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Estimation of the marginal values of water as an instream resource for recreational fishing: a national analysis

LeRoy Thomas Hansen

Iowa State University

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ESTIMATION OF MARGINAL VALUES OF WATER AS AN INSTREAM RESOURCE FOR RECREATIONAL FISHING: A NATIONAL ANALYSIS

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Estimation of the marginal values of water as an instream resource for recreational fishing: A national analysis

by

LeRoy Thomas Hansen

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of the Requirements for the Degree of DOCTOR OF PHILOSOPHY

Major: Economics

Approved:

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Iowa State University
Ames, Iowa

1986
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER I</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CHAPTER II</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conflicts In Water Use: Historical, Legal, and Social Factors</td>
<td>4</td>
</tr>
<tr>
<td>The problem of water allocation</td>
<td>4</td>
</tr>
<tr>
<td>Historical overview</td>
<td>8</td>
</tr>
<tr>
<td>Legal factors</td>
<td>13</td>
</tr>
<tr>
<td>The benefits of nonmarket water use</td>
<td>18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Streamflow and Fishing Quality</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>The focus of this study</td>
<td>22</td>
</tr>
</tbody>
</table>

| Summary | 22 |

<table>
<thead>
<tr>
<th>CHAPTER III</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modeling</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Types of models</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Selection</td>
<td>28</td>
</tr>
<tr>
<td>Household production model -- the theory and supportive literature</td>
<td>29</td>
</tr>
<tr>
<td>Summary of household production theory</td>
<td>49</td>
</tr>
</tbody>
</table>

| Household Production Theory and the Value of Streamflow | 50 |

<table>
<thead>
<tr>
<th>Theory application</th>
<th>51</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problems</td>
<td>52</td>
</tr>
<tr>
<td>An alternative</td>
<td>53</td>
</tr>
</tbody>
</table>

| Summary | 54 |

<table>
<thead>
<tr>
<th>CHAPTER IV</th>
<th>56</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available Data</td>
<td>56</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data</th>
<th>57</th>
</tr>
</thead>
<tbody>
<tr>
<td>A consistent fishing day value</td>
<td>62</td>
</tr>
<tr>
<td>Data Application</td>
<td>Page</td>
</tr>
<tr>
<td>------------------</td>
<td>------</td>
</tr>
<tr>
<td>Dependent-independent variable relationship</td>
<td>67</td>
</tr>
<tr>
<td>Demand determinants</td>
<td>69</td>
</tr>
<tr>
<td>Supply determinants</td>
<td>71</td>
</tr>
<tr>
<td>Summary</td>
<td>84</td>
</tr>
<tr>
<td>CHAPTER V</td>
<td>85</td>
</tr>
<tr>
<td>The Analytical Framework</td>
<td>85</td>
</tr>
<tr>
<td>Statistical theory</td>
<td>85</td>
</tr>
<tr>
<td>Regression Analysis</td>
<td>91</td>
</tr>
<tr>
<td>Outlier observations</td>
<td>94</td>
</tr>
<tr>
<td>The regression variables</td>
<td>95</td>
</tr>
<tr>
<td>Summary</td>
<td>102</td>
</tr>
<tr>
<td>CHAPTER VI</td>
<td>104</td>
</tr>
<tr>
<td>Estimating the Marginal Response</td>
<td>104</td>
</tr>
<tr>
<td>Deriving the marginal impacts</td>
<td>105</td>
</tr>
<tr>
<td>Marginal effects derived from probit coefficients</td>
<td>106</td>
</tr>
<tr>
<td>Marginal effects derived from tobit coefficients</td>
<td>106</td>
</tr>
<tr>
<td>Marginal effects on expected days fishing</td>
<td>107</td>
</tr>
<tr>
<td>A comparison of marginal impacts</td>
<td>108</td>
</tr>
<tr>
<td>Valuing Water in an ASA</td>
<td>110</td>
</tr>
<tr>
<td>Determining day responses</td>
<td>111</td>
</tr>
<tr>
<td>The population response within the resident areas</td>
<td>111</td>
</tr>
<tr>
<td>Response within the wildlife region</td>
<td>112</td>
</tr>
<tr>
<td>Response within the ASAs</td>
<td>114</td>
</tr>
<tr>
<td>Deriving acre-foot water values</td>
<td>115</td>
</tr>
<tr>
<td>Allocation</td>
<td>115</td>
</tr>
<tr>
<td>Water's value as an instream resource</td>
<td>119</td>
</tr>
<tr>
<td>Streamflow significance</td>
<td>120</td>
</tr>
<tr>
<td>Inclusion of all downstream benefits</td>
<td>121</td>
</tr>
<tr>
<td>Instream use vs. consumption</td>
<td>122</td>
</tr>
<tr>
<td>Other consumers</td>
<td>125</td>
</tr>
<tr>
<td>Other instream values</td>
<td>125</td>
</tr>
<tr>
<td>Section</td>
<td>Page</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Summary</td>
<td>126</td>
</tr>
<tr>
<td>CHAPTER VII</td>
<td>128</td>
</tr>
<tr>
<td>Summary</td>
<td>129</td>
</tr>
<tr>
<td>Conclusions</td>
<td>130</td>
</tr>
<tr>
<td>Implications</td>
<td>132</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>135</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>145</td>
</tr>
</tbody>
</table>
CHAPTER I

Introduction

When first discovering the logic, simplicity, and fairness of supply and demand in a market economy, its harmony seems to match that of nature. Indeed, it seems a part of nature itself, laissez faire -- a place where governments do not belong. Individuals allocate their productive effort according to how they feel about work and the reward coupled with it. This reward (income) is allocated (spent) by each individual toward purchasing the type and quantity of goods which will generate the most satisfaction for that individual. Thus, each individual chooses the combination of work-reward and goods-expenditures to maximize their satisfaction (utility). In the aggregate, each market supply curve represents the compensation needed to encourage society members to produce each commodity and each market demand curve represents the desire society feels for various quantities of each commodity. Long-run equilibrium in a perfectly competitive market implies such things as: commodities are produced at their lowest social cost, commodity prices equal their marginal cost, commodity price ratios equal marginal utility ratios, and the negative utility from the last hour worked equals the gain in utility from the commodity(ies) purchased from that hour's income. A state of Pareto optimality is achieved.

No one believes that the real world exists as perfect competition hypothesizes (i.e., with perfect factor mobility, perfect knowledge, homogeneity of outputs, etc.). Some deviations do not complicate
resource allocation and may be desirable (e.g., products are not homogeneous). Other deviations grossly violate the efficiency conditions of perfect competition so that production costs do not reflect full social costs or that prices either do not equal production costs or cannot be efficiently established. Problems with markets or in marketing goods occur due to the presence of monopolies, oligopolies, externalities, public goods, government influences such as taxes and control of the money supply, and international barriers to competition. Proper public policy can be used to overcome the above problems and, to some degree, reestablish the efficiency conditions of the market economy.

The water flowing within the nation's river systems has a variety of uses, some consumptive and some nonconsumptive. Consumptive uses of streamflow remove the water from the river system precluding others from its use. The consumption of water by municipalities and in manufacturing have been shown to reflect a high value for the water's consumptive use. Agriculture is the largest single consumer of water, especially in the more arid western states and has, in most cases, the lowest valued consumptive use of the water. Some nonconsumptive uses of water include freshwater fishing, rafting, swimming, hydroelectric power generation, waste assimilation, scenic beauty, and navigation. The value of water for these nonconsumptive uses is not easily determined (except for power generation). Without knowing the value of water in all its uses, the allocation of water to its highest valued use (as efficiency dictates) is impossible.
The nonconsumptive use of water as it passes freely downstream poses the market complication of being a public good and, thereby, will not be allocated efficiently within a market economy. Water has the characteristics of a public good because first, it allows jointness of consumption (the same water can be swam in, fished in, boated on, etc.), and, second, if the use of water as a public good generates social costs, collecting a price for each use is impractical.

This study is an attempt to estimate the value of one of the nonconsumptive uses of streams (fishing). Water supplies will be shown to be limited to where water can no longer be treated as a free good. As discussed above, optimal allocation of resources occurs when the resources are put to their highest valued use. Streams, and therefore the water within them, are public goods and, as such, will not be best allocated by markets alone. By estimating and using the marginal value of a unit of water for nonconsumptive uses as a "price" for consumptive use of that water, water can be put to its highest valued use and optimal water allocation achieved.

---

Allocation can be efficient within a market economy as long as the no "crowding", i.e., use of the streamflow by others has not diminished there is enjoyment of its use to any individual.
CHAPTER II

Conflicts In Water Use: Historical, Legal, and Social Factors

The problem of water allocation

To make best use of the nation's limited water supply, water must be allocated to its highest valued use. Much legal and legislative work throughout the United States, especially in the western region, has been focused on water rights and water allocation. Water disputes occur among the different parties wishing to consume the limited water supply and also between the consumptive and the nonconsumptive water users. The value of water in its consumptive uses can be obtained directly when demand can be estimated, such as when fees and/or the pumping costs of water represent acre-foot prices or by estimating the shadow price of water from its marginal value product (MVP). The difficulty lies in estimating the value of water as a public good.

Allocating the water within a river system must be done within a national framework for two important reasons. First, river systems can traverse large areas. Depleting water at any location on a river decreases the flow rate throughout the downstream course. For example, should Montana increase water withdrawals from the Missouri River, all downstream states (North Dakota, South Dakota, Iowa, Nebraska, Kansas, Missouri, Illinois, Kentucky, Tennessee, Arkansas, Alabama, and Mississippi) will have less water available for public use. Estimating the value of a unit of water as a public good must include all benefits
generated by that unit of water as it travels throughout the river's course. And secondly, a river's course provides many fishing sites. These various sites can act as substitutes for each other. Since changing streamflow can affect fishing quality at all downstream sites, a national analysis accounts for the substitutions among sites thus providing the necessary general equilibrium solution.

Problems in water allocation can be expected to grow as income and leisure per capita and population grow, thus increasing the demand for river systems as public goods (U.S. Forest Service, 1977). This continued growth in demand will require continued reassessment in water allocation in order to maintain an optimal water use policy.

Have streamflow depletions been significant enough to warrant some reconsideration of current water allocation? The Water Resources Council (WRC) estimated that in 1975 there were about 85 million acres of total surface water in the conterminous U.S. Only 24 percent of this water is considered usable or accessible for recreation. Water may be inaccessible in that there is restricted public access or the water body is so large that much of the surface area is considered remote. For example, in the Great Lakes Region (see Figure 2.1 for regional boundaries) much of the surface area of the water is from the Great Lakes themselves hence only 10 percent of the region's surface water is considered available. The area known as the Great Basin (primarily Utah and western Nevada), though mountainous, has 86 percent of its water area listed as usable. Table 2.1 lists total and usable acres of surface water and acres of surface water per 1,000 population, and the
Figure 2.1. The 18 water resources regions (U.S. Geological Survey, 1979, Vol. N, p. 1)
<table>
<thead>
<tr>
<th>Region</th>
<th>Thousand acres (^b)</th>
<th>Thousand acres (^c)</th>
<th>Percent of total</th>
<th>Acres per 1,000 population</th>
</tr>
</thead>
<tbody>
<tr>
<td>New England (1)</td>
<td>4,103</td>
<td>422</td>
<td>36</td>
<td>152</td>
</tr>
<tr>
<td>Mid-Atlantic (2)</td>
<td>4,366</td>
<td>140</td>
<td>42</td>
<td>59</td>
</tr>
<tr>
<td>South Atlantic-Gulf (3)</td>
<td>8,672</td>
<td>433</td>
<td>23</td>
<td>102</td>
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<tr>
<td>Great Lakes (4)</td>
<td>41,547</td>
<td>1,748</td>
<td>10</td>
<td>179</td>
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<tr>
<td>Ohio (5)</td>
<td>932</td>
<td>56</td>
<td>56</td>
<td>31</td>
</tr>
<tr>
<td>Tennessee (6)</td>
<td>660</td>
<td>236</td>
<td>80</td>
<td>187</td>
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<tr>
<td>Upper Mississippi (7)</td>
<td>2,716</td>
<td>259</td>
<td>28</td>
<td>72</td>
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<tr>
<td>Lower Mississippi (8)</td>
<td>3,433</td>
<td>680</td>
<td>12</td>
<td>83</td>
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<tr>
<td>Souris-Red-Rainy (9)</td>
<td>1,232</td>
<td>2,425</td>
<td>27</td>
<td>656</td>
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<tr>
<td>Missouri (10)</td>
<td>3,504</td>
<td>504</td>
<td>71</td>
<td>359</td>
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<tr>
<td>Arkansas-White-Red (11)</td>
<td>1,855</td>
<td>345</td>
<td>34</td>
<td>118</td>
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<tr>
<td>Texas-Gulf (12)</td>
<td>2,692</td>
<td>346</td>
<td>14</td>
<td>50</td>
</tr>
<tr>
<td>Rio Grande (13)</td>
<td>542</td>
<td>402</td>
<td>12</td>
<td>52</td>
</tr>
<tr>
<td>Upper Colorado (14)</td>
<td>588</td>
<td>2,029</td>
<td>59</td>
<td>1,196</td>
</tr>
<tr>
<td>Lower Colorado (15)</td>
<td>456</td>
<td>237</td>
<td>46</td>
<td>108</td>
</tr>
<tr>
<td>Great Basin (16)</td>
<td>1,752</td>
<td>1,735</td>
<td>86</td>
<td>1,498</td>
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<tr>
<td>Pacific Northwest (17)</td>
<td>3,893</td>
<td>727</td>
<td>38</td>
<td>277</td>
</tr>
<tr>
<td>California (18)</td>
<td>1,674</td>
<td>99</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td><strong>Total, regions 1-18</strong></td>
<td>84,557</td>
<td>507</td>
<td>24</td>
<td>122</td>
</tr>
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| Alaska (19)                | 12,787                | 52,192                | 15               | 7,906                     |
| Hawaii (20)                | -                     | N/A                   | N/A              | N/A                       |
| Caribbean (21)             | N/A                   | N/A                   | N/A              | N/A                       |
| **Total, regions 1-21**    | N/A                   | N/A                   | N/A              | N/A                       |

\(^a\)Estimated "1975" population 12 years and older is about 167 million.
\(^b\)Total of inland and other water from Area Measurement Reports, U.S. Department of Commerce Publication GE-20, No. 1, and 1970 update sheet and comprehensive water basin studies.
\(^c\)Water available and useful for recreation. To be available and useful the water must have adequate public access, be free of obstruction to its use, and be of suitable quality for recreation use.
\(^d\)N/A - Not available.
percent of total surface area of water which is usable. Table 2.2 lists the gross surplus, gross deficit, and net available surface water area of the 18 Water Resources Council regions estimated for 1975, 1985, and 2000. If their projections are correct, 1985 will be nearly a break-even year for total surface water available vs. total demand for free use of water as a public good. However, these numbers are aggregated across the U.S. so that some areas are (or will be) water short while others are (will remain) water abundant. In 1980, the U.S. Department of Agriculture (1981a, Part I) used smaller regions to determine water short areas based on data from the U.S. Water Resources Council's (WRC) Second National Water Assessment (SNWA) and criteria as defined in the 1980 Resources Conservation Act (RCA). The water short areas are shown in Figure 2.2. These areas, called Aggregated Subareas (ASA), correspond to river drainage basins which have been outlined by the WRC.

The following sections examine the history of water use, the laws relevant to water allocation, and the economic principles suggesting why a market fails to allocate water efficiently and how this failure might best be remedied.

Historical overview

From the beginning of European settlement on this continent, high regard has been given to the agrarian potential of the area now known as the United States. Early laws and social institutions were formulated to take advantage of this resource abundance. Ease of land ownership,
Table 2.2. Needs for surface-water area for water-dependent recreation activities—"1975," 1985, 2000 (1,000 acres) (U.S. Water Resources Council, 1978b, p. 107)

<table>
<thead>
<tr>
<th>Region</th>
<th>Gross surplus water</th>
<th>Gross deficit water</th>
<th>Regional surplus or (deficit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New England (1)</td>
<td>902</td>
<td>560</td>
<td>342</td>
</tr>
<tr>
<td>Mid-Atlantic (2)</td>
<td>670</td>
<td>1,679</td>
<td>(1,009)</td>
</tr>
<tr>
<td>South Atlantic-Gulf (3)</td>
<td>607</td>
<td>958</td>
<td>(351)</td>
</tr>
<tr>
<td>Great Lakes (4)</td>
<td>2,900</td>
<td>1,284</td>
<td>1,616</td>
</tr>
<tr>
<td>Ohio (5)</td>
<td>0</td>
<td>961</td>
<td>(961)</td>
</tr>
<tr>
<td>Tennessee (6)</td>
<td>192</td>
<td>0</td>
<td>192</td>
</tr>
<tr>
<td>Upper Mississippi (7)</td>
<td>84</td>
<td>509</td>
<td>(425)</td>
</tr>
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<td>Lower Mississippi (8)</td>
<td>3</td>
<td>182</td>
<td>(179)</td>
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<td>Souris-Red-Rainy (9)</td>
<td>211</td>
<td>0</td>
<td>211</td>
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<tr>
<td>Missouri (10)</td>
<td>1,976</td>
<td>6</td>
<td>1,970</td>
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<td>Arkansas-White-Red (11)</td>
<td>179</td>
<td>250</td>
<td>(71)</td>
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<tr>
<td>Texas-Gulf (12)</td>
<td>0</td>
<td>539</td>
<td>(539)</td>
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<td>Rio Grande (13)</td>
<td>12</td>
<td>129</td>
<td>(117)</td>
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<tr>
<td>Upper Colorado (14)</td>
<td>310</td>
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<td>Lower Colorado (15)</td>
<td>102</td>
<td>94</td>
<td>8</td>
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<tr>
<td>Great Basin (16)</td>
<td>1,360</td>
<td>1</td>
<td>1,359</td>
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<tr>
<td>Pacific Northwest (17)</td>
<td>818</td>
<td>98</td>
<td>720</td>
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<tr>
<td>California (18)</td>
<td>475</td>
<td>806</td>
<td>(331)</td>
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<td><strong>Total, regions 1-18</strong></td>
<td><strong>10,801</strong></td>
<td><strong>8,056</strong></td>
<td><strong>2,745</strong></td>
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<td>Alaska (19)</td>
<td>1,901</td>
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<td>1,901</td>
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<td>Hawaii (20)</td>
<td>N/A</td>
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<td>Caribbean (21)</td>
<td>N/A</td>
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<td>N/A</td>
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<td><strong>Total, regions 1-21</strong></td>
<td><strong>N/A</strong></td>
<td><strong>N/A</strong></td>
<td><strong>N/A</strong></td>
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*Total of subregions with surplus water acreage for needs within each subregion.

*Total of subregions with deficit water acreage for needs within each subregion.

*The algebraic difference between surplus and deficit subregions, i.e., a regional composite view of net needs for the region.

*N/A - Not available.
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<th></th>
<th>2000</th>
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<td>Gross surplus water&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Gross deficit water&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Not regional surplus or (deficit)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Gross surplus water&lt;sup&gt;a&lt;/sup&gt;</td>
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<td></td>
<td>879</td>
<td>681</td>
<td>198</td>
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Figure 2.2. Aggregated subareas (following county boundaries) designated as water-short (U.S. Department of Agriculture, 1981b, p. 94)
low cost farm credit, and development of a transportation infrastructure were among some of the public efforts made to stimulate growth in agriculture. In the more arid regions of the country, legal institutions and publicly funded projects enhanced agricultural production by promoting irrigation development. For example, Congress opened some western areas to homesteading with passage of the Desert Land Act. This act allowed a settler to homestead 640 acres but required a portion to be irrigated within a specified period of time.

Water development policies of the past were written at a time when water supplies were virtually undiminished. In promoting water development, three objectives are argued for: that of promoting the local economy of the project area, that of insuring an adequate food supply for the nation and that of economic growth for the nation (U.S. Department of Agriculture, 1981a; U.S. Water Resources Council, 1978b; U.S. Geological Survey, 1976). As water demands increase, more consideration must be taken in water allocation decisions to achieve the above objectives.

Water policies, in general, have continued to be orientated toward consumptive uses. Figure 2.3 charts the increase in water withdrawals, by source, which have occurred between 1900 and 1975. Water policies with little or no regard for society's loss of this resource from its natural state, are only of late being reconsidered. Since constitutions

---

1 Water development is a term applied to projects involving water diversion/consumption or containment. The definition of this term stems from the past philosophy that water use or containment were always beneficial to society.
Figure 2.3. Sources of water withdrawals since 1900 in the United States (U.S. Department of Agriculture, 1981a, p. 206)
are beginning to be reinterpreted in an attempt to recognize the value of water as an instream resource. Recognition of society's preference for maintaining streams even over the impoundment of their flows is exhibited by legislation such as the Wild and Scenic Rivers Act (Public Law 90-542), the National Environmental Policy Act (Public Law 91-190), and the Federal Waters Powers Act as amended (Public Law 66-280). These laws require that consideration be given to the recreational value of stream segments as an alternative to development proposals.

**Legal factors**

States have agreements among each other about the level and quality of flow between jurisdictions. The allocation of water among individuals is left up to the states. The specific system a state chooses for water allocation is based upon one or a combination of the three basic water right doctrines: the administrative permit system, the prior appropriations doctrine, and the riparian doctrine. Figure 2.4 illustrates the current application of these water use doctrine across the country. Western states tend to follow the law of prior appropriation (or appropriation doctrine) whereas eastern states use the riparian doctrine.

The riparian doctrine was the earlier water use doctrine in the U.S. This doctrine allowed ownership of the water (except for tidal or navigable waters) to those who owned the adjacent land. This system, which is the only system allowing private ownership of the water, was
Figure 2.4. Geographical distribution of states operating under each of the basic water rights doctrines (U.S. Department of Agriculture, 1981a, p. 11)
adopted from the English system with few modifications. However, two
modifications which have been made allow the water to leave an
individual's property diminished slightly in quality and quantity and
thus, an individual may divert the water for irrigation or use the
stream for waste disposal. The limiting condition to be met by the
water user is that the use of the water be "reasonable." "Reasonable"
use of the water means that the water's use may not be damaging to the
downstream users.

Western states have adopted the doctrine of prior appropriations to
encourage the settlement and the development of the area. This doctrine
allows water diversion as long as the water has no existing claim and
that the present diverter will put the water to beneficial use. This
establishes a hierarchy of water rights, seniors to juniors, depending
on who first obtained their rights. Hence, as streamflow varies between
years, junior users may or may not receive their appropriated amount
depending on the water availability. Under this system of water
allocation, senior users may receive their full allocation in drier
years at the cost of junior members receiving none of the water which
they desire.

In more recent times some states have modified or replaced their
water right doctrines with an administrative permit system. Under this
system, permits give no single user priority over other users (except in
special cases). Permits do not establish a permanent right to the
water. They are issued for a limited time, can be revoked if deemed to
be in the public interest, and may be reissued to reconcile disputes between permit holders.

About half of the states in the U.S. hold to the public ownership of water (see Figure 2.5) and those that do are the more arid western states. Thus, those states which have the greatest depletion of their flows (as indicated in Figure 2.2) have the legislative authority to increase their recreational water supplies.

Besides the legal criteria of water allocation within the state, laws regulating interstate flows must also be considered to obtain optimal water allocation across state boundaries. Though a state may allocate water within its boundaries to its highest value use, they have not been known to consider the gains possible by water reallocation across states' boundaries. With this consideration recognized and accounted for by states, water can be allocated to its highest value use and the greatest gains to society can be obtained from this scarce resource.¹ There is no reason to expect states to become so public

¹Though efficiency does not require compensation from those gain to those who lose in a resource reallocation policy, Pareto-optimality does. The compensation only needs to equal the loss thus excess gains are possible. While measuring the losses of those who lose and distributing a monetary compensation may not be difficult, collecting from those who gain will be more difficult because of the public nature of the added good. Voluntary contributions by those who gain may provide the revenue to compensate those who lose and even capture some of the excess gains for society to allocate as desired. However, given the free-rider problem associated with public goods, voluntary contributions are not likely to work (Buchanan, 1970; Boadway, 1979). Though, a clearly Pareto improvement does seem possible in dealing with increasing the availability of this public good, the same problem occurs with other public goods. With such a case, "a convincing argument can be made that public goods theory is actually a theory of government(s)" (Davis and Hulett, p. 40, 1977).
Figure 2.5. Geographical distribution of states which hold the public ownership concept for water (U.S. Department of Agriculture, 1981a, p. 15)
minded (when the public is in another state). The Federal Government has not been particularly successful in persuading states to reallocate their water. Past federal water legislation, though focused on water quality and flood control, does offer avenues for quantity maintenance. "The Water Pollution Control Act Amendments of 1972, while aimed primarily at water pollution problems, may prove to be a useful tool for preserving instream flows. For example, Environmental Protection Agency regulations require that the Colorado River basin states adopt water quality standards for salinity and an implementation plan for the control of salinity, and that the salinity in the lower Colorado River should be maintained at or below the average salinity of 1972"¹ (Weaver, 1976).

The benefits of nonmarket water use

The value of a given unit of water as a public good will be a sum of all values of that unit of water for each type of use for all individuals. As a public good, the uses of streamflow within a river system are many. Potential benefits from decreased consumption of streamflows include: increased waste assimilation, lower sediment and mineral load, increased riparian vegetation, increased wildlife and wildlife habitat, increased fish stocks, increased hydroelectric power, increased swimming areas, improved boating, improved ocean fisheries, and

¹Irrigation return flows increase the water's salinity two ways. First, fresh water is consumed (by the irrigated vegetation) leaving a smaller volume of water for salts to be dissolved in. Second, return flows often have dissolved more salts out of the soil therefore increasing the total quantity of salt within the stream.
and increased natural areas. The combined benefits a unit of water generates as it passes through the river course estimates the public resource value of that unit of water.

While it is true that water development projects may increase growth (as measured by market activity), to argue that increased market activity in itself is desirable fails to recognize the social value of nonmarketed goods (e.g., clean air or a city park). Not all of society's benefits are acquired through market activity. Though the output measure we commonly use, GNP (Gross National Product), may be adversely affected by decreasing water diversions, it is not an accurate measure of societies output or welfare (Branson, pp. 29-31).¹ The use and enjoyment received from public goods such as clean air or a free-flowing stream adds nothing to GNP directly. The value of public goods are not measured by their benefit to society but by their input cost—what's more, only the explicit costs (Shapiro, pp. 11-29, and A-1 to A-65). The gain to society of decreased streamflow diversions will not be reflected in the market, but, instead, the market will reflect the loss in output stemming from decreased irrigation. However, recognition of the social value of natural areas allows society to realize the potential gain from decreasing water diversions and thus making optimal use of society's resources.

¹The use of GNP as a welfare measure stems from the idea that the prices paid for commodities and the quantities purchased represent the value (hence, welfare gain) of these goods to society.
Streamflow and Fishing Quality

With the number of benefits resulting from increasing streamflow and the difficulties of estimating any one, concentration has been focused on fishing benefits for two reasons. First, the most significant benefit to society from public use of the river systems is their use as a fishing resource, though fishing still only represents approximately 50 percent of the total benefits of streamflow as a public good. Second, "it is generally presumed that instream flows for uses other than fishing (water quality, recreation, aesthetics) will be met by base flows" (Bayha, p. 129, 1976). In other words, other public uses of water may not be enhanced by increased flows (beyond some base level) though fishing still can be. In such instances, the only benefits of increased streamflow are those related to improved fisheries.

To estimate fishing benefits from streamflow changes within a national framework, it is essential to have a gross aggregate predictive measure of the response of fisheries to changes in streamflow. Large-scale state and national studies done in the past have also required such an aggregate measure. The most popular method developed to date is known as the Montana Method or Tennant's Criteria.

Biologists do their analysis with aid of hydrological data provided by the U.S. Geological Survey (U.S.G.S.). Detailed field studies were conducted on 11 streams in 3 states between 1964 and 1974, testing the "Montana Method." This work involved physical, chemical and biological analyses of 38 different flows at 58 cross-sections on 196 stream-miles, affecting both coldwater and warmwater fisheries. The
studies, all planned, conducted, and analyzed with the help of state fisheries biologists, reveal that the condition of aquatic habitat is remarkably similar on most of the streams carrying the same portion of the average flow. Similar analyses of hundreds of additional flow regimens near U.S.G.S. gauges in 21 different states during the past 17 years substantiated this correlation on a wide variety of streams" (Tennant, p. 359, 1976).

Average flow (or natural flow) is the level of flow which would occur, during a year of average precipitation, if there were no upstream consumption. Thus, the portion (percent) of natural flow that present flows represent acts as both a fishing quality and water quantity measure.

Biological studies indicate a linear response by fish populations to percent changes in average flows. Wesche (1976) devised a cover rating for small trout streams to determine how various flow levels influence trout standing crop. Here cover rating increased with diminishing returns as a function of percent flow but pounds of trout per acre responded with increasing returns as a function of mean cover rating. Binns (1977, p. 223), in his study of nine Wyoming trout streams, found a log-log relationship between his measure of percent flow and his Habitat Quality Index (HQI) and a linear relationship between HQI and total fish weight per unit area.

1"Standing crop" measures the stock of fish in terms of the weight of the fish population per unit stream area or stream length.
The focus of this study

Recognizing the problems of water allocation: the publicness of water as an instream resource, the wide area over which the benefits accrue, and the emphasis of past water rights doctrine toward increased water consumption, leads one to ask "how has society allocated this scarce resource?" This study will begin to answer this question by estimating the instream value of water as a fishing resource. With estimates of 1980 streamflow, the availability of stream and lake sites, and information on households' fishing activities in 1980, fishing-day response estimates will be made for changes in fishing opportunities, particularly for the change in fishing opportunity due to a change in streamflow diversions.

Summary

This chapter has attempted to clarify the extent of water depletion across the United States and how legal institutions and social development have brought about such a situation. Without a market for allocating water between its various private uses and its public use, a legal setting which allocates water towards its highest valued use can still provide efficient water allocation. For such a system to work, the value of water in all its potential uses needs to be known.

Difficulties in estimating the value of a public good, especially one such as water which travels through many political jurisdictions, further complicates water allocation. The large area a unit of water
traverses makes a national model for determining the public use value of water an appealing approach.

Because other public use of instream flow can (generally) be fully served with lower levels of flow than may be necessary for adequate fish habitat, the valuation of water as a public good will focus on its value as a fishing resource. Biological studies on fish habitat and fish standing crop indicates a linear response between fish standing crop and the level of flow within a stream. These studies also indicate a consistency in standing crop per unit area across streams of various types as long as they each have the same portion (or percent) of their natural flow. This relationship is used to estimating the availability of fishing resources to households whereby the value of water as a recreational fishing resource can be determined.
CHAPTER III

As discussed in Chapter I, the presence of a resource which can also be defined as a public good in a freely operating market economy can remove the economy from an efficient allocation of its resources. Given the zero marginal cost of the use of the public good, efficiency conditions dictate an equal price to consumers. This zero price for public goods provides no incentive for their provision by the private sector. Yet the provision and maintenance of public goods is not always costless to society. Optimal provision of public goods requires the same efficiency condition as in the provision of private goods -- that the marginal social costs equal the marginal social benefits. Thus, market intervention is required to remedy the market's inability to efficiently provide public goods and to obtain efficient resource allocation.

In order to assure the highest valued use of all resources, the value of the resource as a public good must be known. Several theoretical constructs have been developed and applied to estimate a public resource's value. Of these, the four accepted as most theoretically sound and, as such, are most empirically applied are: hedonic pricing techniques, contingent valuation techniques, the travel cost method, and the household production approach. Which of these methods is "best" depends on the specific nature of the data and the valuation problem at hand.
This chapter explains the application of the household production approach to determine the public-use value of water as an instream resource. A brief overview of methodologies for evaluating public goods is followed by a detailed examination of household production theory. Because of problems in the direct valuation of streamflow with the household production approach, the application of a reduced form model is presented.

Modeling

Types of models

**Hedonic technique** Hedonic pricing techniques have been applied to determine the implicit value of characteristics or attributes associated with a marketed good (Rosen, 1972; Griliches, 1971a and 1971b; Brown and Pollakowski, 1977; Brookshire et al., 1982; Dinan, 1984). The hedonic technique operates on the assumption that the price of a market good (such as a house) is the sum of the implicit values for all attributes (both public and private) of that good. Hence, the price of a house reflects implicit market values for neighborhood attributes (e.g., absence of airport noise, quality of schools, proximity of parks, street traffic, etc.) and each of the structural attributes of the building (e.g., size, energy efficiency, number of rooms, etc.). With enough observations on the price/characteristic relationship of this good, an implicit value or shadow price is determined for each of the good's attributes.
Contingent valuation technique

Contingent valuation techniques rely on survey responses in estimating the demand for public goods. The questioning take two basic forms with both producing an estimate of the compensated demand for the good. One method asks the individual the amount of income they would be willing to forgo for preserving or improving a public good (e.g., to maintain a recreational site, to partake in a particular recreational experience, for an improvement in air quality, etc.) and still feel as well off. A second method asks for the respondents' reaction (in terms of trips or outings taken) to changes in the level of environmental inputs supplied by the government. The demand for the inputs is measured in terms of trips or outings and is a compensated demand because the usual form of the contingent valuation question is compensating variation or surplus (Davis, 1963; Hammack and Brown, 1972; Brookshire, Ives, and Schulze, 1976; Freeman, 1979; Schulze, d'Arge, and Brookshire, 1981).

Travel cost method

The travel cost method treats the costs of transportation to a recreation site as a "price" paid by the user. The different distances traveled represent different "prices" faced by consumers. The relationship between population response and "price" gives a demand estimate for the site (Brown, Singh, and Castle, 1965; Clawson and Knetsch, 1966; Freeman, 1979; McConnell, 1980; Cesario, 1980; Sutherland, 1982; Smith, Devouges, and McGivney, 1983; Vaughan and Russell, 1982). Extensions of the travel cost model have incorporated the different environmental attributes of similar recreation sites in an attempt to determine the value of a particular environmental
characteristic (i.e., a hedonic technique applied to the price of travel (Brown and Mendelsohn, 1980)).

**Household production approach** The household production approach was first developed by Becker (1965) in modeling the allocation of nonwork time and was subsequently adapted to outdoor recreation by Deyak and Smith (1978). This theory is a reformulation of consumer theory where the consumer is hypothesized to be both a producer and a consumer of "basic commodities." This reformulation of consumer theory better explains why consumers allocate their time and income as they do. Under traditional consumer theory, the household is said to purchase goods based on the price/utility relationship. Thus, at the margin, the ratio of prices between two goods will equal the ratio of marginal utilities. Under the household production approach the household maximizes utility using market goods and time to produce commodities which enter the household's utility function directly. For example, under traditional demand theory the household purchases a lawn mower by comparing the price with the utility received from it. Under the household production approach the household looks at the lawn mower as an input along with time and gasoline, electricity or other energy sources used to produce a commodity (satisfaction from a nice lawn or acceptance by neighbors) which enters the utility function directly. By focusing attention on the commodities and accounting for all inputs in the commodities' production, the household production approach better explains rational consumer behavior.
Application of the household production approach creates an opportunity to value nonmarket goods or predict behavioral responses from varying levels of a public good. Information on personal characteristics, the availability of the public good, the prices of marketed goods, and the level of participation are used to estimate households' commodity production/consumption behavior. The behavior of the household towards price changes in private goods used in conjunction with public goods in the production/consumption process of a commodity, provides the link to determine the households' value of the public good.

Model selection

Of the four models just described, the household production approach is best suited for the valuation problem at hand. This is due to both the nature of the problem and the data available. For example, the river systems within the U.S. do not define unique sites and so a mileage measure needed in a travel cost analysis is not defined. The contingent valuation technique requires a national survey on people's valuation of changes in stream fishing quality resulting from changes in streamflow (ceteris paribus). No such survey has been done. Hedonic techniques require benefits from stream fishing to be attached to ownership of real property. Given all the public access there is to streams, this method is also eliminated.
The household production approach is described in more detail below followed by a complete explanation of the theoretical application to the problem at hand.

Household production model -- the theory and supportive literature

As mentioned above, household production theory was originally formulated to explain the allocation of time by households. The extension of time allocation towards the use of public goods and the implied value of the goods as an input in production followed. A considerable amount of literature already exists on the application and problems of value estimation under this theoretical framework. The discussion following overviews some of the most significant work relevant to this study.

Traditional utility maximization Traditionally, households\(^1\) are said to maximize utility \(Y\), obtained directly through services of goods \(X\) (where \(X\) is an \(m \times 1\) dimensional vector of the \(m\) goods purchased in the market), environmental goods \(E\), and through leisure time \(L\). Utility maximization is constrained by the household's total income \(I\), the total time \(T\) (which is divided between leisure time, \(L\), and time at work, \(T_w\)), the available public goods or environmental resources \(E\), and the prices of goods \(P\) (where \(P\) is the \(1 \times m\) vector of prices associated with the goods vector \(X\)). Thus, utility maximization is described by maximizing:

\[
Y = Y(X,E,L)
\]  

\(^1\) The terms household and individual are used interchangeably.
subject to

\[ I = PX. \tag{3.2} \]

Time enters traditional utility maximization in its allocation toward leisure (as indicated by 3.1) as opposed to its allocation toward income. Defining \( W \) as the income generated by an hour of work and asset income as \( A \), total income is then defined as:

\[ I = T \cdot W + A. \tag{3.3} \]

This methodology does not account for specific time allocation decisions but, instead, time's allocation between work and leisure. Thus, this does not capture the full use of time by the household (and, therefore, decisions on the allocation of time among different activities. Time away from work is used productively in nonmarket activities such as making dinner, painting the house, washing the car, or driving to the vacation retreat. The household production approach attempts to account for time allocated to all activities whether earning income at the job, producing goods at home, or enjoying a recreational activity.

**Utility maximization decisions in a household production approach**

The household production approach considers time allocation among all activities including work. Further, this model can account for the purchase of goods which do not enter the utility function directly (e.g., a lawn mower) and, thus, provides a more theoretically sound description of consumers' purchases of market goods (Michael and Becker, 1973). (Gronau (1977) provides an interesting study on household time allocation within the household production framework by looking at
household's time allocation decisions, across variations in income, on production of home goods that are perfect substitutes for market goods.)

Becker's approach views the household as being both a consumer and producer of "basic commodities" (Becker, 1965). These "basic commodities" need not be tangible but are consumptive units which enter the household's utility function directly. Commodities are produced by the household using the time, public goods, market goods, and the available technology. Lancaster (1966) extends Becker's approach (or perhaps clarifies the concept of a basic commodity) by defining the basic commodities as characteristics, such as health, taste, warmth, relaxation, which (again) enter the utility function directly. By defining the n commodities as $Z_i$, utility maximization is described as maximizing:

$$U = U(Z_1, Z_2, \ldots, Z_n),$$

subject to

$$Z_i = f_i(x_{i1}, T_i, E)$$

$$X = x_1 + x_2 + \ldots + x_m$$

$$T = T_w + T_1 + T_2 + \ldots + T_n$$

and

$$T^*W + A = PX + (T - T_w)^*W = I$$

where $i=1$ to $n$, $n$ being the total number of commodities the household produces/consumes, $T$ is total time available, $T_i$ is time used in production of $Z_i$, and $E$ is the environmental resource or public good available to the household. "I" now accounts for the value of all time
to the household and therefore defines a full income constraint. The role of time in all of the household's decisions is thus accounted for.

The household production approach in analyzing consumer behavior has several advantages over the conventional approach. Among other things, this approach better explains the phenomenon of new goods (e.g., microwave ovens increase the household food production efficiency), it better explains the purchase and use of goods, which do not directly generate utility, by focusing attention on the commodities, it recognizes time as an important factor in all work/leisure decisions, and it recognizes household productive skills in consumer decision making (Becker, 1976, Becker and Lewis, 1973, Michael, 1973, and Willis, 1973).

**Demand estimation within the household production framework** The demands for goods derived from the household production approach must depend on the same parameters as the demands for goods derived from the traditional theory of utility maximization (e.g., goods prices, the household's income, and tastes). However, the household's technology is an additional parameter of goods demands within the household production approach. In estimating the household's demand for a commodity, the price for the commodity will depend not only on the (observable) goods' prices, but on the household's technology (the other parameters of demand are not of issue here). Remember that the commodity price is not observed but needs to be imputed if demand for the commodity is to be determined. However, the commodity price can vary with the level of commodity output. The simplifying assumptions of constant returns to
scale and no joint production in the household's production of commodities removes technology as a variable in the input/output relationship in commodity production. This assumption ensures a direct relationship between changes in the goods market to changes in costs for the household's commodity production. Estimating commodity demands (and demands for public goods) then becomes straightforward.

Commodity demands -- constant returns and no joint production

A commodity cost function, \( C(P,W,Z) \), can be derived from the first order conditions of (3.4) - (3.8) above. This cost function will represent the least expensive collection of goods capable of producing the utility maximizing commodity vector \( Z^* \). A vector of (implicit) commodity prices \( V \) can be determined because:

\[
V_i(P,Z,W) = \frac{\partial C(P,Z,W)}{\partial Z_i}. \tag{3.9}
\]

These prices are independent of the \( Z_i \)'s (which follows directly from the above assumptions), therefore marginal costs are constant. Thus, the budget constraint in commodity space will be linear and

\[
\sum_{i=1}^{n} V_i(P,W)Z_i = I. \tag{3.10}
\]

With (3.9) and (3.10) there are \( n + 1 \) equations which can be solved for the \( n \) unknown \( Z_i \)'s thus generating the unique solution vector of commodity demands

\[
Z = g(P,I,W). \tag{3.11}
\]

Goods demands With each possible combination of goods (both public and private) and time, the household's technology determines a set of commodity vectors (e.g., there can be more than one vector of commodities produced for any vector of goods.) The optimal
commodity vector $Z^*$ from each set of vectors is the one which maximizes the utility function for the commodities $U(Z)$. Hence, the utility function $Y(X,E,L)$ is defined over goods space by associating each utility level $U(Z^*)$ with the relevant bundle of public and private goods associated with $Z^*$. Maximizing the newly defined utility function $Y(X,E,L)$ subject to the budget constraint $P_X = T^w + A$ yields the vector of goods demand functions $D = D(W,A,P)$.

**Difficulties in commodity demand estimation** The above goods demands estimation indicates the potential use of the household production framework in valuing nonmarket goods. However, the analysis relied on the two important assumptions of constant returns to scale (CRS) and no joint production. Muellbauer (1974) has shown that unless there exist CRS and no joint production, the marginal costs of commodities would not be constant and, thus, (3.10) would no longer hold. On the same point, Pollak and Wachter (1975) emphasize that because of the presence of either joint production or non-CRS, a vector of optimal commodity prices, not only reflect the household's tastes, but also the technology. Joint production is likely to be the rule especially in recreation models where time is often both a good used by the household in production and a commodity directly entering the household's utility function (Pollak and Wachter, 1975).

Before tastes, hence commodity demands, can be revealed, technology must be determined. Without knowing the commodity's production

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1Joint production occurs when a good enters two or more commodity production processes at once or enters the utility function directly besides the production process(es).
technology, the implicit price of the commodity to the household cannot be known. Once a commodity's production technology is known, changes in the goods market can be correlated to changes in the (implicit) commodity price thus outlining the commodity's demand. Further, the effect on the quantity of the commodity demanded from a change in the availability of a public good can be valued. Hori (1975) and Bockstael and McConnell (1981) show how benefits from changes in availability of public goods may be estimated when the household production technology is known. However, the difficulty lies in estimating the technology.

Three approaches have been proposed to measure the household's technology. Two of the approaches apply a direct estimation of the household's technology while the third solves commodity supply and demand simultaneously thus estimating technology indirectly.

Direct technology estimation

Pollak and Wachter (1975) outline both of the methods for direct technology estimation. The first method uses data on the inputs — X, T, E — regressed against data on the outputs — Z to derive the production function. For example, consider estimating the technology of an automobile plant. By observing the relationship between the units of inputs (e.g., pounds of steal, hours of labor, etc.) and the corresponding levels of output, the technology (e.g., returns to scale) is determined. The second approach is to estimate either the total or the marginal cost function of the commodities using observations on input prices, P, and the level of outputs, Z, whereby technology is revealed through the cost function. Again using the auto plant as an example, observations on the changes in
prices of inputs and total or marginal cost and the corresponding effect on output will also reveal technology. Both of the household technology estimation methods are analogous to procedures used in neoclassical production economics. However, both of these methods can be applied only when the commodities (the $Z_i$'s) are observed or when proxies are available. When the commodities or their proxies cannot be observed, the indirect estimation of technology suggested by Pollak and Wachter (1975, 1977) and Barnett (1977) offers a second approach to technology estimation.

**Indirect technology estimation** Even when commodities are not observed, tastes and technology can be separated by estimating the complete system of production and consumption parameters. Given proper model specification and econometric procedures, the resulting functions will have standard neoclassical properties.

To obtain a measure of the household's tastes under this methodology, return to the vector of commodity prices $V$ in (3.9).¹ A hyperplane of commodity shadow prices may be defined around any $Z^*$ as $V^* = V(P, Z^*, W)$. Commodity demands as functions of $V^*$, $I$, and $W$ can be obtained by allowing the consumer to reselect $Z$ by maximizing $U(Z)$ subject to

$$V^* Z = I$$ \hspace{1cm} (3.12)

¹Without the assumptions of CRS and no joint production, $V$ now becomes a function of the commodity bundle chosen (as opposed to (3.9)).
where $I$ is the full income constraint as defined by (3.8). Solving for $Z$ in terms of $I$ and $V^*$ allows an implicit demand function for $Z$ to be written as $K(Z,V^*,I) = 0$. (The first order conditions originating from this hypothetical maximization are the same as those in the actual maximization. Therefore $Z^*$ is again selected and the implicit commodity demand is $K(Z^*,V^*,I) = 0$). Generalizing commodity prices (i.e., substituting $V$ for $V^*$) allows the commodity demands to be written as:

$$K(Z,V,I) = 0. \quad (3.13)$$

To obtain a measure of technology at $Z^*$, define the "constant-commodity-consumption goods demand functions $F_j$ (and $F$ being a $m \times 1$ vector of the $m$ demands, one for each good) which determine the cost-minimizing goods consumptions quantities at given $(Z,P)$" (Barnett 1977, p. 1076). The homogeneity of $F$ in $P$ and Euler's Theorem indicates that the cost function can be determined from $F$. Therefore, by Shepherd's Lemma we know that $F_j(Z,P) = \left[\frac{\partial C(P,Z)}{\partial P_j}\right]$ where $P_j$ is an element in the price vector $P$. The goods demands will be a function of their prices and of the cost minimizing selection of $Z$ and so can be expressed as:

$$X = F(Z,P). \quad (3.14)$$

Joint estimation of (3.13) and (3.14) separate tastes from technology. Parameters of (3.14) capture the household's technology whereas those of (3.13) reflect the household's tastes. Joint estimation will not require observations on commodities.

\(^1\)By fixing the commodity prices at $V^*$ (3.12) holds.
As Pollak and Wachter (1977) point out, the use of this simultaneous system is restricted to cases where a complete estimation of the structural parameters is possible. Estimation requires observations on the large number relevant parameters and, therefore, an appropriately large sample. This can be so limiting as to make implied factor demand analysis impracticable.

Given the above complications in demand estimation, Pollak and Wachter express their doubt of the usefulness of the household production approach. Even when the household's technology is determined, the prices of the commodities are a function of the commodity bundle chosen. They argue that simultaneity of the household production and consumption decisions forces commodity prices to be dependent on both tastes and technology. The consumer will no longer be a price taker, hence traditional demand theory breaks down. Pollak and Wachter recommend dispensing with commodity prices and instead estimate commodity demands as a function of goods prices (thus, admittedly, confounding tastes and technology).

Bockstael and McConnell (1983) refute Pollak and Wachter's suggested use of goods' prices for commodity demand estimation by asserting that, with the nonlinear budget constraint, predictions cannot be made about the signs of the commodity demand coefficients (when estimated using goods' prices). No useful restrictions can be

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1Recall that the budget constraint is the limit on the household's full income. Thus, if the household's production technology does not exhibit CRS and no joint production, a linear budget constraint cannot be assured.
made on the commodity demand systems with the Cournot and Engel aggregations because the cost function $C(P,W,Z)$ will not be linearly homogeneous in $Z$. And, because changes in $Z$ (the commodity sector) can be expected whenever $P$ (goods prices) change, the resulting change in $C(P,W,Z)$ cannot be determined. Therefore, no Marshallian demand function can be estimated.

**Gains in the commodity market derived in the goods market**

Given the undefined Marshallian demand functions for commodities, Bockstael and McConnell show how a utility constant measure of welfare may theoretically be obtained in the commodity market. This measure of welfare is represented graphically (in commodity space) by the area between the compensated marginal value and the marginal cost curves of the commodity. But a welfare measure in the commodity market means little unless it has a corresponding measure in the goods market.

Bockstael and McConnell further demonstrate that when there exists a good which is essential in the production of the commodity, goods space can be used to derive equivalent and conceptually valid, yet empirically feasible, measures of welfare change. As will be explained later, the goods market measure of a change in welfare is the compensating variation measured by the essential good for a change in the availability of the public good. By establishing the link to compensated variation in the goods market, all the neoclassical properties of the households' measures of welfare change are restored.

The discussion which immediately follows describes the derivation of the utility constant measure of welfare obtained in the commodity
market. Subsequently discussed is the derivation of the corresponding measure in the goods market.

**A welfare measure in the commodity market** As was previously shown, the nonexistence of Marshallian demands for commodities results from the nonlinear budget constraint created by the household's technology. However, the compensated marginal value function for a commodity can be derived from the dual of the utility maximization problem in (3.4) through (3.8). Because this function is derived by holding utility and not income constant (thus, becoming a cost minimization problem), the complications associated with the household's nonlinear budget constraint are eliminated.

Consider first that the household's production technology will determine the cost function for \( U^* \). Then, minimizing this cost function, \( C(P, W, Z) \), subject to \( U = U^* \), an expenditure function, \( S(Z_1, P, U^*) \), is defined for any commodity (in this case \( Z_1 \)) by

\[
S(Z_1, P, U^*) = \min_{Z_1} \{ C(Z, W, P) | U = U(Z) \}
\]  

(3.15)

when solved across relevant levels of \( Z_1 \). From (3.15) the change in expenditures necessary to maintain the same level of utility for any change in the level of \( Z_1 \) is given by \( \partial S/\partial Z_1 \). Integration of this marginal function gives the total amount of income necessary to

\[\text{1From the envelope theorem we know that this marginal value will be represented by the negative difference between the compensated marginal value of } Z_1 \text{ at its new level with all other } Z_i \text{'s adjusted optimally and the marginal cost of } Z_1 \text{ at this same point. Or,}
\]

\[
\frac{\partial S}{\partial Z_1} = -(\mu U_1^*(Z, U^*) - C_1(Z, P))
\]

where \( Z \) represents the conditional level of \( Z_1 \) and all other \( Z_i \) (which can adjust).
compensate for a change in $Z_1$ across the range of integration. For example, if the household were to obtain $Z_1^*$ after having no $Z_1$ previously, the amount of income which would be forgone to still maintain the same level of utility $U^*$ is given by:

$$\int_0^{Z_1^*} \left[ \frac{\partial S(Z_1^*, P, U^*)}{\partial Z_1} \right] dZ_1 = S(Z_1^*, P, U^*) - S(0, P, U^*). \quad (3.16)$$

Theoretically what has been estimated is the consumer and producer surplus of the household in the production and consumption of $Z_1^*$ or the area behind the compensated marginal value function excluding the area under the marginal cost function. It is not possible to derive a traditional expenditure function such as a Marshallian demand or an independent compensated demand for the commodity because of the lack of fixed commodity prices. (Remember, commodity prices are determined implicitly from the commodity's marginal cost function which in turn depends on the household's commodity production technology.) This theoretical welfare measure defined in commodity space captures the household's surplus in the production and consumption of $Z_1^*$ at the given set of good's prices/availability, income, and technology.

Now consider why the prior problems of joint production and no CRS have been circumvented. As described before, the technological problem of no CRS is reflected by the nonlinearity of the budget constraint (which stemmed from variable commodity prices), hence allowing no demand measure analogous to Marshallian demand. The expenditure function is derived by constraining utility, not the household budget. With no income constraint required, the problems of nonconstant marginal costs are avoided. Thus, the lack of CRS poses no problem.
To apply the household surplus measure in (3.16) to valuing a public good, the appropriate commodity, \( Z \), must be dependent on that public good. For example, suppose \( Z \) is a recreational fishing experience dependent on, among other things, an environmental public good such as the fishing quality of a stream. If the variation in the production of \( Z \) in the above analysis is due to the variation in streamflow (given that the rate of streamflow affects fishing quality) the welfare measured (in commodity space) represents that value of the change in streamflow.

Some complications occur when the use of a public resource by a household involves joint production\(^1\) (which is not uncommon in the household's use of a public resource). For example, the use of a public fishing site on a stream can act not only as an input in the production of a recreational fishing commodity, but other characteristics of the site (such as the natural environment or the chance of siting wildlife) may also enter the household's utility function directly (hence, joint commodity production). Should joint production occur, an additional assumption is required in order to define the theoretical welfare measure of commodity space. The discussion below explains why an additional assumption (that the environmental good be weakly complementary to the commodity) is required and what conditions it imposes on the relationship between the commodity and the public good.

\(^1\)Joint production can also cause the budget constraint to be nonlinear. For the same reasons mentioned above for no CRS, this is not a problem. What is being discussed are other problems created by joint production which will require specific assumptions.
First, however, a situation of joint production with an environmental good is defined.

Let streamflow be formally defined as an environmental public good E. Also, let E, again, be a good used to produce the commodity \( Z_1 \), a day of recreational fishing, but now assume that utility is also derived directly from E (e.g., \( U(Z) \) now becomes \( U(Z,E) \)), consequently, a situation of joint production. For example, suppose the same environmental good, E, which the household uses to produce the fishing commodity, generates utility directly to the household because it provides an opportunity to view wildlife in their natural setting. Now, with joint production, the expenditure function becomes \( S(Z_1, P, U^*, E) \), a function of E and \( Z_1 \). Because \( Z_1 \) is a function of E, should the availability E change from \( E'' \) to \( E' \), the households adjust their consumption/production of \( Z_1 \) from \( Z_1*' \) to \( Z_1*' \). The difference between the consumer/producer surplus at these points measures the welfare change, or

\[
S(Z_1*' ', P, U^*, E') - S(0, P, U^*, E') - S(Z_1*' ', P, U^*, E'')
+ S(0, P, U^*, E').
\]

An application of (3.17) would be a situation where a stream, already depleted to 80 percent of its natural flow, is depleted five percent more by an upstream irrigation project. This depletion of streamflow lessens the available habitat for fish and other wildlife, lowering their populations and lessening the chances of catching a fish or of viewing wildlife. Before the irrigation project begins, the representative household consumes/produces the utility maximizing amount of the commodity (represented by \( Z_1*' \)) subject to its constraints.
including the availability of $E'$. At this level of $E$, the household's welfare in producing/consuming $Z_1$ is represented by the negative of the last two terms in (3.17). Diverting the streamflow lowers the availability of the environmental resource from $E'$ to $E''$. At $E''$ the household (again maximizing utility subject to its constraints) produces/consumes $Z_1^{*''}$. The household's welfare in producing/consuming $Z_1$ at this point is represented by the first two terms in (3.17). Thus, (3.17) represents the change in the household's consumer/producer surplus obtained in the production/consumption of the fishing day commodities at the two different levels of availability of $E$.

The ultimate goal is to establish a link between a measure of welfare in the commodity market with a change in welfare measured in the goods market and, thus, to value a public good. Equation (3.16) provides a theoretically sound measure of welfare in the commodity market-independent of the unobserved commodity prices. Equation (3.17) extends the measure in (3.16) to a case of joint production and further defines how a change in welfare can be represented in the commodity market when the availability of a public resource, such as streamflow, changes. Before equating this commodity market welfare measure to one in the goods market, equation (3.17) needs to be further simplified.

Given joint production, a sufficient condition for eliminating two of the expenditure values in (3.17), $S(0,P,U^*,E'')$ and $S(0,P,U^*,E')$, is

\[^1\text{Recall that (3.16) represents a welfare measure of } Z_1^* \text{ at its current equilibrium level. Equation 3.17 is measuring the difference in the welfare measured at two equilibrium levels of } Z \text{ (and thus measures a change in welfare due to a change in } E).\]
that $E$ be weakly complementary to to $Z_1$. Weakly complementary implies that the household be indifferent to varying levels of $E$ when no $Z_1$ is consumed.\footnote{Each of these expenditure functions represents the compensation the individual would need to maintain $U^*$ for variations in $E$ though no $Z_1$ is being produced/consumed.} In the previous example, weakly complementary would require that the household be indifferent to varying levels of streamflow ($E$) if the household is not consuming any of the fishing commodity ($Z_1$). Thus, if $E$ is weakly complementary to $Z_1$, 

$$S(0, P, U^*, E') = S(0, P, U^*, E').$$  \hspace{1cm} (3.18)

Another approach to understanding why (3.18) is consistent with the weakly complementary assumption is to first realize that the only difference in these two expenditure functions is in the availability of $E$. And second, remember that the household is indifferent to changing levels of $E$ when no $Z_1$ is consumed (by assumption). Thus, any variation in $E$ when no $Z_1$ is consumed has no effect on the household's expenditure decisions (function).

When there is no joint production in a situation where $E$ is only used to produce the recreational commodity $Z_1$ (such as in (3.16)), $E$ does not enter the expenditure function directly and (3.18) (as it represents the expenditure function when no $Z_1$ is consumed) must hold.

Measures in the goods market  In order for (3.17) to have a practical application in evaluating a change in an environmental good, an equivalent measure to (3.17) must be found in the commodity market. At one point on the expenditure function for $Z_1$, $S(Z_1(P, U^*), P, U^*, E)$, $Z_1$ is adjusted optimally (as in the first order conditions of (3.4) through
(3.8)). At this point $\partial S/\partial Z_1$ equals zero and the expenditure function reduces to the traditional expenditure function $M(P,U^*,E)$. Applying this information and (3.18) to (3.17) reduces the welfare measure to a measure of compensating variation (CV):

$$CV = M(P,U^*,E'') - M(P,U^*,E')$$

(3.19)

and thus provides the link between the commodity market and the goods market. This is a money measure of the compensation necessary to maintain the same level of utility for a change in the availability of $E$ from $E'$ to $E''$. As with $S$, the expenditure function $M$ is also derived from a dual of the utility maximizing problem outlined in equations (3.4) through (3.8). However, whereas $S$ represents the expenditure function for a commodity, $M$ represents the expenditure function for $E$, the environmental public good. Though $M$ establishes a link between the theoretical measure of welfare in the commodity market with an expenditure function in the goods market, the equality of these measures must be clarified.

Because the expenditures are linear in the $X_i$'s, the compensated demand for any good can be obtained by differentiating the expenditure function with respect to its price. Define the good $X_1$ as an input in the production of $Z_1$. The compensated demand for $X_1$ is derived by:

$$X_1(P,U^*,E) = 3M(P,U^*,E)/3P_1.$$

(3.20)

Using this compensated demand, an empirically valid measure of (3.19) is derived.

Define a price $P_1(P,U^*,E)$ as the price of $X_1$ where the quantity demanded on the compensated demand function is zero. Note that $P$
represents the prices for all commodities other than $Z_1$. With $P_1$ thus defined, the area under the compensated demand curve above $P_1^*$, the current price of $P_1$, can be estimated by integrating the compensated demand from $P_1^*$ to $P_1$. This area represents the difference in the expenditure function at these two points or,

$$\int_{P_1^*}^{P_1} X_1(P, U^*, E_1) dP = M(P_1, P_1, U^*, E) - M(P_1^*, P_1, U^*, E). \hspace{1cm} (3.21)$$

Keeping in mind the measure of welfare in (3.21), consider the two expenditure functions of (3.19), $M(P, U^*, E')$ and $M(P, U^*, E'')$, derived when the availability of $E$ is $E'$ and $E''$, respectively. (Remember, these two expenditure functions have their analogous commodity market welfare measure.) There is a compensated demand for $Z_1$ associated with each of these expenditure functions. The difference in the area under these two compensated demand curves represents a change in welfare for a change in $E$. When $E$ changes from $E''$ to $E'$ the change in welfare will be given as,

$$M(P_1, P, U^*, E'') - M(P_1^*, P, U^*, E'') - M(P_1^*, P, U^*, E') + M(P_1^*, P, U^*, E'). \hspace{1cm} (3.22)$$

$E$ enters the expenditure functions in (3.22) directly and through the zero-quantity-demanded prices $P_1$ (as functions of $P$, $U^*$, and $E$). Under certain conditions the expenditure functions $M(P_1, P, U^*, E'')$ and $M(P_1, P, U^*, E')$ of (3.22) are independent of $E$. Under these conditions

$$M(P_1, P, U^*, E'') = M(P_1, P, U^*, E'). \hspace{1cm} (3.23)$$

and the compensated variation given in (3.19) follows from (3.22) and (3.23). Thus, (3.23) represents a dollar measure of welfare equivalent to the welfare measure in (3.17).
The two conditions which allow (3.23) to hold are:

(i) For all commodities in which E is used as an input (Z^), \( \delta U/\delta E = 0 \) if all Z in Z^ equal zero;

(ii) \( X_1 \) must be an essential input in the production of all Z^.

These conditions imply that the individual will be indifferent between varying levels of E when no X_1 is purchased, therefore (3.22) must hold.

Condition (i) means that the household is indifferent to variations in E when none of the commodities which use E as an input (Z^) are produced/consumed. This condition holds trivially when E only enters the production function. Should E enter the utility function, then this condition requires the same weak complementary condition required to derive a welfare measure in the commodity market (note, however, that in this case, this condition must hold for all commodities using E as an input, not just Z^). Condition (ii) means that there must be a market good so essential in the production of the commodities Z^ that the household can produce these commodities only after purchasing this market good (X_1), no matter how much E is available.

For example, if E again represents the level of natural streamflow within a stream (and the associated habitat), Z^ will represent not just the fishing day commodity Z_1 but other commodities using E in production such as a canoeing commodity done while fishing or a commodity associated with camping by the river. Condition (i) means that if the household does not produce any of these commodities, it will be indifferent to changes in streamflow levels. Condition (ii), in this case, requires that in order to produce the fishing day commodity, the
canoeing commodity, or any other commodity where streamflow provides an input, there be a market good which must be purchased before these commodities can be produced by the household. Where a fishing license or fishing equipment may look like they fill this purchased good requirement for the fishing commodity production, they only represent the purchase of fixed inputs (hence, start-up costs) for the fishing commodity production (but those inputs may not be used to produce all of the commodities in $Z_g$). Canoe rentals or purchases represent the purchase of an essential input in canoeing, but the purchases fail to represent an important input into the production of the fishing day commodity. The cost of travel to these sites (when appropriately accounting for the cost of the household's travel time) appears to represent the only possible essential input which condition (ii) requires. Where condition (i) appears applicable to the different streamflow uses, condition (ii) does not appear to be met through a direct purchase of a market good, but instead requires sufficient data to estimate travel as an input cost.

Summary of household production theory

Attempts to measure welfare gains within the household production approach through Marshallian demand estimation have been shown to be successful only under very limiting conditions. The presence of joint production or non-CRS confound the determination of tastes and technology because commodity prices no longer represent a parameter to the household in its commodity selection decisions. To ignore technology and estimate commodity demands only as a function of goods prices may
have some computational ease but, without knowing the household's technology, there is no way to know a priori the sign on such demand estimates.

Bockstael and McConnell (1983) propose an alternative approach to measuring the welfare change stemming from the change in the availability of a public good. By estimating a utility constant welfare measure in the commodity market, the ill-fated Marshallian demand functions are avoided. When the public good is weakly complementary to the commodity(ies) produced, welfare changes in the commodity market due to changes in the availability of the public good will equal the change in the area under the compensated demand curve of a good that is essential as an input in the commodities' production for the same change in availability of the public good.

Household Production Theory and the Value of Streamflow

The household production approach to estimating the value of marginal changes in streamflow requires the condition that there be a market good which is an essential input in the production of all commodities where streamflow acts as an input. No such market good is known for this particular case. As will be made cleaner in Chapter IV, the data available do not provide sufficient information to determine the cost of travel. Advantages of the household production theory include its ability to estimate the value of a public good not defined by a site or by a set of specific sites. This approach also provides a theoretically sound welfare measure. The disadvantage of the theory is that condition (ii) above, required to link the welfare measure within
the commodity market to that within the goods market, cannot be met for a direct value estimation of streamflow. However, though a value can not be determined directly, a reduced form equation for the household's production of the fishing day commodity (proxied by days fishing) can be employed to determine the response of households to variations in streamflow. By applying the value of a day fishing determined in other studies to the households' response to changes in streamflow, the value of streamflow as an input in the fishing commodity production can still be determined.

Theory application

To value streamflow as a public good for fishing, the relevant commodity and goods must be defined. The commodity which the household produces/consumes might be called a "fishing experience, entertainment, relaxation, challenge, sport." The commodity is not observed therefore no common name exists but, it is analogous to the $Z_1$ of the previous discussion. There are many ways $Z_1$ can be explained but the point behind any explanation is that this commodity entering the household's utility function is derived from recreational fishing.

The production of $Z_1$ will rely on the availability of a publicly controlled environmental good -- streamflow. The amount of water within a stream alone does not act as an input in the production of $Z_1$ but the streamflow affects fish production and thus affects the household's ability to produce $Z_1$. Chapter II explains the biological relationship
between streamflow and fish availability. Streamflow will be the environmental variable, $E$, to be valued.

There must be a market good which is essential in the production of $Z_1$ if a measure of welfare change from a streamflow change is to be obtained from the goods market. Stream fishing can be done with the most rudimentary equipment, thus complicating the clarification of the essential market good. Also, most equipment acts as capital which further complicates the association of an essential good $X_1$ with the commodity $Z_1$. More problematic though, is that $E$ enters into the production of many other commodities.

**Problems**

The commodity set associated with streamflow is large and diverse. Chapter II discusses some of the many public benefits attributable to the flowing water in streams. Each of these benefits comes from consumer and producer surplus of the commodities which use $E$ as an input (or from welfare gain where $E$ enters the utility function directly). All will enter the commodity set $Z_E$. In order for (23) to hold, the good $X_1$ must be an essential input into all of the related production functions. It is unlikely that any good exists which can serve this role. Therefore, direct valuation of the fishing benefits (or total benefits) of streamflow cannot be estimated by way of the household production approach.
An alternative

The above problems indicate that there will be no way to use observed household responses in the goods market to obtain the value of streamflow as a fishing resource. It is still possible to obtain some information on the household's preference by estimating a reduced form equation of the household's production of $Z_1$, the fishing experience, with days fishing as a proxy for the commodity being produced. Recall that commodities are not observable but inputs are observed. Time spent fishing represents the quantity of time (an input) used in producing the fishing commodity. Assuming the fishing commodity to be homogenous of degree one with respect to time fishing, then time fishing can serve as a proxy for the level of fishing commodity production. By regressing the commodity proxy against the household's factors of production and their determinants of demand for the commodity, the influence which changes in streamflow has on the production/consumption equilibrium output can be estimated.

To translate the change in activity into benefits, the value of the activity must be known (e.g., the value of a day fishing). As marginal changes in streamflow occur, the commodity supply curve will shift down. The marginal unit value of a day fishing must be applied to estimate the value of the increase in the activity.

The available estimates on values of fishing days can fall anywhere along a spectrum of production input availability. In situations where the availability of factors for producing the fishing commodity are scarce, the marginal value of another commodity will be higher than in
situations where the commodity inputs are plentiful. Not knowing how large the variation is in the valuation spectrum and where the household lies within the spectrum makes the use of an average consumer surplus an appealing approximation. A heuristic argument for such an approach can be found in Vaughan and Russell (1982). The accuracy of this approach to valuing a fishing day is briefly summarized below.

(i) If the actual demand representing the household's value of a day fishing is linear, then the use of an average fishing day value will understate the benefit of an increase in streamflow, with the understatement worse the greater the change in fishing days. For small changes in individual response, the approximation is very close to one half the actual increase in consumer surplus.

(ii) If the actual demand of the household is characterized by constant price elasticity, the approximation is less accurate as the change in the streamflow gets larger. The approximation will overstate benefits for low price elasticities, be very close for elasticities close to 1.5, and understate benefits for higher price elasticities. As an example, should the elasticity equal one and the change in streamflow affect days fished by less than five percent, the approximation will overstate the actual benefit by about 30 percent.

The average values of consumer surplus to be used are discussed in the next chapter.
Summary

The purpose of this chapter was to clarify and justify application of the household production theory as a method to determine the value of streamflow in recreational fishing. Given the data available and global nature of the valuation to be undertaken, the household production approach was shown to be the most theoretically applicable. Though direct (compensated) demand estimation for public goods is possible using household production theory, not all conditions can be met to allow a direct demand estimation for streamflow as a fisheries resource. This problem does not require that the household production approach be disregarded. Instead, application of a reduced form equation of the household's commodity production/consumption relates changes in the availability of the public resource to changes in the equilibrium commodity production/consumption. With days fishing as a proxy for the commodity being measured, the regression results relate changes in streamflow to changes in days fishing. Chapter IV lists values of days fishing obtained in previous studies through such approaches as the travel cost method or the contingent valuation method. Thus, with the estimated effect of streamflow on days fishing and with the value of a day fishing from other studies, the value of water as an instream resource is estimated.
CHAPTER IV

The modelling of the household's behavior toward the production/consumption of the fishing commodity is guided by the theoretical propositions of Chapter III and by the nature of the available data. The data used in this analysis have come from a number of sources. The fact that this is a national model of fishing behavior requires national data sets. Relevant variables from these data sources will be either demand determinants or factors in the household production function. Such large-scale data gathering has been done for a number of purposes, however none specifically for the problem at hand. Because of this, two problems arise. First, not all demand determinants nor supply factors are available from the known data sets. And, second, the data available require some computational manipulation to derive variables reflecting the parameters of the situation at hand. This chapter describes the data sets available, the derivation of some necessary variables, the division of geographical regions where the data are applicable, and how the independent variables in the regression analysis represent supply and demand determinants within the geographical regions.

Available Data

The following is a list of the data sets used to determine how changes in streamflow affect the household's production/consumption of the fishing commodity. No single data set can be called "the most important." Each of the first four listed below provide essential bits
of information in determining fishing day responses to changes in streamflow. Further, the estimates of fishing day values are essential in attaching a value to instream flow as a fishing resource.

The second part of this chapter explains the computational manipulations required of the data to make it of use in this analysis. But, first, a brief description of each data set used, its source and its organization is provided.

Data

FHWAR The 1980 National Survey of Fishing, Hunting, and Wildlife Associated Recreation (FHWAR) (Bureau of the Census) provided the information on fishing participation. Information on fishing participation came from two surveys (thus generating two data sets) within the FHWAR analysis. First, a screening survey identified fishing participants from the continental U.S. population at large. The second survey followed up on the first by selecting a subsample of participants to address more specific questions on their fishing activities.

The screening sample, FH2, interviewed 143,000 households for a total of 340,032 individual observations. Sixty percent of the interviews were conducted by phone and forty percent by a visiting interviewer generating a national response rate of 94.6 percent. Information on household and individual characteristics and on their general level of outdoor recreational participation in 1980 was obtained from this sampling. Questioning was completed in March of 1981.
The participation sample, FH3, was obtained through follow-up visits to those who indicated participation in the screening sample. A total of 35,615 observations were obtained for a 90 percent response rate from those selected for a follow-up interview. This follow-up survey associated the participants' previous responses with their additional responses to questions dealing specifically with their 1980s outdoor activity. The follow-up questions were to determine such things as: where a person fished, how many days the individual fished, the kinds of fish sought and the amount of equipment purchased. The sampling for these questions was completed in June of 1981.

The Water Resources Council initiated the Second National Water Assessment (SNWA) in October of 1974 to provide nationally consistent data on current and projected water use and supply and on existing or emerging critical water problems. In analyzing the water data, the WRC used 1975 as a base year of the estimates and made projections for 1985 and 2000. For the purposes of the SNWA and for statistical reasons, the continental U.S. was divided into 99 hydrologic regions called Aggregated Subareas (ASAs). These ASAs correspond to the various river drainage basins across the U.S. (Return to Figure 1.2 for another outline of the ASAs.)

The SNWA provides data on the current streamflow within ASAs, the level of flow considered to be a natural flow, and the projected change  

A preliminary analysis of the data indicated that there may have been some misclassification of participants in the screening survey thus lowering the actual follow-up response rate to 81 percent.
in water consumption. The U.S. Geological Survey (USGS) currently has gauging stations on all major waterways throughout the U.S. These stations have been estimating streamflow for many (some over 100) years, and so provide a reliable estimate of flow variation within and across years and the flow rate for an average year. County-level socioeconomic data (both current and projected) compiled to the ASA level provided the WRC means to estimate water consumption occurring within each ASA and to project future consumption rate. The SNWA combined the information on flow rates with that of the consumption rates to derive the natural flow rates of water within the river systems (that is, the flow that would occur if there were no effects by man). From the projected water consumption rates, future flow rates were projected.

Field employees of the Soil Conservation Service began collecting data for the National Resources Inventory (NRI) (U.S. Department of Agriculture, Soil Conservation Service, 1984) in the spring of 1980 and concluded their retrieval of data in the fall of 1982. The NRI was designed to collect the most complete set of data on soil and water resources possible given available staff and funding. This inventory was designed to obtain natural resource data usable for analysis at a substate (multicounty) level. Items in the NRI relevant to a study on stream fishing quality include data on the riparian vegetation of streams and lakes and the surface area of streams and lakes. Data are given at the county level thus allowing its aggregation according to any desired collection of counties.
Other sources of data have been used to obtain more minor pieces of information. Given the minor importance or common nature of these data sets, only a brief discussion will be given of each.

To determine the number of people who may be affected by a change in water policy, a measure of population within a region was needed. Population estimates by county from the 1980 Census (U.S. Department of Commerce, 1981) serve as a base measure from which to determine the regions' populations.

The U.S. Weather Service has information available on the average monthly temperature from 1945 to 1970 (U.S. Department of Commerce, 1973). The averaging of January temperatures over this number of years allows an indication of the climate for each of the regions.

The U.S. Department of the Interior, Fish and Wildlife Service provides information on the portions of water within states as being warmwater or coldwater in "National Survey of Hatchery Fish" (1968). Though this is an older data source, it is the most recent found which contains this desired information.

The value of water in its consumptive use in agriculture (irrigation) will be used to compare against the instream value of water as a fishing resource. The consumptive value comes from the 1985 CARD/RCA model and will reflect the 1982 value of water to agriculture. The output levels and cropping patterns suggested by the 1982 run of this linear programming model are compared to the actual output levels and cropping patterns as a test of the model's
performance. This run also provides the shadow price of water to agriculture that year, thus providing an estimate of water's consumptive use value.

**Fishing day values** Several studies have attempted to estimate the value of a day of recreational fishing. John Loomis (1983) provides an overview of several of these studies. What's more, he discusses the failures in some procedures used to derive the day-value estimates and proposes adjustment factors to correct for these estimation errors.¹ Charbonneau and Hay (1978) provide two fishing day-value estimates each obtained through different approaches. Together these studies provide the results of 11 different attempts to estimate the value of a day of fishing.

No single study provides the "right" value of a day of recreational fishing. By examining the range of values resulting from the eleven studies at hand, and correcting specific studies for their weaknesses, some indication of an applicable range of values is determined. More specifics on these fishing day values are covered in the following section.

¹The basic research on determining the size of the adjustment factors in Loomis (1983) was performed under contracts 40-82-FT-2-242 and 714, in cooperation with Land and Resource Management Planning Research Project (RM-4101) and Valuation of Wildland Resource Benefits Research Project. A twelve-member panel composed of professionals in research, academia, and government assisted the efforts of Loomis in determining the size of the adjustment factors. While the complications of obtaining the "right" adjustment factor is formidable (if even possible), the judgement by this group seem reasonable and applicable for the value adjustments necessary in this study. For a list of the panel members see Loomis (1983, p. 56).
A consistent fishing day value

If each approach used to estimate the value of a day of recreational fishing is theoretically sound, the values generated should be approximately the same for similar types of recreational fishing experiences. However, within some approaches, critical factors were not considered or applied, thus, contributing to some variations of the values estimated. These and other factors causing variations in benefit estimates are listed below:

1. The year the data were collected not only affects the nominal value of the estimates but also implies a real difference in travel costs.

2. Omitting the value of travel time in travel cost studies ignores a significant cost of travel.

3. The units used to measure recreational output, i.e., days, trips, hours, etc., vary among studies.

4. Bias can result from the method of data collection, such as when only users are surveyed, if the analysis is not properly applied and/or the results are not properly interpreted.

5. The variation in the quality of the sites can lead to a different day value estimate at each site.

6. The availability of substitute recreational opportunities and the concentration of the surrounding population can lead to different value estimates across regions.

The more important of these points will be covered in some detail as the corrective adjustments on fishing day values of the various
studies are explained. The corrective adjustments applied to the studies listed in Loomis and in Charbonneau and Hay are consistent with those adjustments of Loomis (1983). What follows is a listing of these adjustments and an explanation of their magnitude.

**Travel time** Full consideration of an individual's travel costs must include not only the explicit travel expenses but also the implicit cost of the individual's travel time. Much of the recent literature concerning an adjustment for the omission of travel time when the travel time is known recommends using a value of time somewhere between one fourth to one third of the hourly wage rate. McConnell and Strand (1981) in a sport fishing application found the cost of travel time to be represented by 60 percent of the hourly wage rate. A similar procedure was used by Ward (1982) to find the value of travel time, in general, for southeastern New Mexico (which averaged $7.10 per hour). A precise value for an hour of travel is not known, indeed it likely varies according to the length of the trip, the scenery, the traffic, and other such factors. Further, this procedure only becomes applicable when the travel time is known or estimable.

Another approach to impute travel time cost estimates the portion travel time cost represents of the total trip cost. The value travel time estimated this way still depends (indirectly) on the value of an hour of travel. For example, Ward (1982) found that including travel time increased benefits by 60 percent when 40 percent of the wage rate was used as the travel time cost. A benefit adjustment as a percent of the present benefit has the appeal of ease in implementation. Loomis
used a 30 percent adjustment factor to remove the downward bias caused by travel time omission in travel cost studies. This same 30 percent adjustment factor will be applied here.

**Collection biases** Two approaches in gathering data lead to two possible biases occurring in demand estimation in application of the travel cost method. The first occurs when the survey approach is to question the population at large but fails to include the entire area influenced (e.g., out-of-state users are omitted). The second data collection approach surveys only the participants (e.g., visitors at the site) biasing the sample because of the exclusion of nonusers. A correction for bias is made in each of these cases.

When the population sampling fails to include the entire population influenced, benefit estimates are biased downward (see Loomis, 1983, p. 62). Such a situation occurs in one of the travel cost studies where no out of state users/potential users were sampled. The 15 percent upward adjustment suggested by Loomis (1983, p. 68) is applied here.

In two of the TC studies, only those visiting the site were surveyed. This approach provides a user response measure but not a measure of the change in likelihood of participation. Loomis, in following the work of Brown, Sorhus, Chou-Yang, and Richards (1983), suggests that the values estimated with this type of TC approach be adjusted downward 30 percent (Loomis, 1983, pp. 62-65). This same adjustment is followed here.

**Year adjustments** Dollar amounts across different years cannot legitimately be compared. By standardizing the dollar values to a
specific year, comparisons between the value estimates can be made. While there is no exact measure to adjust for nominal price changes of any one commodity, the GNP price deflator, which is the inflation indicator based on the largest aggregate of prices, offers the best alternative. Because the FHWA survey and the Census both represent 1980 values, all dollar values are adjusted to this year.

Recreational units The unit of recreation used in this study is a day of recreational fishing. Determining water's value as an instream resource from its affect on days fishing requires the value of those days fishing. Fishing day values have been estimated for fishing in general; for fishing coldwater, warmwater, and rough fish;¹ and for fishing a particular species of fish. Fishing day values vary according to particular sites, among states, across species, and through coldwater-warmwater-rough fish classification. Some indication of a hierarchy of fishing day values among species is illustrated in results reported by Charbonneau and Hay (1978, pp. 394 and 396). In general, warmwater fishing ranked five to ten percent lower in value than coldwater fishing. "Other" or rough fishing ranked ten to 25 percent lower than coldwater fishing. For consistency, the values in the table below reflect those estimated for days of coldwater (trout) fishing.

Even with corrections applied to each fishing day value estimate of the different studies, variation in day values of fishing still occur. Most of these values lie in a ten to 20 dollar range. By using this

¹Rough fish refers to types of fish which are less popular fish among U.S. anglers. This includes such fish types as carp, catfish and suckers.
range of day values to estimate the value of water as a fisheries resource, the corresponding range in acre-foot water values is determined.

The values from the studies in the table below come from Loomis (1983, p. 67) unless otherwise noted. All values have been adjusted to 1980 dollars. The corrections for the estimation biases discussed above have also been applied.

Day value selected The variation in day value estimates listed in Table 4.1 does not instill confidence in any one value. Because of

<table>
<thead>
<tr>
<th>Value</th>
<th>Methodology</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.67</td>
<td>CVM</td>
<td>Walsh, Aukerman and Milton</td>
</tr>
<tr>
<td>10.31</td>
<td>CVM</td>
<td>Walsh, Ericson, Arosteguy and Hansen</td>
</tr>
<tr>
<td>17.50</td>
<td>CVM</td>
<td>Walsh and Olienyk</td>
</tr>
<tr>
<td>10.06</td>
<td>TCM</td>
<td>King and Walka</td>
</tr>
<tr>
<td>16.34</td>
<td>TCM</td>
<td>Martin, Gum and Smith</td>
</tr>
<tr>
<td>9.52</td>
<td>TCM</td>
<td>Gordon</td>
</tr>
<tr>
<td>16.64</td>
<td>TCM</td>
<td>Weithman and Haas</td>
</tr>
<tr>
<td>20.79</td>
<td>TCM</td>
<td>Vaughan and Russell</td>
</tr>
<tr>
<td>14.95</td>
<td>CVM</td>
<td>National Survey of Fishing and Hunting</td>
</tr>
<tr>
<td>26.94</td>
<td>CVM</td>
<td>Charbonneau and Hay</td>
</tr>
<tr>
<td>15.60</td>
<td>HPM</td>
<td>Charbonneau and Hay</td>
</tr>
</tbody>
</table>

a1980 dollars.

TCM - Travel cost method
CVM - Contingent valuation method
HPM - Household production method

bLoomis did not provide this or the following estimate. Both of these values are taken from Charbonneau and Hay (1978, pp. 394 and 396, respectively).
this, a high and a low value of a day fishing is applied, thus
determining the sensitivity of the instream flow values to the day
fishing value. Ten, 15, and 20 dollar day values are selected because
they lie within the above range and they provide a range of values
whereby interpolation can be easily applied should the reader have other
values of interest.

Data Application

The independent variables in the reduced form equation are either
determinants of demand or determinants of supply in the household's
production/consumption of the recreational fishing commodity. These
variables are not all of the supply and demand determinants but,
instead, their presence depends on what data are available and what
information are relevant. Below is a description of all the variables
used in the regression analysis, their source, and if they are a proxy
variable, how they were devised and why they are applicable. But,
first, a general discussion of the dependent-independent variable
relationship is provided.

Dependent-independent variable relationship

Chapter III explains the complications of direct demand estimation
using the household production approach. The proposed alternative is to
estimate a reduced form equation on the production/consumption of the
stream fishing commodity. Because the commodity is not observed, it
cannot be used directly as a dependent variable, and so days stream fishing was proposed as a proxy. Of the data sets available, no variable quantifies the days stream fishing. The FHWAR provides the number of days an individual fishes in (non-Great Lakes) freshwater thus including both stream and lake fishing days. What does this mean to the household production analysis?

First, the recreational fishing commodity may be produced from two different sets of inputs (e.g., stream inputs and lake inputs) but, commodity demand is affected by the method of commodity production (by definition of the commodity). Second, the two different sets of commodity input factors/production technologies (e.g., streams and lakes) indicate two distinct commodity supply functions composing total commodity supply. Because the total commodity supply function is the sum of two separate supply functions (a horizontal summation), determining a household's reaction to a change in an input for commodity production is straightforward. To show this, define $S_{\text{strm}}$ and $S_{\text{lake}}$ as the commodity supply functions using the respective stream and lake inputs and technology. Total commodity supply will then be $S_{\text{total}} = S_{\text{strm}} + S_{\text{lake}}$. The reduced form equation may then be written (in general form) as:

$$\text{DAYS} = B \times X + A_1 \times S_{\text{strm}} + A_2 \times S_{\text{lake}} \quad (4.1)$$

where $B$ represents the coefficient vector for $X$, the vector of demand determinants and $A_1$ and $A_2$ are the respective stream and lake commodity supply coefficients. The impact of a change in the availability of an input ($I_{\text{flow}}$) in production of the stream fishing commodity is determined by:
Thus, the dependent variable being total fishing days poses no problem.

Demand determinants

Variables which might explain an individual's taste toward fishing include personal characteristics, surrounding factors (e.g., climatic, resources, locale, etc.) and past experiences. Concerning information on personal characteristics and past experiences, the only source available is the FHWAR. Variables from this data set include the persons' age, sex, education level, urbanization of area reared in, work status (e.g., work, retired, or in school), number of people in the household, and income of the household. Information on the surrounding factors is derived from data sources to be discussed later. Variables available to reflect the surrounding environment as it influences demand are: urbanization of home area, the severity of winters, and the availability of ocean or Great Lakes fishing. Exactly how these variables are obtained and what they represent is explained below.

As mentioned before, the FHWAR survey provides information on personal characteristics and past experiences. The variables extracted from this data set are binomial and ordinal. Both the variable representing age and the variable representing education level of the individual are the actual number of years involved. Sex is a binomial variable, with 1 indicating a male respondent and 0 indicating a female respondent. Urbanization of the area reared in represents the urbanization of the area where the respondent spent most of their life before...
the age of 16. This information is entered as two binomial variables, CITYKID being 1 if the relevant area had a population of 500,000 or greater and 0 otherwise, and CNTYKID being 1 if the relevant population was less than 10,000 and both 0 otherwise. **Work status** is defined by three binomial variables. WORK equals 1 if the individual has a job or owns their own business and 0 otherwise, RETIR equals 1 if the individual is retired and 0 otherwise, and SCL equals 1 if the individual is going to school and 0 otherwise. **Number in household** is the number of all persons, any age, usually staying at that place of residence. For representing the **income of the household**, INC represents the midpoint of the income ranges asked of those surveyed. For an income class greater than $50,000 (the highest income range limit), an income of $57,500 was selected. The income ranges offered are (in thousands of dollars): 0-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-40, 40-50, and greater than 50.

Information on the characteristics of the surrounding environment which act as demand determinants are derived from three different sources. The FHWAR survey provides data on **urbanization of home area**. This is a binomial variable represent the 1970 Census' (U.S. Department of Commerce, 1971) classification of the residential area as urban (URBAN = 1, else 0) or not. The FHWAR survey also provides information on the availability of ocean or Great Lakes fishing resources. The availability of either of these resources indicates the availability of a substitute commodity, and therefore represents a determinant of demand for the recreational fishing commodity. The proxy variables indicating the substitute commodity's availability are binomial variables, OCN60.
being 1 if ocean or Great Lakes fishing is within 60 miles of the resident area and 0 otherwise, and OCN being 1 of either are between 60 and 120 miles of the resident area\(^1\) and zero otherwise. Information from the U.S. Weather Bureau was used to generate a variable indicating the severity of winters. Averaging January temperatures over a 25-year period generated the variable TEMP as an indicator of how much of the year temperatures may discourage fishing.

**Supply determinants**

The availability of the public fishing resources to the household are measured in two dimensions: stream and lake resources vs. local and distant resources. In defining the stream and lake dimension, clarification of the relevant variables and their sources is provided. To explain the local and distant dimension, it will be necessary to detail how the resident areas (the region where the person lives) and the code areas (fishing areas outside of the resident area) have been determined. The following section attempts clarification of the latter dimension.

**Local and distant** The two geographical measures whereby local and distant resource availability is defined, are necessitated by the design of the FHWAR survey. In this survey, the smallest possible area defining where a person lives or fishes is a wildlife region. Therefore, the best description of "sites" where public resources for

\(^1\)These were estimated from the FHWAR responses.
fishing are available must be at least as large as the wildlife regions. Before describing the measurement of the local and distant fishing resources available to a household, the background of the wildlife regions is provided.

**Wildlife regions**  
Before implementation of the FHWAR survey, state wildlife agencies were asked to subdivide their state into as many as ten regions, to try and follow county boundaries, and to use similar wildlife habitat as the cohesive factor (e.g., a wildlife region should encompass a similar habitat). Not all states were divided into ten regions with the average number per state (total regions/total states) being seven regions. The size of the regions varies significantly due to both the variation in the states' sizes and the variation in the number of regions states are composed of. For example, New Jersey is a smaller state but is divided into ten regions while Nevada, a larger state, is divided into three. Figure 4.1 is a map of Texas with its wildlife regions outlined and numbered (from 480 to 489). In the FHWAR survey, respondents report the wildlife regions where they had fished. These responses prove strategic in determining the relevant code area (the area supplying fishing day resources outside of the resident area) for each of the resident areas.

**Resident areas**  
Resident areas indicate a general location of the household's residence. They are large areas being composed of one or more wildlife regions. The reason some resident areas are composed of more than one wildlife region is to insure the anonymity of the respondents. For example, though South Dakota is one of the larger
Figure 4.1. The wildlife regions within the state of Texas
states and is composed of ten wildlife regions, the state represents one resident region because of the state's limited population. The combining of wildlife regions in Texas divides the state into six resident areas. Those regions combined were 480 and 487, 483 and 486, and 485, 488, and 489 (Figure 4.1).

A consistent measure of the local public fishing resources must account for there being only a general location given for household's residence. Therefore, the variables representing the available local public fishing resources are a composite measure of all public fishing resources within the entire residential area. Again, to use South Dakota as an example, because the entire state represents one resident area, the measure of local fishing resources available for that resident area is a generalized measure of the public fishing resources throughout the state. On a smaller scale, in the state of Texas, wildlife region 485 (Figure 4.1) itself composes a resident area so its measure of public fishing resources are those resources within its boundaries.

**Code areas** The wildlife regions outside of a resident area, which can influence a household's fishing decisions, compose the code area. A consistent measure of the distant public fishing resources available (those resources within the code area) must account for three features of the information available. First, the resident area provides only general household location information (e.g., somewhere within the resident area composed of wildlife regions 480 and 487). Second, the resident area may be very large (e.g., the state of South Dakota). And third, the size of resident areas varies significantly (e.g., the size of the resident areas composed of wildlife region 484
vs. the size of South Dakota). These three features of the available information greatly affect the determination the relevant wildlife regions composing the code area (to be discussed in this section). The third feature, the variability in the sizes of the resident areas, also affects the measurement of the code areas' resources and, therefore, is covered in the (later) section on supply variables.

All of the relevant wildlife regions' (composing the code area) fishing resources must be assumed to influence each household equally because of not knowing specifically where in the resident area the household lives. Thus, the code area represents a containment of the wildlife regions providing distant public fishing resources for a resident area. For example, in the resident area composed of wildlife region 484 (Figure 4.1) three surrounding wildlife regions compose the code area: 483, 485, and 406 (406 is the wildlife region immediately above 484 in Oklahoma). Because of not knowing where in 484 a resident may live, the location influence of 483, 485, and 406 is assumed to be equal. Thus, these regions are combined and treated as one area—the code area for 484. Thus, the variables representing the distant public fishing resources are a general measure of the resources within the wildlife regions of the code area.¹

The size and the size variations of the resident areas prevents selecting only and all of the bordering wildlife regions as part of the code area. When the resident area is large, the surround wildlife regions will have much less influence than the wildlife regions

¹More will be explained on the generalization of the code areas' resources when explaining the stream and lake variables.
surrounding a small resident area. For example, not all wildlife regions bordering South Dakota (a resident area) have a significant influence on residents because the state is so large, many of the bordering wildlife regions are too far from most of the resident area's population. Thus, not all of the wildlife regions bordering South Dakota are in its code area. On the other extreme, wildlife region 481 composes a resident area (Figure 4.1). Being as small as it is, and with 483 being as small as it is, 487 is close enough to residents of 481 to influence their fishing commodity production though 487 does not border 481. Thus, without being able to use the wildlife region's location as a selection criteria, a selection rule based on a wildlife region's influence is used to determine which of the wildlife regions should be included as part of the distant resource supply.

A two-pronged qualification criteria in the selection rule prevents biasing the selection of the wildlife regions. The first selection rule examines where the residents of a resident area have fished. If at least five percent of the total days fished by residents were done in any given wildlife region outside the resident area, that wildlife region is included in the code area. This first selection rule defines regions which have been chosen by those who fish and, therefore, may bias entries of the code areas toward being the more fishable regions.

To correct for a bias stemming from a region's quality influence, a second selection rule is applied. In this case, if five percent or more of the total days fished within a given wildlife region were by residents of a particular resident area, that wildlife region is
designated as a part of the code area for that resident area. This selection rule accounts for regions which have limited fishing commodity factors thus allowing the code area to indicate why people fish less than the other parameters suggest.

Having clarified the nature of both the resident and code areas, the discussion below is concerned with the measurement of the resources in the resident and code areas. The similarities and differences between stream and lake resource estimation methods and the similarities between the resident area and code area resource estimation methods are outlined.

Stream vs. lake The availability of stream and lake resources as factors in commodity production are estimated for both the resident areas and the code areas. Both the stream and the lake resources, coupled with the household's technology, define production potential for the recreational fishing commodity. The stream and lake resource measures for both the local and the distant regions define four sources of public fishing resources available to the household.

The variables which comprise the measure of stream and lake resource availability are listed below along with their source and a description of their application. Also note that the stream and lake resource availability measures remain consistent despite the variation in the sizes of the resident areas. But, first, to help understand why the resources are measured as they are, the recreational fishing commodity is made more explicit.

The commodity A better understanding of the recreational fishing commodity allows a clearer understanding of why some inputs have
the significance which they do and how the units of measurement for resource availability affect the modeling of the household's production decisions. The commodity itself is an abstract item. However, one may ask, in what way does freshwater fishing provide enjoyment? The answer to this question provides insight in understanding the commodity.

Fishing is a sport and, like any sport, poses a challenge to the participant. The sporting aspect follows from the challenges nature poses to those fishing to stimulate a fish into taking the bait and, further, keeping it on the line. The idea of challenging nature implies that fishing from a barrel is not generating the same commodity as recreational fishing. Because of being the challenge of nature, the size of the fish and the number of fish caught do not affect commodity production across sites as long as the variation in size and catch rate vary because of natural factors.\textsuperscript{1} Though the catch rate will be higher in the smaller stream and the average fish size will be greater for the larger stream, these differences compensate for each other. Therefore, a surface acre of a small stream has a marginal product (in the household's commodity production) equal to the surface acre of a large stream whenever both have equal flow levels and other conditions. It is the deviations in the challenge of nature that varies the marginal

\textsuperscript{1}As noted in Chapter II, the pounds of fish per surface acre of water does not vary substantially between streams with the same flow level (given that other factors are not being more detrimental to one stream than the other). However, fish do not grow as large in small streams as they might in larger ones. Thus, a surface acre of a very small stream will not have fish as large as the larger stream but, rather, has more fish. It is assumed that the size/quantity variations among streams will not affect the streams marginal product in the household's production function as long as this variation is proportional to their natural size/quantity variation.
product of the fishing resource. Thus, the size and the quantity of fish will not be as relevant a measure of commodity input availability as a measure which indicates how fish populations deviate from what would be their levels.

Supply variables

Three sources which provide data on the availability of commodity input factors the resident areas and the code areas are the Second National Water Assessment (SNWA), the National Resources Inventory, and the 1980 Census. The helpful information provided by these data sets is listed below, followed by a discussion of how these measures provide a consistent estimate of resource availability.

The supply of water resources within each area is provided, in part, by the NRI. The NRI provides county-level information on the surface area of streams and lakes. These water areas can be summed to determine total surface areas of streams and lakes for each of the resident and code areas.

Another supply factor affecting the fishing quality of an area's streams is its current flow level. As noted in Chapter II, the SNWA measures streamflow volumes within river drainage basins (the ASAs). Because it is the relative level of streamflow which characterizes the quality of the streams' fish habitat, the current streamflow is compared to the flow level the basin would have without human alterations. Thus, the streamflow variable is the percent the current flow represents of the natural unaltered flow.

To estimate the percent flow of streams in the resident and code areas, the percent flow is first estimated for each of the 99 ASAs.
Next, these percent flow estimates are associated with the counties composing the ASAs and, with the surface area of streams (by county) as a weight, summed and divided by the total weight (the total surface area of the area's streams) to determine the weighted average flow within each of the resident and code areas.

The NRI provides a county-level estimate of the surface area of different types of riparian vegetation along the waterways. Loss of riparian vegetation degrades the stream's habitat for fish, thus lowering the stream's ability to maintain fish populations. Development along waterways for cities or agriculture can remove the riparian vegetation and decrease the stream's fish productivity. The county estimates of riparian vegetation within each of the resident and code areas are summed to determine the type of riparian vegetation of their streams.

The 1980 Census (U.S. Department of Commerce, 1982) provides county level population estimates. The population of a region provides information on the intensity of use the public fishing resources may have. Populations for areas are arrived at by summing the county populations of the areas.

Finally, the NRI also provides information on the area of each county. Aggregating this county-level information produces the variable which measures the land area of the resident areas. This variable is used to account for the effects of the size variations among the resident regions.

All of the above variables interrelate as a measure of fishing resource availability. From the above description of the commodity and
of the resident and code areas, the interrelationship of these variables follows. This interrelationship generates proxy variables indicating the public fishing resource availability, from streams and from lakes, for each of the resident and code areas. Four interrelationships among the supply variables define the proxy variables which indicate the availability of the public fishing resources. First, the area of the lakes \((L)\) and of the streams \((S)\) serve as a measure of availability of the fishing resources. A problem with this measure is that part of the variation in this measure results from the size variations of the resident or the code areas. Water area per land area \((\text{acre})\) might provide some indication of the change in availability. However, water area per capita \((S/C \text{ or } L/C)\) provides a better availability measure in that it indicates availability in terms of intensity of use.\(^1\) (Implicitly assumed here is that the households' average distance from water areas does not vary significantly as water area per acre varies.)\(^2\)

\(^1\)In Chapter II, it was pointed out that the marginal cost of an additional user of a public good is zero. Yet with enough use of the fishery resources, the resource's quality will be diminished and thus, a cost to society has occurred. Therefore, it can be argued that the marginal cost of the resource's use must be greater than zero. But it is the large number of users which leads to a noticeable cost. The good still represents a public good more than a private good because the marginal cost of an additional user is very close to zero.

\(^2\)One way to realize the plausibility of this assumption is to consider that, historically, the settlement patterns in the U.S. often were based on the availability of surface water. The arid regions have less water per land area and are also likely to have less population per area. And since the population of the arid region is likely to be dispersed with concentrations being nearer water, the average distance to water will not vary significantly.
Second, the level of streamflow (percent flow (F)) indicates the quality of the water area per capita of streams. To fully measure the fish habitat input for commodity production, the percent flow (F) must be a multiplicative factor to S/C (thus the availability measure now becomes $F*S/C$). Percent flow as a direct multiplicative factor in measuring availability consistently follows the streamflow-fish production relationship outlined in the biological studies of streams provided in Chapter II. For example, the direct relationship of streamflow to fish production in the biological studies indicates that decreasing streamflow from 100 down to 50 percent of its natural flow would cut the productivity of streams in half. Thus, a region averaging two acres of stream surface per capita with a 50 percent flow has an equal stream fishing resource availability as a region averaging one surface acre of stream per capita but having 100 percent of the streams natural flow.

Third, the loss of riparian vegetation lessens the quality of fish habitat, thus lowering the water's production of fish from what would be its natural output. The best (and natural) riparian vegetation is trees. By incorporating the portion of trees composing the riparian vegetation into the above relationship, the direct impact of riparian vegetation (V) on the fishing resource availability is simulated by $$(V*F*S/C).$$

Note that the second and third points apply to streams alone. This fourth point accounts for size variations in the sizes of the resident areas thus applies to both stream and lake measures of the code areas. Recall that the selection of wildlife regions belonging to each code area accounts for the size variations of the resident areas. However,
there still must be a calibration of the code area's resource measure to reflect this size variation. Larger resident areas will have a greater average distance to the resources in the code areas. For example, households living in the resident area represented by 484 (Figure 4.1) are (on average) much closer to the resources of their code area (wildlife regions 483, 485, and 406) than households in South Dakota would be to resources of their code area. An inverse relationship is expected between the size of a resident area and the influence of the surrounding resources. By dividing each of the code area's resource availability measure by the square root\(^1\) of the relevant resident area's size (A), the size variation influences are then accounted for.

With these considerations in mind, the supply variables enter the reduced form equation as:

\[
B_1(VFS/C)_{\text{res}} + B_2(L/C)_{\text{res}} + B_3((V*F*S/C)/A)_{\text{code}} + B_4((L/C)/A)_{\text{code}}
\]

where:

- S represents the relevant surface area of streams,
- L represents the relevant surface area of lakes,
- C represents the relevant area's population,
- F represents the percent flow of S,
- F represents the portion of the riparian vegetation which is trees,
- A represents the square root of the total area of the resident area,
- the B's are regression coefficients,

\(^1\)The size variations of the resident region does not represent proportional variations in distances to code area resources because size is a two dimensional measure. However, the square root of the area provides a one dimensional measure with variations in magnitude proportional to the distance variations.
and the subscripts, \( \text{res} \) and \( \text{code} \), signify resources of the resident and code areas, respectively.

Chapter V discusses the results of the regression analysis containing these variables.

Finally, a supply factor not interrelated to the above, measures the relative availability of warmwater area to the total water area. The Fish and Wildlife Service provides this information in a 1968 report where water area is classified, at the state level, as being either warmwater or coldwater. The marginal effect of this factor on commodity production is assumed to be independent of the other supply factors. This variable, \( \text{CDWM} \), directly enters the reduced form equation.

Summary

This chapter focuses on data sources, variable derivation, and the use and interrelationship of the variables. Understanding the data sources facilitates understanding the formulation of supply and demand factors in the commodity production/consumption decisions of households. The derivation of several variables requires specific assumptions about their nature or the nature of the commodity. These assumptions and their justification are outlined here. This chapter also describes each variable as it enters the reduced form equation. Knowing the background on these variables and the assumptions behind the variables' formulation provides an a priori foundation for the testing in Chapter V of the relationships between the dependent and independent variables.
Regression results of the reduced form equation representing the household's production/consumption decision on the recreational fishing commodity indicate that stream fishing resources are a significant factor in commodity production. The derivation of these results and the implications of the coefficients are discussed below. A description of the statistical procedures that were applied and results of alternative runs clarify the selection of the final regression as being "best."

The Analytical Framework

As discussed in Chapter III, the model to be estimated is a reduced form equation of the household's equilibrium production/consumption of the recreational fishing commodity. Household's characteristics and the availability of input resources represent determinants of the commodity's supply and demand and, therefore, are the independent variables. The dependent variable, the days an individual fished in that year, serves as a proxy for the commodity. The framework for determination of the relationship between the dependent variable and the independent variables is discussed below.

Statistical theory

The observations on the individuals' fishing activities were taken from two different surveyings within the FHWAR survey. The first surveying was a sampling of the U.S. population at large to determine whether or not a person fished. The second surveying followed-up the
first by asking those who fished more specific questions directed at their fishing experiences. Variations in the independent variables, such as the availability of fishing resources, are expected to affect responses in both of the surveys. Assuming that participants are a continuum of the population at large, there are two basic ways to model the expected days of freshwater fishing. The first method uses each of the two surveyings separately by applying a joint probability function reflecting: 1) the individual's decision to fish or not (estimated from observations in the first surveying), and 2) given the decision to fish, the number of days the individual decides to fish (estimated from the observations in the second surveying). Using the framework suggested by Cicchetti (1973), the expected days fishing, \( E(D) \), is the product of the probability of fishing, \( P(F) \), and the probable number of days fished given one fishes, \( (D|F) \), or, 
\[
E(D) = P(F) \cdot (D|F). \tag{5.1}
\]
The second method requires that both of the data sets be combined whereby the expected days fishing is derived directly from the entire population, e.g.,
\[
E(D) = D^B. \tag{5.2}
\]
This second methodology was chosen as superior to the first for this analysis in that first, it requires estimating only one equation and second, it does not require cross multiplying the estimated equations. Estimating only one equation prevents losses in degrees of freedom. The cross multiplication of predictive equations results in a loss of precision if the equations do not forecast well. These reasons

\[1\] Both \( D^A \) and \( D^B \) represent the number of days an individual fishes as determined through a Tobit analysis (discussed below). \( (D^A|F) \) represents the predicted number of days freshwater, non-Great Lakes fishing from the sample of those who fished and \( D^B \) represents the predicted number of days freshwater non-Great Lakes fishing from the sample of the entire U.S. population.
are made more clear as the regression results of both techniques are explained.

Before estimating 5.2, the derivation of the sample used in this analysis must be shown to be sound. Recall that the FHWAR survey contains two different data sets from two different surveyings. The first data set is a sample of the entire U.S. population where individuals provided information on their personal characteristics and, also, whether or not they fished in 1980. The second data set is a sample of only those who fished, however, observations here contain not only responses to the same questions of the first data set, but also responses to additional questions on the individuals fishing activities (in particular, the days spent freshwater non-Great Lakes fishing). Note, then, that both data sets have observations on individuals who fished. But, in the first data set, the observations on individuals who fish does not provide information on the number of days they fished. A third data set is required which contains observations on both those who did and did not fish. For those who did fish, this data set should include the number of days fished.

To do this, realize that the first data set contains two subsamples of the population — one on those who fish and the other on those who do not. Also realize that the second data set is a subsample of the population in the first data set with observations only on those who fish. The first data set, that being a subsample of the entire U.S. population, indicates the portion of the population that fishes. This third data set must have the same ration of observation between those who fished and those who did not fish a does the first data set. The
observations on those who did not fish are randomly selected from the subsample of those who did not fish of data set one. The observations on those fished (to be entered in the third data set) are randomly selected from the second data set, thus they include information on the number of days spent freshwater fishing by those who fish. Data set three, derived in this manner, will again represent a random sample of the U.S. population.¹

Qualitative and censored response models The procedures applicable in estimating 5.1 and 5.2 belong to the family of qualitative and censored response models. Much of the pioneer work in this area was done by McFadden (1974, 1976, 1978) and Domencich and McFadden (1975). The modeling of the probability of fishing \( P(F) \) in equation 5.1 requires, specifically, a binary response model. In this particular case, the dependent variable will have a value of zero or one. Applying ordinary least squares (OLS) analysis to such a binary dependent variable yields consistent and unbiased estimates of the coefficients. However, the use of OLS in such a case suffers from three major deficiencies. These deficiencies are: one, the variance of the disturbance term is heteroscedastic biasing the standard deviations of the error terms and causing a loss in the efficiency of the parameter estimates (Goldberger, 1964); two, the error term is not distributed normally, therefore tests of significance are not valid (Pindyck and Rubinfeld, 1981); and three, predictive values of the dependent variable may fall

¹The number of observations selected for the third data set is not in any way restricted by the number of observations in data sets one or two, but by the 4000K core availability of the computer used.
outside of the zero/one interval, thus being inconsistent with the
variables' probability interpretation. The use of either the probit or
logit analysis overcomes these weaknesses.

**Probit and logit models** Both the probit and logit analysis
involve a monotonic transformation of the original model. An arbitrary
index, $Z_i$, is selected and defined to be a linear function of the
regressors. $Z^*$ is a random variable defined such that the value of the
binary dependent variable equals one if $Z^*$ is greater than or equal to
$Z_i$ and zero otherwise. In the probit analysis, $Z$ is assumed to have a
standard normal variate distribution whereas the logit analysis assumes
that the distribution of $Z$ is associated with the logistic cumulative
distribution function. The logit and probit formulations are quite
similar (Hanushek and Jackson, 1977) in that the logistic cumulative
density function approximates the normal cumulative density function
(Judge et al., 1980, p. 591). The advantage of the logit model is that
it is computationally simpler than the probit model. The probit model
is used here because the SHAZAM statistical package provides simple
estimation using a maximum likelihood estimation method. The objective
of the maximum likelihood method is to find an estimator which maximizes
the likelihood of observing that pattern of choice. The maximum
likelihood estimation procedure assures the large sample properties of
consistency and asymptotic normality of the coefficients and therefore,
conventional significance tests apply.

**The Tobit model** The modeling of $(D^A|F)$ of 5.1 and of
$D^B$ in 5.2 requires a censored response model. As first shown by Tobin
(1958), economic surveys which take on limiting values of the dependent variable (truncated samples) must make use of all information in order to adequately portray the full range of household behavior. The dependent variable in both of these equations is days fishing where zero days is the limiting observation.\(^1\) In the situation represented by the second equation of 5.1, \((D^A|F)\), there are day observations clustered around zero which are representative of those who fished only in the Great Lakes or the sea. In the situation represented in 5.2, \(D^B\), there are observations on the dependent variable clustered around zero because the sample represents the overall U.S. population and so must include both those who did and did not freshwater, non-Great Lakes fish in 1980.

The Tobit model may be thought of as a hybrid of the probit analysis and an application of multiple regression. The components of the Tobit model are summarized in Table 5.1. Here, equation (1) defines the number of days fishing for the observations clustered at zero and the other observations with their continuous quantity of days. Equation (2) defines the unconditional expected value, \(E(D)\), which accounts for the behavior of all households. Equation (3) defines the conditional expected value of the days fished, \(E(D^*)\), for those households with day values above zero. The conditional expected days will always be greater

\(^1\)It can be argued that segments of the total population having different characteristics represent distinct populations themselves. Thus, each of these subsamples could have a different response to changes in streamflow. Because of the computational difficulties, such analysis is not made. Given the number of observations and the inclusion of independent variables which may represent these different groups, no estimation bias is expected.
Table 5.1. Components of the Tobit model

\[
D = XB + e \text{ if } XB > 0 \quad (1)
\]
\[
D = 0 \quad \text{ if } XB \leq 0
\]
\[
E(D) = XBF(Z) + \sigma f(Z) \quad (2)
\]
\[
E(D^*) = XB + \sigma f(Z)/F(Z) \quad (3)
\]

where:

- \( X \) = the vector of the independent variables,
- \( B \) = the vector of Tobit coefficients,
- \( e \) = a vector of independent and identically distributed normal random variables assumed to have a zero mean and a constant variance, \( \sigma^2 \),
- \( Z = XB/\sigma \), the normalized index,
- \( f(Z) \) = the standard normal density function, and
- \( F(Z) \) = the cumulative standard normal distribution function

than the unconditional expected days which becomes apparent by rewriting (3) as \( E(D^*) = E(D)/F(Z) \).

Regression Analysis

Results of the probit and Tobit analysis are listed in Table 5.2. Columns one and two represent, respectively, the results for the probability of fishing, \( P(F) \), and the probable number of days fished given one fishes, \( (D^A|F) \), of equation 5.1. Column three represents the Tobit results of equation 5.2. The \( t \)-values for the variable of most concern, the stream resource variable, are significant in all three equations for the resident area's resources. While the R-squared values
Table 5.2. Regression results on estimating $P(F)$, $(D^A|F)$, and $D^{Ba}$

<table>
<thead>
<tr>
<th>Variable</th>
<th>Equation 5.1</th>
<th>Equation 5.2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$P(F)$</td>
<td>$(D^A</td>
</tr>
<tr>
<td>SEX</td>
<td>0.133</td>
<td>7.90</td>
</tr>
<tr>
<td></td>
<td>(3.33)*</td>
<td>(8.10)</td>
</tr>
<tr>
<td>CITYKD</td>
<td>-0.110</td>
<td>-3.08</td>
</tr>
<tr>
<td></td>
<td>(1.68)**</td>
<td>(2.14)***</td>
</tr>
<tr>
<td>CNTYKD</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RETIR</td>
<td>0.180</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.82)**</td>
<td></td>
</tr>
<tr>
<td>WORK</td>
<td></td>
<td>-4.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.82)</td>
</tr>
<tr>
<td>SCL</td>
<td>-4.18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.42)***</td>
<td></td>
</tr>
<tr>
<td>AGE</td>
<td>0.0115</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.18)</td>
<td></td>
</tr>
<tr>
<td>AGESQ</td>
<td>-0.000267</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(5.38)</td>
<td></td>
</tr>
<tr>
<td>EDLEVEL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHSIZE</td>
<td>0.0812</td>
<td>-1.20</td>
</tr>
<tr>
<td></td>
<td>(6.22)</td>
<td>(4.39)</td>
</tr>
<tr>
<td>INC</td>
<td>0.00358</td>
<td>0.0251</td>
</tr>
<tr>
<td></td>
<td>(7.29)</td>
<td>(2.25)***</td>
</tr>
<tr>
<td>INCSQ</td>
<td>-4.16*10^-5</td>
<td>-5.39*10^-5</td>
</tr>
<tr>
<td></td>
<td>(4.89)</td>
<td>(2.82)</td>
</tr>
<tr>
<td>URBAN</td>
<td>-0.135</td>
<td>-2.59</td>
</tr>
<tr>
<td></td>
<td>(3.16)</td>
<td>(2.94)</td>
</tr>
<tr>
<td>OMI60</td>
<td>-0.155</td>
<td>-5.46</td>
</tr>
<tr>
<td></td>
<td>(3.58)</td>
<td>(5.61)</td>
</tr>
<tr>
<td>OMI</td>
<td>-0.232</td>
<td>-5.15</td>
</tr>
<tr>
<td></td>
<td>(2.75)</td>
<td>(2.65)</td>
</tr>
<tr>
<td>STRMRSD</td>
<td>0.0863</td>
<td>2.33</td>
</tr>
<tr>
<td></td>
<td>(4.31)</td>
<td>(5.23)</td>
</tr>
<tr>
<td>LAKRSD</td>
<td>0.0464</td>
<td>-0.751</td>
</tr>
<tr>
<td></td>
<td>(2.48)</td>
<td></td>
</tr>
<tr>
<td>STRMCODE</td>
<td>0.705</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.53)***</td>
</tr>
<tr>
<td>LAKCODE</td>
<td>-0.333</td>
<td>-0.823</td>
</tr>
<tr>
<td></td>
<td>(1.60)**</td>
<td></td>
</tr>
<tr>
<td>CONSTANT</td>
<td>-0.146</td>
<td>17.3</td>
</tr>
<tr>
<td></td>
<td>(1.06)**</td>
<td>(6.59)</td>
</tr>
</tbody>
</table>

R-squared 0.1029 **

\*Variables significant at the 99 percent level unless otherwise noted.

\*t-statistic in parentheses.

**Not significant at the 95 percent level.

***Significant at the 95 percent level but not at 99 percent.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>P(F)</td>
<td>Binary variable: 1 if fished, 0 otherwise</td>
</tr>
<tr>
<td>(D^F)</td>
<td>Days freshwater non-Great Lakes fishing of those who did fish</td>
</tr>
<tr>
<td>D^F</td>
<td>Days freshwater non-Great Lakes fishing for any individual</td>
</tr>
<tr>
<td>SEX</td>
<td>Binary variable: 1 if male, 0 otherwise</td>
</tr>
<tr>
<td>CITYKD</td>
<td>Binary variable: 1 if the population of the area raised in was greater than 500,000, 0 otherwise</td>
</tr>
<tr>
<td>CNTYKD</td>
<td>Binary variable: 1 if the population of the area raised in was less than 10,000, 0 otherwise</td>
</tr>
<tr>
<td>RETIR</td>
<td>Binary variable: 1 if retired, 0 otherwise</td>
</tr>
<tr>
<td>SCL</td>
<td>Binary variable: 1 if in school, 0 otherwise</td>
</tr>
<tr>
<td>AGE</td>
<td>Age in years</td>
</tr>
<tr>
<td>AGESQ</td>
<td>Age in years squared</td>
</tr>
<tr>
<td>EDLEVEL</td>
<td>Number of years attended school</td>
</tr>
<tr>
<td>HHSIZE</td>
<td>Number of people living in household</td>
</tr>
<tr>
<td>INC</td>
<td>Income as a midpoint of (in $1000): 0-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-40, 40-50, and 57.5 otherwise</td>
</tr>
<tr>
<td>INCSQ</td>
<td>Income squared</td>
</tr>
<tr>
<td>URBAN</td>
<td>Binary variable: 1 if 1980 Census classified area of residence as urban, 0 otherwise</td>
</tr>
<tr>
<td>OMI60</td>
<td>Binary variable: 1 if ocean or Great Lakes fishing is within 60 miles, 0 otherwise</td>
</tr>
<tr>
<td>OMI</td>
<td>Binary variable: 1 if ocean or Great Lakes fishing is within 120 miles but over 60 miles, 0 otherwise</td>
</tr>
<tr>
<td>STRMRSD</td>
<td>Variable measuring stream fishing resource availability for the resident area</td>
</tr>
<tr>
<td>LAKRSD</td>
<td>Variable measuring lake fishing resource availability for the resident area</td>
</tr>
<tr>
<td>STRMCODE</td>
<td>Variable measuring stream fishing resource availability for the code area</td>
</tr>
<tr>
<td>LAKCODE</td>
<td>Variable measuring lake fishing resource availability for the code area</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>Regression constant</td>
</tr>
</tbody>
</table>
are not high, this is a characteristic of qualitative choice models.\footnote{For example, Morrison (1972, p. 70) has shown that with a binary dependent variable where the probability of a success is 0.4, the maximum possible R-squared is 0.167.}

The formulation, background, and units of the dependent and the independent variables are as discussed in Chapter IV. Table 5.2 also provides a listing and a short description of the dependent and independent variables used in the regressions. The listed coefficients cannot be directly translated as a measure of marginal effect. The marginal values implied by these coefficients will be discussed in Chapter VI.

The analysis leading to the final regression results is discussed below. The order of the discussion begins with the elimination of outlier observations, followed by an elucidation of the regression variables and their coefficients, and finally, some comments on insignificant variables which were introduced in Chapter IV.

**Outlier observations**

Early regression results produced lower R-squares than those reported. Testing of the data used in the analysis indicated that some observations on days fishing exceeded what might be considered consistent with the majority of responses. The R-square values improved most dramatically when observations on individuals fishing more than 100 days were eliminated. Therefore, this group of observations was
eliminated. There were 13 of these observations out of a total 4,247. R-square increases significantly from .0278 to .0348.¹

The regression variables

The t-statistic of the regression variables indicates that 11 variables in equation 5.1, eight variables in equation 5.2, and 14 variables in equation 5.3 are significant at the 99 percent confidence level. Signs on these variables, if not presupposed, are indicative of the household's tastes. In the discussion below, each regression variable is examined individually for the behavior it indicates. The sign on each variable across each of the three different equations is also discussed.

Before discussing the above variables, recall that the model being estimated is a reduced form equation on the household's decision to produce/consume the recreational fishing commodity. Independent variables represent determinants of both supply and demand for the fishing day commodity. The objective of this analysis is to determine how changes in streamflow influence households' fishing day commodity production/consumption.

Stream fishing resources The availability of the stream fishing resources in the resident area is significant in all three regression equations with t-values ranging from 4.3 to 5.2. The positive signs on

¹Number of observations and the R-squared values come from the analysis on equation 5.2. Regressions estimating (D^A|F) behave similarly.
these variables and on the code area's stream resource coefficients are as expected. Early regression results on the probability of fishing, \( P(F) \), indicated that the (surrounding) code areas' stream (and the lake) fishing resources play an insignificant role in determining the probability of participation, therefore, this variable was repressed in the final regression run. This lack of significant influence of the distant areas' (code areas') resources on whether or not a person fishes is not a surprising result as one would expect the local fishing resource availability to be what encourages a person most to consider fishing. The final regression results show that the distant stream fishing resources do significantly affect the number of days that a person who fishes may fish, \( (D^A|F) \), as well as affect the overall participation decision of the entire population, \( D^B \).

Lake fishing resources The influence of the local availability of the lake resources has a positive effect on the probability of fishing but a (not strongly significant) negative effect on the number of days fished given one does fish, \( (D^A|F) \). The effect on the population's overall fishing commodity decision, as given by \( D^B \), indicates a positive influence toward fishing. This follows logically from four points concerning lake fishing resources. First, lakes often lose much of their fish production potential due to variation in water level, \(^1\)

\(^1\)As defined earlier, the resident area describes the general area where the respondent household lived. The resident area's resources are those natural resources available within the boundaries of the boundary of the household's resident area. The code area describes the area where more distant resources are available to the household. This area is composite of the various wildlife regions which were determined as being close enough to possibly influence the household.
the loss of riparian cover, and the damage that boating imparts on shoreline and other necessary fish cover areas for fish. Thus, overall, many lakes do not provide very productive inputs for the household's fishing commodity production. Second, part of the surface area of most lakes is not so readily accessible as is the surface area of streams. To reach much of the area on lakes may require a boat and other equipment, thus increasing the cost of obtaining the fishing input resources. Third, lakes do have cabins built near them and parks located next to them thus making their fishing resources easy to exploit when picnicking or staying at a cabin. And fourth, lakes provide a source of other inputs that can be used in the production of many other outdoor recreation commodities (e.g., swimming, skiing, sailing, etc.), each of which may act as substitute to the fishing commodity.

Therefore, lakes are not expected to be the quality fishing commodity factor input as do streams, but they are an input. When the choice is to fish or not, lake resources have a positive, as well as significant, influence (perhaps through outings such as a family picnic next to a lake). When the choice is on the quantity of the fishing commodity to produce/consume, the productivity of resources becomes more important, hence, lake resources lose their positive significance. Instead, the availability of lakes may encourage participation in other water related outdoor activities that act as a substitute for lake fishing. Analysis on equation 5.2 indicates that the effect of lake resource availability within the resident area has a positive effect on the population's overall behavior toward fishing.
These same characteristics of lake resources apply to the household's behavior toward the (more distant) lake resources of the code areas. The influence of these resources is not significant in the regression analysis associated with 5.1 but it is significant and negative in determining $D^B$. Thus, lake resources of the code areas do not significantly lower the production costs of the fishing commodity. Instead, the negative coefficient indicates that the code area's distant lakes influence the individual significantly toward the production/consumption use of the other (substitute) water enhanced recreational opportunities.

**Sex** The positive coefficient on the variable indicating the sex of the respondent suggests that males are more likely to produce/consume the fishing commodity. This holds for all three regressions.

**City kid, country kid** The type of area that the respondent was raised in has some influence on the fishing participation decision and significant influence on the number of days fished by those who fish and on the overall decision on the fishing commodity. It was expected that being raised in a rural (urban) area would have a positive (negative) effect on an individual's fishing commodity production. The negative signs on CITYKD and the positive sign on CNTYKD support these expectations.

**Retired, work, school** These three possible livelihoods of individuals were analyzed in each of the regression analyses. Work was expected to have a negative effect, whereas the other two were expected to have a positive effect. The positive effect of retirement is self-evident, however, the positive effect of school (and the negative effect
of work) was expected because of the greater (lesser) vacation/leisure time school (work) allows compared to the remaining activities (e.g., maintaining a household, military enlistment, etc.). A person who works may also face a higher opportunity cost of their time. (Note that the exclusion of any of these three activity variables puts the excluded variable into that group of remaining activities.) The variable work was only significant in influencing the level of fishing by those who fish, \( D^A_{F} \). The school and retired variables were both significant in determining \( D^B \).

**Age, age squared** A younger individual was expected to be more likely to produce/consume the fishing commodity and increases in age were expected to have an increasingly negative effect. This represents tastes in the commodity, not time availability in that the activity variables of work, etc., were to capture this relationship. By entering both age and age squared, the positive effect of the younger ages and the negative effect of increased age was to be accounted for. These effects are demonstrated in the results of equations one and three. Interestingly, age shows no effect on the level of fishing of those who fish, \( D^A_{F} \). Another interesting point is that the effect of an increase in age becomes negative on the probability of fishing, \( P(F) \), at 22 and negative on the overall fishing commodity decision when age reaches 41.

**Education level** The expected effect of an individual's education level on the production/consumption of the fishing commodity by the entire population was uncertain due to the opposing potential impacts of education. First, increased education exposes the individual...
to more ideas and forms of entertainment. These added activities can act as a substitute for recreational fishing. Further, education may increase the technology of the household, thus increasing the opportunity cost of time fishing. However, increased education can increase the individual's appreciation for natural environments and for challenges which are not man-made. As such, education may increase the individual's fishing commodity production. The results reported in Table 5.2 indicate that the education level of the individual has a positive effect, thus implying that the second impact is the dominating effect.

**Household size** The size of the individual's household is also expected to have opposing impacts on the individual's decisions on commodity production/consumption. The positive impact that the household's size has on days fishing stems from fishing being an outdoor activity that the household (family) can enjoy as a unit. However, on the negative side, it might be more difficult to coordinate all household members' activities to allow a fishing trip. The positive effect of household size on the probability of fishing and the negative effect on the number of days fished by those who fish are consistent with the above expectations. Results on $D_B$ indicate that the effect of the household size on the overall fishing decision is insignificant.

**Income and income squared** Income is a function of the wage rate and the hours spent working. Though within any income range there are variations in wage rates, the net relationship between income and value of time is assumed to be positive. Income does provide the necessary
liquidity for fishing commodity production so, in this sense, income's effect can be expected to be positive. However, the higher incomes represent higher opportunity costs of time, therefore, it is logical that increases in incomes will have a diminishing positive effect. In all cases, the coefficients on these variables support these expectations.

**Urban** The variable urban represents the type of area that the respondent currently lives in. Because urban areas make the fishing commodity more costly to produce and the urban area also provides factors for production of other (substitute) commodities, an urban residence is expected to have a negative effect on the fishing commodity production/consumption. Table 5.2 indicates this influence as being consistent across all three equations.

**Ocean, Great Lakes** The availability of resources for production of a similar and, therefore, substitute commodity is expected to have a negative effect on the fishing commodity's production/consumption. These measures of Great Lakes and ocean distance provide just such an availability measure. OMI60 and OMI indicate the availability of either ocean or Great Lakes fishing within 60 miles or between 60 and 120 miles of the resident area respectively. Both measures have the (negative) sign expected and are significant across all three equations.

**Excluded variables** The variables discussed above do not include all of those discussed in Chapter IV. To complete this section on the regression analysis, an explanation of these other variables follows.
Temperature

The variable TEMP, being an average of January temperatures, was expected to show a negative impact toward days fishing. This variable was insignificant in all runs. Some reasons for this include: 1) though areas may have hard winters, there is still ice fishing and perhaps greater advantage taken of the summer fishing opportunities; 2) TEMP does not provide an accurate measure of the winter's severity; and/or 3) being a state level variable might be too general of a measure.

Coldwater and warmwater areas

The ratio of warmwater area to total water area was not a significant variable in explaining days fishing but it did have t-statistics in some cases between 1 and 1.5. This variable was expected to show a negative relationship between production/consumption of the fishing commodity and the portion of warmwater to total water under the assumption that water producing coldwater fish acts as a better commodity input. Signs on the coefficients were negative but the low t-values cannot provide confidence in the above assumption.

Summary

This chapter provides an explanation of two different approaches suitable for estimating the expected number of days that an individual may fish. The first approach uses a sample of the entire population (where no day response was given) to estimate the probability of an individual fishing, P(F), and then, uses the sample of those who fish to estimate the probable number of days a person fishes given they have
decided to fish, \((D^A|F)\). The product of these two probabilities provides one means to estimate the expected number of days an individual will fish. The second approach combines these two data sets by substituting the subsample of observations of those who said they fished in the total population data set with a sample of observations from the data set of those who fished. The resulting data set is an improvement over the sample of the entire population in that the observations on those who fished now includes information on the number of days they fished. The qualitative characteristics of the dependent variable in each of the regression equations is explained along with the necessary estimation procedures. The probit model is applied in the case of a binary dependent variable and the Tobit model applied to cases involving a censored dependent variable.

The regression results of each equation were discussed in terms of their coefficients' significance and expected sign. Also discussed were variables which did not show a significant influence on the households' production/consumption of the recreational fishing commodity. The marginal effects implied by the coefficient cannot be directly interpreted from the estimated coefficients. Chapter VI explains the mathematics behind the regression coefficients and derives the marginal effects.
CHAPTER VI

The goal of this chapter is to derive the value of an acre-foot of water as a recreational fishing resource and compare it to the value of an acre-foot of water used in agriculture. To allow this comparison, the marginal response in days fishing, as implied by the regression analysis on the Tobit equation estimating $D^B$, is determined for each of the 99 river basins (the ASAs discussed in Chapter II). Within each river basin (or ASA), the quantity of water representing a one percent change in flow is derived so that the change in days fishing is then measured by an acre-foot change in streamflow. Finally, by using the values of a day of recreational fishing discussed in Chapter IV, the value of an acre-foot of water for recreational fishing is determined for each of the ASAs. This value is then compared to water's value in irrigation which is taken from the 1985 CARD/RCA Agricultural Input/Output Model.

Estimating the Marginal Response

Recall that this analysis is built around a household production framework. A reduced form equation of the household's recreational fishing commodity production/consumption equilibrium is being analyzed to determine households' reactions to changes in the availability of fishing resources. Because commodities cannot be observed, days fishing act as a proxy for the recreational fishing commodity. To make full use of household behavior data, a Tobit model is applied to a population
sample containing responses of both those who did and those who did not fish in 1980. Observations on those who did fish include the number of days they fished. The section below outlines the mathematics behind the derivation of marginal responses from the Tobit and probit models and then applies this procedure to estimate the marginal responses indicated by the regression results.

**Deriving the marginal impacts**

In Chapter V, the sign and significance of the coefficients for each of the three regression equations were discussed. At that time was pointed out that the coefficients in those equations should not be interpreted as representative of the variable's marginal effect. This was true for the regression equations applying the Tobit analysis as well as the regression equation applying the probit analysis. The mathematics involved in estimation of the marginal effects for both the Tobit and probit equations is clarified below, after which the marginal effects implied by the regression results reported in Table 5.2 are estimated. Though the chosen method for estimating households' responses to changes in streamflow is the procedure suggested by equation 5.2 (the Tobit equation applied to a full population sample -- with the sample including the number of days fished), an analysis of the procedure suggested by equation 5.1 is undertaken for comparative purposes.
Marginal effects derived from probit coefficients

The discussion of the probit model in Chapter V pointed out that the probit analysis relies on a monotonic transformation of the model having the binomial dependent variable. An arbitrary index, $Z_j$, is selected and defined to be a linear function of the regressors. The distribution of $Z$ is assumed to be a standard normal variate so that $F(Z_j)$ represents the probability of the binomial variable equaling one (or, in this case, the probability that the household will fish). Thus, a change in probability resulting from a change in $X_i$, an independent variable (streamflow), must be:

$$\frac{\partial F}{\partial Z_j} \frac{\partial Z_j}{\partial X_i} = f(Z_j)B_i \quad (6.1)$$

where $B_i$ represents the coefficient on $X_i$ and $f$ represents the standard normal density function.

Equation 6.1 may be interpreted as the change in the probability that the household will fish given a change in streamflow ($X_i$). This provides part of the relationship between a change in streamflow and the change in the expected number of days a person will fish $E(D)$. Recall that the estimation of both 5.1 and 5.2 required the use of a Tobit model because both use equations samples having the value of the dependent variable censored at zero. Derivation of the marginal effects of the Tobit model is shown below.

Marginal effects derived from Tobit coefficients

The Tobit model may be thought of as a hybrid of the probit analysis and multiple regression analysis. Equation 6.2, take from Table 5.1,
clarifies the functional form of the Tobit equation used in the regression analysis. Here, the functional form of the Tobit results (for estimating $B^2$ of equation 5.2) describes the expected days fished, $E(D^2)$, for the jth individual as:

$$E(D^2) = XBF(Z_j) + a f(Z_j)$$  \hspace{1cm} (6.2)

where $X$ represents the vector of independent variables, $B$ represents the coefficient vector associated with $X$ (Table 5.2 contains the estimate for this same B vector), $a$ is the standard error, $Z_j$ is the normalized index computed from the normalized coefficient vector ($B/a$) for the jth individual, $F$ is the cumulative normal distribution function, and $f$ is the standard normal density function (see Table 5.1). The Tobit equation representing the conditional probability ($D^A|F$) is similar to the above.

It follows directly from equation 6.2 that the marginal change in the probable days fished, $D^B$ (or in the conditional probability ($D^A|F$)), given a marginal change in streamflow is:

$$\frac{\partial P}{\partial X_i} = B_i F(Z_j).$$  \hspace{1cm} (6.3)

Thus, this product (of the cumulative normal probability function at $Z_j$ and the coefficient of the independent variable $B_i$) estimates the marginal effect that a change in the independent variable $X_i$ has on the days fished for the jth individual (given $X_i$ is linear in $BX$).

**Marginal effects on expected days fishing**

The purpose of estimating an equation determining the probability a person might fish, $P(F)$, and an equation determining the probable number
of days a person might fish given they have decided to fish, \((D^A|F)\), is to use these equations in a second approach estimating the expected number of days a person might fish \(E(D^1)\). Their compound probability, \(P(F) \times (D^A|F)\), allows a comparison between this estimation of \(E(D^1)\) and the preferred estimation of \(E(D^2)\) using \(D^B\). Equation 6.3 provides the methodology for estimating the marginal effects of changes in the independent variables for the equation determining \(D^B\). The impact on \(E(D^1)\) when estimated by \(P(F) \times (D^A|F)\) follows from equations 6.2 and 6.3 above:

\[
\partial E(D^1)/\partial x_i = B_i^p f(Z_{ij}^p) (D^A|F) + P(F) B_i^d f(Z_{ij}^d). \tag{6.4}
\]

The superscripts \(p\) and \(d\) denote whether the coefficient, \(B_i\), or index, \(Z_{ij}\), are from the equation estimating \(P(F)\) or \((D^A|F)\), respectively. It is clear from 6.4 that the estimation of the impact that a change in streamflow has on days fishing relies on the predictive ability of both \(P(F)\) and \((D^A|F)\). And thus, given that their R-square values are not high -- 0.1029 and 0.0348 respectively (Table 5.2), -- the selection of \(D^B\) as the preferred method for estimating \(E(D^2)\) is reinforced.

**A comparison of marginal impacts**

Table 6.1 was produced using the mean values of the independent variables and the marginal value estimation methods as outlined in equations 6.2, 6.3, and 6.4. The independent variables being analyzed in this table were chosen because each is significant in the three regression equations. Note, however, that only the last two equations
have the same dependent variable so caution must be used when cross-comparing marginal effects.

Table 6.1 Marginal effects for changes in selected variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P(F)</td>
</tr>
<tr>
<td>SEX</td>
<td>0.0458</td>
</tr>
<tr>
<td>INC</td>
<td>-0.00466</td>
</tr>
<tr>
<td>URBAN</td>
<td>-0.0464</td>
</tr>
<tr>
<td>OMI60</td>
<td>-0.0533</td>
</tr>
<tr>
<td>OMI</td>
<td>-0.0798</td>
</tr>
<tr>
<td>SACRES</td>
<td>6.64*10^-8</td>
</tr>
<tr>
<td>LACRES</td>
<td>4.18*10^-9</td>
</tr>
<tr>
<td>SPRCNT</td>
<td>0.000343</td>
</tr>
</tbody>
</table>

SEX, URBAN, OMI60, and OMI represent the variables as defined previously. However, recall that the household's income is represented by a second degree polynomial and that the stream and lake fishing resource variables represent a composite of variables (e.g., stream/lake area, population, percent flow, riparian vegetation and the size of the resident area). Also, log values of the stream and lake fishing resource variables were used to account for the diminishing marginal value product of these resources due to increases in their availability. Thus, the variable INC in Table 6.1 defines the partial of the second degree polynomial evaluated at mean income. SACRES and LACRES represent the partial of the dependent variable with respect to a change in the
surface acres of the stream and lake resources available, respectively. SPRCNT represents the partial with respect to a one percent change in streamflow.

SPRCNT is listed to allow a cross-comparison of the estimated responses to changes in this variable of primary interest (streamflow). SACRES and LACRES provide a means of comparing (on a per acre basis) the stream and lake resources as inputs in the fishing commodity production.

All of the response measures in Table 6.1 estimate the response of the average household, with average lake and stream resources available, in the continental United States. Though such a wildlife region may not exist, Table 6.1 does provide a chance to compare the marginal effects of the different coefficients. The ultimate goal in this chapter is to determine the value of an acre-foot of water within each of the 99 ASAs. The framework of the regression analysis was based on the (smaller) areas used in the FHWAR survey (resident areas and code areas). The household and resource variables vary across these areas, thus, so will the marginal responses. Therefore, the estimation of the marginal response begins at the FHWAR survey areas. The subsequent steps necessary to transpose these marginal responses into a measure of response within an ASA is discussed below.

Valuing Water in an ASA

The procedure used in converting the measured responses within the regions of the FHWAR survey to measured responses within the ASAs is similar to the procedure used in converting the percent flow values of
ASAs to percent flow values within wildlife regions in that both methods break down the measures to the county level and then aggregate. However, given the nonlinearity of $\frac{\partial E(D^2)}{\partial SPRCNT}$ (the day response measures), proper steps must be followed in aggregating responses. These steps are outlined and justified in the discussion below.

**Determining day responses**

The modeling of the household's behavior in the regression analysis of $D^B$ estimated the household's production/consumption of the recreational fishing commodity within each of the resident areas. Therefore, the approach to estimating the response of the population begins with the responses within the resident areas.

**The population response within the resident areas**

Because the regression equation models the behavior of the households living within the various resident areas, the marginal responses are determined for these same households. One approach to estimating the total marginal response of the resident area's population is to estimate and sum the marginal response of each and every individual. This procedure requires observations on the entire population of the (continental) U.S. A better approach (and the one used

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1Remember that the resident area is composed of one or more wildlife regions and defines the general area in which the respondent lives. The code area associated with a resident area represents the group of wildlife regions which are close enough to represent another source of recreational fishing resources. The wildlife regions represent divisions of a state containing similar wildlife habitat.
here) is to estimate the average response for individuals within each of the resident areas, and multiply this average response by the area's population.

However, there are two different approaches one might take to estimating the average response: one by solving $\frac{\partial E(D^2)}{\partial SPRCNT}$ using an average of the independent variables and, the other by determining the average of $\frac{\partial E(D^2)}{\partial SPRCNT}$. Equation 6.3 indicates that the function $\frac{\partial E(D^2)}{\partial SPRCNT}$ is not homogeneous of degree one (and/or zero) with respect to the various independent variables. Thus, to avoid bias, $\frac{\partial E(D^2)}{\partial SPRCNT}$ is estimated using observations on the households, not by using an average of the variables.

A resident area's average response multiplied by the population of that area generates the total change in days fishing (for and within, both, the resident area and the code area), given a change in streamflow, by the population of that resident area. The next step is to disaggregate this information to eventually determine the change in days fishing within an ASA given a change in streamflow within the ASA.

**Response within the wildlife region**

Responses within the ASAs can only be determined through aggregating responses within counties. But before disaggregating the above information (on responses within resident areas and code areas) to the county level, a total of the change in days fishing (given a change in streamflow) must be determined for each wildlife region.
All of the wildlife regions used in this study lie within one (and only one) resident area. Wildlife regions also lie in the code areas and, often, they lie in several code areas. For example, consider wildlife region 486 of Figure 4.1. 486 is fished in by the people living in the resident area composed of 486 and 483 (486 being part of the resident area), by people living in the resident area composed of 480 and 487 (486 being part of its code area), and by people living in the resident area composed of 482 (486 being part of its code area). To determine the total days fished in 486, the days fished by residents of each of these areas must be accounted for.

Determining the allocation of days fished within the resident area among the different wildlife regions within that area (for those resident areas made up of more than one wildlife area), follows directly from an assumption made when estimating the stream resources' availability. Recall that the measure of stream resource availability assumed that the impact of a stream surface acre is constant across the resident area no matter where in the resident area the acre of stream surface is located. Therefore, the total days people fished within their resident area is divided among the wildlife regions according to their relative stream surface acres. Admittedly, the division of marginal changes in days fishing among wildlife regions depends more on the proportions of the total days fished than their proportions of stream surface area. However, with no information available on the total days fished in wildlife regions, stream surface area makes an appealing alternative.
This same procedure is used to portion the days fished among the wildlife regions composing a code area. In this way, total days fished within each wildlife region (by all those who might fish there), given a percent change in streamflow, is determined.

Response within the ASAs

To determine the effect which a change in streamflow has on days fishing within an ASA, the fishing response information must be broken down into county units. Again, making use of the assumption that each surface acre of a stream within a wildlife region has an equal impact on the number of days spent fishing within that region, the total days fishing response within a wildlife region can be divided among its counties by, again, using relative stream surface areas. With this county level measure of the fishing days response, the change in days fishing, given a change in streamflow within an ASA, is found by summing the relevant counties' responses.

Because there are 99 ASAs and 291 wildlife regions, the days attributed to streamflow changes per county within the wildlife regions are often added back together because they lie in the same ASA. Thus, this rejoining lessens any bias that the use of relative stream surface area, in determining the breakdown of marginal changes in days fishing among counties or wildlife regions, may cause.
Deriving acre-foot water values

The acre-foot value of water as a recreational fishing resource can now be determined directly by the use of two more relationships. First, now that the days response is in terms of the percent change in streamflow within an ASA, the quantity of water that a one percent change represents can be determined. The product of 0.01 (one percent) and natural outflow of the ASA estimates this water quantity. Thus, the change in days fishing given a one percent change in flow can be simplified to the change in days fishing for an acre-foot change in flow.

Second, using the value of a day of recreational fishing, a dollar value for the change in days fishing is determined. The product of the change in days per acre-foot and dollars per day determines the dollar value of water per acre-foot change in streamflow.

Allocation

With the above procedure for estimating the value of water per acre-foot, the recreational fishing values of water is determined for each of the 99 ASAs. These values have been computed using fishing day values of 10, 15, and 20 dollars as discussed in Chapter V. Table 6.2 below lists these values along with the water's estimated marginal value in irrigation.

As can be seen from Table 6.2, water has a wide range of values in its use as a recreational fishing resource. In 79 of the 99 ASAs, when a day of fishing is valued at $10, the value of an acre-foot of water is
Table 6.2. Acre-foot water values in the WRC's ASAs as a resource for recreational fishing and for irrigation

<table>
<thead>
<tr>
<th>ASAs b</th>
<th>$10/day</th>
<th>$15/day</th>
<th>$20/day</th>
<th>Irrigation</th>
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<td>.43</td>
<td>.58</td>
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<td>8.75</td>
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</tr>
</tbody>
</table>

a All values in 1980 dollars.
b See Figure 1.2 for the location of the ASAs.
c --- indicates no water used in irrigation.
d The CARD/RCA model splits six of the ASAs thus creating two values for these ASAs. All values reported above are the higher of the two values. In five of these six ASAs (1008, 1010, 1105, 1106, 1204) the second value of water is zero. However, in ASA 1203 the second value was estimated to be 13.32.
Table 6.2. continued

<table>
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<tr>
<th>ASAs</th>
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<th>$20/day</th>
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<td>1301</td>
<td>84.40</td>
<td>126.60</td>
<td>168.80</td>
<td>0</td>
</tr>
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</table>
less than $10. Less confidence should be placed in the highest of the acre-foot values (within a column) since these values may be the result of extreme values of the independent variables. For example, ASAs 1503 and 1603 have the highest instream value of an acre-foot of water, but they also have the greatest portion of their streamflow depleted.
Depletion in streamflow of ASA 1503 exceeds 99 percent and in 1603 it exceeds 90 percent of their natural flows, thus, their marginal water values are not likely to be realistic.

The value of water's use in agriculture estimated for ASA 1802 is significantly higher than the other estimates and is not likely to be realistic. However, given the low instream use value of water, the actual value of water to agriculture probably exceeds its instream value nevertheless.

Fishing day values were also estimated based on the alternative method (that method based on equation 5.1, the compound probability) proposed to estimate $E(D^1)$. Values stemming from this approach were usually higher (approximately 90 percent of the time) but usually within 40 percent of the corresponding values reported in Table 6.2.

Water's value as an instream resource

Day values and water values The values reported in Table 6.2 rely directly on the value of a day of recreational fishing. Because this value can vary across the U.S., three different day values (10, 15, and 20 dollars per day) have been used to compute those values listed. Adjusting the water value for the different day values is easy given their direct relationship. For example, notice that the water values in the $20/day column of Table 6.2 are double those of the $10/day values. Thus, adjustment of water values to different day fishing values involves only multiplication or division.
Allocating water can be politically difficult even when the optimal policy is known. Reasons for this include: first, the benefits of the consumptive use of an acre-foot of water are among a much more concentrated group of individuals than the benefits of water's public use. And second, because a stream's natural flow can cross many political boundaries, the upstream water consumption decisions may not have considered the benefits that an acre-foot of water generates downstream (These and other factors of water allocation are discussed in Chapter II.) But, before the political work on water allocation can be effective, the optimal allocation of water must be determined. Determining the optimal allocation of water is complicated by two major factors. First, as a public resource, there exists no market for water from which to derive its demand (as is the problem in demand estimation for all public goods). And second, since a unit of water within a stream can traverse a wide area, benefits are dispersed all along the stream's course. The political difficulties of water allocation are beyond the scope of this work, however, it is the economic problems which this study has dealt with. More specifically, the focus of this work has been on estimating the disbursed benefits which water generates throughout its course, relying on past (demand) estimates in valuing a of day fishing in order to quantify these benefits.

Because this approach estimates the value that a unit of water generates throughout its course, it can account for benefits which have not previously been quantified. Without knowing the level of these
benefits, their full consideration in past water allocation decisions is not likely. Though in many of the ASAs the estimated acre-foot water value as a fishing resource is less than a dollar (19 ASAs in the $10/day column), these values are important because they indicate that water does have value as an instream resource for recreational fishing. The exact value of a day fishing is not known, however, even the $10 fishing day values are significant enough to indicate that water is not being allocated optimally -- that water is being used in agriculture though it has a higher valued use as an instream resource.

Furthermore, the magnitude of these values may understate the actual values because the national scope of this analysis requires the generalizing of a variable's measure. For example, the estimate of percent flow is an average measure for each ASA yet, the actual percent flow across different areas within the ASA likely varies around this average. Therefore, the variation in fishing within an ASA, due to variation of flow within the ASA, cannot be fully estimated.

Inclusion of all downstream benefits

The purpose of this analysis has been to account for the benefits of water within a river system as a public fishing resource. The benefits of streamflow within each basin are estimated by the design of the analysis. The benefits generated by water after it leaves the ASA and flows into another have also been accounted for. To indicate the significance of these benefits, Table 6.3 lists the acre-foot value of water when only the benefits within the ASA are included and compares
them to the total within/downstream ASA benefits. (Values in the "All ASAs" column are the same as those in the $10/day column of Table 6.2). For example, Figure 6.1 indicates that an acre-foot of water leaving ASA 1106 will pass through ASA 1107, then through 802, and finally through 803 where it then flows into the Gulf of Mexico. Table 6.3 indicates that the value generated by an acre-foot of water within ASA 1106 is $15.00. Thus, an acre-foot of water generates $1.15 (16.15 - 15.00) in fishing benefits as it passes through ASAs 1107, 802, 803.

The above table indicates that a significant portion of the water's value for some ASAs is that which is value generated in the downstream ASAs. This, again, emphasizes the importance of considering water as a flow resource and accounting for all benefits an acre-foot of water may generate throughout its course.

Instream use vs. consumption

Table 6.2 indicates that there is no significant use of water in irrigation by 32 of the ASAs. Of the 67 ASAs which do use water for irrigation, 15 have consumptive values of water which exceeds its estimated value as a recreational fishing resource. In 52 ASAs the recreational fishing value of water is greater than its value in irrigation. This holds true for any of the three fishing day values used. In 49 of these ASAs, enough water is used in irrigation so that its marginal value is zero.

The reallocation of water

The results of Table 6.2 indicate that for 52 of the ASAs, water would be allocated to a higher valued use if
Table 6.3. Acre-foot values\(^a\) of water with and without inclusion of the values generated as it passes through the downstream ASAs

<table>
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<tr>
<th>ASA</th>
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<th>Within ASA</th>
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<td>2.78</td>
<td>1.55</td>
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<tr>
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<td>1.23</td>
<td>0.74</td>
</tr>
<tr>
<td>503</td>
<td>4.71</td>
<td>3.48</td>
</tr>
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<td>1.67</td>
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<td>0.49</td>
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<td>4.04</td>
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<td>0.68</td>
</tr>
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<td>0.08</td>
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<td>40.55</td>
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</table>

\(^a\)Acre-foot values based on a $10 fishing day value.
the amount of water consumed in agriculture was decreased. Quantifying the magnitude of these adjustments is beyond the scope of this study because of the many remaining considerations which still must be applied in determining optimal water allocation. Let's consider some of the more important issues. First, the equity of a water reallocation plan must be considered (discussed earlier). Second, efficiency should dictate where the decreases in water consumption occur and the magnitude of these changes (e.g., who should get less and by how much). Third, in any macroeconomic analysis on optimal water allocation applying these results, must consider that these recreational fishing values for water are dependent on streamflow levels (inversely related). And fourth, consider too, that decreasing water use in agriculture decreases agricultural output and, thus, may increase farm output prices. Any rise in farm output prices increases the value of water in agriculture.
Other consumers

While Table 6.2 indicates that decreased use of water in agriculture can be a Pareto move in 52 of the 99 ASAs, there are 32 ASAs in which there is no use of water in irrigation. Given the many other consumptive uses of water (potentially) occurring in these ASAs, comparisons could be made using these other consumptive use values of water. Though only the consumptive use value of water in agriculture is used, this is not to imply that the value of water in these other uses is greater than water's value as a recreational fishing resource. A full analysis of water's consumptive use values is beyond the scope of this study. However, the value of water in other consumptive purposes should be considered in any water allocation policy (this also holds for those 67 ASAs where water is used in agriculture).

Other instream values

Before ending this discussion on water allocation, consideration must also be given to other uses of water as an instream resource. As with consideration of other consumptive uses of water, estimating the other instream values is not undertaken here. However, as opposed to the other consumptive uses of water, alternative instream use values are additive (as with all public good benefits). Thus, the marginal public resource value of water in some ASAs will exceed those estimates in Table 6.2 when increases in streamflow within those ASAs increases the streams' provision of other public goods (for which there exists a positive demand).
Summary

The value of an acre-foot of water for use in recreational fishing has been derived from the regression results reported in Chapter V. The steps followed to obtain these values were: first, the derivation of the marginal response measure; second, the determination of the change in days fished within the wildlife regions due to a change in streamflow; third, the extension of these results to response measures for ASAs; and fourth, the conversion of the ASA response measures from days/percent to dollars/acre-foot of streamflow. The dollar values of an acre-foot of water in recreational fishing for the 99 ASAs are presented in Table 6.2. These values are based on recreational fishing day values of 10, 15, and 20 dollars/day.

Most of the values listed in Table 6.2 indicate that the value of an acre-foot of water for recreational fishing is less than $10/acre-foot (70 ASAs for the $20/day values and 79 ASAs at the $10/day values). Comparing these values to the marginal value of water in irrigation (as determined by the CARD/RCA model), reveals that in 52 of the 67 ASAs which use surface water for irrigation, water has a greater marginal value as a public resource than as an agricultural input. In 49 of these ASAs, the marginal value of the last unit of water consumed in irrigation is zero, thus indicating these ASAs have no significant restriction on the use of water in irrigation though it would be a Pareto move to do so.

Besides the political complications involved in allocating such a mobile resource, past water allocation decisions have (likely) had to be
made without full information on the downstream recreational fishing value of the water. The design of this analysis has been to measure such benefits. Though this analysis has not determined the quantity of water to be reallocated, several points have been made on this issue. The most important point to consider in applying the above results/analysis in determining the (an) optimal water allocation is that the marginal water values which have been derived are functions of the level of flow. Thus, the marginal value of an acre-foot of water changes as water is reallocated.
CHAPTER VII. SUMMARY, CONCLUSIONS, AND POLICY IMPLICATIONS

With the existence of a public good or a public resource within a market economy, suboptimal resource allocation can be assured if the following two conditions are met: first, the resource is scarce and second, only market activity allocates the resource. Past studies on water availability indicate that water (a public resource) is scarce in both its public and private use. However, water is not allocated by the market, but by Federal, State, and Local governments. This study hypothesizes that the present allocation of water fails to put water to its highest valued use, and thus, has failed in achieving optimal water allocation. Whereas political difficulties in achieving optimal water allocation are recognized to exist, these are not considered binding constraints. Instead, it is the lack of information on the value of water as an instream resource which that prevents water from being allocated to its highest valued use. Thus, an estimation of the instream public-use value of water is a necessary preliminary step in obtaining optimal water allocation.

Valuing a scarce public good, such as streamflow, involves estimating its (not readily observable) demand function. Complicating the estimation of the value of water within streams is the dynamic nature of the resource. A stream represents a continuum of sites all of which can be influenced by the withdrawal of water from the stream. Thus, an acre-foot of water in Montana can generate social benefits in Mississippi. The analysis undertaken here provides a method for estimating the public use benefits an acre-foot of water generates throughout its course.
Summary

Because the flow aspect of streams allows each acre-foot of water within to generate benefits over a wide area, the regions over which the evaluation is undertaken must be extensive enough to capture all effects. Using the FHWAR survey, a national analysis on individuals' responses to changes in streamflow was undertaken. The public-use value of water analyzed here is the value water has as a resource in recreational fishing. Water for this public use generates value indirectly in that the level of flow affects the ecology of the stream. Biological analyses of streams testing the "Montana Method," ¹ substantiate the relationship between percent flow and biomass of fish (per surface acre) for all types of streams. Thus, the combined percent flow and the total surface area of the streams in a region provide an indication of an area's fishing resource availability.

Both economics and ecology have the same Greek root, oikos, meaning household. It is through households' behavior that the significance of streamflow as a fishing resource is determined. Application of the household production theory proved to be the most fitting approach to the problem at hand. In some instances, when all the necessary conditions are met, demands for public goods can be estimated directly within the framework of this theory. However, in this particular case, not all of the conditions required to overcome joint commodity production are met.

¹The Montana Method suggests that a stream's percent flow (the percent of the stream's natural flow the present streamflow represents) directly affects the stream's ability to produce fish.
The selected alternative estimates a reduced form equation of the household's commodity production/consumption decisions. By using days spent fishing as a proxy for the recreational fishing commodity, responses to changes in streamflow are estimated for households throughout the U.S. Because the sample on days fishing by households represents a censored sample (where observations are truncated at zero), a Tobit model was use to estimate households' responses. The estimated responses are applied to each river basin and reduced to a measure of days fished per change in acre-foot of streamflow. Past estimates on the value of a day of recreational fishing indicate that its likely value lies between 10 to 20 dollars per day. Thus, based on fishing day values of 10, 15, and 20 dollars, the value of an the acre-foot of water within each drainage basin is derived.

These water values exceed the marginal value of water in irrigation (as estimated by the CARD/RCA model) in 52 of the 67 drainage basins (ASAs) that irrigate crops (see Table 6.2). Acre-foot values of water in recreational fishing are less than $10 in 79 ASAs and less than $1 in 19 of the ASAs when a recreational fishing day is valued at $10. Table 6.3 indicates that the value generated by the public use of water in downstream ASAs can be the greater portion of the water's value, thus, emphasizing the significance of the downstream value of water.

Conclusions

Regression results reported in Table 5.2 indicate that stream fishing resources are an important resource in recreational fishing. The highly significant t-value and the stability of this coefficient across
regressions containing differing combinations of the independent
variables adds further evidence toward the importance of streamflow as a
fishing resource.

The value of an acre-foot of water as a public resource varies
across the different river basins, but water values in irrigation do not
show any correlation to this variability. Hence, it does not seem that
water allocation policies are based (significantly) on the instream value
of water. Table 6.2 indicates substantial gains can be obtained for
reallocating within some regions.

The public use value estimated for water only includes water's value
as a fishing resource. Other benefits from the public use of streamflow
have not been included. Because any of the other benefits that the
public use of water generates are additive to those in Table 6.2, the
estimates of fishing benefits may be thought of as a minimum public use
value of a marginal change in flow.

Finally, it is pointed out that public environmental resources are
been increasing in value as the public obtains more leisure time, the
value of leisure to households' increases, transportation to these areas
becomes easier, and the mechanization of society brings a greater
appreciation for natural areas. As this trend continue, the value of
water as an instream resource will continue to rise and compete with
water's consumptive use.
Implications

A comparison between the consumptive and nonconsumptive use of water indicates that water management has failed to allocate water to its highest valued use. As previously discussed, there are political factors which may play a role in this failure in water allocation. However, it is not likely that previous water allocation policies had information available on the downstream benefits an acre-foot of water can generate. The results listed in Table 6.2 indicate that substantial gains can be obtained by reallocating water to nonconsumptive uses. Though the issue of compensation to those who lose their water rights is not dealt with here, marginal water values in irrigation indicate these costs will be very minor in many of the ASAs (at least for minor adjustments in water allocation), whereas the gains significant.

Water policies and attitudes toward public resources must become more attuned to the value these resources provide society. Water policies are only of late becoming less consumption orientated. Given the social benefits obtained by use of water as a public resource, water policies should adjust their focus toward increasing streamflow and discouraging consumption. Though this sounds easy, this change in policy requires a great deal of change in both interpretation of laws and adjustments of attitudes. As Chapter II points out there are avenues to allow such adaptations in water-use policy. Attitudes towards a belief in the right to consume resources are not so easily changed. For example, the Wall Street Journal discusses a case of resource consumption versus environmental concerns in a front-page article on April 18, 1986,
which involves the South Fork of the Salmon River and the timbering around it. This stream once was one of the best salmon streams in the U.S., having Chinook salmon weighing up to 16 pounds. Lumbering roads built before 1965 allowed that year's heavy rains to create mud slides generating "one of the worst wildlife disasters" from which the river still has not recovered. Currently, the Forest Service plans to build more roads on the hillsides above the South Fork for timbering operations. The article stresses that the Forest Service did not consider the potential environmental loss posed by this project and, in fact, will spend $2 million more on this project than the revenue it expects to obtain from the sale of the trees. Such regard towards the consumptive vs. public use of water (and other natural resources) and the subsequent social costs emphasizes the need for a readjustment in resource policies and attitudes.

Because an acre-foot of water generates substantial benefits in downstream regions, water policies must be analyzed across these same areas to capture all the benefits that an acre-foot of water can generate as an instream resource. To allocate water to its highest valued use requires the cooperation of many state and local governments. Federal water policy should already be allocating water with such considerations. In light of the results listed in Tables 6.2 (showing the differences between the instream and the irrigation values of water) and Table 6.3 (showing the level of benefits water can generate as it moves downstream), there is a substantial need for water policies based on the multi-regional benefits.
Finally, the containment of streamflow for recreational use may actually decrease the fishing resources of the area. While it is true that a lake may offer a number of recreational benefits, results listed in Table 6.1 indicate that an acre of stream surface, as a recreational fishing resource, is equivalent to twenty acres of lake surface. This equivalency is drawn from a very general measure and therefore, it may vary substantially from project to project. However, this data does indicate that consideration must be given to the loss of social benefits from the lost stream area when reservoirs are built.
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I cannot fully explain the appreciation I feel for the assistance provided by those whom helped me technically and emotionally in completing my dissertation. All of my committee members -- Dennis Starleaf, Raymond Beneke, Burton English, Roy D. Hickman, and Wallace Huffman -- provided technical assistance and much needed support, but especially Dr. J. Arne Hallam who provided necessary advice and volunteered his time to complete many tasks at Iowa State which I was unable to do in Tennessee.

Other people whom helped me by their patience, guidance, and friendship include Bruce Eveland who, besides being a good friend, taught me the secrets of PLL, David Pate who encouraged me to not forget the real-world of fishing, Peter Orazem who always willingly answered my econometric questions, Jean Gauger who allowed me to bend her ear more than once, Anisossadat Bahrenian who made the office we shared a "favorite place" for me, and finally S. Devadoss who has been like a brother to me. Becky Kelly and Joan Strong at the University of Tennessee's Center for Business and Economic Research earned much thanks for their editorial assistance. A special thanks goes to Terry Dinan who provided essential encouragement, showed a solid faith in me and whose love during this time was a refuge I can never forget.

I cannot go without thanking my parents, Peter and Cecilia Hansen, and my brother and sisters for understanding why they have not received letters from me for the past two years.
And finally, as the time approaches 1 A.M. and Diana McLaughlin completes the typing of my dissertation, I am left without words to express my gratitude to her for both this late night work and the cooperation she has shown me.