Title: Spatial distribution of economic multipliers for Southwest Alaska fisheries

Chang K. Seung*
NOAA Fisheries
Resource Ecology and Fisheries Management Division,
Alaska Fisheries Science Center,
7600 Sand Point Way NE,
Seattle, WA 98115-6349, USA
E-mail: Chang.Seung@noaa.gov

Edward Waters
Cascade Economics, LLC
Washougal, Washington

* Corresponding author.

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Abstract

Alaska fisheries are characterized by a large leakage of revenues and value-added generated in the fisheries due to heavy reliance on imported inputs. A large portion of the multiplier effects from Alaska fisheries flow to other states, reducing benefits accruing to Alaska households. In this case, various policymakers (national and regional economic development policymakers as well as fisheries managers) may want to know how much of the total economic impact from a fisheries management action remains in Alaska and how much flows elsewhere. To help address this question, this study uses a 10-region multi-regional social accounting matrix (10MRSAM) model for Southwest Alaska (SWAK) fisheries to examine how economic impacts are distributed across regions for each of the major species caught and landed in each of the six SWAK boroughs and census areas (BCAs). We find, among other things, that 60-80% of total US household income generated from the SWAK fisheries is earned by non-Alaska households, depending on the species caught and the region where the fish is landed. The information on the spatial distribution of impacts resulting from fisheries management actions as described by the components of the relevant regional multipliers will be a useful tool for policymakers making decisions regarding Alaska fisheries.

1. Introduction

Fishery managers around the world need information about the economic impacts resulting from their actions as well as other exogenous shocks to the fisheries they manage. They may need to change the level of total allowable catch (TAC) for a fishery depending on the findings from a new stock assessment that may be due to climate change. Often, the economic impacts are not limited to the region where the policies are implemented, but spill over to other regions that have economic linkages with the affected region. This occurs if the first region strongly depends on imported inputs from outside the region. These inputs include not only factors of production such as labor (crew members) and capital (vessels) but also intermediate inputs (e.g., food, fuel and other manufactured goods).

This is the case for many Alaska seafood industries. Alaska seafood industries rely heavily on imported inputs. Other industries in the state also use large volumes of imported inputs although the shares of the imported inputs in these industries are generally smaller compared with Alaska seafood industries. In 2014, 20.8% of the total private and state and local government workers in Alaska were non-Alaska residents, resulting in 15.6 % of total labor income generated in the state that flowed outside Alaska. Leakage of labor income is highest in seafood processing (64.7%); followed by agriculture, forestry, fishing and hunting (49.9%, composed mostly of fishing); mining (31.9%); and accommodation (30.8%) [Alaska Department of Labor and Workforce Development (ADOL) 2016]. Furthermore, nonresident owners control a large fraction of capital used in Alaska industries, especially in seafood industries. This implies that a large share of capital income generated in the state leaks outside Alaska. Moreover, many of the goods and services used by Alaska industries and households are imported from outside Alaska. A previous study (Seung 2013) indicates that in 2008, the total value of Alaska's imports of all commodities from non-Alaska US states ($15.9 billion) was about 31% of the total value of production in Alaska ($51.2 billion).

Input-output (IO) models (Miller and Blair 1985) have been a dominant tool used by economists to conduct economic impact analysis for public policies such as fishery management policies because these models explicitly account for inter-industry linkages. Examples of IO studies for fisheries include Leung and Pooley (2002), Morrissey et al. (2011), and Sigfusson et al. (2013). Leung and Pooley (2002) calculated the economic impacts of an exogenous reduction in the catch of Hawaii-based longline fisheries. Morrissey et al. (2011) quantified the value of the marine sector marine services sector, marine resources sector (which includes fish harvesting and seafood processing), and marine manufacturing sector. Sigfusson et al. (2013) analyzed the importance of fisheries and associated industries to the economy of Iceland. However, IO models have the weakness of ignoring distributional effects inherent in the flow of income from industries to households and governments. Social accounting matrix (SAM) models capture these distributional effects and thus overcome this inherent weakness of IO models. Examples of SAM models applied to fisheries are Seung et al. (2016) and Fernandez-Macho et al. (2008). Seung et al. (2016) estimated the economic impact of Alaska salmon fishery failures. Fernandez-Macho et al. (2008) computed the economic impacts of a reduction in the hake TAC in Galicia, Spain. See, for example, King (1985), Adelman and Robinson (1986), and Holland and Wyeth (1993) for more details about the SAM models.

Most SAM models, however, are single-region models that compute only the effects on the region where a policy shock occurs, ignoring effects occurring in the other regions that are linked to the economy of the first region. When a large portion of factor income and expenditures leak outside a region, a single-region economic impact model will fail to capture a large share of the economic effects of a given policy change because the leakage will generate untracked spillover effects in regions that provide inputs to the region where the policy was implemented.

To address the weaknesses of the single-region SAM model for Alaska fisheries, several studies have been conducted. Seung (2017) developed a three-region SAM model to examine the effects of Alaska fisheries on the West Coast region and the rest of the US region, taking into account economic linkages among the three regions. Since this three-region SAM model is limited in that it can investigate only impacts on relatively large regions (e.g., Alaska as a whole), Seung et al. (2021) developed a more detailed 10-region multi-regional SAM (10MRSAM) model. More recently, Hutniczak (2022) adopted a three-region SAM model to investigate the multi-regional economic effects of Pacific halibut commercial fishing in Alaska. The 10 regions in the 10MRSAM model (Seung et al. 2021) include six Southwest Alaska (SWAK) boroughs and census areas (BCAs), an at-sea region, the rest of Alaska (AK), a West Coast region (Washington, Oregon and California), and the rest of US. This model is capable of assessing BCA-level impacts and spillover effects of fisheries management actions. A Regional Economic Model for North Pacific Fisheries web tool (https://nwecon.psmfc.org/) based on this research was published in 2022.

The 10MRSAM model represents an advancement over previous models developed for Alaska fisheries. While previous multi-regional SAM models for Alaska fisheries are useful for calculating multi-regional economic impacts of fishery management actions, the models compute total impacts on variables of interest but fail to examine in detail how the economic impacts are distributed geographically or spatially across different regions. Furthermore, previous economic impact analyses for fisheries around the world have not included a detailed analysis of the spatial distribution of key fisheries.

The purpose of this study is to analyze comprehensively and for the first time, the geographic distribution of economic impacts by spatially decomposing the economic multipliers. In doing so, this study builds on the 10MRSAM model in Seung et al. (2021). This geographic decomposition may be useful to policymakers, including fisheries managers and national or regional economic development policymakers, who may want to know how the economic impacts of a change in landings of a given species are distributed across regions. Additionally, the methods used in this study will be useful for future economic impact studies for fisheries around the world that aim to investigate the spatial distribution of economic impacts. For example, we find, among other things, that 60-80% of total US household income generated from SWAK fisheries is earned by non-Alaska households, depending on the species caught and the region where the fish is landed.

In our study, multipliers are defined in this study in a different way from how it is usually defined in an IO analysis. The multipliers typically used in an IO analysis are constructed to compute the effects of a change in *final demand*, and account only for impacts in industries that provide inputs to the industry receiving the initial shock (backward linkage effects).

Consequently, these multipliers cannot measure impacts occurring in industries that purchase inputs from the shocked industry (forward linkage effects). This is a problem in the case of fish harvesting. If the multiplier for fish harvesting is multiplied by the change in the amount (dollar value) of fish caught, the calculated impacts include only the effects on the industries supplying inputs to the fishing industry, not for effects occurring in industries that purchase the raw fish (e.g., seafood processing industry). To calculate the full impacts accurately, this study defines the multipliers that account for both the backward and forward linkage effects.

This paper is organized as follows. The next section describes the 10MRSAM model and the data used. Section 3 defines and explains the multipliers derived and used in this study, and demonstrates how multipliers can be decomposed spatially. Section 4 conducts the spatial decomposition of the multipliers. We first describe how we calculated the different types of multipliers, and then present and discuss the results. Section 5 compares the spatial distribution of multipliers in several different dimensions. In that section, we illustrate spatial distributions using three examples: (i) value distribution of the impacts of Pollock fisheries by region of harvest and type of multiplier, (ii) percentage distribution of the impacts of Kodiak Island Borough (KIB) fisheries by species caught and type of multiplier, and (iii) percentage distribution of employment multipliers by species caught and region of harvest. Then we discuss results from the three examples. Section 6 provides some implications and concluding statements.

2. 10MRSAM model

2.1 Model structure

Most IO and SAM models in the literature are demand-driven models designed to calculate impacts from demand-side shocks, e.g., a shift in exports of a given commodity. However, in some cases such as Alaska fisheries, the initial shock is often driven by a supply-side change (i.e., a change in fish production). If demand-driven models are used to analyze such cases, a double-counting of impacts can result [Seung and Waters (2013) and Seung (2014, 2017)]. Many previous studies attempt to address this problem [e.g., Ghosh 1958; Miller and Blair 1985; Oosterhaven 1988, 1989; Roberts 1994; Dietzenbacher 1997; Leung and Pooley 2002]. The present study does not review those studies, however a detailed review of the relevant literature is found in, for example, Seung and Waters (2013) and Seung (2014, 2017).

This study uses an approach called the "adjusted demand-driven MRSAM model" approach (Seung 2017; Seung et al. 2021) to overcome the biases of applying a demand-driven approach. Briefly, to calculate the economic impacts of a policy change involving a change in revenue due to a change in landings by harvesting vessels and corresponding change in first wholesale revenues of fish processors, the model is run just like a demand-driven model with the changes in revenues applied as direct shocks, but with the regional purchase coefficients (the proportion of local demand that is met by local production, or RPCs) for commodities produced by *all* directly impacted industries (fish harvesting and fish processing) and any forward-linked industries set equal to zero. Setting RPCs to zero for the seafood industries fixes the amounts that the seafood processing industry buys from the fish harvesting industry to exactly the amounts required to attain the pre-determined levels of industry output, thus avoiding the double counting problem encountered in a pure demand-driven model. For details on this approach, see Seung (2017).

This section provides a brief description of the model. For more details, see, for example, Waters et al. (2014) and Seung (2017). Table A.1 in the Appendix exhibits the structure of 10MRSAM and Table A.2 lists the acronyms used for regions and species. For simplicity, this section illustrates a three-region SAM model, however the structure of the simplified model is basically the same as the 10MRSAM model.

The MRSAM model can be represented in matrix form as follows:

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} Z_{11} & z_{12} & z_{13} \\ z_{21} & Z_{22} & z_{23} \\ z_{31} & z_{32} & Z_{33} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} + \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \quad , \tag{1}$$

where

$\boldsymbol{y_r}$: column vector of endogenous accounts for region *r*,
$\boldsymbol{x_r}$: column vector of exogenous accounts for region *r*,
$\boldsymbol{Z_{rr}}$: submatrix of coefficients showing intra-regional transactions, and
$\boldsymbol{z_{rs}}$: submatrix of coefficients showing inter-regional transactions.

Equation (1) can be expressed compactly as:

$$Y = (I - S)^{-1}X \quad , \tag{2}$$

the where $Y = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix}$, S= $\begin{bmatrix} Z_{11} & z_{12} & z_{13} \\ z_{21} & Z_{22} & z_{23} \\ z_{31} & z_{32} & Z_{33} \end{bmatrix}$, and $X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$. Here S is the matrix of direct MRSAM coefficients and $(I - S)^{-1}$ is called the MRSAM multiplier matrix or matrix of MRSAM inverse coefficients.

$\boldsymbol{Y_r}$ consists of the following endogenous sub-vectors:

$\boldsymbol{A_r}$ = vector of regional industry output
$\boldsymbol{Q_r}$ = vector of regional commodity output
$\boldsymbol{V_r}$ = vector of total primary factor payments
$\boldsymbol{IBT_r}$ = indirect business tax payments
$\boldsymbol{H_r}$ = vector of total household income
$\boldsymbol{SG_r}$ = total state and local government income or revenue

$\boldsymbol{x_r}$ is a column vector comprising the following exogenous sub-vectors:
$\boldsymbol{ea_r}$ = vector of exogenous demand for regional industry output
$\boldsymbol{eq_r}$ = vector of exogenous demand for regional commodity output
$\boldsymbol{ev_r}$ = vector of exogenous factor payments
$\boldsymbol{et_r}$ = exogenous indirect business tax payments
$\boldsymbol{eh_r}$ = vector of exogenous federal transfers to households

eg_r = federal transfers to state and local government.

As mentioned, in the "adjusted demand-driven MRSAM model", the RPCs for all directly impacted industries (fish harvesting and fish processing) and any forward-linked industries are set equal to zero. This can be accomplished by setting to zero the corresponding elements in the matrix of direct MRSAM coefficients (S in Equation (2)).

2.2 Data used

The IMPLAN data and modeling system (https://implan.com/) is often used to conduct economic impact analysis within an IO framework. However, the data are subject to several limitations. Two of the most critical limitations concerning fisheries industry analysis are (i) IMPLAN tends to underestimate seafood industry employment, especially in the harvesting sector, due to under-counting of self-employed, seasonal, and part-time workers; and (ii) the data include only a single fish harvesting sector and a single seafood products sector that aggregate all combined commercial fishing and seafood processing activities. To overcome these limitations and other weaknesses in the IMPLAN fisheries data, a comprehensive data collection effort was conducted to obtain the data necessary to construct the 10MRSAM model. Details of this are found in Cascade Economics (2016), Seung et al. (2020), and Seung et al. (2021).

2.3 Sectors in 10MRSAM

Based on a data collection project for SWAK fisheries, two different versions of the 10MRSAM model – a gear-based fisheries industries version (GB) and a species-based industries version (SB) – were developed.[1] There are 10 regions in the 10MRSAM model. These regions include an at-sea "region" (AT-SEA), six SWAK BCAs, the rest of Alaska (RAK), the U.S. West Coast (WOC, Washington, Oregon, and California), and the rest of the U.S. (RUS). The six SWAK BCAs are Aleutians West Census Area, Aleutians East Borough (AEB), Lake and Peninsula Borough (LPB), Bristol Bay Borough (BBB), Dillingham Census Area (DCA), and Kodiak Island Borough (KIB).

Both the gear-based and the species-based 10MRSAM versions include eleven aggregated species categories, namely: 1. Tanner Crab (tanner crab and snow crab), 2. King Crab (mostly Bristol Bay red king crab but also includes brown king crab and blue king crab), 3. Other Crab (mostly Dungeness crab), 4. Pacific cod, 5. Pollock, 6. Sablefish, 7. Rockfish, 8. Flatfish, 9. Salmon, 10. Halibut, and 11. all other species combined (in the base year of 2014 this was mostly herring). In the species-based 10MRSAM model version there are eleven different fish harvesting industries and eleven processing industries corresponding to each species harvested

[1] Fishery management policies may involve two different types of changes – a change in harvest of a specific species or in certain cases, a change in fishing activity by a specific gear type. To accommodate this flexibility we developed two different versions of the model – a gear-based fisheries industries version (GB) and a species-based industries version (SB).

and processed. In addition, there are 12 aggregated non-seafood industries, six value-added sectors, three household sectors, and a combined state and local government sector.[2]

The At-sea sector "region" (AT-SEA) is unique in that it consists only of activities associated with fish harvesting and processing by catcher-processors (CP), mothership processors (MS), and catcher vessels delivering to motherships operating in BSAI and Western GOA. In AT-SEA, there are six species-based fish harvesting industries catching Pacific cod, Pollock, Sablefish, Rockfish, Flatfish, and Other species (i.e., excluding Crab, Halibut, and Salmon), and six corresponding fish processing industries. All industry inputs, including factors of production and intermediate inputs, are imported from other regions in the MRSAM. There are no non-seafood industries, households or state and local government sectors in AT-SEA. All value-added generated by seafood industries in AT-SEA is transferred to residents of other regions in the MRSAM. In each of the three non-SWAK regions (RAK, WOC, and RUS), there is a single aggregated fish harvesting industry, one aggregated seafood processing industry, and 12 aggregated non-seafood industries.

3. Multipliers for SWAK fisheries

In 10MRSAM, fish landed in a SWAK region are processed by seafood processing plants in that region. In the case of AT-SEA, fish caught by a vessel are processed on the same vessel or delivered to a mothership floating processor. Economic impacts are generated when the fish is caught, landed, and processed. To catch fish, vessels need to hire crew and purchase intermediate inputs (such as food, fuel and supplies). After paying for crew members, intermediate inputs and taxes, the remainder of ex-vessel revenue is paid to the capital (vessel) owners. Crew members and vessel owners, in their roles as "households", spend money either in SWAK BCAs, RAK, or elsewhere, depending on their region of residency, generating economic impacts across the regions. When vessels purchase inputs, industries supplying the inputs earn revenue. To produce the inputs, these industries in turn hire labor and capital and purchase inputs from other industries, and so on, in a process that continues to generate additional economic impacts. Likewise, to process the raw fish, seafood processors hire labor and capital and purchase intermediate inputs, creating rounds of economic impacts. The 10MRSAM model captures all of these sources and rounds of economic impacts in computing the total economic impacts associated with catching, landing and processing fish. Details of the 10MRSAM model are found in Seung et al. (2021).

In a typical IO analysis, a multiplier measures the total economic impacts resulting from an increase of $1 in the *final demand* for output (household consumption, investment, government expenditure, or exports). For example, if total output in an economy increases by $3 million caused by final demand increasing by $2 million, the multiplier is 1.5. This concept (multiplier) can be applied not only to total regional output but also to other economic variables such as employment, value-added, and household income. Multipliers typically used in an IO analysis are constructed to compute the effects of a change in *final demand*, and account only for impacts in industries that provide inputs to the industry receiving the initial shock (backward linkage

[2] Changes in Alaska fisheries will have impacts on non-US economies through international trade of both seafood and intermediate commodities. However, since international flows of commodities are exogenous in the 10MRSAM model, the model cannot calculate impacts that changes in the value of trade flows may have on non-US economies.

effects). Consequently, these multipliers cannot measure impacts occurring in industries that purchase inputs from the shocked industry (forward linkage effects). This is a problem in the case of fish harvesting. If the multiplier for fish harvesting is multiplied by the change in the amount (dollar value) of fish caught, the calculated impacts include only the effects on the industries supplying inputs to the fishing industry, not for effects occurring in industries that purchase the raw fish (e.g., seafood processing industry).

To address this problem, the multiplier is defined in this study in a different way from how it is usually defined in an IO analysis. The output multiplier in this study is defined as the change in the total regional output per $1 increase in the value of fish landings (not in the final demand for the fish), and includes both the backward-linkage (e.g., fuel and supplies) and forward-linkage (e.g., seafood processing) effects. The multipliers calculated in this study represent all the economic effects generated in a region, not just backward linkage effects. Four different types of multipliers are developed, including output multipliers, value-added multipliers, employment multipliers, and household income multipliers. All measure the total impacts on the variable of interest (output, value-added, employment, or household income) when fish harvest increases by $1. Note that the household income multipliers are zeros for AT-SEA because there are no households (residents) associated with AT-SEA, and all value-added generated in the AT-SEA region flows to other regions where it is added to these other regions' household income. Using the 10MRSAM model, this study computes each type of multiplier for each of the major species landed in each of the six SWAK regions and AT-SEA. Multipliers are then decomposed into different geographical components depending on in which region the impacts occur.

4. Spatial decomposition of the multipliers

4.1 Methods

Based on the 10MRSAM model, this study calculates the four different types of multipliers: output, value-added, employment, and household income by decomposing the multiplier matrix, $MM = (I - S)^{-1}$. To do this, we first define the set of regions as follows:

r, s : regions (r = 1, 2, …, 10, 10 regions).

For each region, the following sets are defined.

a, b : accounts in the column and row in the MRSAM. The following are subsets of a and b.

- sp : species – raw fish (sp = 1, 2, …, 11)
- psp : species – processed fish (psp = 1, 2, …, 11) where each element corresponds to an element in sp
- i : industries (i = 1, 2, …, 34)
- c : commodities (c = 1, 2, …, 24), where sp is a subset of c
- v : value-added accounts (v = 1, 2, …, 6)
- h : households (h = 1, 2, 3)
- sl : state and local government account (one element)

Given the sets defined above, $MS_{a,b}^{r,s}$ is defined as the element in *MM* that measures the multiplier effects on a in region *r* due to a unitary increase in b in region *s*. For example,

$MS_{SERVICE,PCOD}^{WOC,AWCA}$ shows the total multiplier effects on SERVICE industry in WOC when there is a

$1 increase in catch of PCOD in AWCA.

Thus, the multiplier effects on total output in region *s* due to a unitary increase in catch of species *sp* in region *r* is calculated as:

$$M_{s,r,sp}^{output} = \sum_i^I MS_{i,sp}^{s,r} + \sum_i^I \propto_{r,sp} MS_{i,psp}^{s,r} \quad , \tag{3}$$

where $MS_{i,sp}^{s,r}$ is the effect on industry *i* in region *s* of a unitary change in the catch of raw fish *sp* in region *r*, $\propto_{r,sp}$, is the base-year ratio of the first wholesale revenue to ex-vessel revenue for species *sp* caught in *r*, and $MS_{i,psp}^{s,r}$ is the multiplier effect on industry *i* in region *s* of $1 change in processed seafood. Therefore, $\propto_{r,sp} MS_{i,psp}^{s,r}$ measures the effect on industry *i* in region *s* caused by an increase in processed seafood due to $1 increase in catch of species *sp*. Therefore, the left-hand side ($M_{s,r,sp}^{output}$) in Equation (1) includes the total effects on region *s*'s output due to a $1 increase in harvest of *sp* in region *r*.

Similarly, the multiplier effects on total value-added in region *s* due to a unitary increase in catch of species *sp* in region *r* is calculated:

$$M_{s,r,sp}^{vadd} = \sum_v^V MS_{v,sp}^{s,r} + \sum_v^V \propto_{r,sp} MS_{v,psp}^{s,r} \tag{4}$$

Next, the multiplier effects on total employment in region *s* due to a unitary increase in catch of species *sp* in region *r* is calculated:

$$M_{s,r,sp}^{emp} = \sum_i^I E_{s,i} MS_{i,sp}^{s,r} + \sum_i^I E_{s,i} \propto_{r,sp} MS_{i,psp}^{s,r} \tag{5}$$

where $E_{s,i}$ is the ratio of employment to output in industry *i* in region *s*.

Finally, the multiplier effects on total household income in region *s* due to a unitary increase in catch of species *sp* in region *r* is calculated:

$$M_{s,r,sp}^{HH} = \sum_h^H MS_{h,sp}^{s,r} + \sum_h^H \propto_{r,sp} MS_{h,psp}^{s,r} \tag{6}$$

Summing the terms on the left-hand side of equations (3) through (6) above over *s* yields the total effects on the US industry output, value-added, employment, and household income, respectively:

$$M_{US,r,sp}^{output} = \sum_s^S M_{s,r,sp}^{output} \tag{7}$$

$$M_{US,r,sp}^{vadd} = \sum_s^S M_{s,r,sp}^{vadd} \tag{8}$$

$$M^{emp}_{US,r,sp} = \sum_s^S M^{emp}_{s,r,sp} \tag{9}$$

$$M^{HH}_{US,r,sp} = \sum_s^S M^{HH}_{s,r,sp} \tag{10}$$

4.2 Results and discussion

Tables 1 and 2 present the spatial distribution of the multipliers in value and percentage terms, respectively. Employment multipliers in Table 1 are defined as the increase in the number of workers or jobs resulting from a $1 *million* increase in fish harvest, while the other three multipliers are defined as the increase in the variables caused by a $1 increase in the harvest.

For example, when $1 worth of Pacific cod is caught and landed in AWCA (Table 1, rows 29-32), $2.51 worth of total output is produced in its own region (AWCA), and $0.01 and $0.23 worth of output are generated in all other SWAK BCAs combined and the rest of Alaska (RAK), respectively. The total impact on output in Alaska is therefore $2.75. The impacts on output in WOC and RUS are $1.21 and $1.08, respectively. The total US impact when $1 worth of Pacific cod is caught and landed in AWCA is therefore $5.04. Impacts on the own region (AWCA) are about 49.8% of the total US impact (Table 2, rows 29-32). Similarly, for every $1 million worth of Pacific cod caught and landed in AWCA the effect on employment in its own region is approximately 24 jobs, with total impacts on Alaska being about 25 jobs (Table 1). Additionally, about 7 jobs are created in WOC and 6 jobs in RUS. The increase in total US jobs per $1 million worth of Pacific cod caught and landed in AWCA is 38 jobs.

In terms of the spatial percentage distribution (Table 2), the contribution of AWCA's Pacific cod to total employment in its own region (AWCA) is larger than its contribution to total output in the region (rows 29-32). While 49.8% of the increase in total US output occurs in AWCA, a larger percentage (63.2%) of the increase in total US employment occurs in the region. The impact on value-added in the region is much smaller; only 32.4% of the increase in the total US value-added occurs in AWCA. The impacts on household income in AWCA are significantly smaller (only 16.7%). This is because a large portion of the value-added generated in AWCA leaks out of the region and flows to WOC and RUS due to heavy dependence on factors of production from those regions.

AWCA is not alone in showing a large leakage of value-added. Table 2 indicates that a large portion of value-added generated in each of the four major SWAK fishing regions (AT-SEA, AEB, KIB, and AWCA) leaks out of the region. For example, the percentage of value-added impacts occurring in WOC as a result of activities in the SWAK regions ranges from 25.1% (KIB) to 50.8% (AT-SEA), and the percentage of household income generated in the region (WOC) ranges from 31.5% (KIB) to 64.9% (AT-SEA).

The geographic distribution of impacts will vary depending on several different factors. First, it varies depending on the species caught. Harvesting different species requires different combinations of inputs. Second, it varies depending on the region (BCA) where a species is caught, landed and processed. The source regions for the inputs used in harvesting and processing a certain species may vary between regions. Some regions may use a larger portion of imported inputs than other regions. Third, the magnitude of multipliers distributed among different regions varies depending on the size of the economies of the regions. In general, the larger the region, the larger the multiplier. By highlighting the spatial component of economic impacts, this study will enable policymakers and fisheries managers to better understand the spatial heterogeneity of impacts generated for different species and regions.

Fisheries managers interested in how fishing communities will be affected by a fisheries policy change may make the mistake of using indicators such as output, employment, or value-added to base their decisions. However, if a fishing community relies heavily on imported inputs, these indicators will not correctly correlate with the well-being of residents of the affected communities. This is because those variables are measured based on the place where the economic activity (fishing and seafood processing) occurs, and do not necessarily measure the actual benefit accruing to fishing communities experiencing a large leakage of income. In such cases, managers concerned with understanding the well-being of residents of the fishing communities should refer to the household income multipliers presented in this study.

5. Multi-dimensional comparisons of the spatial distribution of multipliers

5.1 Introduction

While the previous section discussed the spatial distribution of multipliers and impacts for a single species caught in a single region (Pacific cod caught in AWCA in the example above), this section conducts a more in-depth investigation of the spatial distribution in several different dimensions using the information in Tables 1 and 2. Spatial distributions can be shown for two different metrics (i.e., value distribution shown in Table 1, and percent distribution in Table 2), for four different types of multipliers across eleven species and seven regions (six BCAs plus AT-SEA region). Thus, theoretically, there are 616 (= 2 x 4 x 11 x 7) different spatial distributions that could be examined, although the actual number is smaller because not all eleven species are caught in all seven regions. Using the decomposed multipliers in Tables 1 and 2, one can derive spatial distributions in several different dimensions and compare the spatially decomposed impacts for different types of multipliers across different fish harvesting regions and species (Figures 1-9). Using Tables 1 and 2 readers can derive other distributions as needed.

In the present study, three examples are presented. We chose these examples to illustrate the diversity of the spatial distributions that could be examined using our model. In the first example, we examine the value distribution of the multipliers for one of the most important species in Alaska fisheries (pollock). In the second example, we analyze the percentage distribution of the multipliers for a particular region (KIB)'s fisheries. The third example illustrates the percentage distribution for a particular type of multiplier (employment multipliers). Note that effects on the rest of SWAK are very small due to limited economic linkages between SWAK BCAs.

5.2 Results and discussion

Example 1: Value distribution of the impacts of Pollock fisheries by region of harvest and type of multiplier

This example features the spatial distributions of Pollock multipliers. Figure 1 shows how the decomposed output multipliers are distributed across different regions when pollock is "landed" in each of four different regions (AWCA, AT-SEA, AEB, and KIB). It is shown that $1 million of Pollock deliveries in the four regions has significant impacts on the own region, WOC, and RUS but very little impact on the Rest of SWAK and the Rest of AK. It is not surprising that among the regions the largest impacts on WOC are from activity by AT-SEA because AT-SEA imports all non-seafood commodities used as inputs in harvesting and processing from other regions, mostly WOC. Heavy dependence by AT-SEA's Pollock fishery on WOC is also shown in Figures 2 and 3.

Figure 2 shows Alaska fisheries' strong dependence on non-Alaska factors of production. The figure indicates that the percentage of household income multipliers accounted for by WOC and RUS is larger than the corresponding percentages for value-added. Table 2 shows that the share of value-added multipliers for Pollock falling on WOC ranges from 25.2% (from harvest by KIB) to 50.6% (from AT-SEA harvest) (rows 7, 35, 59, and 95), while for household income multipliers the corresponding percentages range from 31.1% (from KIB harvest) to 64.7% (from AT-SEA harvest) (rows 8, 36, 60, and 96). Notably, the own region household income impacts in KIB arising from an increase in Pollock harvest are the largest among the SWAK regions (27.2%, Table 2, row 96). This is because, compared to other SWAK regions, KIB relies less on factors of production from sources outside the region.

Figure 3 illustrates that, for all four SWAK regions examined, in general, compared with the other three variables (especially value-added and household income), employment contributes the largest share of multiplier effects on All AK. This means that SWAK Pollock fisheries generate a larger share of employment within Alaska than they contribute in value-added or household income in the state. This is because output, value-added, and employment are measured by the place where the economic activity takes place, while household income is measured by the place where the income is spent.

Example 2: Percentage distribution of the impacts of KIB fisheries by species caught and type of multiplier

Fisheries managers may sometimes be concerned with how a region's fisheries generate impacts from the harvest of a species across different regions in percentage terms for different variables. Figures 4-8 illustrate the impacts on different variables from the harvest of each of the five major species caught in KIB, respectively. The figures illustrate that the impacts of all five species caught in KIB on its own region (and also ALL AK) are larger than those on the two non-Alaska regions (WOC and RUS) (see also Table 2) due to KIB's stronger reliance on inputs sourced from its own region. Among the four variables, impacts on employment in its own region (and ALL AK) are strongest while impacts on household income in the region (and ALL AK) are the weakest. (Figures 4-8).

Example 3: Percentage distribution of employment multipliers by species caught and region of harvest

Fisheries managers may also sometimes want to compare the percentage distributions of employment multipliers by the species caught and region of harvest. Figure 9 illustrates the percentage distributions for employment multipliers by species for four regions (AEB, AT-SEA, AWCA, and KIB). For example, for a given level of initial shock to AEB fisheries, some species (halibut, sablefish, and salmon) generate a larger percentage of the employment effects in their own region (AEB) than is true for other species. Compared to AEB, impacts on its own region for AT-SEA fisheries are much smaller (in terms of percentage) than those shown for AEB. The differences between the two regions are because there are no non-seafood production activities in AT-SEA, so there are no indirect effects of seafood production in this region; indirect effects occur in non-AT-SEA regions (mainly WOC and RUS) that provide inputs and finance AT-SEA's seafood production.

In Figure 9, results for AWCA exhibit a distribution pattern similar to those for AEB. The main notable difference in results between the two regions is that Pacific cod in AWCA has stronger employment impacts on its own region (AWCA) than does the harvest of that species in AEB; 63.2% of total employment impacts from AWCA's Pacific cod harvest fall on its own region, while 56.9% of the impacts from AEB's Pacific cod catch are on its own region. As in the case of AEB, for KIB the largest employment impacts on its own region (KIB) in percentage terms are from halibut, sablefish, and salmon. Employment impacts from KIB fisheries on its own region are among the largest in percentage terms, with those spilling over onto WOC and RUS among the smallest for the four SWAK regions examined.

Often, fishery managers are concerned with the regional economic impacts of a local or regional fishery. Most previous regional economic impact analyses for fisheries rely on single-region models [e.g., Fernandez-Macho et al. (2008), Seung et al. (2016)], and provide impacts only on the region where the policy is implemented. In some cases, however, a change in fisheries in a region generates non-trivial spillover effects on, and feedback effects from, other regions. This is particularly true for certain Alaska fisheries. Some studies such as Seung et al. (2021) and Hutniczak (2022) use multi-regional models. However, these multi-regional models have typically been used to compute total impacts of a specific policy on each of the modeled regions, but not to comprehensively examine their spatial distribution. This study illustrates that the spatial distribution of impacts can be investigated within a multi-regional economic impact modeling framework.

Fisheries managers are concerned with the economic well-being of fishing-dependent communities. By way of an example, suppose that for biological reasons, managers of the Alaska pollock fishery were planning to reduce the TAC for pollock landed in Southwest Alaska. Results from this study imply that regions will be differentially affected depending on the degree of communities' reliance on the pollock fishery. For instance, KIB residents will suffer much greater economic effects from the pollock TAC decrease than, e.g., AEB residents (Figure 2) because KIB is much more dependent on the pollock fishery than is AEB. In order to mitigate some of the negative impacts on KIB residents, for a given reduction in SWAK pollock fishery TAC, managers may want to constrain the harvest for vessels landing pollock at KIB to a proportionately lesser degree than for vessels landing at AEB. By way of another example, suppose AEB's unemployment rate were very high, and that policymakers wanted to increase employment in the region by increasing the harvest of a particular species. In this case, assuming that there is no concern over possible overexploitation due to increased harvest mortality, policymakers may consider increasing the TAC for Pacific halibut because harvest of this species is the most effective at increasing employment in AEB (Figure 9).

6. Conclusion

Economic impact studies for fisheries have been conducted throughout the world. Some of these studies evaluate national-level impacts or the contribution of fisheries using a national-level IO model [e.g., Morrissey et al. (2011), and Sigfusson et al. (2013)], while other studies investigate the local or regional-level impacts of fisheries using a single region model (e.g., Leung and Pooley 2002). Several studies adopt a SAM model to account for distributional effects (e.g., Seung et al. 2016). All these studies present the economic impacts of fisheries only in terms of total impacts, masking how impacts are distributed across different geographical regions. Armed only with information on total economic impacts, fisheries managers may be less able to make informed decisions regarding how actions affect particular communities. Understanding how impacts of fisheries policies are distributed spatially can help managers address the concerns of stakeholders in directly and indirectly affected communities.

This paper introduces the different types of multipliers available for the range of species caught, landed and processed in SWAK BCA fisheries, and then spatially decomposes the multipliers to show the transmission of impacts affecting communities in directly and indirectly affected regions. Multipliers in this study are defined in a manner that differs from what is typically seen in IO or SAM economic impact analyses. Spatially defined multipliers can provide a useful tool for fisheries managers to visualize and evaluate the geographic distribution of economic impacts more quickly and easily than is possible using other resources, including the Regional Economic Model for North Pacific Fisheries web tool (https://nwecon.psmfc.org/). This study illustrates how exploring the spatial distribution of multiplier effects enables fisheries managers to better visualize how impacts of a policy change are distributed across different economic variables, species and regions in a multi-dimensional way, thereby enabling a more complete understanding of concerns by stakeholders in the directly and indirectly affected communities of Southwest Alaska, elsewhere in Alaska, the West Coast and rest of the U.S.

This study has some limitations. The model used in this study is static, and therefore, does not account for the dynamic nature of the economy and fishery resource. First, the biomass of the fisheries will change over time. For example, a reduction in the harvest of a species in the current period may increase the biomass available in the next period, and vice versa, thereby affecting the level of allowable harvest over time. Second, the structure of the economy and fisheries may change over time. Technological change in regional industries may alter the economic structure, leading to change in the indirect and induced effects of fishery management actions. While these are important considerations, the present study first focuses on the current status and spatial distribution of the fishing industry. To address dynamic factors affecting the fishery and the economy, use of a dynamic model, such as a dynamic computable general equilibrium model, may shed more light.

References

Adelman, I., and S. Robinson. 1986. U.S. agriculture in a general equilibrium framework: Analysis with a social accounting matrix. Am. J. Agricult. Econ. 68: 1,196-1,207.

Alaska Department of Labor and Workforce Development. 2016. Non-residents working in Alaska, 2014. Alaska Department of Labor and Workforce Development, Juneau, AK.

Cascade Economics. 2016. Collecting Borough and Census Area-Level Data for Regional Economic Modeling of Southwest Alaska Commercial Fisheries. Final Report to Pacific States Marine Fisheries Commission and Alaska Fisheries Science Center.

Dietzenbacher, E. 1997. In vindication of the Ghosh model: a reinterpretation as a price model. Journal of Regional Science 37 (4): 629–651.

Fernandez-Macho, J., C. Gallastegui, P. Gonzalez. 2008. Economic Impacts of TAC Regulation: A Supply-driven SAM Approach. Fisheries Research 90: 225-234.

Ghosh, A. 1958. Input-output approach to an allocative system. Economica 25 (1):58–64.

Holland, D., and P. Wyeth. 1993. SAM multipliers: their decomposition, interpretation, and relationship to input-output multipliers. Research Bulletin XB 1027, College of Agricultural and Home Economics Research Center, Washington State University.

Hutniczak, B. 2022. Assessing cross-regional flows of economic benefits: A case study of Pacific halibut commercial fishing in Alaska. Fisheries Research 255: 106449.

IMPLAN. Huntersville, NC. https://implan.com/

King, B. 1985. What is a SAM? Pyatt, G. and J. Round (ed.), Social Accounting Matrix, World Bank.

Leung, P., and S. Pooley. 2002. Regional economic impacts of reductions in fisheries production: a Supply-driven approach. Mar. Res. Econ. 16: 251-262.

Miller, R. E., and P. D. Blair. 1985. Input-Output Analysis: Foundations and Extensions. Englewood Cliffs, NJ: Prentice Hall Inc.

Morrissey, K, C. O'Donoghue, and S. Hynes S. 2011. Quantifying the value of multi-sectoral marine commercial activity in Ireland. Marine Policy 35:721–727.

Oosterhaven, J. 1988. On the plausibility of the supply-driven input–output model. Journal of Regional Science 28 (2): 203–217.

Oosterhaven, J. 1989. The supply-driven input–output model: a new interpretation but still implausible. Journal of Regional Science 29 (3): 459–465.

Roberts, D. 1994. A modified Leontief model for analyzing the impact of milk quotas on the wider economy. J. Agricult. Econ. 45(1): 90-101.

Seung, C., and E. Waters. 2013. Calculating impacts of exogenous output changes: Application of a social accounting matrix (SAM) model to Alaska fisheries. Annals Reg. Sci. 51 (2): 553-573.

Seung, C. 2014. Estimating effects of exogenous output changes: an application of multi-regional social accounting matrix (MRSAM) method to natural resource management. Reg. Sci. Pol. Pract. 6(2): 177-193.

Seung, C., B. Muse, and E. Waters. 2016. Net Economic Impacts of Recent Alaska Salmon Fishery Failures and Federal Relief. North American Journal of Fisheries Management 36:351–362.

Seung, C. 2017. A Multi-regional economic impact analysis of Alaska salmon fishery failures. Ecol. Econ. 138: 22-30.

Seung, C. K., E. Waters, and M. Taylor. 2020. Developing a Multi-Regional Social Accounting Matrix (MRSAM) for Southwest Alaska Fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-399, 33 p.

Seung, C., Do-Hoon Kim, Ju-Hyun Yi, and Se-Hyun Song. 2021. Accounting for price responses in economic evaluation of climate impacts for a fishery. Ecological Economics 181: 106913.

Seung,C., , E.C. Waters, and S.J. Barbeaux. 2021. Community-level economic impacts of a change in TAC for Alaska fisheries: A multi-regional framework assessment. Ecological Economics 186 (2021) 107072.

Sigfusson, T., R. Arnason, and K, Morrissey. 2013. The economic importance of the Icelandic fisheries cluster—Understanding the role of fisheries in a small economy. Marine Policy 39:154–161.

Waters, E., C. Seung, M. Hartley, and M. Dalton. 2014. Measuring the multiregional economic contribution of an Alaska fishing fleet with linkages to international markets. Mar. Pol. 50 (Part A): 238-248.

Table 1 Decomposed multipliers

row number	Region	Species	Variable	Own region	Rest of SWAK	Rest of AK	All AK	WOC	RUS	ALL US
1	AT-SEA	PCOD	Output	3.20	0.04	0.21	3.45	2.88	1.89	8.22
2	AT-SEA	PCOD	Employment	19.63	0.29	1.24	21.16	16.41	9.96	47.53
3	AT-SEA	PCOD	Value-added	0.96	0.10	0.15	1.20	2.42	1.14	4.76
4	AT-SEA	PCOD	Household income	0.00	0.03	0.08	0.11	1.60	0.76	2.46
5	AT-SEA	POLL	Output	4.15	0.06	0.30	4.51	4.09	2.70	11.30
6	AT-SEA	POLL	Employment	24.87	0.43	1.78	27.08	23.31	14.24	64.63
7	AT-SEA	POLL	Value-added	1.39	0.15	0.21	1.75	3.45	1.63	6.82
8	AT-SEA	POLL	Household income	0.00	0.05	0.11	0.16	2.28	1.08	3.52
9	AT-SEA	SABL	Output	2.27	0.02	0.11	2.40	1.66	1.09	5.15
10	AT-SEA	SABL	Employment	13.49	0.14	0.68	14.31	9.46	5.74	29.51
11	AT-SEA	SABL	Value-added	0.55	0.05	0.08	0.68	1.40	0.66	2.74
12	AT-SEA	SABL	Household income	0.00	0.02	0.04	0.06	0.92	0.44	1.42
13	AT-SEA	ROCK	Output	3.11	0.04	0.20	3.35	2.76	1.81	7.91
14	AT-SEA	ROCK	Employment	19.02	0.28	1.18	20.48	15.72	9.54	45.74
15	AT-SEA	ROCK	Value-added	0.92	0.09	0.14	1.15	2.32	1.09	4.56
16	AT-SEA	ROCK	Household income	0.00	0.03	0.07	0.11	1.53	0.72	2.36
17	AT-SEA	FLAT	Output	3.27	0.05	0.21	3.53	2.97	1.95	8.46
18	AT-SEA	FLAT	Employment	20.12	0.30	1.28	21.70	16.95	10.30	48.95
19	AT-SEA	FLAT	Value-added	0.99	0.10	0.15	1.25	2.50	1.17	4.92
20	AT-SEA	FLAT	Household income	0.00	0.03	0.08	0.11	1.65	0.78	2.54
21	AWCA	KCRAB	Output	2.51	0.01	0.24	2.76	1.16	1.06	4.98
22	AWCA	KCRAB	Employment	15.44	0.08	1.49	17.01	6.51	5.53	29.05
23	AWCA	KCRAB	Value-added	0.98	0.01	0.36	1.35	1.01	0.61	2.97
24	AWCA	KCRAB	Household income	0.28	0.01	0.27	0.56	0.69	0.40	1.64
25	AWCA	TCRAB	Output	2.79	0.01	0.28	3.08	1.37	1.29	5.74
26	AWCA	TCRAB	Employment	17.38	0.09	1.69	19.16	7.63	6.66	33.45
27	AWCA	TCRAB	Value-added	1.17	0.01	0.40	1.58	1.19	0.74	3.51
28	AWCA	TCRAB	Household income	0.33	0.01	0.31	0.64	0.81	0.48	1.93
29	AWCA	PCOD	Output	2.51	0.01	0.23	2.75	1.21	1.08	5.04
30	AWCA	PCOD	Employment	23.78	0.09	1.43	25.30	6.73	5.61	37.64
31	AWCA	PCOD	Value-added	0.95	0.01	0.33	1.29	1.02	0.62	2.94
32	AWCA	PCOD	Household income	0.27	0.01	0.25	0.52	0.69	0.40	1.62
33	AWCA	POLL	Output	3.57	0.02	0.34	3.93	2.01	1.95	7.88
34	AWCA	POLL	Employment	21.18	0.15	2.05	23.38	11.01	9.84	44.22
35	AWCA	POLL	Value-added	1.53	0.02	0.46	2.01	1.67	1.11	4.79
36	AWCA	POLL	Household income	0.43	0.01	0.34	0.78	1.11	0.71	2.60

row number	Region	Species	Variable	Own region	Rest of SWAK	Rest of AK	All AK	WOC	RUS	ALL US
37	AWCA	SABL	Output	2.39	0.01	0.23	2.63	1.09	0.97	4.69
38	AWCA	SABL	Employment	28.13	0.08	1.42	29.63	6.14	5.11	40.89
39	AWCA	SABL	Value-added	0.93	0.01	0.34	1.28	0.95	0.57	2.80
40	AWCA	SABL	Household income	0.26	0.01	0.26	0.53	0.65	0.37	1.54
41	AWCA	HALI	Output	2.16	0.01	0.21	2.38	0.94	0.80	4.11
42	AWCA	HALI	Employment	33.01	0.08	1.27	34.36	5.30	4.25	43.91
43	AWCA	HALI	Value-added	0.79	0.01	0.30	1.10	0.82	0.47	2.38
44	AWCA	HALI	Household income	0.22	0.00	0.23	0.46	0.56	0.30	1.32
45	AEB	KCRAB	Output	2.07	0.02	0.18	2.27	0.77	1.00	4.04
46	AEB	KCRAB	Employment	13.92	0.14	1.14	15.20	4.31	5.47	24.98
47	AEB	KCRAB	Value-added	0.70	0.03	0.21	0.94	0.72	0.73	2.38
48	AEB	KCRAB	Household income	0.09	0.01	0.15	0.26	0.50	0.51	1.26
49	AEB	TCRAB	Output	2.81	0.02	0.28	3.11	1.25	1.70	6.05
50	AEB	TCRAB	Employment	19.91	0.18	1.69	21.79	6.96	9.18	37.92
51	AEB	TCRAB	Value-added	1.22	0.04	0.33	1.60	1.19	1.23	4.02
52	AEB	TCRAB	Household income	0.17	0.02	0.24	0.43	0.82	0.86	2.10
53	AEB	PCOD	Output	4.00	0.04	0.44	4.47	2.06	2.84	9.37
54	AEB	PCOD	Employment	39.21	0.28	2.65	42.13	11.49	15.23	68.85
55	AEB	PCOD	Value-added	2.06	0.07	0.53	2.67	1.99	2.03	6.68
56	AEB	PCOD	Household income	0.29	0.03	0.39	0.70	1.37	1.41	3.48
57	AEB	POLL	Output	4.61	0.05	0.53	5.18	2.50	3.43	11.11
58	AEB	POLL	Employment	33.42	0.35	3.18	36.95	13.86	18.18	68.99
59	AEB	POLL	Value-added	2.38	0.09	0.62	3.08	2.36	2.39	7.84
60	AEB	POLL	Household income	0.34	0.04	0.44	0.82	1.61	1.65	4.08
61	AEB	SABL	Output	2.23	0.02	0.21	2.45	0.89	1.17	4.51
62	AEB	SABL	Employment	33.45	0.16	1.30	34.92	4.98	6.36	46.26
63	AEB	SABL	Value-added	0.83	0.03	0.24	1.10	0.84	0.85	2.79
64	AEB	SABL	Household income	0.11	0.01	0.17	0.30	0.58	0.59	1.47
65	AEB	SALM	Output	3.64	0.03	0.38	4.05	1.79	2.53	8.37
66	AEB	SALM	Employment	49.63	0.21	2.31	52.15	9.99	13.64	75.79
67	AEB	SALM	Value-added	1.93	0.06	0.49	2.47	1.78	1.85	6.10
68	AEB	SALM	Household income	0.26	0.03	0.36	0.65	1.23	1.29	3.17
69	AEB	HALI	Output	2.07	0.02	0.19	2.28	0.79	1.03	4.10
70	AEB	HALI	Employment	34.60	0.15	1.19	35.94	4.44	5.62	46.01
71	AEB	HALI	Value-added	0.73	0.03	0.22	0.98	0.75	0.75	2.47
72	AEB	HALI	Household income	0.10	0.01	0.16	0.27	0.52	0.53	1.31
73	LPB	SALM	Output	3.65	0.02	0.33	4.00	1.46	1.85	7.31

row number	Region	Species	Variable	Own region	Rest of SWAK	Rest of AK	All AK	WOC	RUS	ALL US
74	LPB	SALM	Employment	92.76	0.14	2.04	94.94	8.10	9.95	112.9 9
75	LPB	SALM	Value-added	1.95	0.13	0.40	2.48	1.33	1.15	4.96
76	LPB	SALM	Household income	0.83	0.04	0.29	1.16	0.91	0.78	2.85
77	BBB	SALM	Output	3.11	0.04	0.29	3.44	1.18	1.68	6.30
78	BBB	SALM	Employment	57.95	0.30	1.73	59.97	6.49	8.97	75.43
79	BBB	SALM	Value-added	1.51	0.33	0.41	2.25	1.22	1.12	4.60
80	BBB	SALM	Household income	0.17	0.12	0.30	0.59	0.85	0.77	2.20
81	DCA	SALM	Output	4.26	0.00	0.52	4.78	1.75	2.26	8.79
82	DCA	SALM	Employment	101.88	0.01	3.19	105.08	9.76	12.36	127.2 0
83	DCA	SALM	Value-added	2.46	0.02	0.67	3.15	1.80	1.52	6.47
84	DCA	SALM	Household income	0.76	0.00	0.50	1.26	1.26	1.05	3.57
85	KIB	KCRAB	Output	3.42	0.01	0.29	3.71	1.14	1.54	6.38
86	KIB	KCRAB	Employment	27.01	0.04	1.73	28.78	6.20	8.07	43.04
87	KIB	KCRAB	Value-added	1.63	0.05	0.35	2.03	0.99	0.94	3.96
88	KIB	KCRAB	Household income	0.57	0.02	0.26	0.84	0.69	0.63	2.16
89	KIB	PCOD	Output	3.54	0.01	0.30	3.85	1.21	1.64	6.70
90	KIB	PCOD	Employment	39.12	0.05	1.82	40.99	6.59	8.57	56.15
91	KIB	PCOD	Value-added	1.70	0.05	0.36	2.11	1.04	1.00	4.14
92	KIB	PCOD	Household income	0.61	0.02	0.26	0.89	0.72	0.67	2.27
93	KIB	POLL	Output	4.40	0.01	0.40	4.81	1.62	2.23	8.66
94	KIB	POLL	Employment	34.81	0.06	2.37	37.23	8.75	11.51	57.50
95	KIB	POLL	Value-added	2.18	0.06	0.46	2.70	1.35	1.33	5.37
96	KIB	POLL	Household income	0.81	0.03	0.33	1.16	0.92	0.88	2.96
97	KIB	SABL	Output	2.53	0.00	0.20	2.73	0.75	0.98	4.46
98	KIB	SABL	Employment	34.12	0.03	1.18	35.33	4.08	5.17	44.58
99	KIB	SABL	Value-added	1.00	0.03	0.23	1.26	0.64	0.60	2.49
100	KIB	SABL	Household income	0.35	0.01	0.16	0.53	0.44	0.40	1.37
101	KIB	ROCK	Output	5.37	0.01	0.50	5.89	2.06	2.87	10.82
102	KIB	ROCK	Employment	44.25	0.08	3.00	47.33	11.18	14.81	73.32
103	KIB	ROCK	Value-added	2.86	0.08	0.59	3.53	1.74	1.71	6.99
104	KIB	ROCK	Household income	1.05	0.04	0.42	1.51	1.19	1.14	3.84
105	KIB	FLAT	Output	4.39	0.01	0.40	4.80	1.62	2.22	8.64
106	KIB	FLAT	Employment	34.46	0.06	2.36	36.89	8.73	11.49	57.11
107	KIB	FLAT	Value-added	2.17	0.06	0.46	2.68	1.35	1.32	5.35
108	KIB	FLAT	Household income	0.80	0.03	0.32	1.16	0.92	0.88	2.95
109	KIB	SALM	Output	4.69	0.01	0.43	5.13	1.73	2.39	9.24

row number	Region	Species	Variable	Own region	Rest of SWAK	Rest of AK	All AK	WOC	RUS	ALL US
110	KIB	SALM	Employment	74.42	0.06	2.59	77.07	9.45	12.48	99.00
111	KIB	SALM	Value-added	2.60	0.07	0.54	3.21	1.53	1.47	6.21
112	KIB	SALM	Household income	0.91	0.03	0.40	1.34	1.06	0.99	3.38
113	KIB	HALI	Output	2.58	0.00	0.20	2.78	0.77	1.00	4.54
114	KIB	HALI	Employment	38.40	0.03	1.21	39.64	4.18	5.30	49.12
115	KIB	HALI	Value-added	1.06	0.03	0.24	1.33	0.67	0.62	2.61
116	KIB	HALI	Household income	0.37	0.01	0.17	0.55	0.46	0.42	1.43

Table 2 Geographic or spatial distribution of impacts (percentage)

row number	Region	Species	Variable	Own region	Rest of SWAK	Rest of AK	All AK	WOC	RUS	ALL US
1	AT-SEA	PCOD	Output	39.0	0.5	2.5	42.0	35.0	23.0	100.0
2	AT-SEA	PCOD	Employment	41.3	0.6	2.6	44.5	34.5	21.0	100.0
3	AT-SEA	PCOD	Value-added	20.2	2.1	3.1	25.3	50.8	23.8	100.0
4	AT-SEA	PCOD	Household income	0.0	1.3	3.2	4.5	64.9	30.7	100.0
5	AT-SEA	POLL	Output	36.7	0.6	2.6	39.9	36.2	23.9	100.0
6	AT-SEA	POLL	Employment	38.5	0.7	2.8	41.9	36.1	22.0	100.0
7	AT-SEA	POLL	Value-added	20.3	2.1	3.1	25.6	50.6	23.8	100.0
8	AT-SEA	POLL	Household income	0.0	1.3	3.2	4.6	64.7	30.7	100.0
9	AT-SEA	SABL	Output	44.0	0.4	2.2	46.7	32.2	21.1	100.0
10	AT-SEA	SABL	Employment	45.7	0.5	2.3	48.5	32.1	19.4	100.0
11	AT-SEA	SABL	Value-added	20.2	1.9	2.9	24.9	51.1	24.0	100.0
12	AT-SEA	SABL	Household income	0.0	1.2	3.0	4.2	65.1	30.7	100.0
13	AT-SEA	ROCK	Output	39.3	0.5	2.5	42.3	34.8	22.9	100.0
14	AT-SEA	ROCK	Employment	41.6	0.6	2.6	44.8	34.4	20.9	100.0
15	AT-SEA	ROCK	Value-added	20.2	2.0	3.0	25.3	50.9	23.9	100.0
16	AT-SEA	ROCK	Household income	0.0	1.3	3.1	4.5	64.9	30.7	100.0
17	AT-SEA	FLAT	Output	38.7	0.5	2.5	41.8	35.1	23.1	100.0
18	AT-SEA	FLAT	Employment	41.1	0.6	2.6	44.3	34.6	21.0	100.0
19	AT-SEA	FLAT	Value-added	20.2	2.1	3.1	25.3	50.8	23.9	100.0
20	AT-SEA	FLAT	Household income	0.0	1.3	3.2	4.5	64.9	30.7	100.0
21	AWCA	KCRAB	Output	50.3	0.2	4.9	55.3	23.4	21.3	100.0
22	AWCA	KCRAB	Employment	53.1	0.3	5.1	58.6	22.4	19.0	100.0
23	AWCA	KCRAB	Value-added	33.1	0.3	11.9	45.4	34.0	20.6	100.0
24	AWCA	KCRAB	Household income	16.9	0.3	16.6	33.9	41.9	24.2	100.0
25	AWCA	TCRAB	Output	48.7	0.2	4.8	53.7	23.9	22.5	100.0
26	AWCA	TCRAB	Employment	51.9	0.3	5.1	57.3	22.8	19.9	100.0
27	AWCA	TCRAB	Value-added	33.2	0.3	11.5	45.0	33.8	21.2	100.0
28	AWCA	TCRAB	Household income	17.0	0.4	15.9	33.2	41.8	25.0	100.0
29	AWCA	PCOD	Output	49.8	0.2	4.6	54.6	24.0	21.4	100.0
30	AWCA	PCOD	Employment	63.2	0.2	3.8	67.2	17.9	14.9	100.0
31	AWCA	PCOD	Value-added	32.4	0.4	11.2	44.0	34.8	21.2	100.0
32	AWCA	PCOD	Household income	16.7	0.4	15.3	32.4	42.8	24.9	100.0
33	AWCA	POLL	Output	45.3	0.2	4.3	49.8	25.4	24.7	100.0
34	AWCA	POLL	Employment	47.9	0.3	4.6	52.9	24.9	22.2	100.0
35	AWCA	POLL	Value-added	32.0	0.4	9.6	42.0	34.8	23.2	100.0
36	AWCA	POLL	Household income	16.5	0.4	13.0	29.9	42.8	27.4	100.0
37	AWCA	SABL	Output	50.9	0.2	4.9	56.0	23.3	20.7	100.0

row number	Region	Species	Variable	Own region	Rest of SWAK	Rest of AK	All AK	WOC	RUS	ALL US
38	AWCA	SABL	Employment	68.8	0.2	3.5	72.5	15.0	12.5	100.0
39	AWCA	SABL	Value-added	33.2	0.4	12.1	45.7	34.1	20.2	100.0
40	AWCA	SABL	Household income	17.0	0.3	16.8	34.1	42.1	23.8	100.0
41	AWCA	HALI	Output	52.5	0.2	5.0	57.7	22.8	19.4	100.0
42	AWCA	HALI	Employment	75.2	0.2	2.9	78.3	12.1	9.7	100.0
43	AWCA	HALI	Value-added	33.1	0.3	12.7	46.2	34.3	19.6	100.0
44	AWCA	HALI	Household income	16.9	0.3	17.6	34.9	42.2	22.9	100.0
45	AEB	KCRAB	Output	51.3	0.4	4.5	56.2	19.0	24.7	100.0
46	AEB	KCRAB	Employment	55.7	0.6	4.6	60.9	17.2	21.9	100.0
47	AEB	KCRAB	Value-added	29.4	1.0	8.8	39.3	30.2	30.5	100.0
48	AEB	KCRAB	Household income	7.3	0.9	12.0	20.2	39.3	40.4	100.0
49	AEB	TCRAB	Output	46.4	0.4	4.5	51.3	20.6	28.1	100.0
50	AEB	TCRAB	Employment	52.5	0.5	4.5	57.5	18.3	24.2	100.0
51	AEB	TCRAB	Value-added	30.5	1.0	8.3	39.8	29.7	30.5	100.0
52	AEB	TCRAB	Household income	7.9	0.9	11.5	20.2	39.1	40.6	100.0
53	AEB	PCOD	Output	42.7	0.4	4.6	47.7	22.0	30.3	100.0
54	AEB	PCOD	Employment	56.9	0.4	3.8	61.2	16.7	22.1	100.0
55	AEB	PCOD	Value-added	30.9	1.1	8.0	39.9	29.8	30.3	100.0
56	AEB	PCOD	Household income	8.2	0.9	11.1	20.2	39.3	40.5	100.0
57	AEB	POLL	Output	41.5	0.4	4.7	46.6	22.5	30.8	100.0
58	AEB	POLL	Employment	48.4	0.5	4.6	53.6	20.1	26.4	100.0
59	AEB	POLL	Value-added	30.3	1.1	7.9	39.4	30.2	30.5	100.0
60	AEB	POLL	Household income	8.2	1.0	10.9	20.1	39.5	40.4	100.0
61	AEB	SABL	Output	49.4	0.4	4.6	54.4	19.7	25.9	100.0
62	AEB	SABL	Employment	72.3	0.4	2.8	75.5	10.8	13.7	100.0
63	AEB	SABL	Value-added	29.8	1.1	8.7	39.5	30.2	30.3	100.0
64	AEB	SABL	Household income	7.5	1.0	11.8	20.3	39.4	40.3	100.0
65	AEB	SALM	Output	43.6	0.3	4.5	48.4	21.3	30.2	100.0
66	AEB	SALM	Employment	65.5	0.3	3.0	68.8	13.2	18.0	100.0
67	AEB	SALM	Value-added	31.6	1.0	8.0	40.6	29.1	30.3	100.0
68	AEB	SALM	Household income	8.2	0.9	11.3	20.4	38.9	40.8	100.0
69	AEB	HALI	Output	50.6	0.4	4.6	55.7	19.3	25.0	100.0
70	AEB	HALI	Employment	75.2	0.3	2.6	78.1	9.7	12.2	100.0
71	AEB	HALI	Value-added	29.6	1.1	8.8	39.5	30.3	30.3	100.0
72	AEB	HALI	Household income	7.4	0.9	12.0	20.4	39.5	40.2	100.0
73	LPB	SALM	Output	49.9	0.3	4.5	54.7	20.0	25.3	100.0
74	LPB	SALM	Employment	82.1	0.1	1.8	84.0	7.2	8.8	100.0
75	LPB	SALM	Value-added	39.3	2.7	8.0	50.0	26.8	23.2	100.0

row number	Region	Species	Variable	Own region	Rest of SWAK	Rest of AK	All AK	WOC	RUS	ALL US
76	LPB	SALM	Household income	29.2	1.4	10.0	40.6	32.0	27.5	100.0
77	BBB	SALM	Output	49.4	0.7	4.6	54.6	18.7	26.7	100.0
78	BBB	SALM	Employment	76.8	0.4	2.3	79.5	8.6	11.9	100.0
79	BBB	SALM	Value-added	32.9	7.2	8.8	49.0	26.6	24.4	100.0
80	BBB	SALM	Household income	7.6	5.3	13.8	26.6	38.4	34.9	100.0
81	DCA	SALM	Output	48.5	0.0	5.9	54.4	19.9	25.7	100.0
82	DCA	SALM	Employment	80.1	0.0	2.5	82.6	7.7	9.7	100.0
83	DCA	SALM	Value-added	38.0	0.3	10.4	48.7	27.8	23.5	100.0
84	DCA	SALM	Household income	21.2	0.1	14.0	35.2	35.3	29.4	100.0
85	KIB	KCRAB	Output	53.5	0.1	4.5	58.1	17.8	24.1	100.0
86	KIB	KCRAB	Employment	62.7	0.1	4.0	66.9	14.4	18.7	100.0
87	KIB	KCRAB	Value-added	41.1	1.2	8.9	51.1	25.1	23.8	100.0
88	KIB	KCRAB	Household income	26.1	0.9	11.9	39.0	31.7	29.3	100.0
89	KIB	PCOD	Output	52.9	0.1	4.5	57.5	18.1	24.5	100.0
90	KIB	PCOD	Employment	69.7	0.1	3.2	73.0	11.7	15.3	100.0
91	KIB	PCOD	Value-added	41.0	1.2	8.7	50.9	25.1	24.0	100.0
92	KIB	PCOD	Household income	26.8	0.9	11.5	39.2	31.5	29.3	100.0
93	KIB	POLL	Output	50.8	0.1	4.6	55.5	18.7	25.7	100.0
94	KIB	POLL	Employment	60.5	0.1	4.1	64.8	15.2	20.0	100.0
95	KIB	POLL	Value-added	40.5	1.2	8.5	50.2	25.2	24.7	100.0
96	KIB	POLL	Household income	27.2	0.9	11.0	39.1	31.1	29.8	100.0
97	KIB	SABL	Output	56.8	0.1	4.4	61.3	16.8	21.9	100.0
98	KIB	SABL	Employment	76.5	0.1	2.6	79.3	9.2	11.6	100.0
99	KIB	SABL	Value-added	40.0	1.2	9.1	50.4	25.7	23.9	100.0
100	KIB	SABL	Household income	25.6	0.9	12.0	38.5	32.2	29.3	100.0
101	KIB	ROCK	Output	49.7	0.1	4.6	54.4	19.1	26.5	100.0
102	KIB	ROCK	Employment	60.4	0.1	4.1	64.6	15.2	20.2	100.0
103	KIB	ROCK	Value-added	40.9	1.2	8.5	50.6	24.9	24.5	100.0
104	KIB	ROCK	Household income	27.4	0.9	11.0	39.3	31.0	29.7	100.0
105	KIB	FLAT	Output	50.8	0.1	4.6	55.5	18.7	25.7	100.0
106	KIB	FLAT	Employment	60.3	0.1	4.1	64.6	15.3	20.1	100.0
107	KIB	FLAT	Value-added	40.5	1.2	8.5	50.1	25.2	24.7	100.0
108	KIB	FLAT	Household income	27.2	0.9	11.0	39.1	31.1	29.8	100.0
109	KIB	SALM	Output	50.7	0.1	4.6	55.5	18.7	25.9	100.0
110	KIB	SALM	Employment	75.2	0.1	2.6	77.8	9.5	12.6	100.0
111	KIB	SALM	Value-added	41.8	1.2	8.7	51.7	24.6	23.7	100.0
112	KIB	SALM	Household income	26.9	0.9	11.7	39.6	31.3	29.2	100.0
113	KIB	HALI	Output	56.7	0.1	4.4	61.2	16.8	22.0	100.0

row number	Region	Species	Variable	Own region	Rest of SWAK	Rest of AK	All AK	WOC	RUS	ALL US
114	KIB	HALI	Employment	78.2	0.1	2.5	80.7	8.5	10.8	100.0
115	KIB	HALI	Value-added	40.6	1.2	9.2	50.9	25.5	23.6	100.0
116	KIB	HALI	Household income	25.5	0.9	12.2	38.7	32.2	29.1	100.0

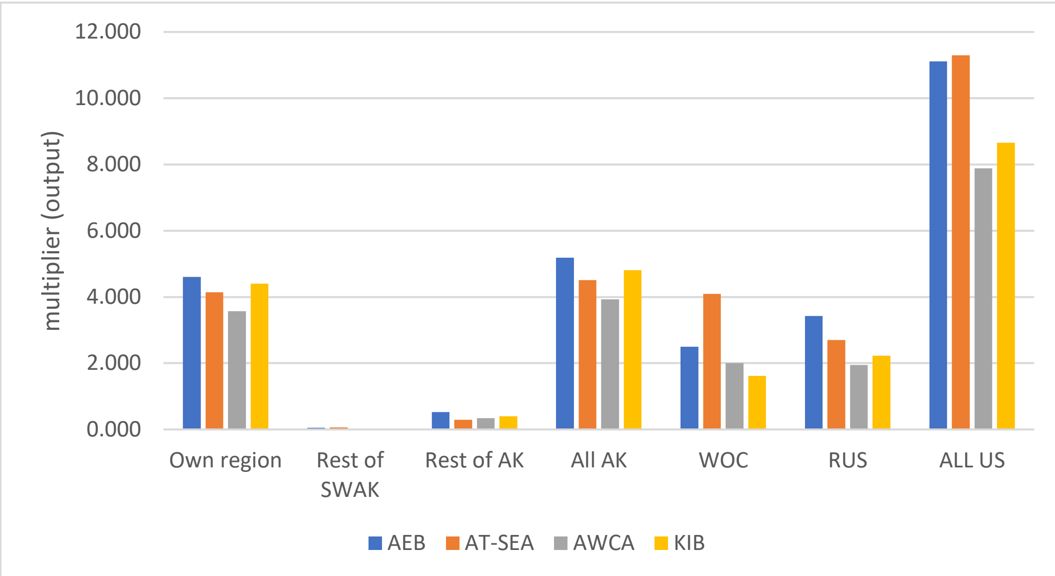

Figure 1 Distribution of output multiplier for Pollock by region of harvest (in $million, per $1 million increase in landings)

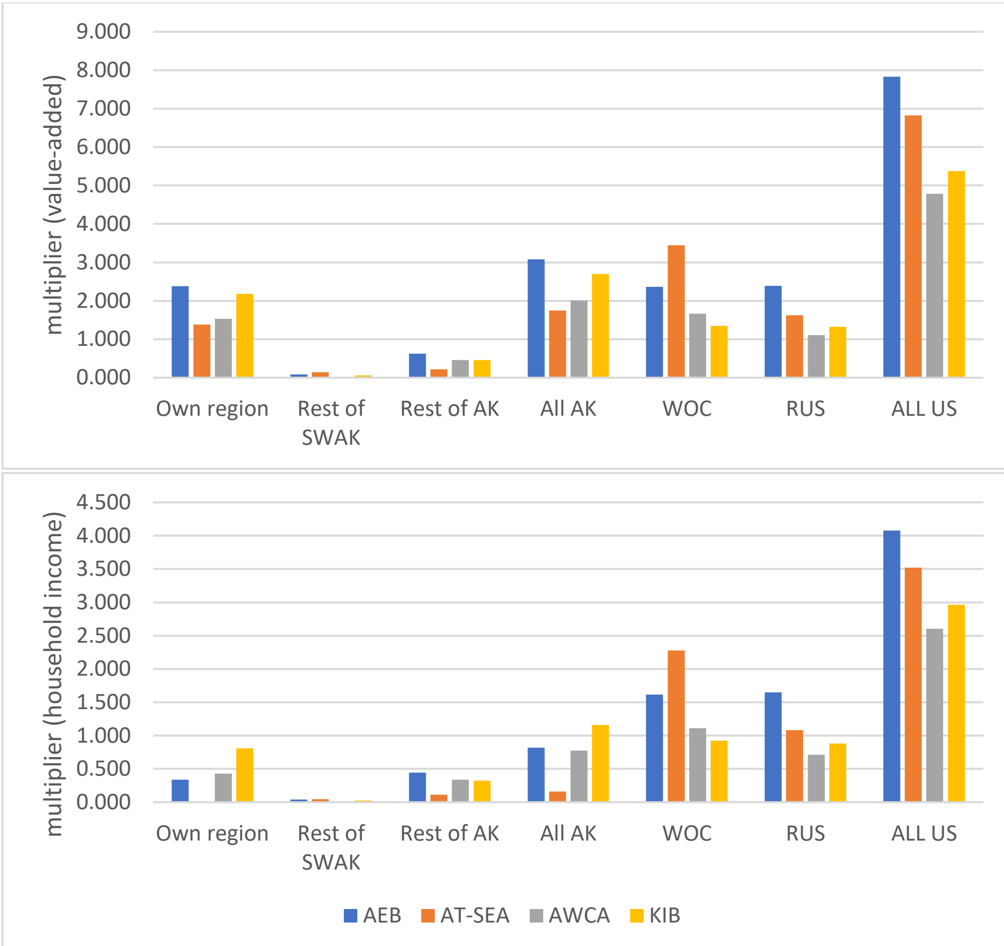

Figure 2 Distribution of value-added and household income multipliers for Pollock by region of harvest (in $million, per $1 million increase in landings)

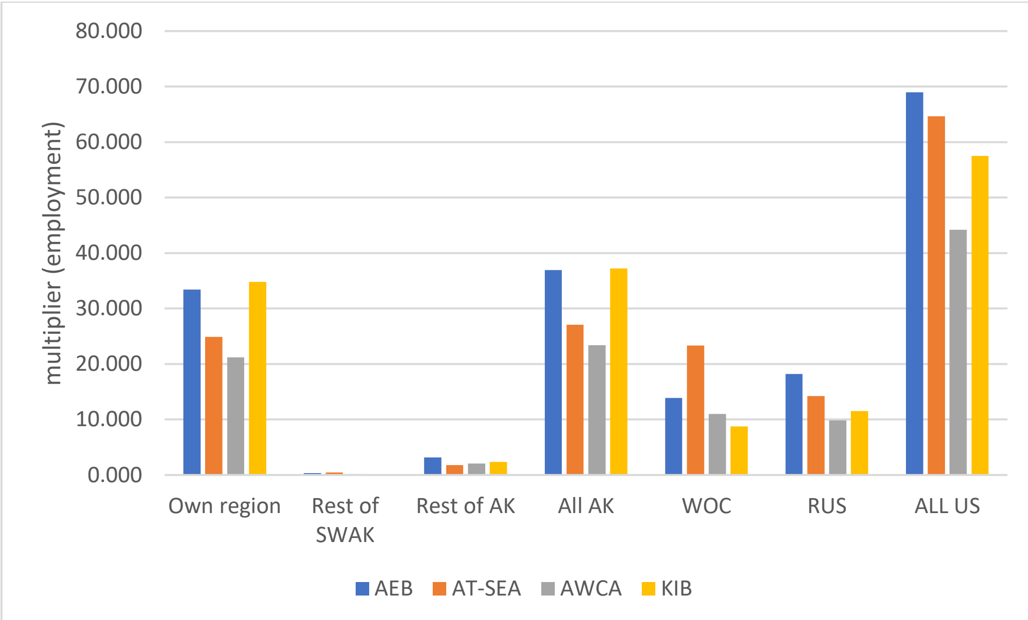

Figure 3 Distribution of employment multiplier for Pollock by region of harvest (in # of jobs, per $1 million increase in landings)

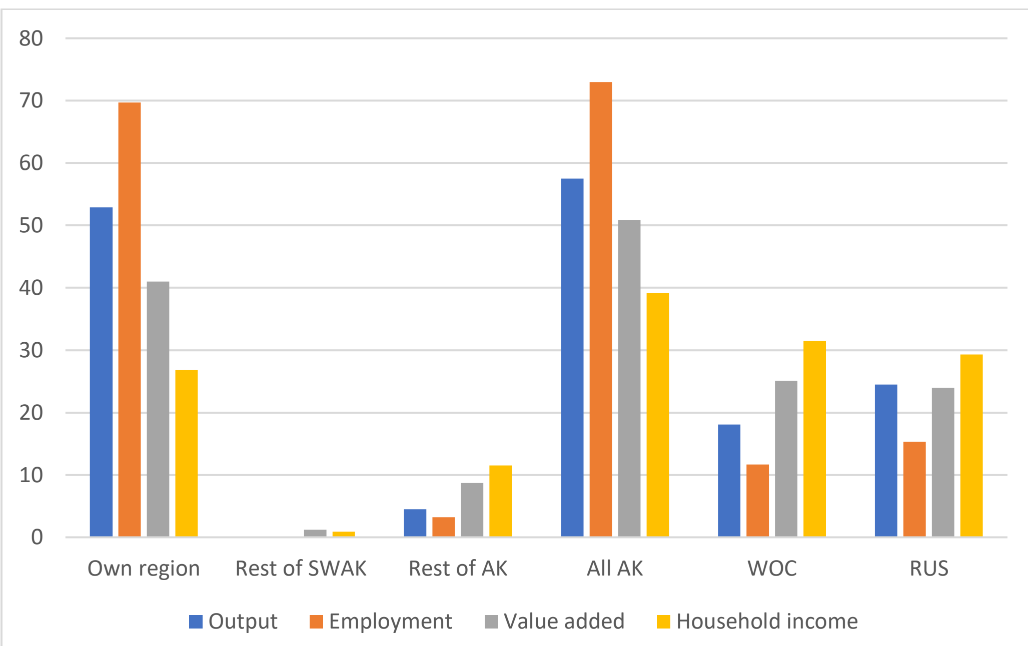

Figure 4 Percentage distribution of multipliers by region for Pacific cod catch in KIB by variable

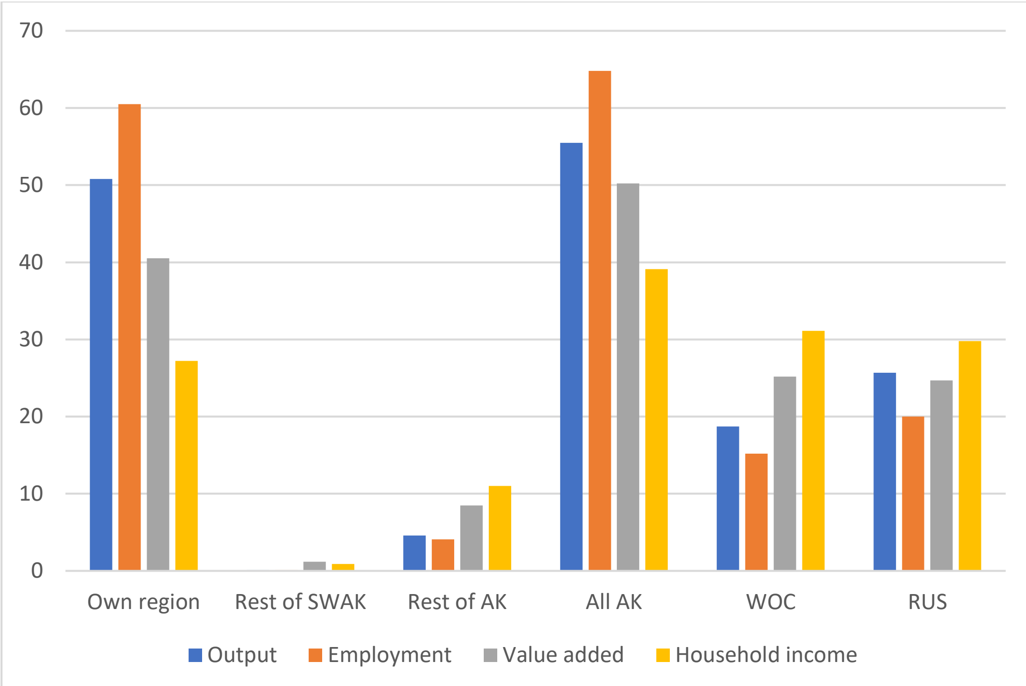

Figure 5 Percentage distribution of multipliers by region for Pollock catch in KIB by variable

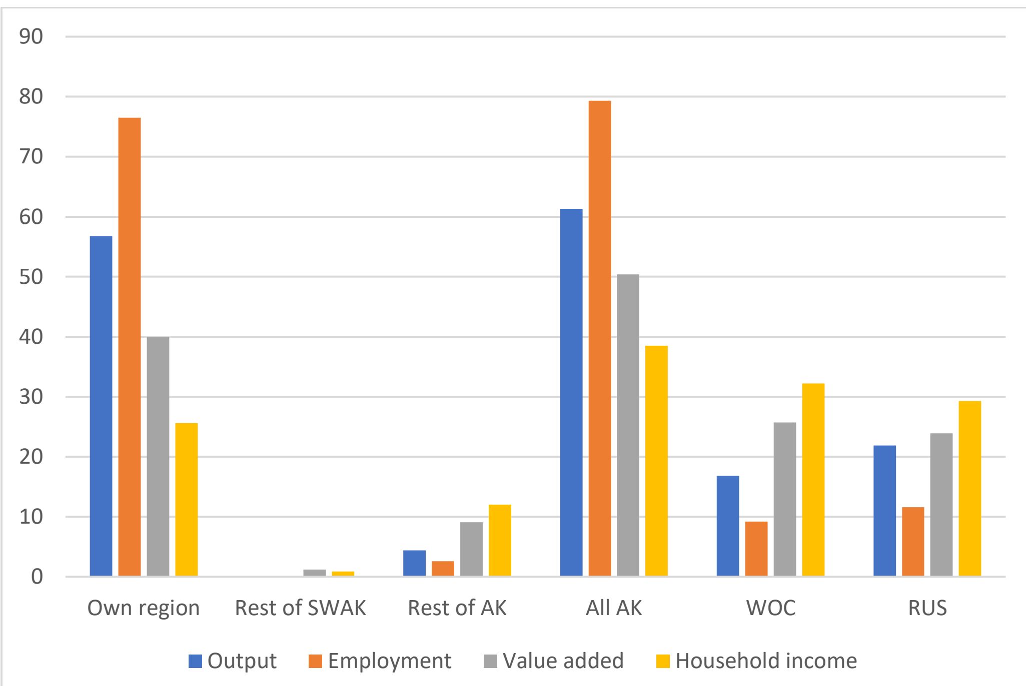

Figure 6 Percentage distribution of multipliers by region for Sablefish catch in KIB by variable

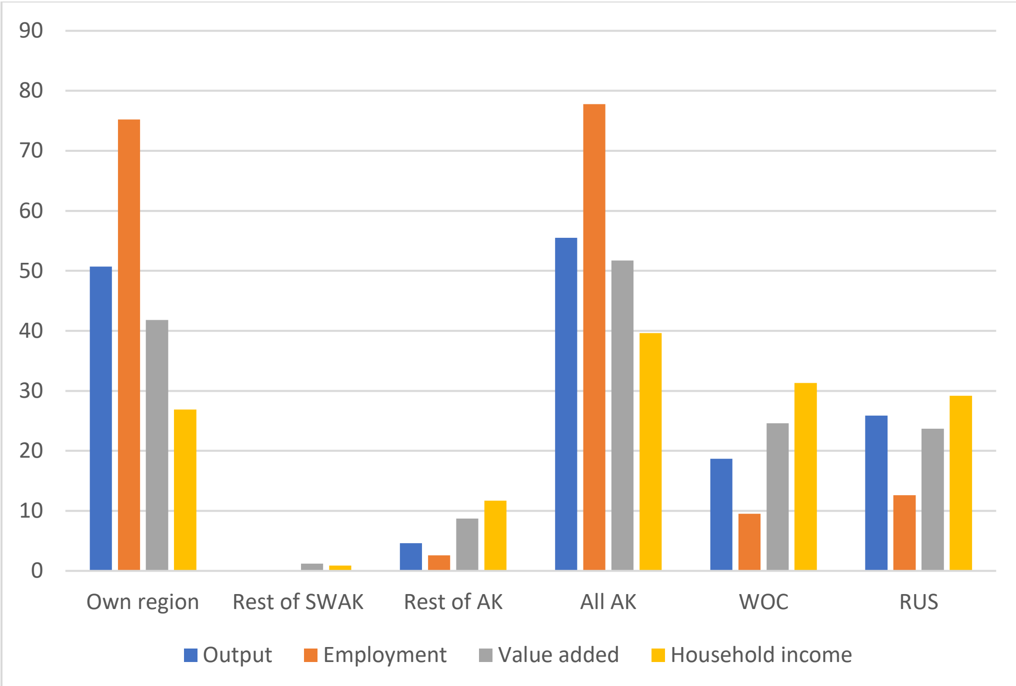

Figure 7 Percentage distribution of multipliers by region for Salmon catch in KIB by variable

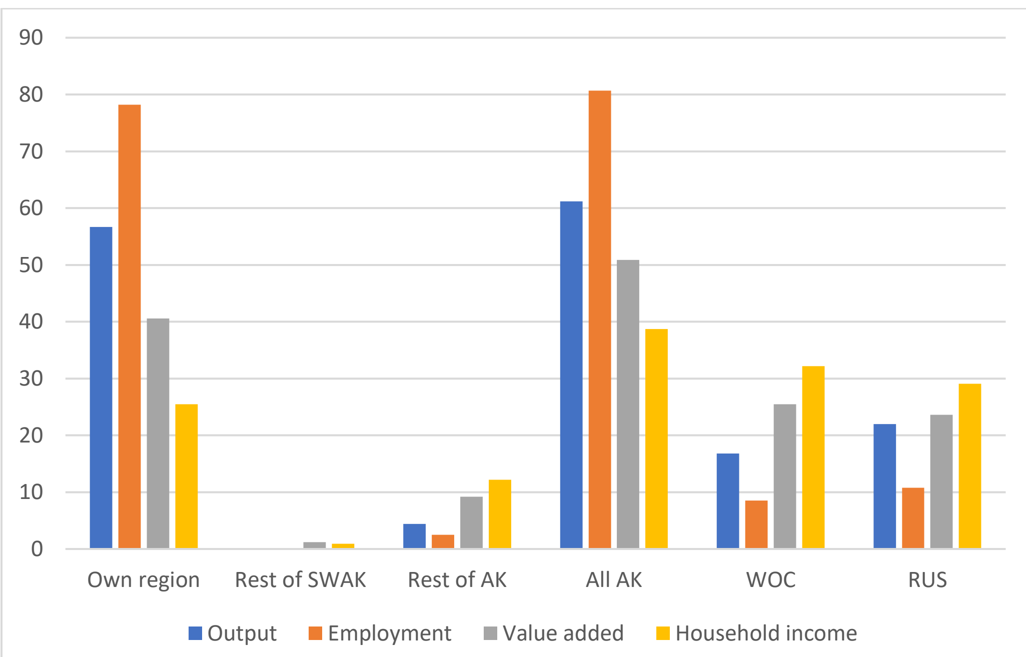

Figure 8 Percentage distribution of multipliers by region for Halibut catch in KIB by variable

Figure 9 Percentage distribution of employment multiplier among regions for catch landed by region and by species

Appendix

Table A.1 Structure of 10MRSAM

	At-Sea	Aleutians West Census Area	Aleutians East Borough	Lake and Peninsula Borough	Bristol Bay Borough	Dillingham Census Area	Kodiak Island Borough	Rest of Alaska	Washington, Oregon and California	Rest of the U.S.	*Exogenous Accounts / ROW*
At-Sea	**AS**	*Exports: AS to AWCA*	*Exports: AS to AEB*	*Exports: AS to LPB*	*Exports: AS to BBB*	*Exports: AS to DCA*	*Exports: AS to KIB*	*Exports: AS to RoA*	*Exports: AS to WOC*	*Exports: AS to RUS*	*Exports: AS to RoW*
Aleutians West Census Area	*Imports: AWCA to AS*	**AWCA**	*Exports: AWCA to AEB*	*Exports: AWCA to LPB*	*Exports: AWCA to BBB*	*Exports: AWCA to DCA*	*Exports: AWCA to KIB*	*Exports: AWCA to RoA*	*Exports: AWCA to WOC*	*Exports: AWCA to RUS*	*Exports: AWCA to RoW*
Aleutians East Borough	*Imports: AEB to AS*	*Imports: AEB to AWCA*	**AEB**	*Exports: AEB to LPB*	*Exports: AEB to BBB*	*Exports: AEB to DCA*	*Exports: AEB to KIB*	*Exports: AEB to RoA*	*Exports: AEB to WOC*	*Exports: AEB to RUS*	*Exports: AEB to RoW*
Lake and Peninsula Borough	*Imports: LPB to AS*	*Imports: LPB to AWCA*	*Imports: LPB to AEB*	**LPB**	*Exports: LPB to BBB*	*Exports: LPB to DCA*	*Exports: LPB to KIB*	*Exports: LPB to RoA*	*Exports: LPB to WOC*	*Exports: LPB to RUS*	*Exports: LPB to RoW*
Bristol Bay Borough	*Imports: BBB to AS*	*Imports: BBB to AWCA*	*Imports: BBB to AEB*	*Imports: BBB to LPB*	**BBB**	*Exports: BBB to DCA*	*Exports: BBB to KIB*	*Exports: BBB to RoA*	*Exports: BBB to WOC*	*Exports: BBB to RUS*	*Exports: BBB to RoW*
Dillingham Census Area	*Imports: DCA to AS*	*Imports: DCA to AWCA*	*Imports: DCA to AEB*	*Imports: DCA to LPB*	*Imports: DCA to BBB*	**DCA**	*Exports: DCA to KIB*	*Exports: DCA to RoA*	*Exports: DCA to WOC*	*Exports: DCA to RUS*	*Exports: DCA to RoW*
Kodiak Island Borough	*Imports: KIB to AS*	*Imports: KIB to AWCA*	*Imports: KIB to AEB*	*Imports: KIB to LPB*	*Imports: KIB to BBB*	*Imports: KIB to DCA*	**KIB**	*Exports: KIB to RoA*	*Exports: KIB to WOC*	*Exports: KIB to RUS*	*Exports: KIB to RoW*
Rest of Alaska	*Imports: RoA to AS*	*Imports: RoA to AWCA*	*Imports: RoA to AEB*	*Imports: RoA to LPB*	*Imports: RoA to BBB*	*Imports: RoA to DCA*	*Imports: RoA to KIB*	**RoA**	*Exports: RoA to WOC*	*Exports: RoA to RUS*	*Exports: RoA to RoW*
Washington, Oregon and California	*Imports: WOC to AS*	*Imports: WOC to AWCA*	*Imports: WOC to AEB*	*Imports: WOC to LPB*	*Imports: WOC to BBB*	*Imports: WOC to DCA*	*Imports: WOC to KIB*	*Imports: WOC to RoA*	**WOC**	*Exports: WOC to RUS*	*Exports: WOC to RoW*
Rest of the U.S.	*Imports: RUS to AS*	*Imports: RUS to AWCA*	*Imports: RUS to AEB*	*Imports: RUS to LPB*	*Imports: RUS to BBB*	*Imports: RUS to DCA*	*Imports: RUS to KIB*	*Imports: RUS to RoA*	*Imports: RUS to WOC*	**RUS**	*Exports: RUS to RoW*
Exogenous Accounts / ROW	*Imports: RoW to AS*	*Imports: RoW to AWCA*	*Imports: RoW to AEB*	*Imports: RoW to LPB*	*Imports: RoW to BBB*	*Imports: RoW to DCA*	*Imports: RoW to KIB*	*Imports: RoW to RoA*	*Imports: RoW to WOC*	*Imports: RoW to WOC*	

Table A.2 Description of abbreviations and acronyms used for regions and species

Acronym	Description
Region	
AT-SEA	At-sea sector including catcher-processors and motherships
AWCA	Aleutians West Census Area
AEB	Aleutians East Borough
LPB	Lake and Peninsula Borough
BBB	Bristol Bay Borough
DCA	Dillingham Census Area
KIB	Kodiak Island Borough
RAK	Rest of Alaska
WOC	West Coast region – Washington, Oregon, and California
RUS	Rest of the United States
Species	
PCOD	Pacific cod
POLL	Pollock
HALI	Halibut
SABL	Sablefish
ROCK	Rockfish
FLAT	Flatfish
KCRAB	King crab
TCRAB	Tanner crab including snow crab
SALM	Salmon

Note: Other crab and all other species are not listed because these two sectors do not produce a large quantity of fish.