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Regional Economic Impacts of Reductions in Fisheries Production: A Supply-Driven Approach

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Abstract *Much debate and subsequent confusion have recently been generated regarding the economic importance of the longline fisheries for tuna and swordfish in Hawaii. Depending on the methodology employed, the measures of the economic importance of these fisheries to Hawaii can vary significantly. This paper attempts to provide an assessment of the alternative measures and their implications for fishery policy. In assessing the economic impact of the reduction in longline activities due to season and area closures as mandated by a recent court order, we suggest that the supply-driven approach is more appropriate. An empirical application using the supply-driven approach is used to estimate the economy-wide impacts of a 100% reduction in Hawaii-based longline activities. In addition, a set of supply-driven multipliers is derived for the other sectors of Hawaii's economy to allow comparison with the fishery sectors.*

Key words Fisheries management, input-output analysis, pelagic longline, supply reduction.

Introduction

In February of 1999, the Earthjustice Legal Defense Fund filed a complaint in Federal Court on behalf of the Center for Marine Conservation and the Turtle Island Restoration Network alleging that the National Marine Fisheries Service (NMFS) failed to follow proper National Environmental Policy Act (NEPA) process. It challenged NMFS' determinations under the Endangered Species Act (ESA) that continued conduct of the Hawaii-based longline fishery was not likely to jeopardize the continued existence of leatherback, loggerhead, olive ridley, or green sea turtles [*Center for Marine Conservation* v. *NMFS* (D. Haw.) Civ. No. 99-00152 DAE (*CMC* v. *NMFS*)].

On November 23, 1999, the Federal Court in Honolulu issued an injunction that led to the temporary closing of certain waters north of Hawaii to fishing by Hawaii-based pelagic longline vessels, as well as permanent requirements that all vessels

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follow prescribed techniques for handling and releasing turtles. There followed a series of court orders including one on June 23, 2000, which would have reduced longline fishing by roughly 95%, although at the request of the Federal defendants and the Hawaii Longline Association, that order was modified before implementation. Subsequently, NMFS prepared and filed a Final Environmental Impact Statement (FEIS) on the fishery (March 30, 2001). The FEIS contains a preferred alternative that includes a series of actions designed to mitigate the fishery's adverse impacts on sea turtles. These measures, which the court ordered NMFS to implement immediately, include a prohibition on swordfish-style longline fishing and a seasonal area closure in waters south of Hawaii. The effect of these measures was expected to reduce Hawaii's longline fishery ex-vessel gross revenue by 10-40% (NMFS 2001, pp. 4–116, 117).

This paper suggests a supply-driven input-output approach for dealing with the economic impact assessment in the FEIS. In the next section, we review various approaches commonly used in assessing the economic contribution of a specific sector of the economy. In particular, we attempt to point out problems with the final-demand approach employed in the FEIS and suggest that a supply-driven approach is more apt in assessing the economic impact of output reduction for a specific sector. An empirical application using the supply-driven approach is used to estimate the economy-wide impact to Hawaii of a 100% reduction in Hawaii-based longline activities. In addition, a set of supply-driven multipliers is derived for all other sectors of Hawaii's economy to allow for comparison with the fishery sectors.

Methodology

The economy-wide contribution of any sector in an economy is commonly measured using a static input-output model. Input-output analysis allows the tracings of both forward and backward linkages of a sector to the rest of the economy and thus provides a systematic assessment of the sectoral contribution to the economy. However, there is a wide variation in the measurement procedures employed. Three approaches are commonly found in the literature: final demand-based, output-based, and hypothetical extraction of sector. The supply-driven approach we explore is most similar to the hypothetical extraction method. A vast literature exists covering the evaluation of regional economic contributions in a number of sectors, particularly agriculture, and we will just scratch the surface of the issues involved (Leones, Schluter, and Goldman 1994). Furthermore, there is no "best" method available for all policy situations, such that each of the methods described can be appropriate for specific policy questions at hand. We are concentrating on a particular use in this paper; *i.e.*, the reduction in output of a single sector, the Hawaii longline fishery.

The final demand-based approach measures the contribution of a sector as the output, value-added, and employment attributable to the final demand for the output of that sector. It can also be viewed as the impact to the economy if the sector's final demand is set to zero. Groenewold, Hagger, and Madden (1987) recommended using the final demand-based method for industries with a high ratio of final demand to output. They also point out the desirable "adding-up" feature of the final demand-based approach in that the sum of all industry contributions equals the actual total contribution associated with that demand. Sharma *et al.* (1999) employed a variant of the final demand approach by including fishery trade and distribution margins in assessing the contribution of the fishery sectors in Hawaii, and these multipliers were used in the FEIS.

The output-based approach generally starts by defining the outputs of the specific sector in question and outputs from related sectors. From there, adjustments are usually made to avoid double counting of sectoral outputs. The usual multipliers are then applied to the adjusted outputs to arrive at the economy-wide impacts of a specific sector. Leones and Conklin (1993), Johnson and Wade (1994), and Tanjuakio, Hastings, and Tytus (1996) used this approach to assess the contribution of agriculture to the economies of Arizona, Virginia, and Delaware, respectively. They all used some form of adjustment to outputs to minimize double counting. Tanjuakio, Hastings, and Tytus (1996) suggested a method through adjustment of the regional purchase coefficients of the industries comprising the agricultural sectors, while Johnson and Wade (1994) estimated the double-counted sales and subtracted them from the total sales of the entire agricultural system. However, most of these procedures are still unable to overcome the double-counting problems entirely. This adding-up problem is inherent in all methods utilizing output as the starting point in assessing economic contribution of sectors using input-output multipliers, and simply adjusting the outputs in the sectors does not solve the problem. In any event, one would be unable to assess the correct contribution, as the sum of all output contributions can never be equal to the actual output unless all the multipliers are one, or some multipliers are less than one, which is impossible (Leung, Sharma, and Nakamoto 1997).

Hypothetical extraction of a sector is the third major approach in the literature. Groenewold, Hagger, and Madden (1987) have provided a detailed mathematical account of this approach using a three-sector, closed input-output model. They have identified three alternative extraction methods assuming: (*a*) disappearance of an entire industry; (*b*) relocation of an industry to another region, but that industry continues to purchase intermediate inputs (excluding labor) from the remaining local industries; and (*c*) sequential extraction of sectors; *i.e.*, where industry sectors are assumed to disappear in some predetermined, sequential manner. Methods (*b*) and (*c*) attempt to alleviate the double-counting problem associated with method (*a*). However, as mentioned by Groenewold, Hagger, and Madden (1987), methods (*a*) and (*b*) suffer from the same weakness that the sum of estimated contributions exceeds actual total. This adding-up problem is more serious in method (*a*) than method (*b*). While method (*c*) alleviates the adding-up problem, the estimated contribution depends on the completely arbitrary order in which industries are assumed to disappear. Harthoorn and Wossink (1987) used a variant of method (*c*) to assess the contribution of Dutch agriculture. Groenewold, Hagger, and Madden (1987) recommended methods (*a*) or (*b*) if industries could reasonably be assumed to disappear or be relocated.

It is obvious from the above discussion that no single method is ideal for measuring the contribution of a sector from an *ex post* point of view. In fact, it becomes apparent that input-output analysis might not add much to the contribution question other than to provide some measures of the inter-industry linkages. Indeed, the traditional ratio measures of a sector's output, value-added (contributions to gross product), and employment to the economy's totals may be more appropriate in addressing the contribution question than application of the more detailed input-output multipliers. This point has also been addressed by Taylor and Smith (1996) who emphasized that economic multipliers were so often misused and misunderstood that they simply used direct employment and sectoral output values to measure the economic importance of agribusiness in Alabama. On the other hand, if one were to assess the impacts of a policy question in an *ex ante* 'what-if' exercise, then some of the above approaches may be appropriate. For example, the hypothetical extraction approach would certainly be most suitable in assessing the impacts of the disappearance of an industry from the economy (as we point out below in the application of a supply-oriented multiplier), and the final demand approach would be most proper in assessing a change in the demand of a product at the final consumption level. Furthermore in assessing a 'what-if' scenario, the adding-up problem is no longer an issue since we are not measuring the contribution of a sector within an existing state of the economy, rather the effect of a shock to the economy whereby the existing state will be altered. The case of evaluating the output reduction of the Hawaii longline fishery is clearly an *ex ante* "what-if" analysis, and the *ex post* measurement approach is certainly not suitable.

The June 2000 Federal Court ruling that would have essentially closed Hawaii's longline fishery, if implemented, stirred up considerable debate as to the potential economic impact of such a shutdown. This debate carried through to the evaluation of the ten fishery management alternatives evaluated in the FEIS for the Pelagic Fishery Management Plan (NMFS 2001). The FEIS relied upon the final demand approach to measure the potential impact of management alternatives (NMFS 2001, pp. 3–170 to 3–173). This approach did not completely reflect the potential impact of the closure alternatives.[1] Because of the high inter-industry sales (over 51%) of the longline industry, a 100% reduction in its final demand alone (*i.e.*, direct sales to consumers) would not shut down the entire Hawaii-based longline industry, unless accompanied by final demand reductions in the other industries related to the longline fishery (in this case the wholesale and retail seafood sectors, including restaurants and fish auctions.) Indeed, the authors of the economic impact analysis in the FEIS had to estimate the longline industry's final demand instead of using the change in ex-vessel gross revenue of the longline fishery as their base. Obviously, the shutdown of the longline fishery is a supply reduction question, and the final demand approach does not completely reflect all economic impacts from such a closure. A supply-driven approach similar to the hypothetical extraction approach described above appears more appropriate. The standard demand-side n-sector input-output model $X = AX + F$ can be partitioned as follows:

$$\begin{pmatrix} X_1 \\ X_2 \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix} \begin{pmatrix} X_1 \\ X_2 \end{pmatrix} + \begin{pmatrix} F_1 \\ F_2 \end{pmatrix} \tag{1}$$

where:

X = n x 1 vector of sectoral outputs;
A = n x n direct requirement matrix;
F = n x 1 vector of final demands;
X_1 = vector of outputs of the exogenized sectors;
X_2 = vector of outputs of the endogenous sectors;
F_1 = vector of final demands of the corresponding exogenized sectors; and
F_2 = vector of final demands of the corresponding endogenous sectors.

In input-output analysis, we normally solve for the sectoral outputs (X) required to support the exogenous change in final demands (F); *i.e.*, $X = (I - A)^{-1} F$. By partitioning the matrix, we can now assume that some of the sectoral outputs are fixed. This allows us to assess the impacts of changes in outputs of the exogenized sectors (X_1) on outputs of other sectors in the economy (X_2), as well as on the final demands of the exogenized sectors (F_1). In other words, we can now assume that X_1 and F_2 are exogenously determined, and X_2 and F_1 are to be solved endogenously. Solving

[1] The FEIS alternatives ranged from 0% change in ex-vessel gross revenue in the no-action alternative to 100% in the complete closure alternative; the actual alternative chosen was estimated to have a potential loss of gross revenue between 10% and 42%.

equation (1) as a result of change in outputs of the exogenous sectors, ΔX_1, and assuming change in F_2 is zero gives:

$$\Delta X_2 = (I - A_{22})^{-1} A_{21} \, \Delta X_1 \tag{2}$$

and

$$\Delta F_1 = (I - A_{11}) \, \Delta X_1 - A_{12} \, (I - A_{22})^{-1} A_{21} \, \Delta X_1 . \tag{3}$$

For example, equation (2) can be used to assess the impacts of a reduction in longline output, ΔX_1, on outputs of all other sectors in the economy, ΔX_2. In this case, ΔX_1 would simply be a predetermined scalar, and ΔX_2 is the resulting (n–1) x 1 vector of outputs of all other sectors. Equation (1) assumes that ΔX_1 will not affect the direct requirement matrix A of the economy. In other words, production technologies of every sector in the economy are assumed to remain unchanged as a result of ΔX_1. It should be noted that equation (1) is still very much in the same spirit of the demand-side, input-output analysis in the sense that the same A matrix is used to trace the backward linkages. Papadas and Dahl (1999) further define the supply-driven multiplier as the sum of column vector $(I - A_{22})^{-1} A_{21}$ when a single sector is exogenized. By exogenizing each sector in the economy one at a time, supply-driven multipliers can be obtained for all sectors in the economy. The supply-driven multiplier of sector i simply measures the total potential change in outputs of all other sectors in the economy due to a change in output of the i^{th} sector. This measure is incomplete when we are dealing with less than a total reduction of sector i. The reason is that a less-than-total reduction of sector i will have an impact on sector i, since a less-than-total reduction of sector i will have an impact on sector i itself, due to intra-sector transactions of sector i and the indirect links of the other sectors to sector i. Thus, it will underestimate the potential impacts when evaluating a less-than-total reduction of sector i. However, in cases where output of sector i is not allowed to vary after an initial exogenous change, this measure is appropriate in providing the output impact of the other sectors even when the total reduction of sector i is not total. In fact, this is the general situation at hand where fisheries production is subject to a predetermined initial exogenous change, and it is assumed that no subsequent changes of the fishery sectors will take place. We will use this measure to estimate the output impacts on the rest of the economy from the reduction in longline output (supply).

While the above analysis provides the potential impact only from a backward linkage point of view, a similar framework can be extended to the analysis of the forward linkage effects using the Ghosh model (Ghosh 1958). The Ghosh model can be expressed as $X'B + W = X'$, where B is the matrix of direct output coefficients, as opposed to the Leontief direct input coefficients A. B is formed by dividing each row of the transaction matrix by the respective gross output of that row, as opposed to dividing each column in deriving A. Thus, B represents the output distribution pattern of each sector; *i.e.*, the forward linkage. As in the Leontief model, the Ghosh model assumes that B is fixed; *i.e.*, the allocation of a sector's output to other sectors is assumed fixed. The usual analysis looks at the effect of a change in final factor input or value added (W) on sectoral outputs (X'); *i.e.*, $X' = W\,(I - B)^{-1}$. Similar to the Leontief model, the Ghosh model can be partitioned as follows:

$$(X_1' \;\; X_2') \begin{pmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{pmatrix} + (W_1 \;\; W_2) = (X_1' \;\; X_2') \tag{4}$$

where:

X' = 1 x n vector of sectoral outputs;
B = n x n direct output coefficients matrix;
W = 1 x n vector of value added;
X'_1 = vector of outputs of the exogenized sectors;
X'_2 = vector of outputs of the endogenous sectors;
W_1 = vector of value added of the corresponding exogenized sectors; and
W_2 = vector of value added of the corresponding endogenous sectors.

Again, assuming ΔW_2 is zero, one can assess $\Delta X'_2$ and ΔW_1 as a result of $\Delta X'_1$ as follows:

$$\Delta X'_2 = \Delta X'_1 B_{12} (I - B_{22})^{-1} \tag{5}$$

and

$$\Delta W_1 = \Delta X'_1 (I - B_{11}) - \Delta X'_1 B_{12} (I - B_{22})^{-1} B_{21}. \tag{6}$$

The row sum of the matrix B_{12} $(I - B_{22})^{-1}$ in equation (5) can be considered as the supply-driven multiplier when a single-sector is exogenized. We will distinguish this multiplier as the input supply-driven multiplier vs. the output supply-driven multiplier as derived earlier. The input supply-driven multiplier measures the total change in outputs of all other sectors in the economy from a change in output of the i^{th} sector similar to the output supply-driven multiplier, except from a forward linkage point of view.[2]

Results

A condensed, eight-sector version of the 1992 Hawaii state input-output model (Sharma *et al.* 1999) is used to analyze the impacts of the reduction in longline output. This model is an extension of the original 1992 State of Hawaii model with a focus on the fishery sectors. Table 1 shows the indirect and induced effects per \$1 reduction in longline output on the outputs, employment, and household income of the remaining sectors in the economy. Induced effects are calculated by endogenising the household sector as normally done in input-output analysis. For example, a \$1 increase/decrease in longline output will generate \$0.33 of output expansion/reduction in construction and manufacturing. The total indirect and induced impact of a \$1 change in longline output on all other sectors combined is estimated to be \$1.42. This is what Papadas and Dahl (1999) refer to as the output supply-driven multiplier. However, the total output change would include the original \$1 change in the longline output. Thus, the total output supply-driven multiplier be-

[2] It should be noted that the theoretical interpretation of the Ghosh model has been criticized in the literature primarily when it is used to explain 'physical' output changes due to 'physical' changes in primary factor inputs, such as labor and capital. Oosterhaven (1988, 1989) has argued persuasively the implausibility of this interpretation. However, as pointed out recently by Dietzenbacher (1997), a theoretically correct interpretation can be made of the Ghosh model as a price model in that "sectoral output values change due to the price changes, which are caused by price changes for the primary inputs." We will not dwell on this theoretical debate, but simply point out that the interpretation of the forward linkage effects using the Ghosh framework can be problematic and certainly less straightforward when compared to the Leontief model. We will further elaborate this point in the results section.

Table 1
Indirect and Induced Impacts per $1 Change of Longline Output

	Indirect and Induced Outputs per $ of Longline Output	Indirect and Induced Jobs per $ of Longline Output	Indirect and Induced Income per $ of Longline Output
	($)	(Jobs)	($)
Small commercial boats	0.0005	0.01	0.0002
Charter boats	0.0003	0.01	0.0001
Recreation and expense boats	0.0012	0.00	0.0000
Agriculture	0.0213	0.58	0.0089
Construction and manufacturing	0.3332	2.72	0.1135
Transportation and trade	0.3816	6.26	0.1472
Finance, services, and government	0.6841	12.14	0.3219
Total	1.4221	21.73	0.5918

comes $2.42. We will use this convention when we refer to the output supply-driven multiplier; *i.e.*, including the direct, indirect, and induced effects. Similarly, the indirect and induced impacts on employment and household income are shown in table 1, with a similar adjustment for the direct effect to estimate the total effect.

Table 2 uses a supply-driven approach and presents the potential economy-wide impacts to Hawaii on output, employment, and income resulting from a 100% reduction in longline output of $43.88 million (the 1992 output or gross revenue). Such a reduction would create a potential decrease of $106.28 million in output, 1,600 jobs, and $47.21 million in household income. The corresponding output multiplier is 2.42, the employment multiplier is 2.46, and the income multiplier is 2.22. Linear interpolations can be used to estimate the impacts with a less than 100% reduction in longline output.

If one used the final demand approach in assessing the impact of a 100% reduction in longline output, as in the FEIS, the economy-wide impact would have been only $42.20 million (longline final demand of $17.41 million times the Type II longline final demand multiplier of 2.4243). Furthermore, out of this $42.20 million, only $17.42 million (slightly more than the original reduction in final demand) can be attributed to the reduction in longline output, and the remainder ($24.78 million) is from the induced output reductions of all other sectors. It is evident that in using this approach, the estimated regional economic impact would not be even close to the reduction in longline output we set forth to analyze.[3] For example, Sharma *et al.* (1999) estimated that the regional economic contribution of the longline sector in 1992, excluding distribution margins, was $31.66 million less than the total output (ex-vessel gross revenue) of the longline sector in that year. The difference in approach can also be seen for less than 100% reductions in longline output, as shown

[3] Under the fishery management alternative selected by NMFS and approved by the Federal Court, the FEIS estimated reductions in direct ex-vessel revenues from longline fishing are in the range of 10–42% ($4–19 million). Evaluated under the final demand approach, this resulted in an overall economic impact to Hawaii of $5 to $20 million (NMFS 2001, pp. 3–173). Using the supply-driven approach, the overall economic impact would have been estimated as at least $10 to $29 million. It should be noted that in applying both approaches, one has to assume that the structure of the other sectors remains the same, and this assumption is generally satisfied when evaluating small change but not necessarily so when the change is substantial.

Table 2
Total Impacts of 100% Longline Output Reduction

	Outputs ($ million)	Employment (jobs)	Income ($ million)
Indirect and induced			
Small commercial boats	0.022	1	0.009
Charter boats	0.011	0	0.004
Recreation and expense boats	0.053	0	0.000
Agriculture	0.933	26	0.393
Construction and manufacturing	14.619	119	4.982
Transportation and trade	16.745	275	6.458
Finance, services, and government	30.018	533	14.124
Subtotal	62.402	953	25.970
Direct	43.880	652	21.244
Total	106.282	1,605	47.214

in the FEIS, where the final demand approach is compared to that proposed in this paper. The difference is roughly 50%. In analyzing the impact of output reduction, the final demand approach is clearly inappropriate, and in many cases it will substantially underestimate the true impact.

A related source of debate has to do with the extent to which small commercial boats can make up for the loss of longline supply (domestic and foreign imports are another potential source, but represent a negative economic contribution in regional economic analysis). As it turns out, the Hawaii longline fishery provides roughly 75% of the pelagic (tuna, swordfish, and other highly migratory species) fishery landings in Hawaii. While a strong seasonal contribution by small commercial boats exists in the summer when the weather is better, this is only true for some species, and does not include the two primary targets of the longline fishery: large-sized bigeye tuna and swordfish.

Using equation (3), one can also assess the effect on the final demand of the longline sector resulting from its output reduction. It can be shown that a 100% reduction in longline output will induce a change of nearly 100% in its final demand.[4] This seems reasonable as the longline sector has no intra-industry transactions and a very weak forward linkage with the rest of the sectors as measured in nominal terms.

Table 3 compares the supply-driven multipliers and the traditional final demand multipliers for all eight sectors. The supply-driven multipliers are derived by exogenizing each sector using the same process as the longline sector. Table 3 presents both type I (direct and indirect) and type II (direct, indirect, and induced) multipliers. Two interesting observations can be discerned from this table. First, the supply-driven multipliers and the final demand multipliers are generally larger for the fishery sectors compared to the other sectors. The likely reason for that can be traced to the relatively higher inter-industry purchases of the fishery sectors and,

[4] While the impact of a 100% reduction in longline output on the final demand of the longline sector is rather obvious, a less than 100% reduction is not so apparent. Equation (3) allows us to estimate such induced changes in the final demand of the longline sector.

Table 3
Output Supply-Driven Multipliers and Final Demand Multipliers

Industry Sector	(Type I) Output Supply-Driven Multipliers	(Type I) Final Demand Multipliers	(Type II) Output Supply-Driven Multipliers	(Type II) Final Demand Multipliers
Longline boats	1.4556	1.4560	2.4221	2.4243
Small commercial boats	1.6205	1.6208	2.5473	2.5487
Charter boats	1.6979	1.6979	2.6863	2.6870
Recreation and expense boats	2.0184	2.0187	2.5792	2.5813
Agriculture	1.1888	1.3230	1.9062	2.1377
Construction and manufacturing	1.1973	1.2923	1.7319	1.9691
Transportation and trade	1.1996	1.3246	1.5920	2.0889
Finance, services, and government	1.0888	1.2548	1.2479	2.1120

thus, the stronger backward linkages. Second, the supply-driven multipliers and the final demand multipliers are very close for the fishery sectors, but not for the other sectors. This means the impact of a dollar change in output or a dollar change in final demand of each of the fishery sectors is very similar. This is primarily due to the lack of intra-industry transactions for the fishery sectors, as well as the relatively small (in nominal terms) forward linkage of the fishery sectors with the other sectors in the economy.[5]

Table 4 compares the derived input supply-driven multipliers with the traditional Ghosh value-added multipliers [derived as the row sum of $(I - B)^{-1}$]. Both multipliers are relatively high for the longline and small commercial boat sectors when compared to the charter, recreational, and expense fishing boat sectors because of the higher inter-industry sales of the longline and small commercial fishing sectors. As in the comparison of the output supply-driven multipliers and the final demand multipliers, the input supply-driven multipliers and the value-added multipliers are very close for the fishery sectors, but not for the other sectors. Again, this is primarily due to the lack of intra-industry sales of the fishery sectors, as well as the relatively small (in nominal terms) backward linkage of the fishery sectors with the other sectors.

Using the input supply-driven multiplier of 1.6540 for the longline sector, a 100% reduction of $43.88 million in this sector will cause a total economy-wide output reduction of $72.58 million from a forward linkage point of view. This appears to be lower than the backward linkage effect of $106.28 million, because no corresponding type II multipliers can be derived satisfactorily. However, the forward linkage effect is, in fact, stronger when compared with the type I multipliers of the output supply-driven multipliers.

[5] It can be shown that if the exogenized sector has no intra-sectoral sales ($A_{11} = 0$) and a weak forward linkage with the other sectors (elements of A_{12} close to zero), the corresponding elements of $(I - A_{22})^{-1}$ are very similar to those of $(I - A)^{-1}$. Hence, the derivation of the supply-driven multiplier of the exogenized sector as the column sum of $(I - A_{22})^{-1} A_{21}$ in equation (2) would be very close to the column sum of the exogenized sector in $(I - A)^{-1}$. It is also important to point out that since sectors other than the fishery sectors are highly aggregated in this analysis, some of the sub-sectors within these aggregated sectors could exhibit similar properties as the fishery sectors.

Table 4
Input Supply-Driven Multipliers and Ghosh Value-Added Multipliers

Industry Sector	Input Supply-Driven Multipliers	Value-Added Multipliers
Longline boats	1.6540	1.6544
Small commercial boats	1.6139	1.6142
Charter boats	1.0543	1.0543
Recreation and expense boats	1.1694	1.1696
Agriculture	1.7257	1.9205
Construction and manufacturing	1.2642	1.3646
Transportation and trade	1.1618	1.2828
Finance, services, and government	1.0731	1.2367

The backward linkage effects cannot be added to the forward linkage effects to arrive at some "total" economy-wide impacts, since that would amount to double counting of the effects of the same exogenous change under two different configurations of the same input-output model (Papadas and Dahl 1999). Furthermore, while the backward linkage effect is relatively straightforward, the same cannot be said about the forward linkage effect. For example, one can assume the reduction in output of the longline sector would certainly reduce the outputs of other sectors in the economy that sell to the longline sector, as well as the subsequent indirect and induced effects. However, the forward linkage impact is generally less well defined and tricky. For example, we would need to know whether restaurants that lose access to a supply of local fish would reduce their total sales, or would they simply replace the local catch with imports from the rest of the US and abroad? If so, would that affect fish quality and prices and, hence, the prices of meals at the restaurants and thus final demand? These types of effects are not generally handled very well by input-output analysis. Similar issues arise for the distribution sectors. Unless we are willing to make assumptions, say, a certain number of fish markets will be closed due to the reduction in longline output,[6] it is not meaningful to make a general economic assessment of these forward linkages.

Conclusions

It is evident from the foregoing analysis that the supply-driven approach is most appropriate in assessing the economy-wide impact of output reduction of a sector. Supply-oriented multipliers represent measurement of inter-relationships and economic changes beginning from the point of production, rather than the more traditional demand-oriented multipliers, which represent measurement beginning from the point of final consumption (consumer demand, business investment, government use, and exports). It is extremely difficult, if not impossible, to use demand-oriented multipliers to estimate the impact of a change in supply if there is not a clear identification of how the supply of the product will affect its final demand. In the case of Hawaii seafood, the initial change in production (supply) passes through a variety of intermediate steps before final consumption (demand) so that final consumption is frequently indeterminate from other contributions to that demand. In such a situa-

[6] Empirically, this would appear to be the case for a number of seafood dealers.

tion, supply-oriented multipliers applied to the initial change in supply (*i.e.*, ex-vessel revenue) are superior to demand-oriented multipliers applied to estimates of the final demand derived (although not straightforwardly) from that same change in initial supply. As it turns out, the absolute values of the multipliers in this case are roughly equivalent, but by their difference in application, the results are considerably different.

Using a final demand approach in assessing the economy-wide impact of a 100% output reduction in Hawaii's longline sector would substantially underestimate the total impact. While there is no perfect and universal method or tool available for socio-economic assessments, choosing the most appropriate technique for the problem at hand can be very important.[7] The final demand approach is an attempt to measure the contribution of the fishery sectors in Hawaii in order to alleviate the double-counting effects of most of the input-output related techniques. However, as we can see in this paper, the final demand approach does not appear to do a good job in assessing the effects of output reduction for Hawaii's longline fishery.

Further, it is interesting to note that for the fishery sectors in Hawaii the traditional final demand and value-added multipliers are very close to their corresponding supply-driven multipliers and, hence, can be used as a good approximation to the supply-driven multipliers. The closeness between the two types of multipliers may be a property of sectors with no intra-sectoral transactions and with minimal interactions (in nominal terms) with other sectors.

Finally, the supply-driven approach presented here can be extended to investigate the tradeoff between the economy-wide impacts as measured by output, income, and employment with the degree of fishery interactions with federally protected species of sea turtles. While neither this approach, nor any input-output related approach, estimates the non-consumptive economic value of sea turtle preservation, it does provide a method for measuring the cost-effectiveness of alternative methods of sea turtle conservation, as well as indicates the cost to society of such conservation and the distribution of those costs across the economy.

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[7] Indeed, the authors of the FEIS included a discussion of our objections (cf. FEIS pp. 3–173).

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