	4.63	561.73	0.44072	16.98867	0.95613	56	12	4	676	12	17	518.30	11.20
POTTERY, CHINA, & EARTHENWARE	3610	456.27	0.97	746.58	3.27139	281.45353	0.53781	295	148	103	1151	0	349	44.74	111.03
GLASS AND GLASS PRODUCTS	3620	211.54	17.15	136.09	21.92624	27.89397	0.05949	3378	6721	1810	862	142	1348	1.47	10.38

Table A-1 (continued)

		Toxic Pollutants (lbs)			Toxic Metal Pollutants (lbs)			Other Air Pollutants (lbs)						Water Pollutants (lbs)	
Four Digit ISIC Description	ISIC Code	Air	Water	Land	Air	Land	Water	SO2	NO2	CO	VOC	FinePart.	TotSusPart	BOD	TSS
STRUCTURAL CLAY PRODUCTS	3691	949.03	1.88	418.32	13.56241	357.62311	0.96446	3029	29265	6952	2378	4681	22972	0.56	9.92
CEMENT, LIME, AND PLASTER	3692	27.95	43.17	79.76	0.97916	40.24784	0.00200	128688	59751	7273	340	107003	62238	1.18	2587.58
NONMETALLIC MINERAL PRODUCTS, N.E.C.	3699	417.88	2.08	687.98	6.89522	48.66003	0.05402	3195	1425	684	392	1953	5383	23.43	34.37
IRON AND STEEL	3710	985.15	350.16	5647.07	169.11075	3728.57600	25.56861	17867	7761	27843	2392	4938	4140	13.22	194732.90
NONFERROUS METALS	3720	2988.29	116.07	7920.98	206.75134	6849.72510	4.11579	38646	1259	17977	1406	355	3246	2963.03	42830.90
CUTLERY, HAND TOOLS, & GENERAL HARDWA	3811	726.01	2.50	397.16	12.40038	142.39501	0.18294	161	1035	83	260	0	45	0.00	0.47
FURNITURE & FIXTURES OF METAL	3812	602.41	1.30	308.07	1.41604	20.85579	0.00525	43	36	14	2855	0	27	0.00	0.78
STRUCTURAL METAL PRODUCTS	3813	289.96	72.85	326.82	6.44334	99.00756	1.44592	155	653	261	714	10	34	1.25	1.72
FABRICATED METAL PRODUCTS	3819	1226.97	41.14	1498.62	9.96440	447.75330	3.42524	161	362	1850	1556	7	129	26.86	773.24
ENGINES AND TURBINES	3821	565.63	6.87	497.01	32.08626	90.68544	0.24768	612	445	1993	663	4	163	1.71	0.00
AGRICULTURAL MACHINERY & EQUIPMENT	3822	250.49	9.32	69.07	1.31171	10.98973	0.08610	2573	700	896	1511	0	430	0.00	4.99
METAL & WOOD WORKING MACHINERY	3823	154.24	3.55	338.54	2.84263	237.87564	0.01883	37	8	850	535	0	7	0.17	152.21
SPECIAL INDUSTRIAL MACHINERY & EQUIPME	3824	148.61	2.67	245.51	1.04243	34.06052	0.02855	497	426	75	322	1	99	6.63	5.42
OFFICE, COMPUTING, & ACCOUNTING MACHIN	3825	111.20	0.08	39.46	0.09409	4.75338	0.01238	5	4	0	64	0	2	0.00	0.56
MACHINERY & EQUIPMENT, N.E.C.	3829	472.39	14.95	212.51	3.38111	107.63395	0.19662	479	181	399	608	2	43	1.63	38.49
ELECTRICAL INDUSTRIAL MACHINERY	3831	381.77	1.97	188.64	9.42386	68.93694	1.12017	2865	754	118	469	1	53	0.93	5.15
RADIO, TV, & COMMUNICATION EQUIPMENT	3832	732.25	6.47	660.59	0.84656	73.06101	0.16177	67	34	9	408	3	5	40.49	56.03
ELECTRICAL APPLIANCES & HOUSEWARES	3833	203.56	0.04	117.99	0.13175	15.64426	0.02837	2	15	2	696	1	0	0.00	0.00
ELECTRICAL APPARATUS AND SUPPLIES, N.E.C.	3839	414.90	10.33	858.69	12.36444	468.82073	0.44238	391	846	1772	412	11	306	0.36	2.19
SHIPBUILDING AND REPAIRING	3841	1970.26	0.28	284.00	45.03666	30.33649	0.14603	335	150	20	1243	336	105	0.15	0.48
RAILROAD EQUIPMENT	3842	413.34	0.24	221.70	10.10466	41.54692	0.00041	6814	2729	486	1898	1	1812	0.00	3.73
MOTOR VEHICLES	3843	445.62	2.21	201.48	1.93992	40.61347	0.03838	279	141	189	1298	12	140	0.23	1.17
MOTORCYCLES AND BICYCLES	3844	236.54	95.74	171.69	4.56468	33.19767	1.81550	264	154	44	7430	0	160	4.26	25.33
AIRCRAFT	3845	607.54	1.35	314.53	0.46358	39.15878	0.09015	106	87	222	329	3	16	1.03	8.99
PROFESSIONAL & SCIENTIFIC EQUIPMENT	3851	306.97	1.09	149.92	0.15088	16.51296	0.02142	14	23	3	34	0	4	0.69	0.77
PHOTOGRAPHIC AND OPTICAL GOODS	3852	773.23	0.07	420.85	0.07313	37.03495	0.00000	84	130	3	157	0	32	0.61	0.37
WATCHES AND CLOCKS	3853	531.95	0.00	275.08	1.26891	0.21148	0.00000	0	0	0	0	0	0	0.00	0.00
JEWELERY AND RELATED ARTICLES	3901	136.69	13.57	49.22	0.25672	10.34696	0.24495	189	63	16	52	0	61	0.00	24548.94
MUSICAL INSTRUMENTS	3902	779.85	0.00	590.22	4.26161	42.43790	0.00000	80	599	142	1870	52	132	0.00	0.00
SPORTING AND ATHLETIC GOODS	3903	381.74	0.28	117.42	0.30504	17.51545	0.27657	9	13	2	553	53	66	0.00	23236.49
MANUFACTURING INDUSTRIES, N.E.C.	3909	496.12	4.10	226.19	7.70294	82.68296	0.29224	29	14	11	408	0	7	0.09	0.52

Source: Hettige, Hemamala, et. al. (1996), *Industrial Pollution Projection System*, World Bank PRDEI,
Web site: http://www.worldbank.org/html/prdei/ipps/ippshome.html.

Note: all data is lower bound estimates

Table A-2. Direct Risk Weighted Pounds Toxic Pollution per $MM Final Demand

Four Digit ISIC Description	ISIC code	Risk weight lbs
MEAT PRODUCTS	3111	5.04
DAIRY PRODUCTS	3112	42.74
PRESERVED FRUITS & VEGETABLES	3113	28.32
FISH PRODUCTS		
OILS AND FATS	3115	72.28
GRAIN MILL PRODUCTS	3116	8.14
BAKERY PRODUCTS	3117	15.96
SUGAR FACTORIES & REFINERIES	3118	14.62
CONFECTIONERY PRODUCTS	3119	5.53
FOOD PRODUCTS, N.E.C.	3121	17.07
PREPARED ANIMAL FOODS	3122	9.35
DISTILLED SPIRITS	3131	16.80
WINE INDUSTRIES	3132	15.88
MALT LIQUORS AND MALT	3133	1.99
TOBACCO MANUFACTURES	3140	5.32
SPINNING, WEAVING, & FINISHING TEXTILES	3211	154.38
MADE-UP TEXTILES EXCEPT APPAREL	3212	46.88
KNITTING MILLS	3213	102.28
CARPETS AND RUGS	3214	7.18
CORDAGE, ROPE & TWINE		
TEXTILES, N.E.C.	3219	72.21
WEARING APPAREL	3220	17.52
TANNERIES AND LEATHER FINISHING	3231	318.93
FUR DRESSING AND DYEING		
LEATHER PRODUCTS		
FOOTWEAR	3240	11.70
SAWMILLS, PLANING & OTHER WOOD MILLS	3311	144.69
WOODEN & CANE CONTAINERS; SMALL CANE WARE		
WOOD & CORK PRODUCTS, N.E.C.	3319	67.91
FURNITURE & FIXTURES, NONMETAL	3320	61.29
PULP, PAPER, & PAPERBOARD	3411	116.90
PAPER & PAPERBOARD CONTAINERS & BOXES	3412	122.87
PULP, PAPER & PAPERBOARD ARTICLES,	3419	87.44
PRINTING & PUBLISHING	3420	109.25
INDUSTRIAL CHEMICALS EXCEPT FERTILIZER	3511	609.77
FERTILIZERS & PESTICIDES	3512	966.60
SYNTHETIC RESINS, PLASTICS MATERIALS, & MANMADE FIBRE	3513	544.60
PAINTS, VARNISHES, & LACQUERS	3521	46.29
DRUGS AND MEDICINES	3522	42.82
SOAP, CLEANING PREPS., PERFUMES, & TOILET PREPS.	3523	39.96
CHEMICAL PRODUCTS, N.E.C.	3529	75.92
PETROLEUM REFINERIES	3530	78.63
MISC. PETROLEUM & COAL PRODUCTS	3540	29.44
TIRES AND TUBES	3551	2.89
RUBBER PRODUCTS, N.E.C.	3559	60.76
PLASTICS PRODUCTS, N.E.C.	3560	175.56
POTTERY, CHINA, & EARTHENWARE	3610	29.16

Table A-2 (continued)

Four Digit ISIC Description	ISIC code	Risk weight lbs
GLASS AND GLASS PRODUCTS	3620	43.58
STRUCTURAL CLAY PRODUCTS	3691	7.90
CEMENT, LIME, AND PLASTER	3692	18.47
NONMETALLIC MINERAL PRODUCTS, N.E.C.	3699	56.60
IRON AND STEEL	3710	349.90
NONFERROUS METALS	3720	151.22
CUTLERY, HAND TOOLS, & GENERAL HARDWARE	3811	75.45
FURNITURE & FIXTURES OF METAL	3812	30.10
STRUCTURAL METAL PRODUCTS	3813	201.71
FABRICATED METAL PRODUCTS	3819	212.82
ENGINES AND TURBINES	3821	17.13
AGRICULTURAL MACHINERY & EQUIPMENT	3822	9.24
METAL & WOOD WORKING MACHINERY	3823	30.30
SPECIAL INDUSTRIAL MACHINERY & EQUIPMENT	3824	25.10
OFFICE, COMPUTING, & ACCOUNTING MACHINERY	3825	3.16
MACHINERY & EQUIPMENT, N.E.C.	3829	51.90
ELECTRICAL INDUSTRIAL MACHINERY	3831	18.71
RADIO, TV, & COMMUNICATION EQUIPMENT	3832	29.21
ELECTRICAL APPLIANCES & HOUSEWARES	3833	23.42
ELECTRICAL APPARATUS AND SUPPLIES, N.E.C.	3839	57.62
SHIPBUILDING AND REPAIRING	3841	17.43
RAILROAD EQUIPMENT	3842	8.46
MOTOR VEHICLES	3843	15.73
MOTORCYCLES AND BICYCLES		
AIRCRAFT	3845	28.71
PROFESSIONAL & SCIENTIFIC EQUIPMENT	3851	16.21
PHOTOGRAPHIC AND OPTICAL GOODS	3852	15.37
WATCHES AND CLOCKS	3853	19.48
JEWELERY AND RELATED ARTICLES	3901	59.12
MUSICAL INSTRUMENTS	3902	52.07
SPORTING AND ATHLETIC GOODS	3903	44.92
MANUFACTURING INDUSTRIES, N.E.C.	3909	38.03

Source: Hettige, Hemamala, et. al. (1996), *Industrial Pollution Projection System*, World Bank PRDEI, Web site: http://www.worldbank.org/html/prdei/ipps/ippshome.html.

Note: index is exponentially weighted

Table A-3. Average Direct Abatement Costs per Pound

Four Digit ISIC Description	ISIC	ACTXAIR[a]	ACWTXOG[b]	ACPB[c]	ACWTXMT[d]	ACSO2[e]	ACNO2[f]	ACAOTH[g]	ACVOC[h]	ACPT[i]	ACWCON[j]
MEAT PRODUCTS	3111	55.9689	0.1434	0.1185	0.3360	1.4384	1.6224	1.1471	31.0342	0.0427	0.0316
DAIRY PRODUCTS	3112	0.6386	0.1434	0.1185	0.3360	0.7331	0.1653	0.1937	0.0977	0.0830	0.0445
PRESERVED FRUITS & VEGETABLES	3113	0.6386	0.1434	0.1185	0.3360	0.1175	0.6305	0.2386	0.0977	0.1404	0.0334
FISH PRODUCTS	3114	0.6386	0.1434	0.1185	0.3360	0.1175	0.1653	0.1937	0.0977	0.0375	0.0765
OILS AND FATS	3115	0.6386	0.2453	76.6387	0.3360	0.1293	0.1653	0.1937	0.0977	0.0265	0.0742
GRAIN MILL PRODUCTS	3116	0.6386	0.1434	0.1185	0.3360	0.1175	0.1653	0.1937	0.0772	0.0606	0.0402
BAKERY PRODUCTS	3117	0.0320	0.1434	0.0320	0.3360	0.0320	0.0320	0.0320	0.0977	0.0324	0.0821
SUGAR FACTORIES & REFINERIES	3118	0.6386	0.1434	0.1185	0.3360	0.1175	0.1653	0.1937	0.0977	0.0287	0.0030
CONFECTIONERY PRODUCTS	3119	0.1185	3.0948	0.1185	0.3360	0.1185	0.1185	0.1185	15.8751	0.1247	0.0921
FOOD PRODUCTS, N.E.C.	3121	0.6386	0.0738	0.1185	0.3360	0.0175	0.1653	0.1937	0.0977	0.1005	0.0322
PREPARED ANIMAL FOODS	3122	0.6386	0.0842	0.1185	0.3360	0.0300	0.1653	0.1937	0.0977	0.0328	0.1983
DISTILLED SPIRITS	3131	0.6386	0.1434	0.1185	0.3360	0.3113	1.4816	0.1937	0.0977	0.0882	0.0917
WINE INDUSTRIES	3132	0.6386	0.1434	0.1185	0.3360	0.1354	1.4816	0.1937	0.0977	0.0882	0.0286
MALT LIQUORS AND MALT	3133	0.6386	0.1434	0.1185	0.3360	0.1354	5.9059	0.1937	0.0977	0.0827	0.0079
TOBACCO MANUFACTURES	3140	0.0917	0.1434	0.0917	0.3360	0.0917	0.0917	0.0917	10.5586	0.1093	0.2930
SPINNING, WEAVING, & FINISHING TEXTILES	3211	0.2721	0.0839	0.6811	0.3928	0.1354	1.3351	0.1937	0.4097	0.1219	0.0418
MADE-UP TEXTILES EXCEPT APPAREL	3212	0.2721	0.0839	0.7100	0.3928	0.1354	0.9687	0.1937	0.4097	0.1344	0.0328
KNITTING MILLS	3213	0.2721	1.9957	0.7100	0.1410	0.1354	0.9687	20.1779	0.4097	0.4283	0.1688
CARPETS AND RUGS	3214	0.2721	0.0839	0.7100	0.3928	0.1354	0.9687	0.1937	0.4097	0.1344	0.0328
CORDAGE, ROPE & TWINE	3215	0.2721	0.0839	0.7100	0.3928	0.1354	0.9687	0.1937	0.4097	0.1344	0.0328
TEXTILES, N.E.C.	3219	0.1437	0.0839	0.1437	0.3928	0.1437	0.1437	0.1437	0.4710	0.0977	0.0135
WEARING APPAREL	3220	0.2721	0.0839	0.8288	0.3928	0.1354	0.9952	0.1937	0.3987	0.1280	0.0358
TANNERIES AND LEATHER FINISHING	3231	0.1501	0.0839	0.1501	1.3769	0.1501	0.1501	0.1501	0.1834	0.1648	0.0742
FUR DRESSING AND DYEING	3232	43.6580	5.0803	0.0118	0.6221	0.1354	3.6527	0.3882	0.0118	0.0136	0.1354
LEATHER PRODUCTS	3233	0.2226	0.0839	0.0432	0.6221	0.1354	2.6142	0.3275	0.1068	0.0434	0.1269
FOOTWEAR	3240	1.0835	0.0839	21.9443	0.3928	0.3573	0.9952	0.8031	0.9118	0.3824	0.5447
SAWMILLS, PLANING & OTHER WOOD MILLS	3311	0.1026	0.1434	0.1185	0.2498	0.1354	0.0433	0.1937	0.1635	0.0209	0.0864
WOODEN & CANE CONTAINERS; SMALL CANE WARE	3312	0.1026	0.1434	0.1185	0.3360	0.1354	0.0433	0.1937	0.1635	0.0221	0.0616
WOOD & CORK PRODUCTS, N.E.C.	3319	0.1026	0.1434	0.1185	0.3360	0.1354	0.0433	0.1937	0.1710	0.0236	0.0492
FURNITURE & FIXTURES, NONMETAL	3320	13.0886	0.1434	0.1185	0.5404	1.5428	0.0433	0.1937	0.1635	0.0201	0.0204
PULP, PAPER, & PAPERBOARD	3411	0.2721	0.1434	0.1185	0.3360	0.0531	0.0681	0.0315	0.0787	0.0204	0.0421
PAPER & PAPERBOARD CONTAINERS & BOXES	3412	0.0708	2.3414	0.0708	5.4349	0.2470	0.0708	0.0708	0.4725	0.0599	0.0899
PULP, PAPER & PAPERBOARD ARTICLES,	3419	0.2721	0.1434	0.1185	0.3360	0.0564	0.0681	0.0308	0.1635	0.0203	0.0421
PRINTING & PUBLISHING	3420	5.5603	0.2210	0.0390	0.0563	0.0390	0.1258	0.0390	0.1233	0.0388	0.0491
INDUSTRIAL CHEMICALS EXCEPT FERTILIZER	3511	0.0112	0.1030	0.2222	0.3360	0.1112	0.0732	0.0199	0.0667	0.0012	0.0879
FERTILIZERS & PESTICIDES	3512	0.6761	0.2241	0.0397	0.3360	0.0920	0.2553	0.0799	0.1479	0.0345	0.4772
SYNTHETIC RESINS, PLASTICS MATERIALS, & MANMA	3513	0.0350	0.2664	0.7067	0.3360	0.1112	0.0603	0.0255	0.0409	0.0356	0.2960
PAINTS, VARNISHES, & LACQUERS	3521	0.1911	0.1052	0.1911	0.4123	0.1911	0.1911	0.1911	0.4850	0.1202	0.0477

Table A-3 (continued)

Four Digit ISIC Description	ISIC	ACTXAIR[a]	ACWTXOG[b]	ACPB[c]	ACWTXMT[d]	ACSO2[e]	ACNO2[f]	ACAOTH[g]	ACVOC[h]	ACPT[i]	ACWCON[j]
DRUGS AND MEDICINES	3522	0.0410	0.8965	0.1772	0.3360	0.6559	0.3533	0.1937	0.0706	0.1302	0.2264
SOAP, CLEANING PREPS., PERFUMES, & TOILET PREPS.	3523	0.0573	0.1179	0.0573	0.3360	0.0573	0.0573	0.5096	0.1560	0.0595	0.1625
CHEMICAL PRODUCTS, N.E.C.	3529	0.0410	1.4151	0.1772	1.1846	0.5656	0.0052	0.2079	0.1181	0.0198	0.2838
PETROLEUM REFINERIES	3530	0.0019	0.5083	0.0019	0.3360	0.0939	0.0329	0.0019	0.0942	0.0117	0.1346
MISC. PETROLEUM & COAL PRODUCTS	3540	0.0410	2.0268	0.1772	0.0087	0.3128	0.0095	0.1937	0.0426	0.0323	0.0088
TIRES AND TUBES	3551	0.1208	0.0549	0.1208	0.0549	0.4316	0.1208	1.1262	0.1208	0.1436	0.0544
RUBBER PRODUCTS, N.E.C.	3559	0.0956	0.0560	0.0956	0.0560	0.2310	0.0956	0.0956	0.0956	0.1078	0.4305
PLASTICS PRODUCTS, N.E.C.	3560	0.0410	0.1341	0.1772	0.3360	0.1112	0.0095	0.1937	0.0879	0.0882	0.1169
POTTERY, CHINA, & EARTHENWARE	3610	0.0329	0.0248	0.0329	0.0641	0.0290	5.6485	3.4433	2.5219	0.0344	0.0245
GLASS AND GLASS PRODUCTS	3620	0.0681	0.1434	0.0681	0.3276	0.0290	0.2552	0.0681	0.0681	0.0706	0.1491
STRUCTURAL CLAY PRODUCTS	3691	0.2721	0.1434	0.1185	3.0215	0.2748	0.1653	0.1937	0.1635	0.0293	0.0273
CEMENT, LIME, AND PLASTER	3692	0.2721	0.1434	0.1185	0.3360	0.0070	0.1653	0.1937	0.1635	0.0065	0.0059
NONMETALLIC MINERAL PRODUCTS, N.E.C.	3699	0.2721	0.1434	0.1185	0.3360	1.8892	0.1653	0.1937	0.1635	0.0326	0.0482
IRON AND STEEL	3710	0.3340	0.0437	1.0882	0.2435	0.0203	0.0530	0.1937	1.2105	0.0839	0.0456
NONFERROUS METALS	3720	1.0106	0.0504	0.4371	0.3360	0.0756	0.0584	0.1937	0.6634	0.0997	0.0425
CUTLERY, HAND TOOLS, & GENERAL HARDWARE	3811	0.2721	0.6465	0.0611	0.3937	0.2127	1.4851	0.1937	0.5940	0.4059	0.1696
FURNITURE & FIXTURES OF METAL	3812	0.2721	0.1639	0.0611	0.3824	0.5479	0.0347	0.1937	0.1108	0.1527	0.1574
STRUCTURAL METAL PRODUCTS	3813	12.2454	0.0529	0.0611	0.1785	0.5479	0.0347	0.1937	0.1811	0.1986	0.0519
FABRICATED METAL PRODUCTS	3819	0.2721	0.1434	0.0611	0.0823	0.4608	0.0347	0.4717	0.1892	0.1490	0.1011
ENGINES AND TURBINES	3821	0.2314	0.1434	0.2314	0.1398	0.5689	0.2314	0.2314	0.2314	0.2647	0.2886
AGRICULTURAL MACHINERY & EQUIPMENT	3822	1.0690	0.1434	0.0611	0.4197	0.1940	2.6513	10.0359	2.8819	0.0705	0.1108
METAL & WOOD WORKING MACHINERY	3823	1.0690	0.1434	0.0611	0.0200	1.7129	0.1653	0.1937	0.1868	0.3427	0.0400
SPECIAL INDUSTRIAL MACHINERY & EQUIPMENT	3824	1.0690	0.1434	0.0611	0.1398	0.2316	0.1653	0.1937	0.1868	0.2147	0.0977
OFFICE, COMPUTING, & ACCOUNTING MACHINERY	3825	17.1374	0.1434	0.1589	0.1398	0.1589	0.1589	0.1589	0.2450	0.1917	0.1132
MACHINERY & EQUIPMENT, N.E.C.	3829	0.9329	0.1434	0.0611	0.1398	0.1259	0.1653	0.1937	0.1310	0.1791	0.1100
ELECTRICAL INDUSTRIAL MACHINERY	3831	0.2334	0.1269	0.0611	1.0523	0.2689	0.1717	0.4375	0.2794	0.1896	0.3278
RADIO, TV, & COMMUNICATION EQUIPMENT	3832	0.2978	0.0719	0.0611	0.0719	0.0297	0.2923	0.5577	0.3551	0.2676	0.0719
ELECTRICAL APPLIANCES & HOUSEWARES	3833	2.5080	0.4187	0.0382	0.8893	0.0382	0.0382	19.1130	0.1209	0.0235	0.1568
ELECTRICAL APPARATUS AND SUPPLIES, N.E.C.	3839	0.2334	0.2430	0.1116	0.5739	0.0297	0.4976	0.2907	0.2369	0.1416	0.2369
SHIPBUILDING AND REPAIRING	3841	0.0352	0.3367	0.0352	0.1398	0.6158	0.0352	0.0352	0.0352	0.0538	0.2186
RAILROAD EQUIPMENT	3842	0.2721	0.0893	21.7512	77.9935	0.5473	0.3454	0.1937	0.7924	0.0658	0.0971
MOTOR VEHICLES	3843	0.2721	0.3367	21.5301	0.2986	0.1354	0.3454	0.1937	0.7670	0.2525	0.2039
MOTORCYCLES AND BICYCLES	3844	0.2721	0.0772	21.7512	0.0772	0.1354	0.3454	0.1937	0.7924	0.2537	0.6544
AIRCRAFT	3845	2.5421	0.8351	21.7512	0.2498	0.7205	0.3454	0.1937	0.5865	0.4455	0.2638
PROFESSIONAL & SCIENTIFIC EQUIPMENT	3851	0.2721	0.1553	0.0611	0.2291	0.1354	0.4817	0.1937	0.8140	0.4407	0.1654
PHOTOGRAPHIC AND OPTICAL GOODS	3852	1.3274	0.1317	1.3274	0.8026	21.8515	23.0095	0.1937	0.8301	0.8285	6.4064
WATCHES AND CLOCKS	3853	0.2721	0.1317	0.0611	0.2055	0.1354	0.4938	0.1937	0.8301	0.4530	0.1415
JEWELERY AND RELATED ARTICLES	3901	0.2721	0.5195	3.6407	0.3360	9.4038	0.1653	0.1937	0.0395	0.2410	0.3588
MUSICAL INSTRUMENTS	3902	0.2721	0.0180	3.6407	0.0180	0.1354	0.1653	0.1937	0.0395	0.0203	0.1333
SPORTING AND ATHLETIC GOODS	3903	0.1109	0.1434	0.1109	0.3360	0.1109	0.1109	0.1109	0.1109	0.1052	0.0880
MANUFACTURING INDUSTRIES, N.E.C.	3909	0.0027	0.2228	0.0027	0.2228	0.0027	0.0027	0.1937	0.0377	0.0112	0.2287

Table A-3 (continued)

Source: Hartman, Rammond S. et.al. (1994, December), ***The Cost of Air Pollution Abatement***, World Bank working paper,
Web site: http://www.worldbank.org/html/prdei/ipps/abcost/abate.htm.

Note: 1990 dollars per pound

[a]ACTXAIR - toxic air (toxic air)

[b]ACWTXOG - water toxic organic (toxic water)

[c]ACPB - lead air (toxic metal, air)

[d]ACWTXMT - water toxic metal (toxic metal, water)

[e]ACSO2 - SO2

[f]ACNO2 - NO2

[g]ACAOTH - other air (CO)

[h]ACVOC - volatile organic compounds

[i]ACPT - particulates (fine particulates and total suspended particles)

[j]ACWCON - water, conventional (TSS)

APPENDIX B

MAJOR AIR, WATER AND TOXIC POLLUTANTS (Hettige, 1996)

Toxic Pollutants

Toxic Chemicals: Many chemicals in industrial emissions are poisonous to humans, either on immediate exposure or over time, as they accumulate in human tissues. Humans can ingest severely damaging or fatal quantities through repeated exposure, or by consuming plants or animals in which these compounds have accumulated. Toxic chemicals may cause damage to internal organs and neurological functions; can result in reproductive problems and birth defects; and can be carcinogenic. Quantities and length of exposure necessary to cause these effects vary widely. Benzene and asbestos are known carcinogens linked to leukemia and lung cancer.

Bioaccumulative Metals: In bioaccumulation, relatively low concentrations of contaminants in air, water, soil and plants become far more concentrated further up the food chain. Some metals can be converted to organic forms by bacteria, increasing the risk that they will enter the food chain. Bioaccumulative metals are particularly dangerous because they are dissipated very slowly by natural systems. They may cause both mental and physical birth defects. Metals can also become rapidly oxidized and converted to soluble form when sediment is exposed to oxygen. Some of the metals which are commonly measured and particularly dangerous are mercury, lead, arsenic, chromium, nickel, copper, zinc and cadmium.

Air Pollutants

Total Suspended Particulates (TP) and Fine Particulates (PM10): Particulates are fine liquid or solid particles such as dust, smoke, mist, fumes or smog found in air emissions. In heavy concentrations, airborne particulates interfere with proper functioning of the human respiratory system. High levels of ambient TP in urban/industrial areas are therefore associated with greater morbidity and mortality from respiratory diseases. Particulate coatings on leaves inhibit plant growth. High TP concentrations may also force the use of high-cost filtration equipment by manufacturers. Fine particulates (PM10) are less than 10 micron in diameter. They pose the greatest respiratory hazard.

Sulphur Dioxide: Sulphur dioxide is a heavy, pungent, colorless, gaseous air pollutant formed primarily by fossil fuel combustion. It is associated with morbidity and mortality from respiratory disease. In addition, SO2 is a prime source of the acid rain which has damaged huge forest tracts in the OECD and several transitional socialist economies. Acid rain and runoff have raised the acidity in numerous lakes beyond the point where indigenous fish species can survive. Acid rain also degrades concrete, mortar, marble, metals, rubber and plastics.

Nitrogen Oxides (NOX): Nitrogen dioxide (NO2) and nitric oxide (NO) are oxides of nitrogen, often collectively referred to as "NOX." The primary source of NO is thermal combustion of fossil fuels, which emits NO. Higher combustion temperatures, sometimes recommended to reduce emissions of Volatile Organic Compounds (VOCs), are associated with higher production rates of NOX. NOX emissions have important ecological impacts, since they are integral to the formation of acid rain and tropospheric ozone. Inhalation of concentrated NO2 damages the respiratory tract, resulting in a range of effects from mild reductions in pulmonary function to life-threatening pulmonary edema.

Carbon Monoxide (CO): Carbon Monoxide is a colorless, odorless, and tasteless poisonous gas produced by incomplete fossil fuel combustion. CO binds with hemoglobin in human blood 200 times faster than oxygen. Thus, the blood's ability to carry oxygen to tissues is significantly impaired after exposure to only small concentrations of CO. High doses of CO can result in heart and brain damage, impaired perception and asphyxiation, and low doses may cause weakness, fatigue, headaches and nausea.

Volatile Organic Compounds (VOC): The term volatile organic compounds, describes a class of thousands of substances used as solvents and fragrances. VOCs are particularly important in the petrochemical and plastics industries. Human exposure to VOCs is mainly via inhalation, although some VOCs appear as contaminants in drinking water, food, and beverages. Many VOCs are suspected carcinogens. Acute effects from industrial exposures include skin reactions and central nervous system effects such as dizziness and fainting. Recently, sick-building syndrome (SBS) and multiple chemical sensitivity (MCS) have been linked to the relatively low (part per billion) concentrations of VOCs which are more typical of ambient environments. In addition, VOCs may form photochemical oxidants which have been identified as eye and lung irritants.

Water Pollutants

Biological Oxygen Demand (BOD): Organic water pollutants are oxidized by naturally-occurring micro-organisms. This 'biological oxygen demand' removes dissolved oxygen from the water and can seriously damage some fish species which have adapted to the previous dissolved oxygen level. Low levels of dissolved oxygen may enable disease causing pathogens to survive longer in water. Organic water pollutants can also accelerate the growth of algae, which will crowd out other plant species. The eventual death and decomposition of the algae is another source of oxygen depletion as well as noxious smells and unsightly scum. The most common measure for BOD is the amount of oxygen used by micro-organisms to oxidize the organic waste in a standard sample of pollutant during a five-day period (hence, '5-day BOD').

Suspended Solids (SS): Small particles of non-organic, non-toxic solids suspended in waste water will settle as sludge blankets in calm-water areas of streams and lakes. This can smother plant life and purifying micro- organisms, causing serious damage to aquatic ecosystems. The loss of purifying micro-organisms enables pathogens to live longer, raising the risk of disease. When organic solids are part of the sludge, their progressive decomposition will also deplete oxygen in the water and generate noxious gases.

APPENDIX C

How to evaluate the costs of particular development choices

Real development decisions come down to looking at the costs and benefits of factory X with W jobs and factory Z with Y jobs. The pollution data presented here was aggregated to the four digit ISIC code. The numbers estimate the pollution of a broad category of industry. If the name and kind of facility is known, the most accurate estimates of pollution can be found by using the TRI and AIRS databases directly. The researcher could look for similar existing plants in other locations to get the direct pounds of pollution. This would allow more accurate analysis. Unfortunately, the only risk data and abatement cost data I know about is the aggregated data. The most available estimate of size is most often the number of employees. Direct pollution per employee can be estimated from the similar facility.

Once this is known, IMPLAN, which has disaggregated data to the four digit US SIC sector, can be used to estimate value added per job. The indirect economic effects upon the region could also be found using IMPLAN. The development researcher would then have the proposed number of jobs, estimated indirect jobs, direct and indirect value added per job, and direct pounds of pollution per job.

APPENDIX D

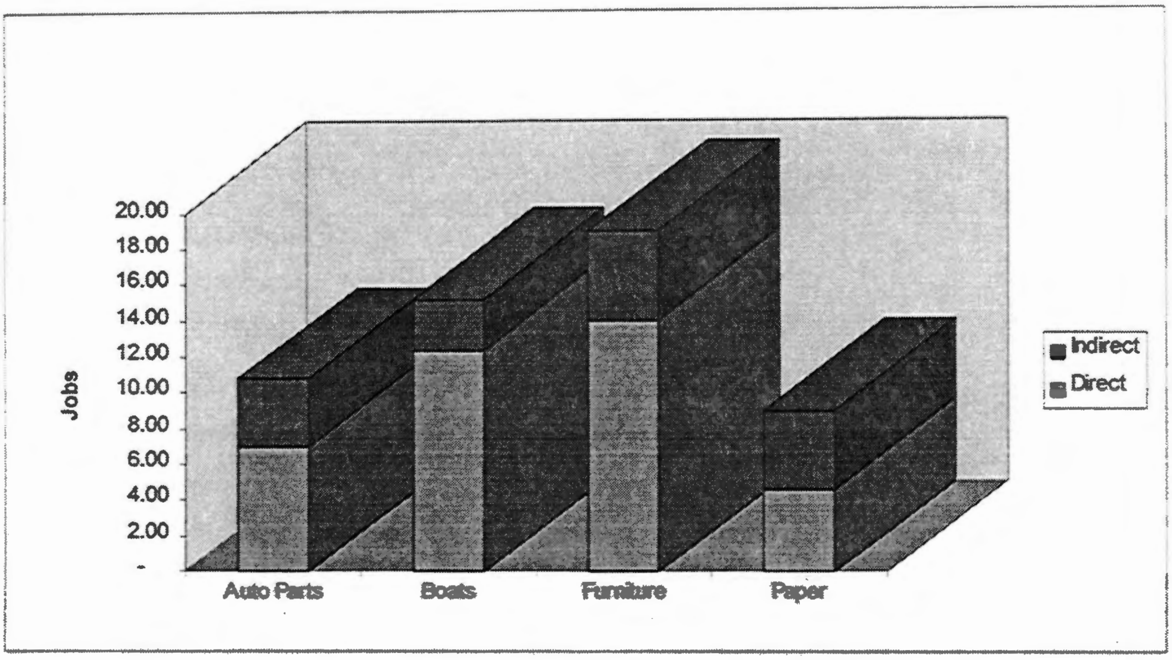

Figure D-1. Jobs per Million Dollars Final Demand

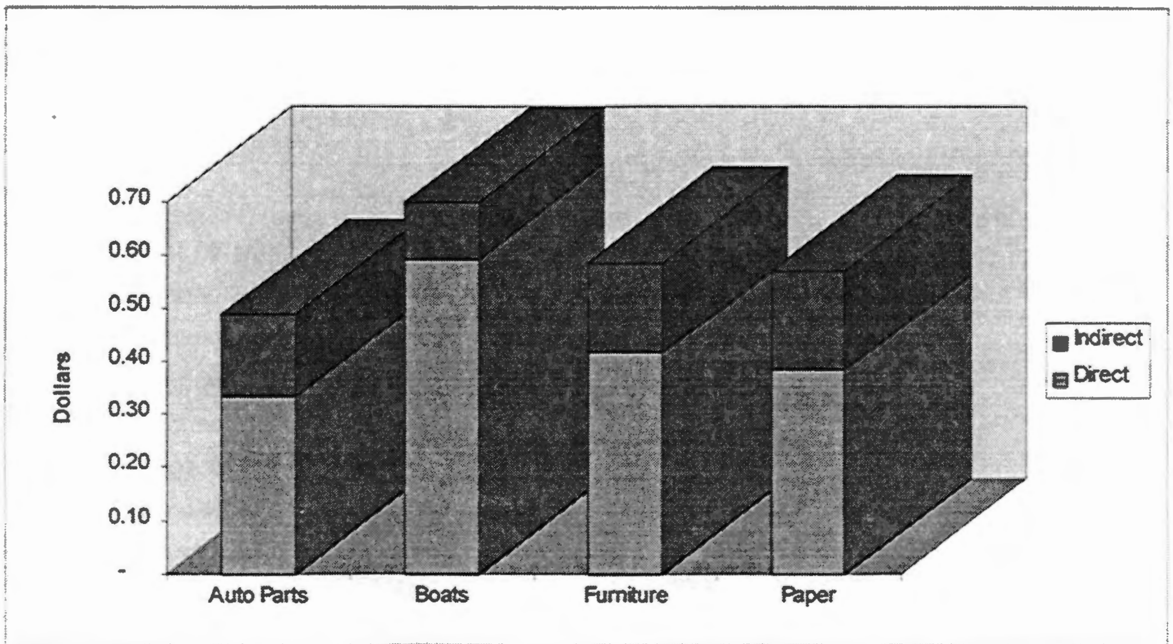

Figure D-2. Value Added per Million Dollars Final Demand

Figure D-4. Abatement Cost per Million Dollars Final Demand

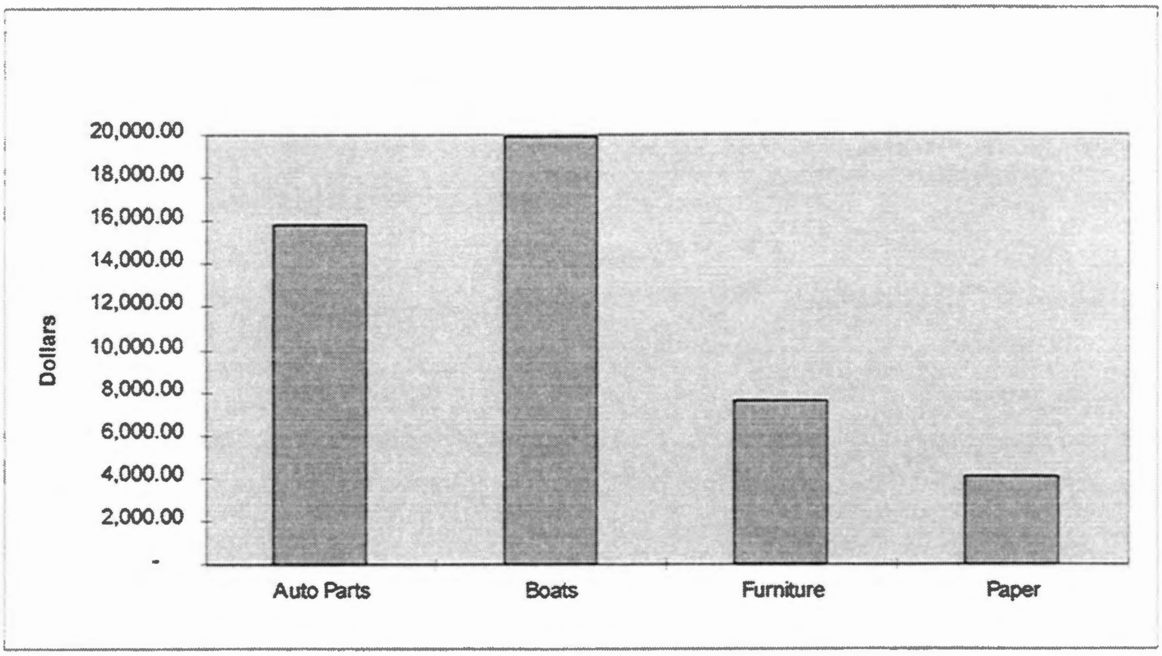

Figure D-5. Value Added per Risk Pound

VITA

Chad Hellwinckel was born in Hutchinson, Minnesota, in 1969. After moving to several small towns in Minnesota, Miami, Florida, and North Canton, Ohio, Chad attended high school in Olathe, Kansas and graduated in 1987. He attended St. Olaf College in Northfield, Minnesota and received a B.S. in Economics and Urban Studies in 1991. Chad spent 1992 as an intern at The Land Institute in Salina, Kansas learning about and helping to develop a perennial system of agriculture. In 1994, Chad entered the master of science program in the Agricultural Economics Department of the University of Tennessee. He received his degree in December of 1996.