Indirect Benefits and Fisheries Management-A Case Study in the Mid Atlantic Region

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Indirect benefits have a long history in the literature of benefit-cost (B-C) analysis. A common measurement tool for indirect benefits is the Leontief or Input Output Model (I-O), and this paper discusses indirect benefits as if they are identical to I-O analysis. The B-C literature disparages I-O for assessing the economic efficiency of a project but does admit its possible usefulness in connection with distributional considerations, including inter-jurisdictional cost sharing. To illustrate, the paper draws on recent research on Mid-Atlantic recreational fisheries. The nature of fisheries is such that I-O is an especially ill-suited tool for efficiency analyses. However, in a concluding section, reference is made to a way in which I-O could be useful. It appears that this application may be better suited for the commercial fisheries than for recreational fisheries.

Preferred Framework: Social Surplus as a Measure of National Benefit

In analyzing optimal allocation of scarce resources among activities, we will search for that allocation which makes society "better off." A classical notion for determining whether we are "better off" is that of social surplus. This concept takes into account the "surpluses" or benefits that accrue to consumers or to producers in market transaction. Consumers' surplus (CS) is the excess or surplus of the total amount consumers would have paid for quantity received above what was actually paid. The Producers' Surplus (PS) is total revenue to an industry, minus total costs. The social surplus is the sum of producers' and consumers' surpluses. A change is said to be more efficient than the status quo if it increases the social surplus. The references below contain paradoxical examples contrasting I-O and social surpluses. For formal development of these surplus concepts, the reader is referred to Harberger (1971), Rothschild, et al (1977) or Edwards (1991). PS is also a residual or "surplus" that is often termed economic rent; a somewhat narrower term, although in empirical work the two tend to be regarded as equivalent. PS reflects profit in the sense of a residual remaining after allowance for return to all purchased or owned inputs including an average or normal rate of return on capital. The term producers' surplus is be used to emphasize the analogy with consumers' surplus. Both PS and CS are discussed in the references just cited and in standard microeconomic textbooks.

I-O as a Trivial Linear Programming Problem

I-O has long been recognized as a sort of trivial Linear programming (LP) problem (Dorfman, *et al* (1958), Brink and McCarl (1977), Rothschild, *et al* (1977). There are several properties of LP that can then be exploited, viz.:

(1) Substitution and slack possibilities

In contrast to the typical A matrix of I-O, a typical A matrix for LP has N columns and M rows with N being many times larger than M. A modest LP problem might have a hundred rows and several thousand columns.

(2) The $C_{j-}Z_j$ row and Dual variables

The simplex algorithm(s) are direct expressions of the Arrow-Uzawa conditions for a quasi saddle point in mathematical programming and game theory. As such they give insight into what is happening, the dual variables and the mysterious multipliers of I-O.

(3) Sensitivity Analyses

Typical LP software has a range of options for sensitivity analysis.

(4) Any LP problem can be recast as a two-player zero sum game and conversely, such a game can be recast and solved using the simplex algorithm of LP (Vajda, 1956).

Mathematical Programming and Saddlepoints

Mathematical programming (MP)includes both linear and nonlinear (NLP) variants and LP can often be used to efficiently solve both via grid linearization techniques. MP has close associations with the theory of saddlepoints in mathematical economics. Every MP has associated with it two related problems known as the Primal and Dual problems. Our interest in each depends on which corresponds to our focus. For example, a firm might wish to maximize profits (the Primal) subject to resource constraints while an entrepreneur might wish to minimize the

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imputed value of the firm's assets whose purchase he is considering subject to the imputed value of resources used in production exhausting the value of product produced (the dual). By convention we consider these problems as the primal and dual problems, respectively.

The primal and dual problems have saddlepoint representations in game theory. The saddlepoint solutions are minimax or maximin solutions. In general the relation between the two is one of inequality. However in the linear case, minimax and maximin are equal. Thus, the seller and buyer with identical information would value the firm identically. Of course, each may have differing perceptions because the buyer would use the assets differently, but he has an incentive to pay no more than the value in production to the seller. In short, all LP problems can be represented as two-person zero sum games and vice versa. Now there certainly are zero and negative sum games and the choices made in fisheries management often fall in these categories. But economists try to focus on positive sum formulations. They do so by focusing on consumers' demands, which are presumed to be utility maximizing and producers' profit maximizing supplies. This leads to a NLP problem of maximizing the sum of producers' and consumers' surplus. When this is done both producers and consumers are potentially better off, although compensation (side payments) may be needed to realize the condition "all better off".

In I-O, Gross Domestic Product (GDP) is constant; there is only one solution so its optimality is moot. The zero sum nature is seen most clearly when GDP is examined from an input versus output point of view; total exchange values (revenues and costs) are equal and opposite in sign; revenues to producers are costs to consumers. CS is not even measured in I-O; to do so requires a non linear model. In Benefit Cost Analysis it is the residual surpluses to producers and consumers that are positive sum. An example of particular interest in this paper is would be an increase in fish density (abundance) available to recreational fishermen, about which more later. The I-O approach, we will see in due course, is particularly uninformative.

In the examples in the literature, the indicated direction of change in induced impacts often does not accord well with common-sense notions of people being "better off." In fact, induced benefits, like the gross national product, were never intended as indices of economic well-being *per se,* but simply an accounting of the exchange values of goods and services exchanged in markets. These exchange values are irrelevant to benefit cost analysis because they are zero sum transfer payments between production and consumption sectors. It is of course true that there must exist at least some correlation between these measures and economic welfare. Presumably society is better off with a GDP of $1 trillion than with zero GDP simply because the social surpluses mentioned earlier cannot be generated without also generating (some) GDP and induced impacts. Indeed, as discussed above in connection with saddlepoints, maximizing the social surplus also leads to maximum GDP, although indirectly. Costs are necessary to produce product and sales, but maximizing cost is not the objective of the enterprise.

More or less Valid Uses of I-O:

Given all these difficulties with induced benefits, why do they retain their fascination?
Let us first of all acknowledge that the problematic aspects of I-O do not stem from any skill deficiencies or ignorance of analysts. Rather, the participants in the management game keep asking for economic impacts for their own use in collective fisheries management bargaining in a manner analogous to the regulated dictating how stock assessments "should" be conducted..

1. As a planning Tool

One reason for the persistence of I-O is that it provides a systematic tool or device for identifying "bottlenecks" which makes I-O a useful planning aid. A similar reason derives from the regional impact orientation of much input-output analysis (Tiebout 1957). Induced regional benefits tend to cancel out at a national level; benefits are induced in one region at the expense of other regions(s). However, the cost of programs is frequently borne in part by the federal government. From the viewpoint of the receiving region, it receives a (relatively) costless expenditure that induces net regional benefits. Hence, to the extent that the public decision makers seek to differentiate beneficiaries by region, induced impacts may receive weight in their decision[3] ·

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3 Appropriations and "earmarked" funds have exploded since the Rothschild, *et al* article was written. Multipliers once provided a modicum of public relations; it seems that even this fig leaf is no longer necessary in Federal appropriations processes.

2. Regional (Keynesian?) Economics

Another reason might be to extend Keynesian reasoning to regions and sectors in periods of insufficient aggregate demand. Indeed, the premise of I-O is Keynesian. We don't wish to digress into alternative macroeconomic theories [4]. Suffice it to say that there is good reason to be skeptical of Keynesian models except in unusual conditions. One difficulty with doing so is that of knowing the regional incidence of demand insufficiencies in real time and correctly targeting expenditures in time and space rather than two or three years after the fact. A related difficulty is distinguishing between short term macroeconomic demand insufficiency and a long term structural change in I-O coefficients. Such structural change could happen due changing comparative advantage or stock depletion- fisheries are a non-linear system. Trying to address inevitable long term structural change with short term expenditure increases is palliative only and unlikely to solve the underlying problem. Indeed, the disruptions of macroeconomic events are often unanticipated events that perturb coefficients and may cause I-O coefficients to become unreliable in the short run. That regional concerns are important is, as we have just seen in the U.S. “stimulus” program of 2009, an undeniable fact of life. But, the actual distribution and uses of such funds owes more to entrenched political structures than to the recommendations flowing from I-O models. There is another interesting aspect of the static I-O matrix equation. By using the sequence indicated, a time sequence is asserted out of nowhere. The standard I-O model is static; nothing is said about the time required for realization of multipliers. But if we explicitly dynamize the structure of (5), using a scalar analogue,

$$X(t+1) = (1-a)X(t); \quad 0 < a < 1$$
$$\text{Lim } X(t) = X(0)(1 + a2 + a3 + \ldots\ ) = (1/(1-a))X(0)$$

This is rarely noted in I-O studies and it may be untrue because the static equation is actually silent regarding the time required for its realization[3].

3. State-Federal Cost Sharing

It has been suggested that another valid use of induced benefits would be in construction of federal-regional cost sharing arrangements for public programs (Ciriacy-Wantrup 1962). This application could, of course, attenuate the demand for induced benefits by the receiving region. As indicated earlier, primary benefits can also be decomposed regionally. Their incidence, however, is frequently across regional boundaries; consumers' surplus benefits from fish conservation may be incident as much on Midwest consumers as on New England consumers, depending on regional market distribution patterns. So, for example, paying for part of CS gains from Federal revenues or a market level sales tax on fish or inputs to fishing might make some sense, distributionally speaking, under this consideration.

4. Secondary impacts of increased Social Surplus

Many economic studies suggest significant increases in PS accruing from stock rebuilding programs. This need not always be the case, of course, but when it is so, are there no secondary benefits? Yes, there are, and a recent paper shows how to use I-O in this context. Steinback, *et al* (2008). They examined a set of management scenarios for the American lobster fishery using the simulator SIMLOB. They linked the increased income (PS) from improved management with a regional I-O model. Not surprisingly regional incomes increased. Somewhat more surprisingly, the reduced employment found from looking only at harvest sector PS were more than offset by employment increases induced by the increased PS. Of course, the induced expenditures were not in the harvest sector, but they were in the region and were high enough to more than offset employment losses in the harvest sector.

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4 Even though we are in the midst of a fascinating test of the Keynesian versus monetarist theories.

3 The I-O static matrix equation involves both a mathematically true relationship and a logical analogy with time. Analogies are a particularly low form of logic which is unfortunate because they are often persuasive. We all use them.

Fisheries in the Mid-Atlantic Region

The author recently revised a 2009 study done for the Pew Foundations and involving the Black Sea Bass, Bluefish, Butterfish and Summer Flounder fisheries. The butterfish fishery is purely commercial; the others are mixed recreational-commercial fisheries. One of the conditions of the study was to eschew allocation issues; which condition has serious negative implications for potential social surplus (efficiency) gains from management measures. The study was retrospective; it addressed *what would have been* the economic benefits of meeting recommended fishing mortality targets in a more timely fashion. This required estimation of biomass difference equations, projection of catches under alternative scenarios, calculation of gains in profits and consumers' surplus over time. The producers' and consumers' surpluses were expressed as future values in 2007 dollars and then re-expressed as perpetual annuities from 2007 onwards. With allocation possibilities off the analysis table, it was not possible to examine reductions in the capital stock in harvesting. As per request, secondary benefits were examined but difficulties arose as will be discussed in due course.

The primary or direct economic benefits of a more timely rebuilding of stocks depends on the species, the sector and the rebuilding scenario adopted. The scenarios were as follows:

For each fishery, four scenarios are considered; Scenarios 1, 2, 3 and 4. The scenarios differ in the level of fishing mortalities (F). For a given biomass and year, current catches (C), vary directly with biomass and fishing mortality. Increases in F, for a given B and year, result in increases in current catch, C(t), but future catches, C(t+1), C(t+2),…. may be lower (or higher) unless biomass growth and catch are equal. Similarly, for a given F, a larger B will yield higher catches, C.

Scenario 1 is a reconstruction of the observed or status quo situation; F(t) = observed F values. For **Scenario 2**, the F values are constant at the target level, Ftarget , recommended in stock assessment reports for each species. Usually, this is a level that is projected to result in an annual yield that is the "Maximum Sustainable Yield" (MSY). In that case, $F(t) = F_{target}$ also equals F_{msy} , the value of F compatible with MSY. For various reasons, including uncertainty, F_{target} may be less than F_{msy} .

Scenario 4 uses constant values for F that maximize the annualized revenue subject to the terminal biomass, B(T) being at least as large as the initial biomass, B_0. In general, this F is larger than F_{msy} unless the discount rate is zero which would be the case if capital were free and unlimited; an unrealistic situation. As a consequence of this higher F in scenario 4, the biomass trajectory will not reach B_{msy} .

Scenario 3 uses a constant intermediate $F = F_3$ such that $F_{target} \leq F_{msy} < F_3 < F_4$. The butterfish fishery is incidental to the Mackerel, Squid and Butterfish fishery and is entirely commercial for export to Japan. The other species have both commercial and recreational components.

Results for the Commercial Sector:
The following Excel table indicates the equivalent annualized changes in revenues in 2007 dollars for the commercial sector, by species:

Commercial Landed Values-Annualized $-year^{-1}							
Scenario	Black Sea Bass	Bluefish	Butterfish	S Flounder	Total Landed Values	Δ$$	%
	$-year^{-1}						
1	$3,252,852	$5,621,760	$2,497,587	$43,943,165	$55,315,365	na	na
2	$3,752,609	$6,373,345	$4,974,728	$72,863,640	$87,964,321	$32,648,956	59%
3	$9,827,601	$7,432,972	$4,319,110	$84,411,230	$105,990,913	$50,675,548	92%
4	$10,248,240	$8,054,348	$4,347,047	$90,940,240	$113,589,876	$58,274,511	105%

It is noteworthy that scenario 4 offers almost double the revenue enhancement of scenario 2. This is consistent with the ordinal expectations of economic theory, but under the "rebuild stocks to MSY levels", Federal policy, maximizing revenues either individually or in aggregate is not legal. The scenario 2 target F includes allowances for various risks as perceived by the biological community. From an economic measurement perspective, we could say that the risk allowance of biological reference points amounts to almost 100% in terms of foregone risk neutral benefits. For another fishery it has been observed that the risk averse F_{target} differs little from that of a non-discriminating monopsonist as discussed in Rothschild et al *op cit*. If non discriminating monopoly is coupled with rent exhaustion through excessive effort, we would have both pathologies at the same time.

There are also some savings in trip costs. Reductions in fishing effort were assumed proportionate across sectors[4]. If there were no changes at all in trips, the indicated revenue increase of about $27.3 million per year (scenario 2), would also be the total direct commercial sector benefit, since costs would be unchanged. This would be the case if conservation could be achieved without any added cost via gear/season/size regulations. Unfortunately, these regulations are not costless either for fishermen or regulators and enforcement officials. At the other extreme, we might assume that trip costs are reduced in proportion to fishing mortality coefficients. But then, the issue is what F to use. For Scenario 2, the most extreme case involves Summer Flounder (60 percent reduction). With trip costs amounting to about one-third of revenue, we can add 60%/3 ≈ 20% percent, in the form of cost savings, to the revenue increase. This seems improbable, but it is a sort of upper bound on trip cost savings. Using a biomass weighted F one finds a 10-11 percent reduction. That would imply a trip cost reduction of about 10 percent in addition to the indicated revenue increase. With trip costs amounting to about 30 percent of revenue, we can add 10%/3 ≈ 3% cost savings to the revenue increase. Thus, cost savings of 3%*27.3 million/year ≈ $0.82 million per year might be realized. This would raise the total benefit from revenue increases and trip cost savings to 27.3+0.82 ≈ $28.1 million/year (decimals rounded), in perpetuity. The greater cost savings would be realized if rights based systems would be introduced.
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Indirect Benefits- Commercial Sector

Despite misgivings expressed in 1977 and restated earlier in this paper, we applied the multipliers generated by the Social Sciences Group at the Northeast Fisheries Science Center. For groundfish sales in the Atlantic Coast, the sales multiplier effect is about 1.85 per million dollars. Thus, the increased $27.3 million/year in sales by the commercial sector would allegedly yield a net change of $50.5 million per year in local expenditures. The income multiplier for groundfish harvesters is 1.59. The increased $27.3 million/year in local expenditures might lead to

4 It is observed that the biological community behaves as if reductions in F do not involve allocation. This seems to be a cultural adaptation to the unpleasantness of saying the obvious. It is perhaps analogous to the (not unusual) inattention of economists to distributional matters.

increased income of (1.59)* $27.3 or $43.4 million/year in incomes. The multiplier for jobs is approximately 1.4. So an additional 38 jobs might be realized[5] .

Direct Benefits-Recreational Sector

The appropriate measure of primary benefits for the recreational sector is the increase in *Willingness to Pay* (WTP) for a user-day that is enhanced by an increase in catch rate. A decade old Hicks, *et al* (1999) value was used on the pragmatic grounds that it was the best available. Dr. Mazotta has updated estimates but found that the old and new numbers are quite close. The following Excel table contains the enhancement of catch rates due to the rebuilding scenarios:

Recreational Catch -Annualized MT-year-1							
Scenario	Black Sea Bass	Bluefish	Butterfish	Sflounder	Total Catches	Δcatches	%
Recreational Catch in mt per year							
1	2,712	30,170	NA	5,055	37,937	0	0
2	3,255	34,174	NA	9,306	46,734	8,797	23%
3	3,190	44,457	NA	9,758	57,405	19,468	51%
4	3,326	46,703	NA	10,513	60,543	22,605	60%

The boxes for Δcatches in Scenario 2 are highlighted only because that scenario was the of particular interest to the Pew staff. The increased catches and (proportionately) reduced recreational Fs result in a higher Catch per unit effort of catch per trip(CPUT). Specifically, CPUT would increase by approximately 0.73 fish per day. The associated increase in consumers' surplus or WTP is $139 million per year in perpetuity. What this value does not take into account is the fact that its realization required a reduction in Fs caused by recreational fishing effort. While remaining recreators are made better off by the enhanced catch rate, the consumers' surplus of excluded recreators is lost. Thus, $139 million overstates the recreational benefits. The overstatement has been corrected as follows. By assuming proportional reductions of effort for both recreational and commercial sectors, and proportionality between visitor-days and F, an annualized reduction in visitor days was calculated. Using a WTP of $48 per visitor-day, the reduced WTP was about $60 million. The net increase in recreational WTP was $139-$60 = $79 million per year. A sensible question is *how much it would be worth* to the recreational sector to buy harvest share from commercial harvesters (or vice versa). At the status quo stocks, this would be about $48 per visitor day or $60 million to avoid the indicated reduction in visitor days. One way to do so could be to buy and retire harvesting shares from the commercial sector. At 1-2 fish per visitor day, the reduced visitor days are equivalent to 2-4 million fish, which works out to $15-$30 per fish. But, this digresses into allocation issues. We would add a residual concern. A priori, one would expect that the observed decline in CPUT of recreational fishermen would have caused a fall in demand for user days, or at least a rate of growth slower than that observed, but we have no data on this and in any case, have treated trips as exogenously controlled via fishing mortality controls.

Indirect Benefits-Recreational Sector

The staff at Pew Trusts were also interested in indirect impacts of the recreational sector. Our response was that there is no immediate way to deliver the numbers sought. That is because I-O measures the *cost* of economic activity; not its benefits. Indeed, lower Fs imply either tighter bag limits which, by diminishing the quality of the recreational experience, vitiates the purpose of the rebuilding exercise), or reduced visits which imply **less** visitor day expenditures. Again, this illustrates the difficulties with I-O in fisheries applications. It is possible to blindly apply output multipliers, if recreational catch has increased, but the inputs or costs required to generate the output decline; in short, the presumed fixed coefficients of the I-O model change when the stocks change. Another way of

5 Numbers rounded in these calculations, and do not include trip cost savings although, strictly speaking, trip cost savings would reduce the induced impacts.

putting the issue is this: The reduced recreational trips imply reduced expenditures on trips. The money thereby saved will be allocated to other expenditures. If we knew where, we might apply an I-O model to the changed expenditure pattern. The reallocation of expenditures and induced impacts could favor or disfavor coastal communities.

Concluding Comments

The recreational CPUT has declined by 7.8 percent per annum; a trend that lowers the value of a representative trip. Although not discussed in the Pew report, It is interesting that recreational participation rates have experienced a steady 30 year increase of about 1.5% per year. The extent to which this is restrained by bag limits, changing tastes and preferences, demographic trends, etc., is not clear. This upward trend is incompatible with conservation from either an economic or biological perspective. Attainment of conservation requires that allocation issues be addressed sooner or later. As it happens, our colleagues, Professors Burkett and Tyrell have recently completed a study of outdoor recreation for the US Park Service. There there has been a secular decline that is of Congressional concern. Perhaps recreational fishing will not continue its increase.

On a more technical note, it appears from the data that declining recreational catches may be due as much to declining fish size as to declines in numbers caught. The annual percent declines in lbs/fish caught have been Black Sea Bass (3.4%), Bluefish (6.6%) and Summer Flounder (2.6%). These declines may suggest use of dynamic pool models rather than lumped parameter models. The declines may also suggest that size limits are selecting for quicker maturing, smaller strains of fish and that coefficients of surplus production model may drift over time in response to management measures such as size limits. On the valuation side, WTP studies need to incorporate sizes of fish as a determinant of WTP because a size dependent WTP is likely to support a fishing mortality lower than would be the case with an unconditional WTP (Gates, 1975, Wang and Kellogg, 1981, 1986, Richardson and Gates,1986, Richardson, 1993).

The current focus on biological reference points as management targets include quite substantial premiums for biological risk. This risk allowance may not carry over to economics because economics aggregates across species to work with dollar metrics. Moreover, the low discount rate used is a risk-free rate on the premise that we wish to exclude risk considerations in public benefit cost analysis. The tendency for excessive risk allowances by natural scientists is partially if not fully offset by an economic factor that is often ignored by both natural and social scientists. Specifically, incorporation of size as a determinant of demand often supports a more conservative exploitation rate as noted above. The species focus of fisheries management is also a hindrance to a more rational approach because it channels the scarce time of natural and social scientists into excessively narrow compartments that often do not correspond to economic reality. A stock complex or fleet based approach could make the task of integrating the natural and social sciences less problematic.

The problematic aspects of I-O stem from the various flaws discussed above and the sources of demand for I-O; not from skill deficiencies of analysts. Local interests press for I-O multipliers because that is their perception of economics. I see no cure in sight for these mis-perceptions that have bedeviled economics at least since the time of the Physiocrats more than three centuries ago. It is difficult to dissuade one whose income is perceived as dependent on conservation of beliefs.

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