
Linkages of Fisheries Sectors to Hawaii's Economy & Economic Impacts of Longline Fishing Regulations

Junning Cai¹, PingSun Leung¹, Minling Pan², Sam Pooley²

¹College of Tropical Agriculture & Human Resources, UHM

²Pacific Islands Fisheries Science Center, NMFS



Objectives

- **Linkage analysis:**

Input-purchasing and output-selling relationship between Hawaii's fisheries and non-fisheries sectors

- **Impact analysis**

Linkage impacts of Hawaii longline fishing regulations



Linkage Analysis

Methodology



Hawaii's 1992 Input-Output Model

Sectors	Longline boats	Small boats	Charter boats	R&E boats	Agri-culture	Manufac-turing	Trade	Service	PCE	Other Final Demand	Total output
Longline boats	0	0	0	0	0	3	13	6	4	17	44
Small boats	0	0	0	0	0	3	2	1	5	2	14
Charter boats	0	0	0	0	0	0	0	0	4	11	16
R&E boats	0	0	0	0	0	2	1	0	21	0	24
Agriculture	0	0	0	0	76	298	9	117	58	211	769
Manufacturing	10	5	3	13	43	489	938	682	753	4,850	7,785
Trade	4	1	3	4	39	541	1,054	1,123	3,909	5,947	12,625
Services	2	1	3	2	32	414	1,158	3,286	9,444	11,795	26,136
Labor income	21	6	6	0	323	2,653	4,869	12,297	0	0	20,176
Other value added	2	1	1	0	146	715	2,927	6,592	0	0	10,385
Imports	5	1	0	5	109	2,667	1,653	2,032	4,304	4,322	15,097
Total input	44	14	16	24	769	7,785	12,625	26,136	18,502	27,156	93,072



Leontief Input-Output Model

$$\begin{pmatrix} X_1 = a_{11}X_1 + a_{12}X_2 + \dots + a_{1n}X_n + F_1 \\ X_2 = a_{21}X_1 + a_{22}X_2 + \dots + a_{2n}X_n + F_2 \\ \vdots \\ X_n = a_{n1}X_1 + a_{n2}X_2 + \dots + a_{nn}X_n + F_n \end{pmatrix} \quad \begin{pmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \dots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{pmatrix} \begin{pmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{pmatrix} + \begin{pmatrix} F_1 \\ F_2 \\ \vdots \\ F_n \end{pmatrix}$$

$$\mathbf{X} = \mathbf{A}\mathbf{X} + \mathbf{F} \quad \Rightarrow \quad \mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1} \mathbf{F}$$

Leontief inverse

$$(\mathbf{I} - \mathbf{A})^{-1} = \mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \dots$$



Ghosh Input-Output Model

$$\begin{pmatrix} X_1 = b_{11}X_1 + b_{21}X_2 + \dots + b_{n1}X_n + W_1 \\ X_2 = b_{12}X_1 + b_{22}X_2 + \dots + b_{n2}X_n + W_2 \\ \vdots \\ X_n = b_{1n}X_1 + b_{2n}X_2 + \dots + b_{nn}X_n + W_n \end{pmatrix}$$

$$\mathbf{X}' = \mathbf{X}'\mathbf{B} + \mathbf{W}'$$



$$\mathbf{X}' = \mathbf{W}'(\mathbf{I} - \mathbf{B})^{-1}$$

$$(X_1 \ X_2 \ \dots \ X_n) = (X_1 \ X_2 \ \dots \ X_n) \begin{pmatrix} b_{11} & b_{12} & \dots & b_{1n} \\ b_{21} & b_{22} & \dots & b_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ b_{n1} & b_{n2} & \dots & b_{nn} \end{pmatrix} + (W_1 \ W_2 \ \dots \ W_n)$$

Ghosh inverse

$$(\mathbf{I} - \mathbf{B})^{-1} = \mathbf{I} + \mathbf{B} + \mathbf{B}^2 + \mathbf{B}^3 + \dots$$



Input-Output Linkages

- **Backward linkage**
 - Input-purchasing perspective
 - Upstream sectors
 - Quantity model
- **Forward linkage**
 - Output-selling perspective
 - Downstream sectors
 - Price model
- **Total linkage (?)**



Linkage Measures

- **Backward linkage**
 - Leontief column sums (traditional demand-driven measure)
 - Absolute backward linkage (Dietzenbacher & van der Linden, 1997)
 - Pure backward linkage (Sonis et al., 1995)
 - Leontief supply-driven multiplier (Leung and Pooley, 2002; Cai and Leung, 2004)
- **Forward linkage**
 - Leontief row sums
 - Ghosh row sums (traditional primary-input driven)
 - Absolute forward linkage (Dietzenbacher & van der Linden, 1997)
 - Pure forward linkage (Sonis et al., 1995)
 - Leontief supply-driven multiplier (Leung and Pooley, 2002; Cai and Leung, 2004)



Backward Linkage Measures

Leontief demand-driven multiplier

$$\mathbf{X} = \mathbf{A}\mathbf{X} + \mathbf{F}$$

$$\Delta\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1} \Delta\mathbf{F}$$

Demand
driven

Leontief supply-driven multiplier

$$\begin{pmatrix} \mathbf{X}_i \\ \mathbf{X}_j \end{pmatrix} = \begin{pmatrix} \mathbf{A}_{ii} & \mathbf{A}_{ij} \\ \mathbf{A}_{ji} & \mathbf{A}_{jj} \end{pmatrix} \begin{pmatrix} \mathbf{X}_i \\ \mathbf{X}_j \end{pmatrix} + \begin{pmatrix} \mathbf{F}_i \\ \mathbf{F}_j \end{pmatrix}$$

$$\Delta\mathbf{X}_j = (\mathbf{I} - \mathbf{A}_{jj})^{-1} \mathbf{A}_{ji} \Delta\mathbf{X}_i$$

Supply
driven



Forward Linkage Measures

Ghosh primary-input-driven multiplier

$$\mathbf{X}' = \mathbf{X}'\mathbf{B} + \mathbf{W}'$$

Primary
input
driven

$$\Delta\mathbf{X}' = \Delta\mathbf{W}'(\mathbf{I} - \mathbf{B})^{-1}$$

Ghosh supply-driven multiplier

$$\begin{pmatrix} \mathbf{X}_i & \mathbf{X}_j \end{pmatrix} = \begin{pmatrix} \mathbf{X}_i & \mathbf{X}_j \end{pmatrix} \begin{pmatrix} \mathbf{B}_{ii} & \mathbf{B}_{ij} \\ \mathbf{B}_{ji} & \mathbf{B}_{jj} \end{pmatrix} + \begin{pmatrix} \mathbf{W}_i & \mathbf{W}_j \end{pmatrix}$$

Supply
driven

$$\Delta\mathbf{X}'_j = \Delta\mathbf{X}'_i \mathbf{B}_{ij} (\mathbf{I} - \mathbf{B}_{jj})^{-1}$$



Linkage Measures and Indices

Backward linkage measure

$$\text{LSD}_i = (\mathbf{I} - \mathbf{A}_{jj})^{-1} \mathbf{A}_{ji}$$

Forward linkage measure

$$\text{GSD}_i = \mathbf{B}_{ij} (\mathbf{I} - \mathbf{B}_{jj})^{-1}$$

Backward linkage index

$$\text{BL}_i = \frac{\text{LSD}_i}{\left(\text{LSD}_i + \sum_j \text{LSD}_j \right) / n}$$

Forward linkage index

$$\text{FL}_i = \frac{\text{GSD}_i}{\left(\text{GSD}_i + \sum_j \text{GSD}_j \right) / n}$$



Hawaii's Fisheries Sectors (1997)

Sectors	Output (\$ million)	Value added (\$ million)	Wage Income (\$ million)	Proprietor Income (\$ million)	Wage Jobs	Proprietor jobs
Tuna longline	27.37	16.46	7.30	2.49	215	191
Swordfish longline	22.67	11.24	4.15	1.45	116	102
Small commercial boats	11.70	6.55	0.29	5.40	10	507
Charter boats	14.17	8.39	4.67	1.42	175	67
Expense boats	3.94	-0.32	0.00	-0.78	0	1,008
Recreation boats	10.30	0.00	0.00	0.00	0	0
Total fishing industry	90	42	16	10	516	1,875
Total Hawaii economy	58,660	38,537	21,626	2,088	615,545	126,686

Source: Hawaii 1997 input-output table (SMS, 2004)



Linkage Analysis

Results

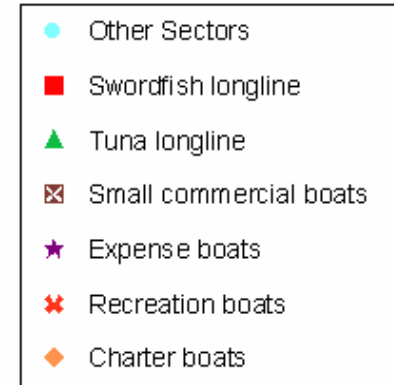
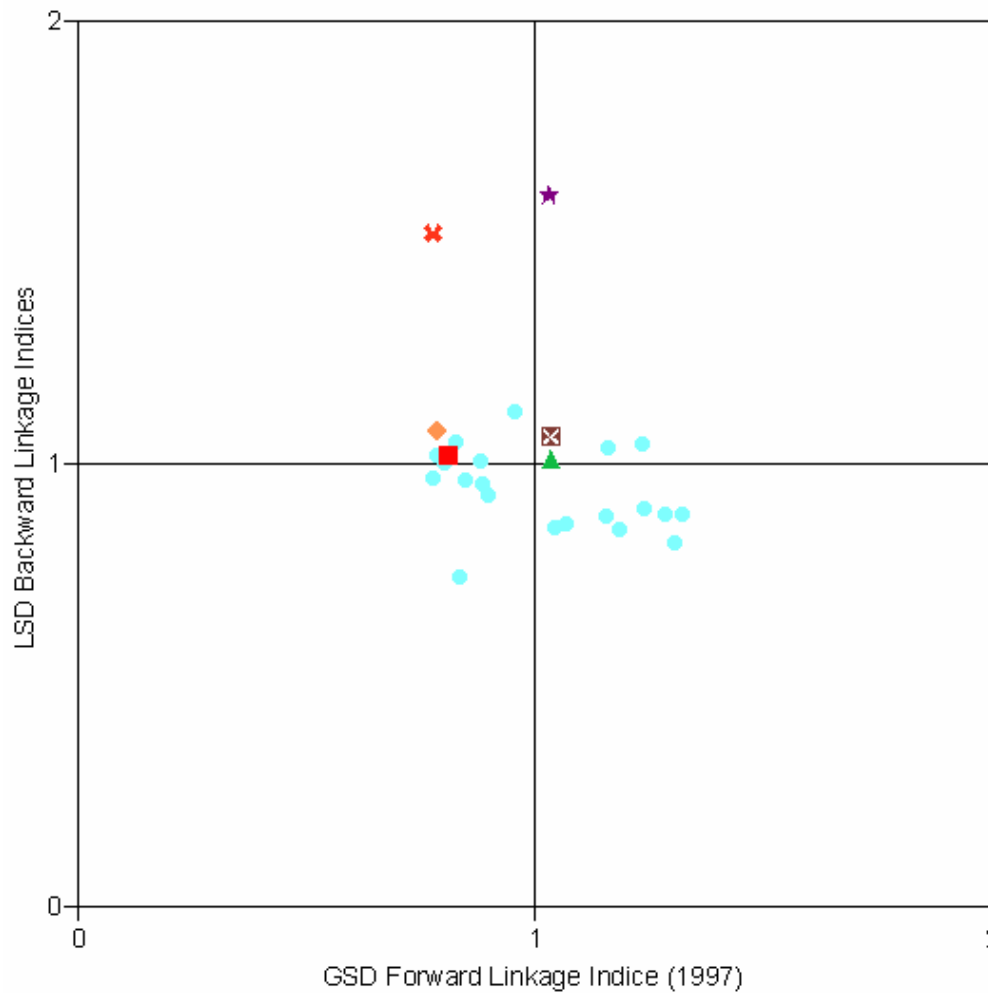


Linkages of Hawaii's Fisheries Sectors (1997)

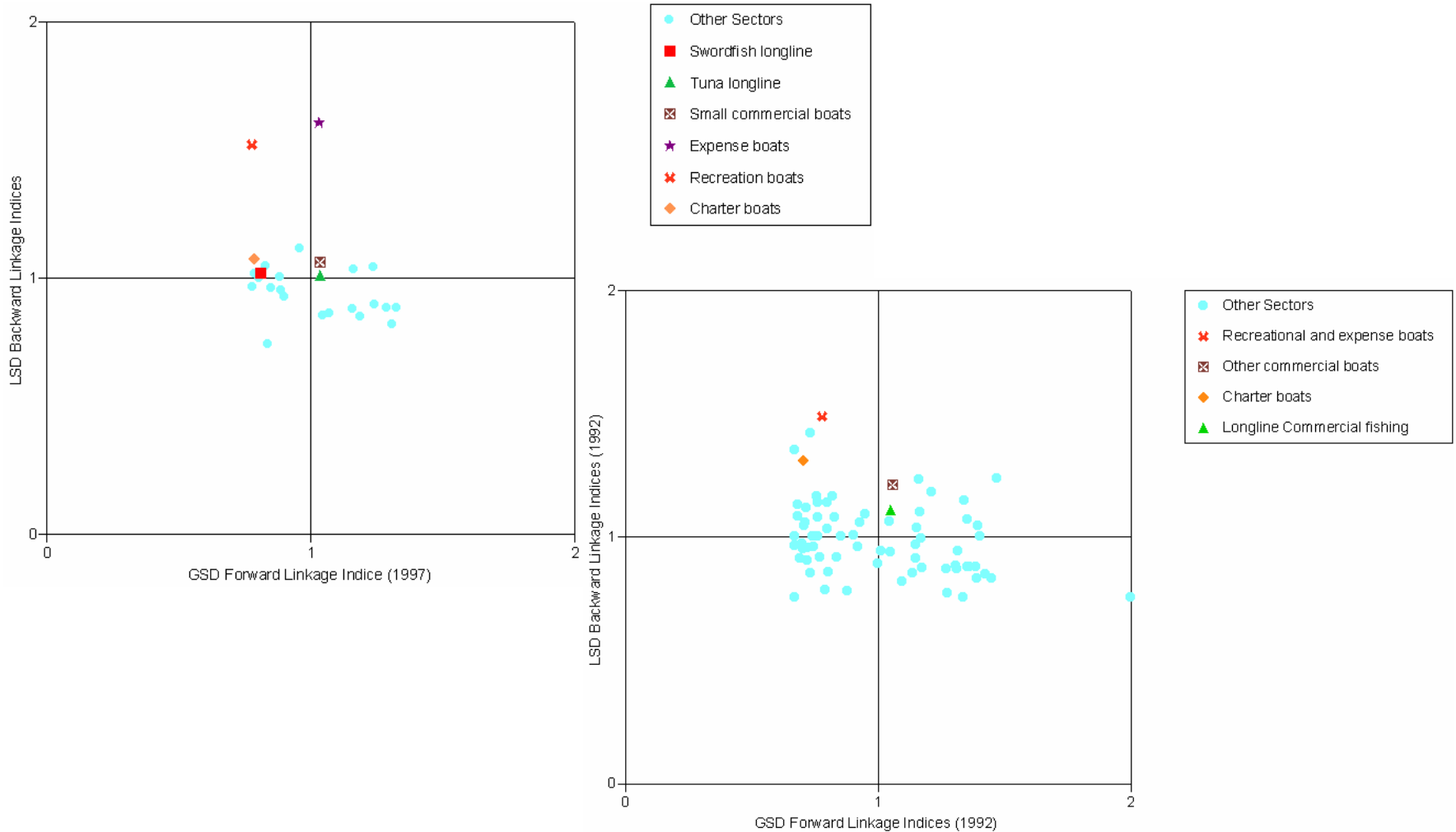
Sectors	Backward linkage		Forward linkage	
	Measures	Indices	Measures	Indices
Tuna longline	1.42	1.01	1.33	1.03
Swordfish longline	1.44	1.02	1.04	0.81
Small commercial boats	1.49	1.06	1.33	1.03
Charter boats	1.52	1.07	1.01	0.79
Expense boats	2.26	1.60	1.33	1.03
Recreation boats	2.15	1.52	1.00	0.78



Linkages of Hawaii's Fisheries Sectors (1997)



Linkages of Hawaii's Fisheries Sectors (1997 vs. 1992)



Impact Analysis

Background and Methodology



Impacts of Hawaii's Longline Regulations

- **Background**
 - 1999: CMC *versus* NMFS
 - Effective swordfishing shutdown
 - 2004: New regulations
 - Restricted swordfishing
 - Leung and Pooley (2002)
 - 1992 I-O model
 - 4 fisheries sectors
 - An update
 - 1997 Hawaii Fisheries Input-Output Model
 - 6 fisheries sectors (tuna & swordfish longline separated).
- **Objectives**
 - A refined and updated study on impacts of longline regulations
 - Complementary with the linkage analysis



Hawaii's Longline Regulations: Four Scenarios

Scenarios	Descriptions
Swordfishing shutdown	A basic scenario Longline swordfishing production lost entirely
Swordfishing shutdown with partial capacity shift	Old regulations Longline swordfishing production lost entirely Longline tuna production up by 15% Interaction within the longline sector
Swordfishing restriction with capacity shift	New regulations Longline swordfishing production down by 50% Longline tuna production up by 10% Interaction within the longline sector
Longline fishery shutdown	A benchmark upper bound



Impact Analysis

Results



Impacts of Hawaii Longline Regulations

Scenarios	Impacts	Output (\$ million)	Value- added (\$ million)	Wage income (\$ million)	Proprietor's income (\$ million)	State taxes (\$ million)	Wage jobs	Proprietor's jobs
Swordfishing shutdown	Self impact	-22.67	-11.24	-4.15	-1.45	-0.67	-116	-102
	Backward-linkage impact	-9.93	-5.68	-3.03	-0.29	-0.67	-89	-25
	Forward-linkage impact	-0.86	-0.45	-0.29	-0.01	-0.05	-14	0
Swordfishing shutdown with partial capacity shift	Self impact	-18.56	-8.77	-3.05	-1.08	-0.53	-83	-74
	Backward-linkage impact	-8.20	-4.69	-2.49	-0.24	-0.56	-72	-20
	Forward-linkage impact	0.49	0.24	0.16	0.01	0.02	9	0
Swordfishing restriction with capacity shift	Self impact	-8.60	-3.98	-1.34	-0.48	-0.24	-36	-32
	Backward-linkage impact	-3.81	-2.18	-1.16	-0.11	-0.26	-33	-9
	Forward-linkage impact	0.47	0.23	0.15	0.01	0.02	8	0
Longline fishery shutdown	Self impact	-50.04	-27.71	-11.45	-3.94	-1.64	-331	-293
	Backward-linkage impact	-21.44	-12.30	-6.64	-0.67	-1.41	-200	-58
	Forward-linkage impact	-9.85	-5.05	-3.25	-0.15	-0.54	-167	-6



Detailed Impacts of Hawaii Longline Regulations

Table A.1: Backward-linkage Impacts of Swordfishing Shutdown

Affected Sectors	Output (Million \$)	Value-added (Million \$)	Wage income (Million \$)	Proprietor's income (Million \$)	Total income (Million \$)	Wage jobs	Proprietor's jobs	Total jobs	State taxes (Million \$)
Small commercial boats	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Expense boats	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Recreation boats	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Charter boats	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Agriculture	-0.06	-0.04	-0.02	0.00	-0.02	-1	-1	-2	0.00
Mining and construction	-0.06	-0.03	-0.02	0.00	-0.02	0	0	-1	0.00
Food processing	-0.23	-0.08	-0.04	0.00	-0.04	-1	0	-2	0.00
Other manufacturing	-2.00	-0.48	-0.27	-0.04	-0.31	-7	-2	-9	-0.02
Transportation	-0.44	-0.22	-0.13	0.00	-0.13	-3	0	-3	-0.01
Information	-0.18	-0.11	-0.05	0.00	-0.05	-1	0	-1	-0.01
Utilities	-0.10	-0.05	-0.02	0.00	-0.02	0	0	0	-0.01
Wholesale trade	-3.77	-2.70	-1.46	-0.05	-1.51	-38	-7	-45	-0.46
Retail trade	-0.20	-0.13	-0.08	-0.01	-0.09	-3	-1	-4	-0.03
Finance and insurance	-0.50	-0.30	-0.14	-0.01	-0.15	-3	-1	-4	-0.02
Real estate and rentals	-0.54	-0.41	-0.03	-0.02	-0.05	-1	-1	-2	-0.02
Professional services	-0.20	-0.13	-0.08	-0.04	-0.12	-2	-2	-3	-0.01
Business services	-0.33	-0.24	-0.15	-0.03	-0.18	-7	-2	-8	-0.02
Educational services	-0.01	0.00	0.00	0.00	0.00	0	0	0	0.00
Health services	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Arts and entertainment	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Hotels	-0.01	0.00	0.00	0.00	0.00	0	0	0	0.00
Eating and drinking	-0.02	-0.01	-0.01	0.00	-0.01	0	0	0	0.00
Other services	-1.14	-0.61	-0.43	-0.08	-0.52	-18	-8	-26	-0.05
Government	-0.14	-0.13	-0.11	0.00	-0.11	-3	0	-3	-0.01
Total backward linkage impacts	-9.93	-5.68	-3.03	-0.29	-3.33	-89	-25	-114	-0.67



Detailed Impacts of Hawaii Longline Regulations

Table A.4: Forward-linkage Impacts of Swordfishing Shutdown with Partial Capacity Shift

Affected Sectors	Output (Million \$)	Value-added (Million \$)	Wage income (Million \$)	Proprietor's income (Million \$)	Total income (Million \$)	Wage jobs	Proprietor's jobs	Total jobs	State taxes (Million \$)
Small commercial boats	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Expense boats	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Recreation boats	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Charter boats	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Agriculture	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Mining and construction	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Food processing	0.10	0.03	0.02	0.00	0.02	1	0	1	0.00
Other manufacturing	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Transportation	0.01	0.00	0.00	0.00	0.00	0	0	0	0.00
Information	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Utilities	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Wholesale trade	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Retail trade	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Finance and insurance	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Real estate and rentals	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Professional services	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Business services	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Educational services	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Health services	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Arts and entertainment	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Hotels	-0.02	-0.01	-0.01	0.00	-0.01	0	0	0	0.00
Eating and drinking	0.38	0.20	0.14	0.01	0.14	8	0	9	0.02
Other services	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Government	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00
Total Forward linkage impacts	0.49	0.24	0.16	0.01	0.16	9	0	9	0.02



Supply-Driven: A Powerful and Flexible Approach

- Shocks
 - Regulations
 - Oil prices
 - Other supply-side shocks
- Interactions
 - Between swordfish and tuna longline
 - Between longline and other fisheries sectors (Pradhan et al. 2003; Sharma et al., 2003)
 - Other non-input-output linkages
- Impacts
 - Quantity
 - Price
- Extensions
 - More refined input-output models
 - Social Accounting Matrices (SAM)
 - Computable Equilibrium Models (CGE)



Overview of SAM Framework

	Industry	Commodity	Factors	Institution	Exports	TOTAL
Industry		Make				Total Industry Output
Commodity	Use			Consumption	Exports	Total Commodity Output
Factors	Value Added				Exports	Total Factor Income
Institution	Sales and Taxes	Sales	Distribution	Transfers	Exports	Total Institutional Income
Imports	Imports		Imports	Imports	Trans-shipment	Total Imports
TOTAL	Total Industry Outlay	Total Commodity Outlay	Total Factor Outlay	Total Institutional Expenditures	Total Exports	



Thank You



Presentation Outline

- **Linkage analysis**

- Input-output framework: a brief introduction
 - Leontief I-O model
 - Ghosh I-O model
- Input-output linkages: basic concepts
 - Backward linkage
 - Forward linkage
 - Total linkage?
- Linkage measures: revisit and suggested alternative
 - Demand driven
 - Supply/output driven
- Linkages of Hawaii fisheries sectors

- **Impact analysis**

- Longline regulations: background
- Economic impacts of longline regulations: Leung and Pooley (2002)
- Economic impacts of longline regulations: an update (more I-O information and newer regulations)

