# Agricultural Economics Report

REPORT NO. 460          NOVEMBER 1984

# METHODS FOR ASSESSING THE ECONOMIC BENEFITS OF FOOD SAFETY REGULATIONS: A CASE STUDY OF PCBs IN FISH

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## TABLE OF CONTENTS

# LIST OF TABLES AND FIGURES

LIST OF TABLES AND FIGURES (Cont.)

LIST OF FIGURES

# 1  INTRODUCTION

This report examines methods of valuing the economic
benefits of regulations which limit unintentional chemical
contaminants in food.  Theoretical and empirical issues
involved in this type of benefit valuation are explored
by examining the case of polychlorinated biphenyls (PCBs)
in fish.  Estimates from three studies of willingness
to pay for risk reductions are used to derive benefit
estimates for alternative regulations which limit the
allowable levels of PCBs in marketed fish.  Sensitivity
of estimates to risk assumptions and method are examined.
Net benefits of alternative regulations are estimated and
policy implications are discussed.

## 1.1  The Research Problem and Research Objectives

Mercury in seafood, polybrominated biphenyls
(PBBs) in meat and milk, and polychlorinated biphenyls
(PCBs) in Great Lakes fish are well-known examples of
unintentional contamination of food by chemicals in the
environment.  The development of analytical methods
which detect minute amounts of chemicals have revealed
that low levels of environmental contaminants in food
are an increasingly common problem (50).  Even

low levels of these contaminants are suspected of posing risks to human health.

Unlike most other types of food safety problems, environmental contaminants cannot be avoided in food by "good" manufacturing practices (41,50). They can only be avoided by declaring food containing them to be unfit for human consumption.[1] This necessitates setting some type of standard as to what level of environmental contaminants in food will be tolerated. Setting this tolerance level involves a difficult trade-off between level of risk and level of food loss.[2]

At present, this trade-off is considered using a type of cost-effectiveness approach (50). The health risks (e.g., number of new cancers) associated with alternative tolerance levels are compared with the cost of

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[1]Presence of contaminants in the environment may be controlled, however, thus lessening risks of food becoming contaminated over time. This approach is taken through environmental policies on the use of industrial and agricultural chemicals.

[2]The Food and Drug Administration discussed the difficulty of making this trade-off in its announcement lowering tolerance levels for several foods containing PCBs. Federal Register, Vol. 44, No. 127, June 29, 1979, pp. 38330-38340.

food that would be lost. While this approach allows information to be generated about the cost per health risk averted (e.g., cost per cancer averted) for each alternative tolerance, it is hardly a guide to choice. Even if the cost per cancer averted is $1,000,000 under one tolerance level and $500,000 under another, some may believe the value of averting one cancer is $2,000,000. However, there are few studies which address these valuation issues for food safety regulations (39, 50). Consequently, regulators must essentially guess at the value of risk reductions in order to decide whether or not to choose a particular tolerance level.

Legal constraints are one reason why few economic studies of food safety regulation have been conducted (38). Food safety decisions tend to be made on the basis of other criteria that have evolved over the course of almost 80 years and generally leave little room for consideration of economic ramifications (41). Some more recent regulations involving environmental contaminants in food do include consideration of the costs of regulation versus the benefits of reduced risk in non-monetary terms. However, because such regulations are so recent, and because most food safety decisions do not call for economic input, few economic studies have been conducted to date. Some examples of economic studies

that have been carried out include an analysis of sulfa regulations and the swine subsector by Kramer (35), and an analysis of the impact of deboning regulations in red meat by Bullock and Ward (5).

A second reason for the lack of economic analysis is the conceptual difficulty associated with developing economic theory to value the type of benefits that stem from food safety regulations. The primary benefit is reduction of the risk of adverse impacts to human health -- an impact that is difficult to measure and value for a variety of reasons. There is a controversy over whether it is ethical to measure benefits of regulations affecting human life in dollar terms (3,48,55). The basis of the argument against such measurement is that no amount of money is adequate to compensate for the loss of a human life -- a life is a resource of infinite value.

The counter argument is that while it is indeed impossible to place a value on human life, it is often necessary to make choices among government policies or programs which aim to save lives, or more accurately to reduce the statistical risk of injury, disease or death within a given population (57). In order to allocate regulatory resources most efficiently and equitably some measure of the magnitude of risk reduction achieved by alternative programs is necessary. Since the costs of

the programs are expressed relatively easily and
accurately in dollar terms, it would be best if benefits
could also be expressed in dollars. Experience has shown
that when costs are precisely quantified, while benefits
are only expressed qualitatively, the costs receive more
attention and weight (18). Thus, while it may be
impossible to measure the "value of life," it may be
worthwhile to attempt to more precisely quantify the extent
to which regulations reduce risk, and if possible, express
the value in dollar terms. The methods to do the quanti-
fication are limited, however, in part because of the
reluctance of many analysts to become involved in the
controversial subject.

Underlying the perspective that reduction in risk
cannot be expressed in dollar terms is the belief that
such efforts would underestimate the value of "lifesaving"
regulations and would be used to support decisions biased
against environmental health and safety regulations in
general. In fact, there are many examples of overly
simplistic applications of benefit measurement which have
underestimated the value of risk reducing regulations (38).
However, recent evidence indicates such bias is not the
norm. Rather, benefit quantification studies tend to
uphold the validity of lifesaving regulations. In a
recent review of 35 studies involving cost-benefit

comparisons of 57 sets of policy options, the benefits
of lifesaving programs were found to exceed costs in
over 3/4 of the cases (23). In other words, in the
majority of benefit quantification studies, quantification
of benefits supported the regulatory effort. Thus,
even if the value of the benefits of reducing risk to
life were underestimated, the benefit values were still
found to be greater than the costs of the regulation.

A third reason for the lack of economic analysis
of food safety regulatory benefits is that such studies
are difficult to conduct from an empirical standpoint.
One difficulty is that the level of risk associated with
exposure to even the most thoroughly studied environmental
contaminants is highly uncertain. In many cases one set
of scientific data will indicate that a substance is
hazardous while another indicates absence of hazard (51).
Economic methods are unable to meaningfully incorporate
this uncertainty in the economic analysis (3,71).

Another empirical problem is that the benefits
of food safety regulation tend to involve small, long-
term reductions in risk spread out over a large population.
The cumulative risk reduction is significant, but the
statistical reduction in risk per individual is small.
Measurement and valuation of the benefits of reducing
such risks is difficult. A related problem is that there

are many different types of risks -- voluntary vs. involuntary; reversible vs. irreversible (74). Distinctions between such risks are usually not considered in quantitative analysis of risk reduction (9).

Despite problems associated with analyzing the benefits of food safety regulations, and the lack of methodology to conduct such analysis, the need for economic information is apparent. As the problem of environmental contamination grows, the need to carefully allocate limited resources to control the contaminants increases. Systematic economic analysis including benefit quantification can facilitate the control effort.

## 1.2  The Research Approach

Ideally, the benefits of risk reducing regulations should be assessed by estimating their value to people whose risk of exposure would be decreased. This would involve an assessment of peoples' willingness to pay for that particular risk reduction. However, such an approach is costly and time consuming.

A less costly, although admittedly less ideal, approach is to adapt existing estimates of willingness to pay for risk reductions to a particular case of risk reduction. This study employs this approach.

Several estimates of willingness to pay for reduction in health risks exist. Currently, there appears to be little agreement among federal agencies about which estimate should be used (27). In this case study, alternative estimates are critiqued and three are selected for application to the case of PCBs in fish. The application of three different estimates represents an approach that might be used in evaluating the benefits of other risk reducing regulations, given the lack of agreement on existing estimates of the value of risk reductions. This case study examines the limitations and advantages of such an approach.

The regulation of PCBs is selected as a case study because of the relatively large amount of risk data available on the chemical. Since the major exposure of people to PCBs through food is in the consumption of fish, the benefit assessment if confined to four alternative regulatory standards called tolerances, for PCBs in fish (i.e., No tolerance, 1 ppm., 2 ppm., and 5 ppm.).* Since the major health risk associated with exposure to PCBs is cancer, the benefit assessment concentrates on the cost

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*The tolerance standard now in place for PCBs in fish is 2 ppm. A tolerance of 4 ppm or 3 ppm was not considered for reasons explained in Chapter 3.

savings of reduced cancer risks associated with each of the four regulatory standards.

The research does not result in a definitive dollar figure for the value of PCB regulations. Rather, the research shows the range of benefit estimates which may be obtained through application of state-of-the art economic research and best available scientific information. It is stressed at the outset that serious informational and conceptual limitations exist in both the scientific and economic aspects of benefit estimation which the study will attempt to clarify.

## 1.3 Organization of the Report

Methods for valuing reductions in risk are examined in Chapter 2 and the three approaches chosen for use in this study are described. Chapter 3 discusses the risks posed by PCB residues in fish and quantitative estimates of risk used in this study are described. Benefit estimates are developed in Chapter 4 and compared to costs of regulation. Chapter 5 presents policy implications and research recommendations.

CHAPTER 2

THEORY AND METHODS

There are three types of methods which are
used to value reductions in risk. They are the human
capital (hk) approach, the willingness to pay (wtp)
approach, and the adjusted human capital/willingness
to pay (hk/wtp) approach. Each is reviewed below. Their
application in this study is then discussed.

## 2.1  The Human Capital Approach

The human capital (hk) approach assumes that the
value to society of a human's life is measured by future
production potential. This is usually expressed as the
present discounted value of expected before-tax labor
earnings.[1] Income foregone by persons of a given age, sex
and occupation who are affected by a health risk is used
to estimate the value of a reduction in that risk.

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[1]Early work on the methodology was carried out by
Fein, Mushkin and Collings, Weisbrod, Klarman and Rice
(17, 43, 73, 34).

Determination of the number of individuals who would die or become ill in different demographic classes is derived from actuarial data. Income lost from sickness or death of individuals in a demographic class (e.g, white, middle-aged males) is based on projected before-tax income of that class. The discount rate used represents the social opportunity cost of society investing in life saving programs rather than other alternative investments (38).

In one variation of the standard hk methodology, the value of life is calculated by estimating foregone earnings net of consumption. This net loss approach is based on the idea that when an individual dies, or is ill, not only is future production lost, but future consumption as well (42). Another variation of the hk approach adds medical expenses associated with illness diagnosis and treatment to foregone earnings to obtain a total cost estimate (8, 24). Values estimated for one life in existing hk studies vary from $100,000 to $400,000 in 1975 dollars (38). These estimates are sensitive to choice of discount rate and demographic class considered.

The hk approach is criticized for its lack of foundation in economic theory. It has no necessary relationship to an individual's willingness to pay to avoid risk, nor does it recognize individual attitudes or preferences towards risk. The approach relies on the assumption that individuals' utility functions are based

solely on maximization of earned income, specifically in terms of contribution to GNP. This narrow definition of the utility function is difficult to defend on theoretical grounds. Dimensions of illness and death beyond economic output, such as pain and suffering, the value of leisure, and other intangible dimensions of life are completely ignored. Moreover, such a description of the utility function with respect to risk valuation does not reflect how people actually behave. For example, if the full value of life is actually measured by GNP contribution, people would, if given the choice, work more than a 40 hour week, sacrificing leisure for higher income. While some people do behave in such a fashion, most do not.

Most users of the hk method do not argue that the approach produces estimates of the value of life that are consistent with economic theory. Instead, they maintain that the hk estimates simply represent the impact of loss of given lives on GNP. It is also argued that the hk estimates provide precise information because they are based on actuarial data, thus providing full, age specific accounting. Most analysts agree that estimates based on life expectancy, labor force participation, and projected earnings are accurate estimates of the impact of death and injuries on GNP. However, it is also widely acknowledged that these marketplace estimates are not the

most appropriate measures of the overall value of risk reduction.

Application of the hk approach also leads to illogical policy conclusions. For example, because white, middle-aged men earn, on the average, more than nonwhites, women and young people, the hk estimates could be interpreted to the effect that a program that saves white, middle-aged men's lives is more worthwhile than programs which save the lives of people in other demographic groups. (For further discussion of the method and its empirical application, see Mishan (42), Cooper and Rice ( 8 ) and Hartunian, Smart and Thompson (24).)

### 2.2 The Willingness to Pay Approach

It is widely agreed that valuation of reductions of loss of life should be based on the same criterion used by economists in other areas of cost-benefit analysis, namely that the worth or value of a thing is determined by what a person is willing to pay for it (42). Thus, willingness to pay (wtp) estimates of the value of risk reduction are considered conceptually more appropriate than the traditional human capital estimates.

As discussed by Mishan, the value of a reduction in risk is not the value of an identified person's life. Rather it is the value of the reduction in the probability

of death or sickness for a given population. The
appropriate benefit measure, then, is the aggregate value
a population at risk places on programs that save
statistical lives. This is equivalent to the sum of the
amounts individuals are willing to pay ex-ante to buy
small reductions in the probability of their own death
(42).

A simplified model showing the tradeoffs between
wealth and survival probability illustrates the concepts
underlying the wtp approach to assessing the value of
risk reduction. Figure 2-1 presents an indifference
function showing the tradeoff of wealth for survival
probability in a one-period situation. In this case,
survival can be thought of as a probabilistic term for
an increase in life expectancy; the demand for survival
would be willingness to pay for this increase. The
problem is to determine an individual's preferences with
respect to survival versus wealth choices. In other
words, the price at which wealth can be exchanged for
enhanced survival probability, or vice versa, must be
determined. The basic behavioral assumption is that
individuals make choices so as to maximize their expected
utility. The actual choices that will be made will
depend on the initial endowment of wealth and the initial
probability of survival. Other factors likely to influence

W

P - - - - - - - - - ->1
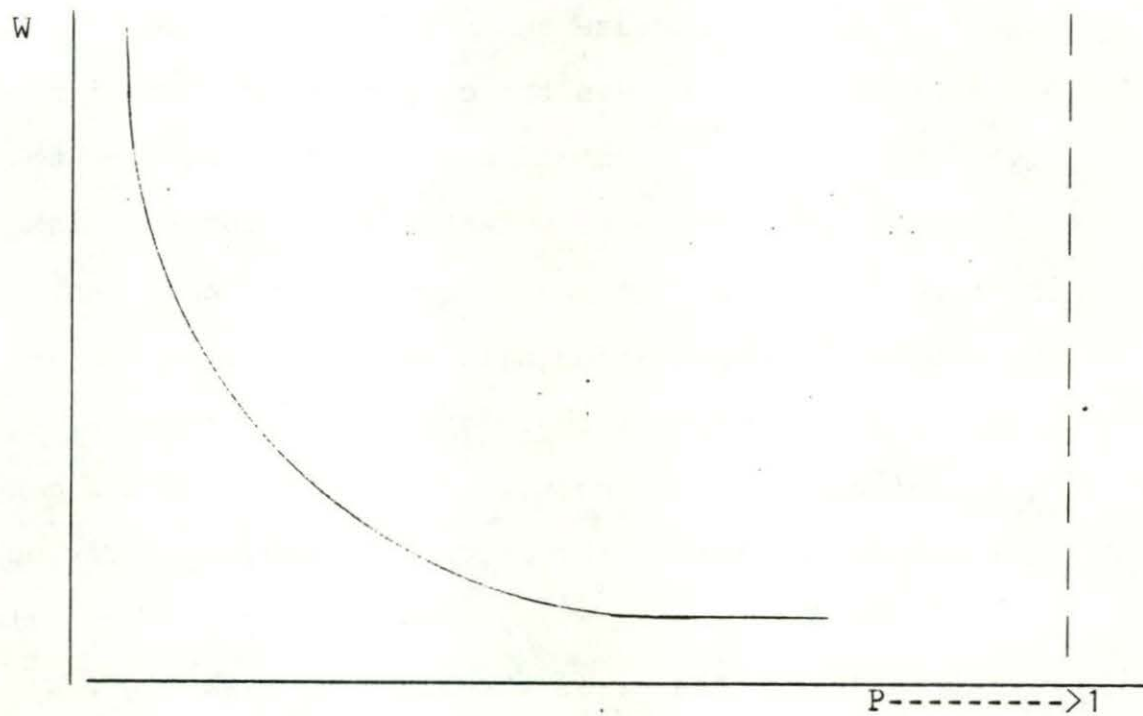
P = Probability of survival.

Figure 2.1    An Indifference Function Showing the Tradeoff of
              Wealth for Survival Probability

the wealth-survival tradeoff would include anticipated
lifetime, the number of dependents and family, and the
nature and timing of the probabilistic death.

There are two approaches to determining the
impact of a risk increase on an individual's welfare.
One approach is to assess the compensating variation
(cv). This is the amount of compensation required to
induce the individual to voluntarily accept the risk
increase. Obviously as the level of risk increases,
the amount of compensation will go up (in a nonlinear
fashion) until, when asked to accept certain death,
no amount of compensation will be adequate. The second
approach is to measure the amount of money an individual
would pay to avoid a risk increase, called the equivalent
variation (ev). Again, as the level of risk rose, a
person would be willing to pay more and more, until when
faced with need to avoid certain death, a rational
person would likely give up all wealth to save their life.

From these concepts, it can be seen that the
value of a risk reduction is theoretically bracketed
by the amount a person is willing to pay to avoid it
(up to all their wealth) and the amount of money required
to fully compensate a person for the risk (which is
infinite for certain death).

Two types of procedures are used to estimate wtp:
1) analysis of direct survey responses of individuals'
wtp, followed by aggregation of the results to obtain
a societal wtp value; 2) statistical estimation of peoples'
revealed preferences based on either studies of the labor
market or studies of consumption services, again followed
by aggregation of the value to obtain a societal wtp
estimate. The two methods produce a wide range of
estimates of the value of reductions in risk. No
concensus exists as to which method is the most valid.
The process of aggregating individual wtp values to
estimate the market demand for risk reduction requires
several restrictive assumptions about income distribution
and risk preferences that can be criticized on
theoretical grounds (21).

Three major studies have been conducted using the
survey method to obtain estimates of the wtp for risk
reductions. Acton (1) posed open-ended questions about
individuals' wtp for a coronary care unit that would provide
a small (.002) reduction in the risk of death from heart
attack. Two different formulations of the question led
to values of a statistical life of $28,000 and $43,000
(1972$). Jones-Lee (26) asked a similar question concern-
ing individuals' wtp higher air fares to travel on
airlines that had lower probabilities of a fatal crash.

The value of a statistical life saved in his study was
approximately $5 million (1975$). Landefeld (37) surveyed
individuals on their wtp to reduce cancer mortality.
He found a value of $1.2 million (1977$) per statistical
life saved.

The survey approach has several methodological
problems that may account, to some extent, for the
variability of the benefit estimates. The first and most
obvious drawback is the inability of individuals to deter-
mine their preferences with respect to risk in hypothetical
and complex situations. A second problem surrounds
how individuals expect the survey information to be used.
Individuals may overstate or understate their wtp
depending on whether or not they believe that they will
be eventually charged  their wtp for a program (38).
A final problem is that individuals do not evaluate very
small changes in risk in a consistent fashion, even if the
risk information is clearly presented. For example,
one study shows that people tend to underestimate the
chance that a low-probability, high loss event will happen
to them, while overestimating the likelihood of high-
probability, low-risk events (60).

Some economists feel that the problems are
serious enough to preclude obtaining reliable estimates of
wtp from surveys. Other economists, however, accept the

variability of survey results as a reflection of the
fact that different types of risks (i.e., higher vs.
lower; voluntary vs. involuntary) are valued differently
and that people's risk preferences vary.

Estimates of the value of life obtained from
labor market studies provide the most accessible direct
evidence of the amount people are wtp for their own
safety.  This method is based on the observable
wage differentials between risky and less risky work.
In theory, a worker with a given skill and education
level can choose from among several types of jobs having
markedly different accident rates.  Risky jobs typically
pay more for a given skill requirement than less risky
positions.  By examining the wage differential between
the two jobs, theoretically, the value placed on a given
increment of risk can be estimated.

Analysis of the labor market to generate estimates
of the value of a statistical life has been conducted by
Dillingham (13), Smith (62), Viscusi (72), Thaler and
Rosen (65), and Olson (52).  The estimates of the value of
saving a statistical life range from $140,000-$260,000
(1967$, 65), to $1.5 million (1967$, 62).  The variation
in the methodologies used in the different studies may
account for some of the variability in estimates as well
as operational problems in data collection.

Landefeld and Seskin (38) have summarized the most common criticisms of the labor market approach in five points. Wage premiums may not accurately reflect worker risk preferences if workers have incomplete information regarding risks to which they are exposed. Wage premiums may not provide accurate measures of worker preferences if there are significant imperfections in the labor market (i.e., an immobile labor force). Sample self-selection may bias results. Because of low incomes, lack of economic opportunities, or specific individual preferences, those who work in riskier jobs may exhibit less risk adverse behavior than the population as a whole. Statistical problems occur when trying to separate risk of death from risk of injury since compensating wage differentials will try to account for both. Data constraints may bias statistical evidence, for example, using aggregate industry data instead of data from an individual firm.

A third measurement approach attempts to assess risk preferences in a larger, general population by observing how much people are willing to pay in the marketplace for various goods or services which reduce the risk of death or injury. Blomquist (4) has estimated the value of life based on the use of automobile seatbelts. Dardis (12) estimated the value of life based on use of

smoke detectors, and Portney (54) developed estimates
based on housing values and environmental risks.

The range of values obtained from the consumption
activity method are narrower than those from the labor
market studies. The values range from approximately
$100,000 (1973$, 12) to approximately $355,000 (1977$, 4).
However, according to Landefeld and Seskin (38), many
of the same data and statistical problems that weaken
labor market studies also affect consumption activity
estimates. As with labor market studies, it is statistially
difficult to separate risk premiums from other confounding
factors such as income and education level. Extrapolation
of the value of risk from the narrow "study group" (i.e.,
seatbelt users, smoke detector consumers, etc.) to the
general population may not be valid. It is also extremely
difficult to obtain data on purchase or use of risk-
reduction items. Finally the assumption that people who
make such purchases are aware of risk implications at the
time of purchase is questionable.

## 2.3  The Adjusted WTP/HK Approach

The theoretical appeal of the wtp approach and
the operational strengths of the hk approach have prompted
research efforts to meld the 2 methodologies. The result
is the "adjusted wtp/hk approach."

Empirically, the adjusted wtp/hk approach is identical to the hk approach except for two points incorporated from implicit features of the wtp approach. First, in adjusted wtp/hk estimates, the individual's, as opposed to society's opportunity cost of investing in risk-reducing activities forms the basis for choosing a discount rate. Because this is measured by the "real" rate of return on investment, after-tax earnings are used to represent labor income. Secondly, a risk aversion factor is included in the adjusted wtp/hk model to reflect the assumption that persons should be at least as risk averse with respect to loss of life as to other financial assets.

Based on these two adjustments and their underlying assumptions, it is argued that foregone earnings provide a theoretically correct estimate of an individual's wtp to avoid risk (7, 70). This argument rests, in turn, on the assumption that the only variable entering an individual's lifetime utility function is lifetime income (40). This assumption is flawed for the same reasons that traditional hk assumptions are flawed. The value of life is not fully captured by contribution to GNP even if a lower discount rate based on an individual's opportunity costs is used. However, it does seem reasonable to accept the assumption embodied in the addition of a risk aversion factor that individuals are at least as risk averse with respect to

loss of life as to other financial assets. Given this
assumption, the adjusted wtp/hk estimates represent a lower
bound value of risk reduction activities.

Only one study has been conducted to estimate value per
statistical life using the adjusted willingness to pay
method. Landefeld and Seskin derived estimates for males
and females by 19 age categories. They found, as expected,
that the estimates with the wtp/hk method were consistently
larger than those based on the hk approach. For example, the
adjusted wtp/hk estimate for a male, aged 40-44, is $660,193
(1977$) versus $108,052 (1977$) using a hk method (38). As
pointed out above, the difference in value is associated with
the use of a lower discount rate (3% versus 5% in this
example) and with the inclusion of a risk aversion factor
(based on life insurance purchasing behavior).

### 2.4 Using the Methods to Assess PCB Tolerances for Fish

Based on the discussion presented in this chapter, only
wtp approaches are used to develop alternative benefit
estimates for PCB tolerances. Three approaches are selected,
for reasons described below.

As discussed earlier, the adjusted wtp/hk approach pro-
vides a lower bound value of the benefit of risk reduction
consistent with economic theory. The model also has the
advantage of ease of calculation and also provides useful
information on the impact of risk on GNP based on

fairly detailed actuarial data.  The Landefeld and Seskin estimates of individuals' opportunity cost of investment and risk aversion are used to adjust hk estimates of foregone income.  Third party medical costs stemming from PCB related health risks are added to this estimate.

With the exception of the adjusted wtp/hk estimate however, it cannot be argued that one particular wtp estimate is more theoretically correct than another.  In other words, we cannot say whether wtp approaches yielding high estimates are theoretically better than those yielding low or medium estimates.

Discrimination, then, must be based solely on methodological grounds.  However, this still leaves several potentially useable estimates.  Given the theoretical uncertainty, it is appropriate to develop a range of estimates.

Since the adjusted wtp/hk approach gives a theoretical lower bound estimate, two well-known and methodologically sound wtp estimates are chosen to develop middle and high value estimates.  These are taken from two labor market studies, one by Thaler and Rosen and one by Smith.  The rationale for selecting wtp values derived from labor market studies, rather than surveys or consumption studies, is that more of these type of studies have been conducted with more consistent results.  These

estimates are adjusted to reflect third party effects including medical costs and lost indirect business taxes.

An important point concerning use of existing estimates is that the type of risk reduction considered differs in the three studies. The adjusted wtp/hk model addresses the benefits of preventing one liver cancer. The two wtp studies deal with the value of preventing one statistical death. The risk of liver cancer is obviously different from the risk of death. However, the actual difference may not be great. Unlike some other types of cancer, survival rates for patients with liver cancer are low (see 24, p. 217). Thus, liver cancer can be assumed to eventually lead to death, perhaps after a long and painful illness. It is not improbable that some people would be willing to pay more to avoid cancer than some other quick and painless death. Moreover, exposure to PCBs may cause other types of health problems than cancer which, for reasons discussed in the next Chapter, are difficult to include in a measure of risk. Thus, bias toward overestimation from using the two labor market estimates of wtp may not be a serious problem.

After the three estimates of alternative regulations are developed. A point estimate is suggested and net benefit estimates are derived. They are compared with cost effectiveness estimates and policy implications of benefit estimation approaches are discussed.

Quantitative estimates of the risks posed by PCBs in fish must be chosen before benefits can be estimated. This is discussed next.

CHAPTER 3


ASSESSING RISKS POSED BY PCBs IN FISH


3.1  PCBs

PCBs are a class of toxic, highly stable industrial chemicals that were manufactured and sold in the U.S. from 1929 until 1977. The properties of chemical stability and insolubility made PCBs a valuable and widely used industrial chemical. From the 1930s through the 1970s PCBs were a common component of manufacturing equipment, paint and other protective coatings for wood, metal and concrete, adhesives, and carbonless reproducing paper (see Table 3.1). During the period from 1930 to 1975, U.S. commercial sales of PCBs totaled nearly 570,000,000 kg from domestic sources and about 14,000,000 kg from imports (47). No special steps were taken to control or monitor use, handling, or disposal of PCBs.

In the mid-1960s, scientists discovered accumulation of PCB compounds in tissues of fish taken from the Baltic Sea. This discovery prompted monitoring efforts in the U.S. and by 1972, significant levels of PCBs had been discovered in many foods including milk, poultry, dairy products, eggs, animal feed and freshwater fish.

Table 3.1 Domestic Uses of PCBs

| Category | Type of Product | Percent of New Total Use |
|---|---|---|
| Closed Electrical Systems | Transformer, capacitors, other (minor) electrical insulating/cooling applications | 61 until 1971; 100 after 1971 |
| Nominally Closed Systems | Hydraulic fluids, heat transfer fluids, lubricants | 13 until 1971; 0 after 1971 |
| Open-End Applications | Plasticizers, surface coatings, ink and dye carriers, adhesives, pesticide extenders, carbonless copy paper, dyes | 26 until 1971; 0 after 1971 |

Note: NAS. Polychlorinated Biphenyls, 1979.

Sources of the PCBs included industrial leaks and accidents, contamination from agricultural uses of PCBs (such as farm equipment and PCB-containing coatings in silos) and contamination from food-packaging materials which contained PCBs. The most significantly contaminated food was freshwater fish which accumulated PCBs released into the water via land runoff and industrial effluent in their tissues.

Initially, the presence of PCBs in food and the environment received attention because it appeared to be such a ubiquitious problem and because the compound was extremely persistent. It was not until the late 1960s that information became available showing conclusively that PCBs were harmful to human health. One incident in particular provided powerful evidence that PCBs could be highly toxic. In 1968, in Yusho, Japan, PCBs from heat transfer fluid leaked into rice oil during the manufacturing process. Over 1,000 persons consumed the contaminated oil. Mild to severe symptoms of poisoning appeared. Skin diseases, blindness, gastrointestinal illness, reproductive disorders, and possibly cancer were associated with the accident (56).

Following the Yusho incident, the distribution of PCBs in the environment and the risks to health associated with them came under extensive study. Comprehensive

surveys reported the existence of PCBs in the atmosphere, soil, water, sediment, fish, wildlife and human blood and tissue (47, 25, 31). Thorough reviews of the effects of PCBs on human health were reported by NAS (47), Hutzinger (25), Drill et al. (14), Kimbrough (30), Khan and Stanton (28), and Rodericks (56), D'Itri and Kamrin (11).

The major health impacts appear to take the form of "subtle impairments rather than gross morphological or pathological changes" (47). Acute toxicity to either humans or wildlife rarely occurs, and those effects that have been observed are the result of cumulative contacts over a long period of time. This kind of low-level, chronic exposure is posed by unavoidable food contamination.

There is a significant body of evidence indicating that PCBs are animal carcinogens (29, 33, 32, 44, 68, 11). While the evidence is not conclusive, the compound has been classified as "probably carcinogenic for humans" by the International Agency for Research on Cancer (IARC). Table 3.2 shows the IARC carcinogenicity evaluation for a variety of chemicals and industrial processes. As indicated in the Table, IARC judged the degree of evidence regarding cancer and PCBs as "sufficient" from animal studies, but "inadequate" from human studies (51). Lack of sufficient epidemiological evidence is not surprising considering the generally low concentrations of PCBs in

Table 3.2  Chemicals and Industrial Processes Evaluated for Human Carcinogenicity by the International Agency for Research on Cancer (IARC)

| | Degree of Evidence | |
| | Humans | Experimental Animals |
| --- | --- | --- |
| **Chemicals and processes judged carcinogenic for humans** | | |
| 4-aminobiphenyl | Sufficient | Sufficient |
| Arsenic and certain arsenic compounds | Sufficient | Inadequate |
| Abestos | Sufficient | Sufficient |
| Manufacture of auramine | Sufficient | Not applicable |
| Benzene | Sufficient | Inadeuqate |
| Benzidine | Sufficient | Sufficient |
| N,N-bis(2-chloroethyl)-2-naphthylamine (chlornaphazine) | Sufficient | Limited |
| Bis(chloromethyl)ether and technical grade chloromethyl methyl ether | Sufficient | Sufficient |
| Chromium and certain chromium compounds | Sufficient | Sufficient |
| Diethylstilboestrol (DES) | Sufficient | Sufficient |
| Underground hematite minine | Sufficiet | Not applicable |
| Manufacture of isopropyl alcohol by the strong acid process | Sufficient | Not applicable |
| Melphalan | Sufficient | Sufficient |
| Mustard gas | Sufficient | Limited |
| 2-naphthylamine | Sufficient | Sufficient |
| Nickel refining | Sufficient | Not applicable |
| Soots, tars and mineral oils | Sufficient | Sufficient |
| Vinyl chloride | Sufficient | Sufficient |
| **Chemicals and processes judged probably carcinogenic for humans** | | |
| Group A:  Chemicals and processes with "higher degrees of evidence." | | |
| Aflatoxins | Limited | Sufficient |
| Cadmium and certain cadmium compounds | Limited | Sufficient |
| Chlorambucil | Limited | Sufficient |
| Cyclophosphamide | Limited | Sufficient |
| Nickel and certain nickel compounds | Limited | Sufficient |
| Tris(1-aziridnyl)phosphine sulphide (thiotepa) | Limited | Sufficient |
| Group B.  Chemicals and processes with "lower degrees of evidence." | | |
| Acrylonitrile | Limited | Sufficient |
| Amitrole (aminotriazole) | Inadequate | Sufficient |
| Auramine | Limited | Limited |
| Beryllium and certain beryllium compounds | Limited | Sufficient |
| Carbon tetrachloride | Inadequate | Sufficient |
| Dimethylcarbamoyl chloride | Inadequate | Sufficient |
| Dimethyl sulphate | Inadequate | Sufficient |
| Ethylene oxide | Limited | Inadequate |
| Iron dextran | Inadequate | Sufficient |
| Oxymetholone | Limited | No data |
| Phenacetin | Limited | Limited |
| Polychlorinated biphenyls | Inadequate | Sufficient |
| **Chemicals and processes that culd not be classified as to their carcinogenicity for humans** | | |
| Chloraphenicol | Inadequate | No data |
| Chlordane/heptachlor | Inadequate | Limited |
| Chloroprene | Inadequate | Inadequate |

Note:  Modified from OTA-H-138.  Technologies for Determining Cancer Risks from the Environment.  June, 1981.

the environment, and the long time horizon for manifestation
of carcinogenic effects. Inability to prove carcinogen-
eity conclusively from human studies is thus an insufficient
basis to conclude whether PCBs are carcinogenic. Taking
a conservative perspective, PCBs can be considered as
potential human carcinogens.

Other health effects of PCBs suggested by animal
studies include reproductive effects such as alterations
in the menstrual cycle, births of abnormally small infants
and greater frequency of early abortions. Infants born
to primate mothers exposed to PCBs during gestation and
lactation also show some loss of immunological competence
and learning and behavioral deficiencies (14).

Additionally, nonspecific health effects possibly
attributable to PCBs include dermatological abnormalities,
abnormal fatigue, abdominal pain, numbness of limbs,
swelling of joints and chronic cough (47). Abnormal tooth
development and anemia have also been associated with PCB
exposure (68).

## 3.2 The Benefits of Food Safety Regulations

PCBs in food were first regulated by the Food and
Drug Administration in 1973 when tolerance levels were
established for fish, eggs, dairy products, meat, and
poultry. In the early 70's, the sole producer of PCBs

in the U.S. voluntarily curtailed sales and then
production in 1977. However, materials containing PCBs
were still in service and residues, though declining,
remained in the environment (see Table 3.3).

Because of the reduced incidence in food, the
PCB tolerances were lowered in 1979. The tolerance
for fish was reduced from 5 ppm to 2 ppm. In explaining
their action, FDA concluded that "the increment of public
health protection afforded at least theoretically by a
further reduction of the tolerance to 1 ppm did not
justify such a reduction in light of the substantially
greater loss of food that would result.[1] The FDA did not
report considering a 4 ppm or 3 ppm tolerance.

Another reason for the reduction in tolerances was
that new toxicity data showed increased risk of adverse
reproductive effects, tumor production, and possibly,
carcinogenicity from PCB exposure. How these risks would
be lowered by reductions in tolerance levels was illustrated
by the FDA by a quantitative risk assessment of the upper
limit on the lifetime risk of cancer for heavy eaters of
fish.[2]

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[1]Federal Register, Vol. 44, No. 127, June 29, 1979
p. 38331.
[2]Ibid, p. 38332.

Table 3.3   Environmental Distribution of PCBs Not in
            Service as of 1975

|                                    | Amount $(\text{x } 10^6 \text{ kg})$ |
| ---------------------------------- | ---------- |
| Mobile PCBs in the Environment     | 68.2       |
| Degraded or Incinerated            | 25         |
| Landfills or Equipment Dumps       | 130        |

Note:   NAS.   Polychlorinated Biphenyls, 1979.

One reason why the FDA chose the risk of cancer to
illustrate the benefits of reducing the tolerance levels is
that methods to quantify noncarcinogenic health effects are
not currently available. Thus, although there are many types
of possible health consequences from PCBs, the reductions in
risks of cancer are illustrative of the benefits of alterna-
tive tolerance levels.

Following the lead of the FDA, this study uses re-
ductions in cancer risks to value the benefits of alterna-
tive regulations. Some health risks other than cancer would
also be reduced by reducing human exposure to PCBs. However,
since these health risk reductions have not been determined
quantitatively, the value of reducing them cannot be
estimated. This fact should be kept in mind in evaluating
the benefit estimates derived below.

The estimate of risk of cancer from PCBs used in this
research is based on a FDA study (56). The study develops
four estimates of the risk of cancer per year from PCBs
based on two experimental studies; Kimbrough et al. (29) and
a National Cancer Institute (NCI) study (56). In this
research, the risk estimates based on the Kimbrough data
are relied upon most heavily, but one set of data from the
NCI is also used.

The NCI risk data was used by the FDA in 1979 as the basis of their estimate of PCB-related risk (20). The NCI study is procedurally flawed in that the sample size used was smaller than that recommended by standard protocol for carcinogenic tests (24 animals versus the recommended minimum of 100). However, the results of the NCI test are consistent with the procedurally valid Kimbrough study in that both studies indicate that the liver is the target organ for toxicity, and a high incidence of prolierative lesions occurred in both studies (56). The NCI data is used here as a upper bound risk estimate of cancer risk posed by PCBs.

In the Kimbrough study, Sherman female rats were fed Aroclor 1260 at 100 mg/kg in their diet for 21 months and sacrificed at 23 months. At this dosage, 26 of 184, and 1 of 173 in the control group, exhibited heptacellular carcinomas (29). The NCI study involved groups of male and female Fisher 344 rats (24 of each sex per group). They were administered Aroclor 1254 in the diet at 25, 50, and 100 ppm for a period of 104-105 weeks. At the high dosage, 21 out of 48 rats from both groups exhibited heptacellular proliferative lesions and 4 out of 48 exhibited liver carcinomas and adenomas (56).

To extrapolate risk of cancer to humans from
the Kimbrough study and the NCI study, the FDA used a
linear model. The model was justified by the assumption
that it was the model least likely to underestimate risk.
Although it was not specifically stated in the study, it
appears that the risk estimates were corrected for species
conversion on the basis of total lifetime exposure
divided by body weight. It should be noted that the
model used by the FDA -- linear, no threshold extrapolation,
and relating animal and humans on the basis of total
lifetime exposure divided by body weight -- has been
reported to estimate human cancer incidence within a
factor of 10 to 100 when compared to incidence measured by
epidemiologic studies (51).

In order to calculate cancer risks to humans,
the next step is to estimate exposure to PCBs. The FDA
assumed that the PCB in fish was the same compound
(Aroclor 1260) used in the lab test. To calculate human
exposure, data on PCB in fish was obtained from FDA
surveys conducted in 1978-1979. Mean PCB levels were
calculated for the 11 species that contained the highest
levels of PCBs. All other fish types were put in a 12th
category. PCB contamination in fish was estimated for
the situation of no tolerance, 2 ppm, 3 ppm, and 5 ppm.
Rough approximation of the effect of a given tolerance

level on mean PCB levels for each species was arrived at by eliminating samples with PCB levels greater than the assumed tolerance and recalculating the mean.

Data on the type, and mean daily amount of each type, consumed by the population was obtained from the National Marine Fisheries Service Study. The study included 25,947 eaters selected as a sample of all U.S. fish eaters. Total estimated daily exposure to PCBs was then calculated for the estimated 15.2% of the U.S. population assumed to eat the species of interest. Using the risk extrapolation and the exposure data, the number of new cancers/year in eaters of fish species of interest was calculated.

Three estimates of risk (high, medium and low) are used in this study since the risk assessment process contains many uncertainties. These uncertainties should be incorporated into economic analysis by examining the sensitivity of the benefit valuation process to the risk estimates. The risks, expressed as numbers of new cancers per year, are shown in Table 3.4 for each of the alternative PCB tolerances considered in this study. These tolerances exclude the alternatives of 4 ppm and 3 ppm since the FDA did not report risk data on them and apparently did not consider them.

The high risk estimate is based on total malignancy data from the NCI bioassay and a "heavy fish consumption" assumption. The low estimate is based on the Kimbrough

Table 3.4  Number of New Cancers Per Year* - High, Medium,
          Low Estimate

| Risk Level | Number of New Cancers Per Year | | | |
|---|---|---|---|---|
| | No Tolerance | 5 ppm | 2 ppm | 1 ppm |
| Low | 6.2 | 5.8 | 3.8 | 2.4 |
| Medium | 16.3 | 14.7 | 10.0 | 6.7 |
| High | 50.6 | 46.8 | 34.3 | 21.0 |

*Numbers of new cancers per year in the 15.2% of the U.S.
population assumed to consume freshwater fish.

data, assuming light fish consumption. The medium level estimate is based on the Kimbrough data but assuming heavy fish consumption. The FDA used the high risk estimates in its justification for lowering the tolerance for PCBs in fish from 5 ppm to 2 ppm.

CHAPTER 4

APPLICATION TO PCBs

In this chapter, estimates derived from the three benefit valuation studies described in Chapter 2 are used to assess the value of reductions in risk from PCBs in fish. Benefits of reducing the risk of cancer under four different tolerance levels for PCBs in fish (1 ppm, 2 ppm, 5 ppm, and no tolerance) are examined.

In this study, the benefits of a given tolerance level are defined as the costs saved under the particular tolerance versus under a no tolerance level situation. The benefits, or costs saved, from using one tolerance versus another are presented at the end of the chapter. The first part of the chapter identifies the dollar costs stemming from PCB-related cancers under a particular tolerance level. The health costs stemming from various combinations of four tolerances, three risk estimates and three benefit assessment methods have been calculated for this study. However, to reduce repetition, only the costs of the no tolerance situation are presented. The no tolerance values represent

the maximum dollar costs that would result from cancer
if PCBs in fish were not regulated at all.

The estimates of the value of risk reduction
applied to the PCB data were orginally expressed in
dollars ranging from 1967 to 1979 dollars.  For purposes
of evaluation, all values are converted to 1982 dollars
using the Consumer Price Index (CPI) with one exception--
medical costs were converted to 1982 dollars using the
Medical Price Index of the CPI.

The three approaches to assessing the value of
risk reduction, including some modifications, are presented
one at a time yielding a lower bound, medium, and high
estimate of benefits.  Whether the range can be narrowed
is considered and "best" point estimates of risk reduction
are developed.  The policy implications of the risk
reduction estimates are then addressed by examining the
net benefits of each risk/tolerance scenario.  Finally,
the alternative approach to evaluating benefits, cost-
effectiveness analysis, is applied and the results
evaluated.

### 4.1  The Lower Bound Estimate: The Adjusted WTP/HK Approach

The lower bound estimate of the benefits of PCB
regulations is calculated using the adjusted wtp/hk
methodology.  An hk based estimate of the costs of cancer

is developed first.  It includes an hk estimate of foregone
earnings and an estimate of third party medical costs.
The present value of the foregone earnings estimates,
discounted at the individual's opportunity cost of invest-
ment, are weighted by a risk aversion factor.  The medical
costs are discounted at the social opportunity cost of
investment.  The weighted estimate of foregone earnings
is added to medical costs to obtain the wtp/hk estimate.

This approach differs from that of Landefeld and
Seskin, who do not include medical costs in their figures.
They are added here on the grounds that these costs are
likely to be borne outside the family and thus not
accounted for in an hk estimate based on foregone earnings
only.

The foregone earnings and medical costs are
initially calculated by age and sex categories using
estimates developed by Hartunian, Smart, and Thompson.
However, only foregone earnings and medical cost data for
males, aged 35-44, are used to calculate the lower bound
estimate of the value of one statistical life saved.  This
is necessary to achieve a lower bound value comparable
to the middle and high estimates based on the wtp methods.
The wtp methods use one number based on empirical studies
of middle aged men as the value per life saved for people
of all ages and sex.  In achieving comparability, however,

we overestimate the cost of cancer since cancer incidence increases with age while labor earnings decline.

In order to apply the hk model of Hartunian, et. al. to the PCB case, the high, medium and low risk estimates of total new cancers per year from PCB in fish are broken down into number of new cancers per year by sex and age group. To illustrate the process, Table 4.1 presents calculations of the age-sex breakdown for cancers from PCBs based on the medium risk estimate and a no tolerance situation. Data presented in Hartunian, et.al. (based on data from the Third National Cancer Survey) are used for the disaggregation.

Note that it is necessary to specify the type of cancer expected to result from PCB exposure in order to develop these calculations. In the animal experiments, the liver is the organ affected by PCB (29). Lacking further information, it is assumed that the liver is also the target organ in humans. In Hartunian, et. al. specific data on liver cancers are not presented; liver cancer costs are instead included in the broader category of digestive system cancers. It is likely that liver cancer costs would be greater than general digestive system cancers since survival rates for males aged 35-44 years are lower than the other

Table 4.1   Incidence of PCB-Related Cancers by Age and Sex,
No Tolerance, Medium Risk Estimate.

| Age/Sex Group | Incidence | Proportion | Cancers From PCBs/Age Group |
|---|---|---|---|
| **Male** | | | |
| 0-14 | 145 | .169 | .014* |
| 15-24 | 301 | .342 | .029 |
| 25-34 | 768 | .873 | .074 |
| 35-44 | 2241 | 2.548 | .217 |
| 45-54 | 9673 | 11.000 | .936 |
| 55-64 | 21130 | 24.028 | 2.045 |
| 65-74 | 28802 | 32.752 | 2.788 |
| 75+ | 24879 | 28.291 | 2.408 |
| Total Males | | | 8.512 |
| **Females** | | | |
| 0-14 | 84 | .104 | .008 |
| 15-24 | 175 | .218 | .017 |
| 25-34 | 634 | .794 | .062 |
| 35-44 | 2052 | 2.550 | .199 |
| 45-54 | 7643 | 9.498 | .740 |
| 55-64 | 15689 | 19.496 | 1.518 |
| 65-74 | 24440 | 30.370 | 2.365 |
| 75+ | 29750 | 36.969 | 2.879 |
| | | | 7.79 |

*This figure is produced by multiplying the actual proportion of
cancers occurring in each age-sex group by the number of new cancers
from PCB (at medium risk level, no tolerance).   In this case, 16.3
new cancers are expected.   Of these, 8.51 would occur in males, 7.79
would occur in females.   Thus, for males, multiplying 8.51 times the
proportion would result in the cancers from PCBs/age group.

cancers in this category.[1]  In other words, this choice
will mean foregone earnings will be underestimated.

### 4.1.1  Calculation of Medical Costs

The model used by Hartunian, et. al. to calculate
medical costs is presented below in order to clarify how
the cost estimates were developed.  The model estimates
total medical expenditures for each type of cancer by age,
sex and stage of cancer when diagnosed.

$$\text{Present value of costs (PVC)} = \sum_{n=1}^{99} (P_{L,s}^{i}(n) \cdot DC_{L,s}^{i}(n-L+1) \quad 4.1$$

where:  n = the various ages of the individual
                (99 is the maximum age considered)

L = the age at impairment onset

(n) = the probability that a person of
        sex s who acquires cancer i at age
        l will survive to age n

$DC_{L,s}^{i}(n-L+1)$ = the dollar value of the average
        annual medical costs generated by
        such persons during year (n-L+1)
        following cancer onset.

r = the discount rate

---

[1]Life expectancies for digestive system cancers for
35-44 year old males by type of cancer are:  liver, 0.5 years;
esophagus, 0.8 years; gall bladder, 2.3 years; stomach, 3.6
years; rectum, 11.4 years; colon, 13.1 years; pancreas, 13.2
years (Hartunian, et. al., p. 217).

The variable $P^i_{L,s}(n)$, the probability that a person of sex s who acquires cancer i at age L will survive to age n, is calculated based on the survival rates of persons in the general populations of the same age and sex. Hartunian, et. al. obtained the survival data from U.S. Census life tables; and the statistics on survival from cancer from the Third National Cancer Survey (10).

The medical cost figures are based on hospital costs plus non-hospital costs. Hospital payment data were obtained by Hartunian, et. al. from an indepth study of hospitalization and payment patterns by Scotto and Chiazze (58). Average hospital costs during the first and second years following diagnosis were calculated and used to project cost estimates for subsequent years. Non-hospital costs as calculated by Hartunian et. al. included cost of physicians services, private nursing, nursing home and attendant care, drugs, physical therapy, special equipment and prosthetics and other miscellaneous services. This information was derived primarily from the Third National Cancer Survey.

Using the model, Hartunian, et. al. produced estimates of medical costs per cancer for persons of a given age and sex as shown in Table 4.2. As explained above, the cancer costs for the male, aged 35-44, are used as the estimate of medical costs from PCB-related cancers.

Table 4.2  Estimated Medical Costs Per Cancer by Age and Sex

| Age Group | Medical Costs of 1 Cancer by Age Group (1975$) | Medical Costs of 1 Cancer by Age Group (1982$) |
|---|---|---|
| Males | | |
| 0-14 | 5488.00* | 9329.60** |
| 15-24 | 11276.00 | 19169.20 |
| 25-34 | 10986.00 | 18676.20 |
| 35-44 | 11186.00 | 19016.20 |
| 45-54 | 10510.00 | 17867.00 |
| 55-64 | 8340.00 | 14178.00 |
| 65-74 | 7875.00 | 13387.50 |
| 75+ | 7341.00 | 12479.70 |
| Females | | |
| 0-14 | 5172.00 | 8792.40 |
| 15-24 | 10721.00 | 18225.70 |
| 25-34 | 11351.00 | 19296.70 |
| 35-44 | 11615.00 | 19745.50 |
| 45-54 | 11480.00 | 19516.00 |
| 55-64 | 9987.00 | 16877.90 |
| 65-74 | 8669.00 | 14737.30 |
| 75+ | 7921.00 | 13465.70 |

*Estimate of total medical expenses required to treat one cancer
diagnosed in 1975 in a male, aged 0-14.  The cost estimates were
developed by Hartunian et. al. (24 ) and are based on estimates of
total hospital plus non-hospital costs generated by cancer victims
and estimates of how long a person of a given age and sex will
survive after getting the disease.
**Costs converted to 1982$ using the Medical Costs Index.

### 4.1.2  Calculation of Foregone Earnings Associated with PCB Related Cancers

The second step is to calculate lost or foregone output of patients suffering premature death or disability. Since the adjusted wtp/hk method is based on an individual perspective, foregone earnings should include both labor and non-labor income (including transfer payments) available to an individual after taxes (38). However, foregone earnings estimates for cancer patients available in Hartunian, et. al. are measured in terms of the before-tax wages that would have been earned by the individuals if they had not become ill. Further, the only non-labor income included in their estimate is the computed market value of work performed in the home. Transfer payments and other non-labor income (e.g., interest and rents) are excluded.

By using before-tax wages, we overestimate available earnings. By excluding transfer payments and some types of non-labor income, we underestimate available earnings. However, the net effect may be an underestimate. Landefeld and Seskin (37) report that decreases in disposable income caused by taxes are more than offset by the value of transfers and non-labor income. They estimated that the value of transfers, work performed in the home, other non-labor income and after-tax wages is approximately 1.33 times reported pre-tax wages.

To calculate earnings foregone as a result of
cancer, Hartunian, et. al. compared earnings expectations
of the patient at the time of initial cancer diagnosis
with those realized after diagnosis. Using information
from mortality analyses and on the functional status
of cancer survivors from the Third National Cancer Survey
Project, they calculated the mean number of weeks during
the first year that a previously employed patient with
cancer would be out of work. Based on these results,
they calculated the fraction of potential first-year
productivity lost by cancer patients working before illness
who survived and returned to work one year after diagnosis.

Using the Third National Cancer Survey, Patient
Interview Book (PIB) unpublished data, and incorporating
mortality/survival information, Hartunian, et. al. estimated
by age, sex and cancer type: (1) the fraction of potential
first-year productivity actually generated by cancer
patients $(\alpha_{L,s}^{i})$; (2) the proportion of previously employed
cancer patients (including both previously employed
patients and those engaged in homemaking activities) who
survive and return to work one year after diagnosis
$(\beta_{L,s}^{i}$ ). Incorporating the two parameters, they modeled
the expected postmorbid earnings of a cancer patient as:

Present Value of Postmorbid Earnings $= [\alpha^i_{L,s} \cdot Y_s(L) \cdot E_s(L)] +$  4.2

$$\{\beta^i_{L,s} \cdot [\sum_{n=L+1}^{85} P^i_{L+1,s} \cdot Y_s(n) \cdot E_s(n) \cdot (\frac{1+\delta}{1+r})^{n-1}]\}$$

$\alpha^i_{L,s}$ = fraction of potential first year productivity actually generated by cancer patients

$\beta^i_{L,s}$ = proportion of previously employed cancer patients (including previously employed patients and those engaged in homemaking activities) who survive and return to work one year after diagnosis

$L$ = age at onset (+/or death)

$s$ = sex

$\delta$ = average annual rate of growth in labor production (assumed 1%)

$Y_s(n)$ = mean annual earnings of employed people and homemakers in general population of age n and sex s measured at incidence year 1975

$E_s(n)$ = proportion of general population of age n and sex s employed in labor force or engaged in housekeeping

$P_s(n)$ = probability of a person in general population of age L and sex s surviving to age n

$r$ = discount rate

The first term on the right side of the equation represents the present value of average before-tax earnings in the first year after diagnosis. The second term represents the present value of average before-tax earnings generated in subsequent years by cancer patients.

Using the model described above, Hartunian, et. al. estimated average postmorbid earnings for cancer patients of different ages, sexes, and diagnostic types and combined and averaged them to yield results for each of the diagnostic categories. They next subtract a cancer patient's postmorbid earnings from the estimate of his/her expected future earnings had he/she not contracted the disease to find the estimated net foregone earnings owing to the disease. Table 4.3 shows foregone earnings from cancer by age and sex. Again costs for a male, aged 35-44, will be used in this report.[2]

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[2]Note that the Hartunian, et. al. estimate of foregone earnings for males aged 35-44 years old with digestive cancers is $143,847.00 (1975 $; r = .06). Their estimate for a fatality in this group is $205,687 (24, p. 52, Table 2-5). Thus the difference is $62,840. Since survival rates for patients in this group with liver cancer is 0.5 years, the amount we have underestimated foregone earnings is close to this difference.

Table 4.3   Estimated Foregone Earnings per Cancer by Age and Sex

| Age Group | Foregone Earnings per Cancer $1975, r = 6% | Foregone Earnings per Cancer $1982, r = 6% |
|---|---|---|
| Males | | |
| 0-14 | 117720.00* | 188352.00** |
| 15-24 | 159551.00 | 255281.60 |
| 25-34 | 172638.00 | 276220.80 |
| 35-44 | 143847.00 | 230155.20 |
| 45-54 | 95982.00 | 152571.20 |
| 55-64 | 34690.00 | 55504.00 |
| 65-74 | 3740.00 | 5984.50 |
| 75+ | 373.00 | 596.80 |
| Females | | |
| 0-14 | 83372.00 | 133395.20 |
| 15-24 | 103735.00 | 165976.00 |
| 25-34 | 101095.00 | 161752.00 |
| 35-44 | 82148.00 | 131436.80 |
| 45-54 | 54208.00 | 86732.80 |
| 55-64 | 24334.00 | 38934.40 |
| 65-74 | 7095.00 | 11352.00 |
| 75+ | 1456.00 | 2329.60 |

*This figure refers to the estimate developed by Hartunian of earnings foregone by one male, aged 0-14, who got cancer in 1975. As explained in the text, the estimate is calculated based on expected years of survival, first year productivity following cancer onset, expected productivity in subsequent years, and expected income during those years.
**Costs converted to 1982$ using the Consumer Price Index.

### 4.1.3 Converting the HK Values to Adjusted WTP/HK Values

The estimated cost of foregone earnings from cancer for the representative group considered (male, aged 35-44) is $230,155 (1982$). The medical costs associated with the cancer are $19,016 (1982$). Two other adjustments must be made be convert these hk values to adjusted wtp/hk estimates: 1) the foregone earnings figure must be multiplied by a risk aversion factor to reflect assumed risk preferences; 2) the figure must be adjusted to reflect application of individuals' opportunity cost of investment as opposed to the social opportunity cost rate.

The risk aversion factor developed by Landefeld and Seskin (37) is based on risk premiums paid for life insurance. For a representative life insurance policy, premiums paid by households are approximately 1.6 times the value of claims. In other words, households are willing to pay a premium for potential losses associated with the death of an income-earning household member. Assuming that people would be at least as risk averse in choosing to pay for a program which would reduce the risk of death as they would be in insuring against losses from death, this premium is used to proxy risk aversion. In fact, paying for risk reduction protection, such as a PCB regulation, would actually keep an individual alive longer, which insurance would not do. Thus, the actual aversion factor for valuing

the risk reduction from PCB programs may be higher than the life insurance factor.

Since Hartunian, et. al. used a discount rate of 6% to reflect a social rate of time preference, their estimates of foregone earnings and medical costs need to be adjusted to reflect an individual's opportunity cost of investment. Landefeld and Seskin's estimate of this individual discount rate, based on the after-tax rate of return on individual investment adjusted for inflation, is 3%. However, to incorporate this 3% rate into equation 4.2 and the Hartunian, et. al. estimate of foregone earnings requires having their original data. Unfortunately, the raw data is not available in Hartunian, et. al.

The next best approach is to use an adjustment factor based on a sensitivity analyses done by Hartunian, et. al. However, their sensitivity analysis only compared the use of a 2% versus a 6% discount rate. They report that use of the 2% rate raised estimates of foregone earnings by 34% and medical costs by 11%. Thus, we adjust foregone earnings by a factor of 1.34 and medical costs by a factor of 1.11.

By using a 2% rather than a 3% rate we overestimate the present value of postmorbid earnings and medical costs. The magnitude of the effect is large because of the relatively low life expectancies for 35-44 year old males

with digestive system cancers (see footnote 1 above).  For

example, if the average male aged 35-44 years with a

digestive cancer survived approximately 7 years (see foot-

note 1 above), but would have survived 40 years otherwise,

foregone earnings would be mainly due to earnings lost

in years 8 through 40.  If that person would have earned

$1,000 per year in each of those years, the present value

of those foregone earnings would be $20,883 if a 2% rate

were used and $16,834 if a 3% rate were used.

However, it should be kept in mind that we have

underestimated foregone earnings because transfer payments

are not included in the earnings data and survival rates

for liver cancer (i.e., 0.5 years) are lower than other

types of digestive system cancers.  Continuing the example

above, if years 1 through 7 were added to the foregone

earnings, the present value would be increased by over

$6,000 using either a 2% or a 3% discount rate.  This amount

is greater than the amount of increase in the present value

of foregone earnings caused by using the 2% rather than the

3% rate.  The net effect, then, is that the cost of liver

cancer is still underestimated for males aged 35-44 years

(see footnote 2 above).

The adjustments to the hk figures to obtain an

adjusted wtp/hk estimate are summarized in Table 4.4.  The

final figure of cost per cancer is $514,560.  This value is

Table 4.4   Adjusted WTP/HK Estimate of the Value of Saving
            One Life

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1.   Hartunian estimate of the earnings          $230,155
     foregone by a male, aged 35-44, who
     gets cancer, calculated at a 6%
     discount rate (1982$)

2.   Adjust figure upward to reflect               x 1.34
     use of individual's opportunity cost
     of investment (2%) vs the social
     opportunity cost of investment (6%);
     multiply by 1.34                            = 308,408

3.   Multiply by risk aversion factor              x 1.6
     of 1.6                                      = 493,452

4.   Adjust medical costs by 1.11                  19,016
     to reflect individual's vs social            x 1.11
     opportunity cost of investment        + =     21,108
     and add

                                                  514,560


                              LOW ESTIMATE = $514,560

multiplied by the number of new cancers from PCBs under
various tolernace levels to obtain total costs from PCB
related cancers. The lower bound estimates for males
aged 35-44 years are shown in Table 4.5. It should be
kept in mind that the only reason for choosing this demo-
graphic category is to make the adjusted wtp/hk estimate
comparable to the other wtp estimates. In fact, cancer
incidence is greater among older age categories whose
earnings, including transfer payments, are lower.

## 4.2  Middle Estimate:  Thaler and Rosen, Labor Market Survey

The second set of data used to estimate the benefits
of PCB regulations is taken from a well known labor market
study by Thaler and Rosen (65). Thaler and Rosen estimated
the influences of numerous variables, including risk, on
occupational wage differentials. They applied data on 900
male workers in 37 risky occupations from the Survey of
Economic Opportunity to identify the industry and occupation
of a sample of workers, along with their earnings and other
job characteristics. Data provided by an insurance industry
organization was used to measure the occupational risk
associated with each industry/occupation category. Occupa-
tional risk was measured by excess mortality from all causes.
Other variables were used to control for the influence of
age, education, race, geographic location on wage rates

Table 4.5  Cost of PCB-Related Cancers Adjusted WTP/HK

|             | No Tolerance | 5 PPM      | 2 PPM      | 1 PPM      |
|-------------|--------------|------------|------------|------------|
| Low Risk    | 3,190,272    | 2,984,448  | 1,955,328  | 1,234,944  |
| Medium Risk | 8,387,328    | 7,564,032  | 5,145,600  | 3,447,552  |
| High Risk   | 26,036,736   | 24,081,408 | 12,503,808 | 10,805, 760 |

within the sample. Regressions were run in both linear and
semilog linear form. There was no statistical basis for
choosing one functional form as superior to the other (65).
Because of the numerous formulations of the Thaler and
Rosen estimating equation, it is only discussed in general
terms here.

Thaler and Rosen estimated each functional form in
two alternative specifications with different sets of
socioeconomic control variables. The linear functional form
dictated a constant marginal wtp for all members of the
sample. When this estimate was applied to calculate the
aggregate value of a statistical life, the results were
$176,000 and $160,000 (1967$) for two alternative specifi-
cations. When the semilog form was used, the marginal wtp
varied across the sample. Marginal wtp was evaluated at the
mean, resulting in aggregate values of a statistical life
of $136,999, or $189,000 for the two specifications. Thaler
and Rosen concluded that their best estimate of a statistical
life is $200,000 plus or minus $60,000. The value of
260,000 is used here in order to develop a conservative,
middle range estimate.

Based on work by Bailey (2), several adjustments
are made to the Thaler and Rosen estimate. First, it is
noted by Bailey, that workers in risky jobs, such as those
studied by Thaler and Rosen, have lower wages than other

workers despite compensation for risk. Their lower income therefore produces a lower wtp estimate than we would expect for workers in higher paying jobs. Assuming that higher paid workers are no more risk averse than workers in risky jobs, but have a greater wtp because their income is higher, the income difference can be incorporated into the Thaler and Rosen wtp estimate by multiplying it by the ratio of national income per worker to the Thaler-Rosen earnings figure per worker.[3] In 1967, the national income per worker was $8,089; the Thaler and Rosen figure was $6,600. The Thaler-Rosen figure is adjusted upward by multiplying by 1.23 (8089/6600 = 1.23).

A second adjustment suggested by Bailey is to consider the third party effect of the loss of indirect business taxes as a result of workplace mortality. The reasoning is that the sum of all household incomes is national income; the sum of all final products, net of depreciation of capital, valued at market prices is net national product. Net national product exceeds national income by the amount of indirect business taxes - sales

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[3]In fact, more highly paid workers may be more risk averse than workers who chose risky jobs, but additional research is needed to determine this.

and excise, primarily. The value of the loss of a worker's contribution to output includes these indirect taxes as well as the loss of his income. Because society loses . the worker's labor earnings but not the income from other sources, the adjustment should be based on labor income only, not on national income per worker.

Bailey develops a figure to use to adjust for the loss of indirect business taxes in the following manner. In 1972-74 indirect business taxes added an average of 11.5% to the value of the product. The ratio of national product to national income, on the average, was .1115. Labor income was about 80% of total national income. Hence the indirect business taxes on labor income added 0.8 times 0.1115 to the total value of the product or approximately 9% (2, p. 62). Thaler and Rosen's estimate of the value of risk reductions is adjusted to account for the third party effect of lost indirect business taxes by multiplying by 1.09.

A final adjustment is to add the third party effect of medical costs associated with risk assuming that they are not borne by the family of the victim. The medical costs of liver cancer, as calculated by Hartunian and cited earlier in this chapter, are used for this adjustment.

The Thaler and Rosen estimate of the value of saving one statistical life and the adjustments to the figure are shown in Table 4.6. The final figure of $925,329/life saved is used as the conservative middle range estimate. Note that if we had used the $200,000 Thaler and Rosen estimate the value of a life saved would be $716,180, or $209,149 less. If their lower bound estimate was used, the value of a life saved would be $507,031, or $418,298 less, which is close to the estimate produced by the adjusted wtp/hk method. Given that the estimate is for middle aged males and that cancer incidence is higher among older age groups, the use of the top end of the wtp range produced by Thaler and Rosen results in a very conservative estimate.

Estimates of PCB-related cancer costs are obtained by multiplying the modified Thaler and Rosen estimate by the number of new cancers from PCBs under various risk and tolerance assumptions. Table 4.7 shows these cost figures.

4.3  High Estimate:  Smith, Labor Market Survey

The data used to generate a high estimate of the value of saving a statistical life is from a labor market survey by Robert Smith (62). Like the Thaler and Rosen study, the Smith research is often cited in reviews of the

Table 4.6   Adjusted Thaler and Rosen Estimate of the Value
            of Saving One Life

| | | |
|---|---|---|
| 1. | High estimate of the wage differential associated with the riskiness of a job (Range: $140,000 - $260,000) | $260,000 |
| 2. | To reflect average worker income in 1967 (vs income of risky job workers): multiply by 1.23 | x 1.23 |
| 3. | Adjust for indirect business tax losses: multiply by 1.09 (third party effect) | x 1.09 |
| 4. | Convert to 1982 dollars | x 2.6 |
| 5. | Add medical costs (third party effect) | + 19,016 |
| | MEDIUM ESTIMATE = | $925,329 |

Table 4.7  Cost of PCB-Related Cancers Medium Estimate - Thaler and
          Rosen

|             | No Tolerance | 5 PPM | 2 PPM | 1 PPM |
|-------------|--------------|-------|-------|-------|
| Low Risk    | 5,737,039    | 5,366,908  | 3,516,250  | 2,220,789  |
| Medium Risk | 15,082,863   | 13,602,336 | 9,253,290  | 6,199,704  |
| High Risk   | 46,821,647   | 43,305,397 | 31,738,785 | 19,431,909 |

value of life literature. It is usually used as a high estimate.

Smith's study relies on the assumption that, in the absence of full ex post compensation for injuries, workers would obtain ex ante compensation in the form of wage premiums that would be sufficient to cover the losses imposed on them by injuries. An estimating equation is developed where an individual's wage is regressed against the probability of his sustaining an injury resulting in death. Independent variables included as determinants of wage are education, union membership, experience, class of worker, occupation, demographic characteristics, geographical dummies, migration variables, and industry dummies. Owing to the lack of data on occupational disease (the type of occupational risk most relevant to this study), only job safety risks were considered.

Smith's equation is as follows:

$$\text{Ln } W_{ij} = r^A P_{ij} B_{ij} + \text{Ln} W^n (H_j, Z_j) \qquad 4.3$$

where:

$W_{ij}$ = gross (observed) wage of the ith worker in the jth class of worker (class = type of industry)[4]

$W^n$ = net wage stated as a function of human capital (H) and other variables (Z)

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[4] Data on $W_{ij}$ and determinants of $W^n$ were obtained for 3,183 white males from May 1967 Current Population Survey.

$P_{ij}$ = probability of injury resulting in death
during any hour of work[5]

$B_{ij}$ = hourly injury rate

$rA$ = loss in wages associated with death

$Z$ = other independent variables including
education, experience, union membership,
class of worker, occupation, demographic
characteristics, geographical dummies,
migration dummies, and industry dummies.

Using equation 4.3 Smith calculated that workers would be willing to sustain a 64% cut in wage to reduce the hourly chances of death by one in one million. At $4.00 per hour (1967 wages) this implies that 1,000,000 workers would be willing to pay $2.56 each or $2,560,000 in total, to avoid the loss of one life. Thus, according to Smith's study, workers act as if the value of saving one life is around $2.6 million (1967$). Clearly, this figure is exceedingly high. If you make $4.00 an hour and give up $2.56 to avoid the loss of one statistical life, you would probably be giving up food necessary to stay alive.

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[5] Obtained by Smith by SIC code from U.S. Department of Labor, Bureau of Labor Statistics, Injury Rates by Industry, 1966 and 1967, Report No. 360, 1969. Smith originally calculated values of reducing injuries that did not result in death. The value of such reductions was not found to be significant.

Smith noted that the $2.6 million figure was several orders of magnitude greater than values calculated in other labor market studies. To check his numbers, he recalculated the equation under slightly different assumptions. The major change was to include only employees in the manufacturing industries versus all industries to eliminate as much as possible variation in job disability or union strength correlated with job safety. Such biases might exist if "strong union" industries such as coal mining or construction workers were included. With this revision, the total amount workers were willing to pay to save one statistical life was $1.5 million dollars (1973$). This estimate is still very high.

Several adjustments can be made to the Smith figure to reflect social costs not included in the estimate. The first adjustment is for the third party effect of the loss of indirect business taxes and involves adjusting Smith's value upward by multiplying by 1.09 (as discussed in section 4.2). The second adjustment, also for third party effects, involves the addition of medical costs. The adjustments are shown in Table 4.8. The final, high bound value of saving one statistical life is $3,125,516 when converted into 1982 dollars.

Table 4.8   Adjusted Smith Estimate of the Value of Saving
            One Statistical Life

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1.  Estimate of the wage differential       $1,500,000
    associated with the riskiness of
    a job

2.  Adjust for indirect business tax          x 1.09
    losses (third party effect):  multiply
    by 1.09

3.  Convert to 1982 dollars                    x 1.9

4.  Add medical costs (third party            19,016
    effect)

                                    HIGH ESTIMATE = $3,125,516

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To obtain estimates of PCB-related cancer costs, the Smith value is multiplied by the number of new cancers from PCBs under various risk estimates (note again that this calculation assumes that one cancer equals one death). The final high estimates of the value of PCB tolerances in fish are shown in Table 4.9.

### 4.4    Summary - Range of Estimates of PCB-Related Cancer Costs

Based on these three studies a range of the value of saving one statistical life is constructed. The low value, based on an adjusted wtp/hk approach is about $514,560. The middle level, based on Thaler and Rosen's labor market analysis, is $925,329 and the high value, based on a labor market study by Smith, is approximately $3,125,516 per life saved. The range is shown in Table 4.10.

The range of estimates of the maximum cancer costs from PCBs in fish (i.e., under a no tolerance situation), obtained using the three valuation studies and three risk assumptions, is shown in Table 4.11. The values seem to be slightly more sensitive to the level of risk assumed versus the benefit value applied. Changing the risk estimate applied, from low to high, causes the cost estimates to increase approximately seven to eightfold.

Table 4.9   Cost of PCB-Related Cancers, High Estimate - Smith

|             | No Tolerance | 5 PPM | 2 PPM | 1 PPM |
|-------------|-------------|-------------|-------------|-------------|
| Low Risk    | 19,378,199  | 18,127,993  | 11,876,961  | 7,501,238  |
| Medium Risk | 50,945,911  | 45,945,085  | 31,255,160  | 20,940,957 |
| High Risk   | 158,151,110 | 146,274,150 | 107,205,200 | 65,635,836 |

Table 4.10  Range of Values for Saving One Statistical Life

| Low | Medium | High |
|-----|--------|------|
| $514,560 | $925,329 | $3,125,516 |

Table 4.11  Cost of PCB-Related Cancers - No Tolerance*

|  | Adjusted WTP/HK | Thaler & Rosen | Smith |
|--|-----------------|----------------|-------|
| Low Risk | 3,190,272 | 5,737,039 | 19,378,199 |
| Medium Risk | 8,387,328 | 15,028,863 | 50,945,911 |
| High Risk | 26,036,736 | 46,821,647 | 158,151,110 |

*These figures represent the range of maximum estimated costs of PCB-related cancers.  The benefits of the PCB tolerance levels will be determined in terms of how much each tolerance reduces costs relative to the no tolerance situation.

Changing the estimate of the value of a statistical life from low to high, on the other hand, causes the estimates to increase approximately sixfold. However, it should be kept in mind that the benefit estimates themselves are sensitive to assumptions employed in developing them. For example, all the estimates are based on middle aged males. Because cancer incidence is greater among older people, all the estimates are higher than would be true if all demographic groups were considered.

Looking at the data more closely, it can be seen that the cost of not regulating PCBs in fish at all, based on a low level of risk, ranges from $3,190,272 using the adjusted wtp/hk approach to $19,378,000, using the Smith's labor market estimate. If the high level estimate of risk is used, total cost estimates range from $26,036,736 (adjusted wtp/hk estimate) to $159,151,110 (Smith's estimate).

### 4.5  Narrowing the Range of Estimates and Developing a "Best Point" Estimate

At this point in benefit-cost studies, it is customary to provide a sensitivity analyses of the various parameters incorporated into estimates. While this is necessary in analysis, our major concern is comparing the alternative methods used to produce the estimates.

The range of maximum costs of the PCB-related cancers (from $3,190,272 to $158, 151,110) is too great to provide much meaningful policy information to decision-makers. The sources of variation between the estimates of cost per life saved need be clarified to see if it might be possible to narrow the range of estimates somewhat, and to illustrate the problems we have in developing an estimate of the cost of PCB-related cancers. This process is illustrated by trying to find "best point" estimate within the range.

Looking first at the lower bound estimates, the reasons for it being so much lower than the middle and high estimates are obvious. The estimate is based on the assumption that an individual's wtp to reduce risk can be derived from foregone income if an individual rate of return on investment is used to discount foregone earnings and risk aversion is accounted for. However, the foregone earnings estimates used here excluded transfer payments and the only non-labor income included is the market value of in-home services. This downward bias is not off-set by the fact that pre-tax earnings are used. The foregone earnings are further underestimated by using estimates for patients with digestive system cancers. Patients with liver cancer have a much lower life expectancy (i.e., 0.5 years). Another source of error is the risk aversion factor. One might expect risk aversion to be greater for

investments which reduce the risk of death and illness than for those which protect against income losses from death. These downward biases in the estimate are not off-set by the use of the lower discount rate reflecting an individual rate of return on after-tax income for invest-ment. With further research these sources of bias could be eliminated, but must be considered here.

The estimate based on Thaler and Rosen's work is a measure of wtp to avoid a statistical death. Given that life expectancy of liver cancer patients is low, a wtp measure based on loss of life would not appear to cause much upward bias in the estimate. In fact, faced with the choice of sudden death versus a slower and painful death, the former may be preferred. However, the question remains as to what figure to use in the range of $140,000 to $260,000 they report.

Using the low end of the range produces an estimate which is somewhat less than that obtained by the adjusted wtp/hk method. Therefore, it may be too low given that the adjusted wtp/hk estimate is based on income loss only.

Using the middle value in the Thaler and Rosen range produces a higher estimate than the adjusted wtp/hk estimate. However, it should be noted that the major reason why it is higher is that the original Thaler and Rosen estimate was adjusted (by 1.23) to reflect income

differences between the general working population and the population studied by Thaler and Rosen. Had this not been done, use of the middle range value and making the other adjustments described in Section 4.2 would produce an estimate not much higher than the (low) adjusted wtp/hk estimate (i.e., $585,816 or approximately $80,000 greater). The question then becomes whether the income adjustment factor is sufficient for producing a more reliable estimate. As pointed out earlier, use of an income based factor implies that other workers are not more risk averse than workers in the risky jobs studied by Thaler and Rosen. This assumption is doubtful. Therefore, a wtp estimate based on the middle value of the Thaler and Rosen range may be an underestimate.

Using the higher end of the range (i.e., $260,000) may not make up for this. Thaler and Rosen stated a range based on possible errors in their estimates. Furthermore, the much higher wtp estimate produced by Smith throws doubt on the validity of the Thaler and Rosen estimates. Simply using the higher end of the range and adjusting for income may still produce an underestimate because Thaler and Rosen only examined workers in high risk industries. The Smith estimate may be higher because it captures differences in risk averseness as well as income among occupational groups.

On the other hand, the Smith study used occupations as a control variable in the analysis. This approach may have made it difficult to distinguish between the part of the wage that was due to risk and that due to other characteristics of the job, possibly resulting in some upward bias in the estimate. Another comment about the Smith study is that Smith originally sampled all industries and then later redid the study focusing solely on manufacturing industries. All other methods and assumptions were kept the same in the two analyses yet a difference in the value of risk reduction of over $1 million was observed. While some of the variation could be attributable to the difference in the two groups studied, another possibility is that the use of aggregated occupational data led to error. The underlying idea is that with job risks reported only for industry averages, the wage differentials could be smaller and, because they were averages, could mask actual variation among occupational categories (again, making it difficult to discern that part of high wages due to risk versus other job characteristics).

It is worth noting how other researchers' estimates of the value of life compare with the Thaler and Rosen and Smith estimates. Two analyses of the labor market report estimates fairly close to the Smith figures. Viscusi (72) found an average (unadjusted) value of life of $2.5 million

(1979$). Olson (52) found a value of life about $3.2 million (1979$). Another labor market study by Dillingham (13), on the other hand, reported a value of life saving of approximately $458,000 [1978$, as adjusted by Bailey (2)]. Blomquist (4) in a study of seatbelt use reported a value of $715,000 (1978$, as adjusted by Bailey for third party effects).

Given this evidence from other studies supporting both the Smith and the Thaler and Rosen estimates, it is not possible to definitively identify one value as more valid than the other. However, for the purposes of assessing the PCB regulations it would be useful to include a point estimate reflecting the limitations of these two studies in a range based on all the estimates. Based on the criticisms of the two studies presented earlier, the midpoint value between the Thaler and Rosen and the Smith estimate would be a reasonable best point estimate. The Thaler and Rosen value is possibly a low estimate because it is based only on workers who self-selected risky occupations. The Smith estimate, on the other hand, may be biased upwards because of the aggregated data used and the difficulties in separating out the component of wage attributable to risk versus other job characteristics. The midpoint value between the Thaler and Rosen and the Smith estimates represents a compromise between the two points.

The best point estimates, calculated for various tolerances and risk estimates, will be referred to throughout the discussion of the PCB benefit calculations. The values are shown in Table 4.12.

## 4.6  Calculation of Benefits

The values presented in Table 4.12 are estimates of the maximum costs of PCB-related cancers expected if there were no tolerance regulation on PCBs in fish. With this information the benefits of alternative PCB tolerance levels can be calculated. As discussed earlier, benefits are defined as the savings in health costs achieved under each regulatory option. Thus, the benefit stemming from a given tolerance level is the difference between the health costs incurred at the tolerance level and the health costs of a no tolerance situation. For example, to find the benefit (i.e., cost savings) of a 5 ppm tolerance, using the adjusted wtp/hk method and a low risk assumption, the cost of cancers at the 5 ppm tolerance is subtracted from the cost of no tolerance: $3,190,272 - $2,984,448 = $205,824. Table 4.13 a, b, c presents estimates of the benefits of each tolerance level, using the three valuation methods and risk assumptions.

Table 4.12 Best Point Estimates - Costs of PCB-Related Cancers

| Risk Level | No Tolerance | 5 PPM | 2 PPM | 1 PPM |
|------------|--------------|-------|-------|-------|
| Low | 12,557,619 | 11,747,451 | 7,696,606 | 4,861,013 |
| Medium | 33,014,387 | 29,773,711 | 20,254,225 | 13,570,331 |
| High | 102,486,379 | 99,789,771 | 69,471,992 | 42,533,873 |

Table 4.13  Calculation of Benefits - Cost Savings

|  | No Tolerance | 5 PPM | 2 PPM | 1 PPM |
|---|---|---|---|---|
| **a) Adjusted wtp/hk** | | | | |
| Risk Level | | | | |
| LOW | 3,190,272 | $2,984,448 | $1,955,328 | $1,234,944 |
| C.S.* | | (205,824) | (1,234,944) | (1,955,328) |
| MEDIUM | 8,387,328 | 7,564,032 | 5,145,600 | 3,447,552 |
| C.S. | | (823,296) | (3,241,728) | (4,939,776) |
| HIGH | 26,036,736 | 24,081,408 | 12,503,808 | 10,805,760 |
| C.S. | | (1,955,328) | (13,532,928) | (15,230,976) |
| **b) Thaler and Rosen** | | | | |
| Risk Level | | | | |
| LOW | 5,737,039 | 5,366,908 | 3,516,250 | 2,220,789 |
| C.S. | | (370,131) | (2,220,789) | (3,516,250) |
| MEDIUM | 15,082,863 | 13,602,336 | 9,253,290 | 6,199,704 |
| C.S. | | (1,480,527) | (5,829,573) | (8,883,159) |
| HIGH | 46,821,647 | 43,305,397 | 31,738,785 | 19,431,909 |
| C.S. | | (3,516,250) | (15,082,862) | (27,389,738) |
| **c) Smith** | | | | |
| Risk Level | | | | |
| LOW | 19,378,199 | 18,127,993 | 11,876,961 | 7,501,238 |
| C.S. | | (1,250,206) | (7,501,238) | (11,876,861) |
| MEDIUM | 50,945,911 | 45,945,085 | 31,255,160 | 20,940,957 |
| C.S. | | (5,000,826) | (19,690,751) | (30,004,954) |
| HIGH | 158,151,110 | 146,274,150 | 107,205,200 | 65,635,836 |
| C.S. | | (11,876,960) | (50,945,910) | (92,515,274) |
| **d) Best Point** | | | | |
| Risk Level | | | | |
| LOW | 12,557,619 | 11,747,451 | 7,696,606 | 4,861,013 |
| C.S. | | (810,168) | (4,861,013) | (7,696,606) |
| MEDIUM | 33,014,387 | 29,773,711 | 20,254,225 | 13,570,331 |
| C.S. | | (3,240,676) | (12,760,162) | (19,444,056) |
| HIGH | 102,486,379 | 99,789,771 | 69,471,992 | 42,533,873 |
| C.S. | | (3,240,676 | (33,014,388) | (59,952,507) |

*C.S. = Cost Savings

### 4.7 Calculation of Net Benefits

Given the benefit estimates, the question becomes how can the information facilitate the policy-making process. One approach to answering the question is examine the net benefits associated with each tolerance. In order to consider net benefits, cost data is now introduced.

Cost data on the economic impact of the tolerances is available from studies by the FDA (19). The FDA estimates are based on the premise that if a certain percentage of fish species in a given area is violative, then a valid estimate of the economic loss would be to assume that the same percentage of the total catch would be condemned. It is acknowledged that this approach could lead to some over and underestimation of costs. For example, it would be unlikely that a fisherman would risk catching and selling any fish if 30% were expected to be inspected and found violative. In such cases, he would perhaps stop fishing, so that there would actually be a 100% loss. This underestimation would, however, be balanced by cases where a smaller percentage of fish were violative but were not inspected or condemned.

Using this approach, the FDA calculated that
approximately 2% of total catch of freshwater fish would
be condemned under a 5 ppm tolerance.[6] Under the 2 ppm
tolerance, approximately 14% of the total catch would be
lost and about 35% would be lost under a 1 ppm tolerance.
Based on these figures, the landed value of the condemned
fish was calculated.[7] These costs, adjusted for inflation,
are shown in Table 4.14. Note that the FDA made no
adjustments for indirect costs such as potential unemploy-
ment or loss of income in the fishing and fish processing
industry. These costs were considered secondary, and not
relevant for use in comparisons with the primary (quantified)
benefit of risk reduction. It is also important to point
out that the fishing industry would likely act to minimize
losses from a PCB tolerance level by shifting resources to
a different type of fish, or perhaps fishing in an area where
PCB contaminated fish were not common. The cost of the
tolerance levels might thus drop the year following the
initiation of the regulation.

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[6]Freshwater fish are the most highly contaminated with
PCBs. Very few marine species have detectable levels of
PCBs though some loss of shellfish is included in the cost
estimates.

[7]These "official" estimates are explained and then
critized for being too high by Talhelm in Kamrin and D'Itri
(11).

Table 4.14 Cost of PCB Tolerances in Fish

| | No Tolerance | 5 PPM | 2 PPM | 1 PPM |
|---|---|---|---|---|
| One Year Cost*<br>(1982$) | -- | $ 790,000 | $ 7,520,000 | $21,120,000 |

*Landed value of commercial fish condemned because of PCB
contamination over tolerance level.

To calculate net benefits, the estimated costs of condemned fish under each tolerance level are subtracted from estimated benefits (costs saved). The results are presented in Table 4.15 a, b, c and d which shows net benefits using low, medium and high risk estimates and the adjusted wtp/hk, medium, high and best point estimates of benefits respectively.

The results are not uniform. Rather, the tolerance level that offers the greatest net benefit (or lowest net cost) seems to vary depending on which benefit value and risk estimate is applied. When the adjusted wtp/hk and the Thaler and Rosen values are applied to the low risk estimate, the greatest net benefits (equal to zero) would occur if there were no tolerance at all. When the medium risk estimate is used, the 5 ppm tolerance offers the greatest net benefits. When the high risk estimate is used, greatest net benefits occur at 2 ppm tolerance. When the high bound value (the Smith estimate) or the best point estimates are applied, the 5 ppm tolerance provides maximum benefits based on the low risk estimate, the 2 ppm tolerance provides maximum benefits based on the medium risk estimate, and the 1 ppm tolerance provides maximum benefits based on the high risk estimate.

From an overall perspective, the 5 ppm tolerance produces maximum net benefits (or minimum cost) no

Table 4.15 Net Benefits (Cost Saved - Cost of Fish Condemned)
by Tolerance Level

|  | 5 PPM | Tolerance Level 2 PPM | 1 PPM |
|---|---|---|---|
| a) Adjusted wtp/hk |  |  |  |
| LOW | * -$584,176 | -6,285,056 | -19,164,672 |
| MEDIUM | * 33,396 | -4,278,272 | -16,180,224 |
| HIGH | 1,165,328 | * 6,012,928 | -5,889,024 |
| b) Thaler and Rosen |  |  |  |
| LOW | * - 419,869 | -5,299,211 | -17,603,750 |
| MEDIUM | * 690,527 | -1,690,427 | -12,236,841 |
| HIGH | 2,726,250 | * 7,562,862 | 6,269,738 |
| c) Smith |  |  |  |
| LOW | *18,588,199 | - 18,762 | -9,243,039 |
| MEDIUM | 4,210,826 | *12,180,751 | 8,884,954 |
| HIGH | 11,086,960 | 43,425,910 | *71,395,274 |
| d) Best Point |  |  |  |
| LOW | * 20,168 | -2,658,987 | -13,423,394 |
| MEDIUM | 2,450,676 | * 5,240,162 | -1,675,944 |
| HIGH | 1,906,609 | 25,494,388 | *38,832,507 |

*Indicates the maximum net benefit (or minimum net cost) of a tolerance
level for a given risk level and method of calculation. For example,
net benefits are highest at the 1 ppm level for the high risk level
of the best point estimate ($38,832,507).

matter which benefit value is considered if a low risk
estimate is used. Two of these cases are negative, in-
dicating the tolerance should be higher than 5 ppm. If
a medium or a high risk estimate is used, choice of
tolerance depends on which benefit assessment method
is used.

Looking at the best point estimates, the selection
of the most appropriate tolerance level in terms of
maximum dollar benefits varies depending on the level of
risk assumed. The difference in net benefits between
the 5 ppm and the 2 ppm tolerance levels for the low and
medium risk levels is relatively small - about $2.5 million.
However, the difference between the 2 ppm and 5 ppm
tolerance levels based on a high assumption of risk is
quite large -- the 1 ppm tolerance provides about $13 million
more benefits than the 2 ppm tolerance. The final selection
of tolerance thus appears to depend on the level of risk
assumed. However, a 2 ppm tolerance is probably most
appropriate if a high level of risk is assumed given that
all the cost savings estimates are based on middle-aged
males, whereas cancer incidence is greatest among older
segments of the population.

4.8   Cost Per Cancer Prevented Estimates

The final approach considered to assess the benefits
of PCB regulations in fish is cost-effective analysis.
This is a straightforward method in which the estimated
net cost and the reduced human risk at each of the pro-
posed tolerance levels are estimated and compared.
Specifically, the net change in cost from moving from
one tolerance to the next is divided by the net change in
number of new cancers to obtain a "cost per cancer avoided"
figure.

The cost data used to generate the cost per cancer
estimates are the same as the cost data used in the last
section.  The data are shown in Table 4.16, along with the
estimated marginal changes in costs of moving from one
tolerance to the next.  Given these marginal cost figures,
the cost per cancer prevented is calculated.

Results are shown in Table 4.17.  The lowest cost
is $210,000 per cancer prevented from changing from a no
tolerance situation, to a 5 ppm tolerance, assuming a high
risk level.  The highest cost figure is almost $10,000,000
per cancer prevented when moving from a 2 ppm to a 1 ppm
tolerance, assuming a low risk situation.

Table 4.16   Direct Cost of Commercial Fish in Violation of PCB
Tolerances

| Tolerance | One Year Cost (1974$) of Commercial Fish (Landed Value) | % ΔCPI 1974 - 1982 | One Year Costs 1982$ | Increase in Costs |
|---|---|---|---|---|
| No tolerance | | | | |
| 5 PPM | 0.6 million | 1.32 | .79 million | .79 |
| 2 PPM | 5.7 million | 1.32 | 7.52 million | 6.73 |
| 1 PPM | 16.0 million | 1.32 | 21.12 million | 13.6 |

Table 4.17   Cost Per Cancer Prevented

| | NUMBER OF NEW CANCERS Prevented* | | | | COST PER CANCER Prevented** | | | |
|---|---|---|---|---|---|---|---|---|
| Risk Level | No Tolerance | 5 PPM | 2 PPM | 1 PPM | No Tolerance | 5 PPM | 2 PPM | 1 PPM |
| High | | 3.8 | 12.5 | 3.3 | | 210,000 | 540,000 | 1,000,000 |
| Medium | | 1.6 | 4.7 | 3.3 | | 490,000 | 1,400,000 | 4,000,000 |
| Low | | .4 | 2 | 1.4 | | 2,000,000 | 3.400,000 | 9,700,000 |

 *Change in number of new cancers prevented moving from a given tolerance to the next.
**Change in costs (value of fish condemned) moving from one tolerance to the next.

To see how the cost per cancer values compare to the estimated value of a statistical life used in this report, it is necessary to refer back to the benefit data before it is coupled with the PCB risk data. As discussed earlier, the benefits of preventing one cancer range from approximately $514,560 to $3,125,516. As can be seen in Table 4.16, the cost per cancer prevented at almost all of the tolerance levels, falls under the highest estimate of benefit per cancer averted of $3,125,516. However, if the low level of risk is used, the cost per cancer at the 2 ppm and 1 ppm tolerance, exceeds the maximum benefit value of preventing one cancer.

## 4.9 Summary

The results of the risk assessment/benefit analysis vary depending on the level of risk assumed, and on the method used to quantify the value of risk reduction. Benefit values vary as much as eightfold through use of alternative risk estimates. Values vary up to sixfold through application of alternative approaches to benefit quantification. By comparison, use of alternative discount rates or detailed demographic data has less effect on benefit values.

The value of preventing one cancer applied in this study ranges from $514,928 (the adjusted wtp/hk estimate)

to $3,125,516 (the wtp estimate developed by Smith).
Estimates of total benefits (costs-saved) if all PCBs
could be eliminated (i.e., if all cancers predicted under
a no tolerance situation could be prevented) range from
$3,190,272, based on a low estimate of risk and the
adjusted wtp/hk benefit values, to approximately $158,151,110
based on a high estimate of risk and the Smith wtp values.
The best "point" estimates of the benefits of such
"100% effective" PCB regulation range from $12,557,619
under low risk assumptions, to $102,486,379 under high
risk assumptions.

Conclusions reached from analyzing net benefit data
are sensitive to both type of valuation method used and to
level of risk. Based on the adjusted wtp/hk and the Thaler
and Rosen estimates, net benefits of a 5 ppm tolerance are
negative when the low risk estimate is used, but are
maximized at the 5 ppm tolerance when the medium risk
estimate is used. The 2 ppm tolerance produces maximum
net benefits when a high risk estimate is used. If the
Smith or the best point estimates are applied however, the
5 ppm tolerances leads to maximum benefits based on a low
risk estimate, the 2 ppm tolerance provides maximum benefits
based on the medium risk estimate and the 1 ppm tolerance
provides maximum net benefits based on the high risk

estimates. Thus which tolerance level should be selected based on the benefit measured clearly depends on the level of risk assumed. However, it appears that overall the 2 ppm tolerance is the most appropriate tolerance assuming low or medium risk levels and the 1 ppm tolerance best based on a high risk estimate, according to the best point approach.

If the cost per cancer prevented is compared with the estimated benefit per cancer prevented, using the medium and high risk estimates, the costs are less than the maximum benefit estimate for all tolerances except for the 1 ppm tolerance with the medium risk estimate. If the low risk estimate is applied, costs per cancer exceed benefits per cancer avoided.

CHAPTER 5

CONCLUSIONS

A number of theoretical and methodological consid-
erations must be taken into account in evaluating the
benefit estimates developed in this study.  These
considerations have implications for the use of existing
wtp estimates in developing information for decision makers.
Research needs are also apparent.

5.1  Sensitivity of Results to Benefit Valuation Method

The three wtp approaches used in this study were
selected to reflect the range in estimates of the value
of risk reductions.  Each estimate is based on data for
middle aged males.  Thus, the estimates are comparable, but
biased since cancer incidence is not confined to this group.

The estimates of the cost of health damage from PCBs
in fish vary up to sixfold.  Using the adjusted wtp/hk
approach the value of preventing one cancer is about
$514,560.  The Thaler and Rosen wtp work (after adjustments
to correct for the lower income of the study group and to
include third party effects) led to an estimate of $925,329
for preventing one statistical death.  The wtp work by Smith

(adjusted to include third party effects) led to an estimate of $3,125,516 for preventing one statistical death.

The adjusted wtp/hk values produce the lowest estimates of PCB related cancer costs. The major reason why is that it is an estimate of how individuals value reductions in the risk of losing future income, not how they value reductions in the risk of pain, suffering, and loss of life. The item at risk in this method is future earnings. Risk aversion is proxied by life insurance purchasing behavior. Time preference is proxied by after-tax return on financial investments. Clearly, reducing the risk of cancer yields more than protected income. Thus, while the method produces a willingness to pay estimate, only the financial implications of reducing the risk of cancer are captured. At best, the adjusted wtp/hk estimates represent the lower bound value of preventing one cancer case.

A second reason why the adjusted wtp/hk values are low estimates is that foregone earnings are underestimated. In order to take into account the fact that cancer does not mean immediate death, we used foregone earnings data for cancer patients developed by Hartunian, et. al. Since the data for liver cancer patients was grouped with the data for patients with digestive system cancers, the foregone earnings data is underestimated. Furthermore, the earnings data did

not include transfer payments and some forms of non-labor
income which should be included when this method is used.

The medium and high benefit estimates based on
labor market application of wtp theory attempt to measure
both tangible and intangible values of reducing the risk
of death, not cancer. The estimates used here are based
on actual risk vs. income choices made by workers.
Theoretically, all of the components of the value of
living are implicitly included in these wtp values.
Adjustments to the estimates allow for some third party
effects. However, the questionable assumption is made that
wtp for reductions in risk of death approximates wtp for
reduction in risk of cancer.

As pointed out in Chapter 4, the Thaler and Rosen
estimate is possibly too low an estimate of wtp because
they only considered workers in high risk industries.
Such workers may be less risk averse and, thus, less willing
to pay to reduce risk, than others who have chosen less
risky jobs. The Smith estimate allows for this but may be
biased upwards because of the aggregated data used and the
difficulties in separating the component of wage due to
risk and that due to other job characteristics. It is
possible that some of the variation in labor market wtp
estimates is a result of actual differences in wtp for
risk reductions. It is also possible that they reflect

differences in the actual type of risk involved. Variation is also undoubtedly due to statistical problems.

Finally, the labor market studies are based on voluntarily assumed risk. Risks posed by PCBs in fish cannot be considered voluntary because consumers cannot know whether the fish they eat contain PCBs. Whether willingness to pay to reduce involuntary risk is greater or smaller is unknown.

The calculation of a range of estimates expresses the uncertainty inherent in the process of valuing reductions in risks to health and life. This study has indicated that the endpoints of the range represent conservatively low and high risk value estimates. This implies that some value in between the endpoints of the range is more likely to reflect willingness to pay. The "best" point estimates derived here represent this, but they are only medians of the wtp estimates, not empirically grounded measures.

5.2 Sensitivity of Estimates to Risk

Estimates of the value of risk reduction varied approximately seven to eightfold as the risk assumption varied from low to high. For example, the best point estimates of the cost savings yielded by a 2 ppm tolerance varied from about $4,900,000 based on the low risk figures to about $33,000,000 based on the high risk figures. The

usefulness of benefit estimates thus depend on the selection of an "official" risk estimate by decision-makers.

It should be pointed out that the most crucial risk uncertainty in this study is whether or not PCBs are carcinogenic. This study has proceeded under the conservative assumption that they are carcinogenic, an assumption also accepted by the FDA. However, it is clear that PCBs pose risks other than that of cancer.

In actual decision-making situations where benefit assessment is employed, the most significant question is what type and level of risk to assume. From the perspective of the economist, an "official" risk estimate will not always be available. Economists will have to make their own judgements as to which risk assumption is most valid. Familiarity with the problems inherent in this judgement about risk is essential.

## 5.3  Net Benefit Estimates

The net benefits associated with each tolerance level were calculated to put the risk valuation data in a form useful for policy comparisons. It was found that if the low or medium benefit estimates were used, the 5 ppm tolerance offered the greatest net benefits (or minimum costs) for low and medium risk assumptions and the 2 ppm tolerance maximized benefits based on a high risk assumption.

Based on both the high and best point estimates, the tolerance level which offered the highest net benefits varied according to risk assumption. Overall it appeared that the 5 ppm tolerance would be the best conservative choice if the low risk assumption was used. The 2 ppm tolerance would be most appropriate based on a medium risk estimate. The 1 ppm tolerance yields maximum net benefits if the high risk estimate is used.

These results are interesting because the FDA used the high risk estimates in citing evidence for its choice of the 2 ppm tolerance in 1979. Thus, their valuation of benefits, which presumably included both reductions in cancer and other risks, is similar to that suggested by the adjusted wtp/hk estimate and the estimate based on work by Thaler and Rosen. The best point and high estimates in this study suggest that 1 ppm maximizes benefits if a high risk estimate is used. However, it should also be noted that the estimates used in this study are based on the valuation of middle aged males. Cancer incidence is greater in later life and, thus, the estimates may be too high.

5.4  The Usefulness of Benefit Quantification

A key question of this research is whether existing estimates of wtp for risk reductions provide information useful for analysis of regulation of PCBs in fish and more

generally, whether it is a useful tool for food safety
regulatory analysis.  We conclude that even if a given risk
level is assumed, the range of estimates is too wide to be
useful in analyzing alternative tolerances.  Even after
accounting for potential sources of bias in the wtp methods,
the range cannot be meaningfully narrowed.  Therefore,
further research is needed to produce more valid and
reliable measures of willingness to pay for risk reductions.
Better specified risk assessments are also needed.

One of the chief drawbacks of wtp estimates based on
labor market studies is the methodological problem of
separating out the component of wage due to risk and that
due to other components of the job.  The range in current
estimates suggest they are unreliable.  Furthermore, it is
unknown to what extent risks are correctly perceived by
workers and, thus, it is unknown whether risk aversion
differs among workers in different kinds of jobs.  Even
if this were known, it is not at all clear that involuntary
risks would produce the same response as voluntary risks.

Another problem with the labor market studies is
that they have focused on middle-aged males.  This is a
serious flaw if cancer incidence rates are greatest in
later life.  Ideally willingness to pay measures should
focus on the full range of age and sex categories.

Labor market and other willingness to pay studies have focused on the risk of death. Cancer is a disease which in many cases can be cured. To evaluate the benefits of programs which reduce cancer risk using wtp estimates based on the risk of death is unacceptable methodologically. Moreover, it takes attention away from the very real issue of which types of health risks we wish most to reduce. Whether willingness to pay to reduce different types of health risks could be accurately gauged by labor market or consumption studies is doubtful. Personal knowledge about the consequences of various types of cancer is likely to be very limited.

Unless and until further research produces more reliable and valid wtp estimates, adjusted wtp/hk measures may be of use to policy-makers if their operational meaning is fully understood. The adjusted wtp/hk method does not produce an inclusive measure of wtp to reduce the risk of cancer or death. Rather, it measures wtp to reduce the possible financial loss associated with the risk of cancer or death. In other words, use of such estimates would give policy-makers a lower bound measure of the tangible benefits of reducing health risks, but still require them to make a judgement about the amount of tangible benefits involved. Furthermore, because age and sex breakdowns could be

developed using this method, policy-makers could take distributional considerations into account.

Doing this, however, would involve a number of refinements not included in this study. These include refinements in measures of risk and measures of financial loss.

In this study, it was assumed that liver cancer was the major kind of cancer involved. Ideally, the risk assessment should specify the particular type of cancer (or other diseases) involved. Survival rates vary widely for different types of cancer. Thus, any evaluation of the benefits of regulation, whether put in dollars or not, should entail an assessment of the type of cancer involved and the associated survival probabilities. If the type or category of cancer cannot be specified, alternative assumptions should be employed in developing a range of adjusted wtp/hk estimates.

Second, in this study the costs of cancer were based on costs for middle aged males. However, if expected incidence by age and sex categories were known, more realistic cost estimates could be developed. Thus, risk assessments should not only specify the type of cancer involved, but its expected incidence by age and sex categories. If expected incidence can be assumed to be proportional to known incidence rates, these known rates

can be used (as illustrated in Chapter 4) to estimate expected incidence. However, the validity of this assumption would depend on food consumption (i.e., exposure) patterns and, thus, the assumption should be examined during the risk assessment process.

If the type of cancer and expected incidence by age and sex groups is known, the adjusted wtp/hk method can be used to estimate individual wtp to avoid financial losses associated with the cancer risk. However, refinements to the foregone earnings data would also be necessary. Transfer payments and non-labor income would have to be included. After-tax income would have to be derived from total earnings. Foregone earnings would have to be developed for the particular type of cancer involved rather than the category involved (e.g., digestive system cancers). Since foregone earnings estimates depend on assumptions about the number of years of survival after onset of cancer and the degree of impairment involved, possible errors in these survival and impairment rates should be explicitly examined. Hartunian, et. al. do report margins of error in their data and these should be incorporated in a sensitivity analysis.

Finally, refinements could be made in the risk aversion factor and discount rate used. Existing studies suggest that persons of different income classes, sex, and

age evaluate risks differently (61). Thus, different risk
aversion factors might be used for different sex and age
categories. After-tax rates of return on investment may
also be different and not properly proxied by an average
rate.

Ideally, benefit quantification would be just one
aspect of the regulatory evaluation process. The process
should begin with complete identification of likely
impacts of regulation. Each of the impacts should then be
described as fully as possible and expressed in some
physical unit (such as number of people affected, number of
new cancers, etc.). Ideally, health risks should be more
carefully specified in terms of the particular type of
disease involved and longevity expectations. The distri-
bution of expected health risks across age and sex categories
and geographical location should also be discussed. This
information could be prepared for several alternative designs
of a particular regulation and the alternative designs
compared. Then, in conjunction with the above analysis,
the value of the anticipated risk reduction could be
expressed in dollar terms, using wtp/hk estimates. The
adjusted wtp/hk estimates would provide an estimate of the
minimum cost to society, in terms of personal financial
loss, stemming from a health hazard such as PCBs. Decision-
makers would have to place their own judgement on intangible
benefits involved.

While it would be ideal to have inclusive wtp estimates unique to each regulatory decision, the cost of doing so is too large. Unless wtp estimates are developed which can be used in more than one public choice problem, it is fairly certain that economic assessments of benefits rarely will be used or trusted by decision-makers. Adjusted wtp/hk methods could be used relatively easily in developing lower bound estimates of willingness to pay in a variety of regulatory settings if risk assessments and foregone earnings data bases for cancer patients were improved.

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