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Analysis

A Multi-regional Economic Impact Analysis of Alaska Salmon Fishery Failures

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ABSTRACT

Recently, the harvest of Chinook salmon (*Oncorhynchus tshawytscha*) in some areas of Alaska was severely curtailed due to a significant reduction in the salmon runs. This generated adverse economic impacts in the areas. Unlike previous studies of impacts of changes in fisheries, which often rely on single-region economic impact models, this study uses a multi-regional social accounting matrix (MRSAM) model of three US regions – Alaska, West Coast, and the rest of US – to calculate the multi-regional economic impacts of the Chinook salmon fishery failures, considering the countervailing effects of federal disaster funds paid to commercial salmon fishermen. To estimate the negative effects of the reduced salmon harvest, this study uses "adjusted demand-driven MRSAM model", which avoids the double-counting problem encountered when a demand-driven model is used to compute the effects of exogenous output change, and overcomes the weakness of Ghosh (1958) approach in estimating the forward-linkage effects. To calculate the positive effects of federal relief payments, this study uses a Leontief demand-driven MRSAM model. Results indicate that the salmon fishery failures have significant adverse economic impacts including both intra-regional (Alaska) and inter-regional (West Coast and the rest of US) impacts, and that the disaster relief mitigates only a small portion of the adverse impacts.

1. Introduction

During the period from 2010 to 2012, several areas of Alaska saw a significant reduction in Chinook salmon (*Oncorhynchus tshawytscha*) runs. Many physical and biological factors may have contributed to the low Chinook salmon runs. Fluctuations in the survival of Chinook salmon smolts[1] can affect the strength of the salmon runs. It is also believed that juvenile salmon survival can be affected by environmental conditions such as precipitation, air and ocean temperatures, and water currents.[2] Scientists are investigating to identify the primary factors that caused the low salmon runs [Alaska Department of Fish and Game (ADFG), 2013].

The low Chinook salmon runs prompted the State of Alaska to lower the harvest levels of Chinook salmon allowed to be caught by commercial, recreational, and subsistence fishermen. The State of Alaska limited commercial and subsistence harvests of Chinook and co-occurring salmon species on the Yukon and Kuskokwim rivers. For many years prior to this, restrictions had also been placed on the harvest of Chinook in the Arctic-Yukon-Kuskokwim (AYK) region, which included the Shaktoolik and Unalakleet rivers. The main gear types used in the commercial and subsistence salmon fisheries in these areas include drift gillnets (or drift nets), set gillnets (or setnets), and fish wheel gear types. In Cook Inlet, the state closed commercial set gillnetting for much of the 2012 season, and imposed limitations on recreational fisheries for Chinook salmon in fresh and salt waters.

The low Chinook salmon runs and the ensuing government salmon harvest restrictions have adversely affected the commercial, recreational, and subsistence fishermen in the Yukon, Kuskokwim and Cook Inlet areas relying on the salmon fisheries. The annual average ex-vessel revenue from commercial harvest of Chinook salmon from the Yukon area was about $215,000 over the years from 2010 to 2012. The annual average ex-vessel revenue from the Kuskokwim area was about $240,000 for the same period. In the Yukon area, virtually no fish were caught from commercial Chinook salmon fisheries in 2012 (ADFG, 2015) and subsistence fisheries on these two rivers (Yukon and Kuskokwim) were severely reduced (Washington Examiner, 2012).

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[1] Salmon smolt is a young salmon about two years old which is covered with silvery scales and is ready to migrate from fresh water to the sea.

[2] Some other U.S. regions have also experienced salmon fishery disasters, e.g., the fishery disasters in Klamath River and Sacramento River areas in California. The Klamath River fishery disaster was caused by severe drought conditions and reduced salmon stocks in the upper Klamath basin during the period 2001 to 2005. The drought resulted in very low flows in the river and its tributaries, which made the fish vulnerable to diseases, and resulted in the death of many juvenile and adult Chinook salmon. This led to returns of Klamath River fall Chinook salmon falling significantly in 2004 and 2005. The fishery disaster in the Sacramento River area occurred mainly because of unfavorable ocean conditions. As a result, the survival rate of juvenile salmon fell drastically in 2005 and 2006. This brought about a collapse of the Sacramento River fall Chinook salmon run (Upton, 2013).

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In the Cook Inlet area, from 2007 to 2011, the average annual ex-vessel revenue from commercial salmon fisheries with setnet gear was about $13 million, while in 2012, total ex-vessel revenue for setnetters was about $2.5 million (CFEC). A State of Alaska (Alaska Department of Commerce, Community, and Economic Development and ADFG, 2012) estimate indicates that, for guided and unguided recreational fishing in fresh and salt water in the Cook Inlet area, the number of angler-days has declined by about 29,600 and the direct spending has been reduced by about $10.4 million in 2012, compared to what would have happened to the recreational fishing in the area in 2012 if the salmon disaster did not occur and the recreational fishing was not closed in the year. The harvest of Chinook salmon was restricted severely due to shortened seasons, and estimates of subsistence catch of salmon are not yet available. However, many subsistence salmon fishermen had the opportunity to catch more abundant but less desirable salmon species such as chum (*Oncorhynchus keta*), sockeye (*O. nerka*) and coho (*O. kisutch*) salmon (Washington Examiner, 2012).

The unexpected low Chinook salmon runs and the drastic decreases in the fish harvest prompted the Governor of Alaska to request fishery disaster determinations under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) for commercial and subsistence fisheries on the Yukon and Kuskokwim Rivers, and commercial and recreational fisheries in Cook Inlet region. In response to the request, in September 2012, the U.S. Secretary of Commerce determined that a commercial fishery failure caused by a fishery resource disaster did exist for those three regions. Following the declaration of the fishery disaster, Congress allocated funds for fishery disaster relief. If a fishery disaster is declared, the federal government must determine the amount of economic damage incurred by the affected stakeholders. Federal law requires the federal government to compare the commercial fishery revenues in the disaster years to revenues for the five previous years.

In August 2014, the first round of fisheries disaster relief applications in the amount of $7.8 million was approved by the federal government (National Marine Fisheries Service's Alaska Regional Office) to help fishermen suffering from the 2012 commercial fisheries failure for the Yukon Chinook fishery, Kuskokwim Chinook fishery, and the Cook Inlet salmon fishery. Direct payments of $3.2 million and $4.6 million were made to commercial fishermen from the Yukon-Kuskokwim Region and the Cook Inlet Region, respectively. The allocations of the relief funds to these two regions were determined by the relative losses in the ex-vessel revenues arising from the disaster in the two regions (National Marine Fisheries Service, 2014). However, the allocation of disaster relief payments is calculated based only on a permit holder's gross receipts, not on their net income levels. The allocation does not consider income losses for crew members, input suppliers and seafood processors in affected communities.

In January 2015, the federal government approved the second round of relief funds, totaling $13 million, to be awarded to businesses and governments in the regions. Of this, $4.5 million will be paid to the recreational fishing sector (sport fishing guides and related businesses), $7.5 million for disaster research, restoration, education, gear replacement/modification, and outreach ($6.4 million for the Yukon/Kuskokwim region and $1.1 million for Cook Inlet), and $700,000 to commercial buying stations and salmon buyers in the Cook Inlet area (National Marine Fisheries Service, 2015).

The salmon failures and the federal relief payments will generate two different types of effects on the economies of the regions depending the salmon fisheries. The salmon failures will lead to reduced fish harvesting and processing activities, and produce negative economic impacts. The negative economic impacts will occur not only in the Alaska communities that rely on the fisheries but in non-Alaska regions which export a large quantity of inputs to the salmon fishing industry (and other fishing industries) in Alaska. For example, if a fishing vessel buys nets directly from a company in Seattle or if a processing plant in Alaska purchases boxes from a company in Seattle, then this will generate economic impacts in the Seattle area. Also, if a processing worker spends most of his/her income earned from working in Alaska in his/her home state of Washington, the economic impacts will be produced in that state. In this case, a single-region model for Alaska would not be able to calculate the economic impacts occurring in the non-Alaska regions.

However, the federal relief payment to the stakeholders affected by the fishery failures will generate some positive economic impacts. These impacts will occur in Alaska and elsewhere in the country because not all of the fishermen (permit holders) who receive a relief payment live in Alaska, and therefore, the spending of the federal relief funds will occur both in Alaska and non-Alaska regions in United States. In this case, a single-region model would be the wrong tool to calculate the full (i.e., the total US) economic impacts from the federal relief payment because the impacts will not be limited only to Alaska.

Many previous studies of the economic impacts of fishery management and exogenous shocks use a single-region model (e.g., Seung et al., 2016). The serious limitation of a single-region model is that the model cannot estimate the economic impacts of an initial shock occurring in the regions that have strong economic ties with the original region. Therefore, the objective of this study is to calculate the multi-regional economic impacts of the commercial Chinook salmon fishery failures by using a multi-regional social accounting matrix (MRSAM) model, thereby overcoming the limitation of a single-region model.[3] In doing so, this study takes into account the effects of the first round of the federal relief funds ($7.8 million) paid to commercial salmon permit holders. Thus, this study calculates, first, the economic impacts of salmon failures only, and, then the net impacts of both salmon failures and federal disaster relief payments to permit holders. The MRSAM model has three separate regions – Alaska, West Coast (WC), and the rest of US (RUS). The regional economic impacts calculated in this study include changes in output, employment, and other variables.

The structure of MRSAM model is described in the next section. Section 3 describes the data used and Section 4 discusses the results, followed by the final section which offers some conclusions.

2. Method

2.1. Previous Approaches

The Leontief input-output (IO) model is a major tool that has been used for economic impact analysis. The model includes the transactions of intermediate inputs among industries, and so captures a major portion of linkages in a regional economy. The model is a demand-driven model in that the impacts of changes in final demand are computed. However, the demand-driven model produces biased results if used to compute the impacts from an exogenous output change without any adjustment to the model. This led some researchers (e.g., Leung and Pooley, 2002) to use a mixed endogenous-exogenous (MEE, Miller and Blair, 1985) version of the IO model, based on the argument that an MEE version of the model is a more appropriate tool than a Leontief demand-driven IO model when the output level for an industry (e.g., harvest level in fisheries) is exogenously changed and no information is available about the associated change in the final demand. Some studies used an MEE version of SAM model in order to quantify the distributional effects of policies or exogenous shocks (e.g., Roberts, 1994).

In calculating the forward-linkage effects using the MEE approach (whether they use IO or SAM framework), some studies ignore the effects because the effects are negligible while other studies use the Ghosh approach (Ghosh, 1958) to calculate the forward-linkage effects. However, the Ghosh approach has been criticized due to a serious

[3] Also, the SAM framework used in this study enables investigation of distributional effects, thereby overcoming the limitation of an input-output (IO) model.

problem in interpreting the model results.[4] For details on existing approaches to computing the economic impacts from exogenous changes in industry output, see Seung (2014) and Seung and Waters (2013).

2.2. Suggested Approach

This study uses an approach called an "adjusted demand-driven MRSAM model." The model overcomes the limitations of the previous approaches to calculating the impacts of exogenous changes to output (or productive capacity) in the following way. The model is run with (i) the exogenous changes in output treated as final demand shocks and (ii) regional purchase coefficients (RPCs) for the output of *all* the directly impacted industries and the forward-linked industries set equal to zero.[5] Zero RPCs for the directly impacted industries prevent the regional industries from purchasing output from the directly impacted industries. This avoids the biased results or double-counting encountered when erroneously using Leontief demand-driven models for calculating the impacts of exogenous changes in industry output. Additionally, with zero RPCs for the output of *all* forward-linked industries, the problem of the Ghosh approach can be avoided. Details on the adjusted demand-driven model approach are found in Seung (2014) and Seung and Waters (2013).

2.3. Structure of Three-region MRSAM Model

This section relies heavily on Seung (2014) and Waters et al. (2014). This section describes the 2008 MRSAM constructed for three regions – Alaska, WC, and RUS. Readers are referred to King (1985) for a detailed discussion of a SAM and Holland and Wyeth (1993) for the structure of a regional-level SAM model. The structure of the MRSAM model in the present study is similar to those used in Round (1985) and Roberts (2000). Due to space limitations, this study presents the structure of a two-region SAM (Appendix A, Table A.1). However, the structure of the three-region MRSAM is similar to that of the two-region SAM and is available upon request.

Each region in the MRSAM has 97 endogenous accounts. This means that the MRSAM has a total of 291 (97 × 3) endogenous accounts. The 97 endogenous accounts for each region include 42 industries, 48 commodities, 3 value-added income accounts (labor income, capital income, and indirect business tax), 3 household accounts (low-, medium-, and high-income households), and a combined state and local government account. The 42 industries (Table A.2, Appendix A) include 9 seafood industries (6 harvesting industries and 3 processing industries) and 33 non-seafood industries. The 48 commodities include 14 fish species, 1 processed seafood, and 33 non-seafood commodities. The 6 harvesting industries are Catcher-Processors (harvesting),[6] Trawlers, Longliners, Crabbers, Salmon Netters,[7] and Other Harvesters. The 3 processing industries are Catcher-Processors (processing), Motherships, and Shore-based Processors. Major species (commodities) include Pacific cod, pollock, sablefish, crab, halibut, and salmon. The MRSAM model has 4 exogenous accounts: federal government, capital (savings and investment), an account to handle international trade and financial flows, and an account balancing between the three regions and the rest of the world (ROW). The complete sectoring scheme showing detailed industry and commodity accounts is provided in Table A.2 in Appendix A. The MRSAM model can be expressed as:

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

where y_i and x_i denote the column vectors of endogenous and exogenous accounts, respectively, for region i and Z_{ii} is a submatrix containing coefficients showing the intra-regional transactions and z_{ij} a submatrix containing coefficients showing inter-regional transactions, respectively. All the coefficients in Z_{ii} and z_{ij} are derived by dividing the elements in the columns in the MRSAM by the column totals. Alternatively, Eq. (1) can be written as:

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

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 $X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$. S is the matrix of direct MRSAM coefficients and $(I - S)^{-1}$ is called the MRSAM multiplier matrix or the matrix of MRSAM inverse coefficients.

y_i is a column vector for region i consisting of the following endogenous sub-vectors:

A_i = vector of regional industry output
Q_i = vector of regional commodity output
V_i = vector of total primary factor payments
IBT_i = indirect business tax payments
H_i = vector of total household income
SG_i = total state and local government income or revenue
Z_{ii} for region i is:

$$Z_{ii} = \begin{bmatrix} 0 & M_i & 0 & 0 & 0 & 0 \\ U_i & 0 & 0 & 0 & C_i & GD_i \\ V_i & 0 & 0 & 0 & 0 & 0 \\ IBT_i & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & F_i & 0 & 0 & STR_i \\ 0 & 0 & SF_i & BTS_i & HTX_i & IGT_i \end{bmatrix}$$

where:

U_i = absorption matrix
V_i = matrix of primary factor payments coefficients
IBT_i = matrix of indirect business tax coefficients
M_i = market share matrix
F_i = matrix of factor payment to household coefficients
SF_i = matrix of state and local factor tax coefficients
BTS_i = matrix of state and local indirect business tax coefficients
C_i = matrix of household consumption coefficients
HTX_i = matrix of state and local government direct household tax coefficients
GD_i = matrix of state and local government demand coefficients
STR_i = matrix of state and local government transfer coefficients
IGT_i = matrix of intergovernmental transfers
z_{ij} is:

$$z_{ij} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & IM_{ij} & 0 & 0 & 0 & 0 \\ 0 & 0 & LK_{ij} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

[4] Specifically, the Ghosh approach has been criticized because it is used to explain changes in physical output arising from changes in physical factor inputs. The Ghosh model assumes that sales from industry i to the industries that use industry i's output as an intermediate input are proportional to industry i's output (i.e., fixed output allocation coefficient assumption). However, this assumption seems neither intuitive nor economically valid. For more discussion of the implausibility of assumptions that Ghosh model uses, see Oosterhaven (1988, 1989).

[5] This approach is similar to the approach in Tanjuakio et al. (1996) and Steinback (2004). An important difference between the present study and these previous studies is that the present study uses a MRSAM model while these two previous studies use single-region IO models.

[6] Catcher-Processors engage in both fish harvesting and fish processing. The present study divides catcher-processing sector into two separate sectors, harvesting and processing sectors.

[7] This sector includes not only the salmon gillnet fisheries, which are mostly impacted by the salmon disaster, but also a small salmon fishwheel fishery on the upper Yukon River.

where IM_{ij} is matrix of imports from region i to j and LK_{ij} is matrix of leakage of factor income from region j to region i. x_i is a column vector consisting of the following exogenous sub-vectors:

ea_i = vector of exogenous demand for regional industry output
eq_i = vector of exogenous demand for regional commodity output
ev_i = vector of exogenous factor payments
et_i = exogenous indirect business tax payments
eh_i = vector of exogenous federal transfers to households
eg_i = federal transfers to state and local government.

There are three non-zero exogenous demand vectors – eq_i, eh_i and eg_i. The elements of eq_i are components of final demand for commodities including federal government demand, investment demand, and export demand. The elements of eh_i include Federal government transfers to households and remittances from ROW to households. The components of eg_i include Federal government transfers to state and local government. Injections of income into a region occur through final demand components in eq_i and extra-regional payment components in eh_i and eg_i. Leakages include taxes paid to the Federal government, savings, and payments for commodities imported from ROW.

2.4. Modeling Exogenous Changes in Seafood Industries' Output

The two Alaska seafood industries whose output (level of Chinook salmon harvest and level of seafood processor' output) is directly altered from salmon disasters are the Alaska Salmon harvesting industry (Salmon Netters)[8] and the Alaska seafood processing industry (Shoreside Processors). The direct impact on the salmon harvesting industry is the curtailment in the Chinook salmon harvest from the salmon failures. The resulting reduction in the sales of the processed seafood is the direct impact to the seafood processing industry. The direct impacts on the two seafood industries were estimated by the Alaska Department of Fish and Game (ADFG) to be −\$16.8 million and −\$25.1 million, respectively (Muse, 2014). The estimates of the direct impacts to the two Alaska seafood industries were applied as direct "shocks" to the MRSAM model.[9]

When the adjusted demand-driven MRSAM model is run, this study treats the exogenous reductions in the output of the two seafood industries as final demand shocks, and set to zero the RPCs for all the commodities produced in all the seafood industries in all the three regions. The exogenous reductions in output include not only the decreased output of the directly impacted industry (i.e., the Alaska salmon harvesting industry) but also the reduced output of the forward-linked industry (i.e., the Alaska seafood processing industry). The reduction in output of the forward-linked industry (-\$25.1 million in this study) is specified exogenously, *before running the model*, based on data (i.e., the ADFG data), and is applied to the model as an initial shock. By treating as initial shocks the reduced output of the forward-linked industry as well as the reduced output of the directly impacted industry, this study does not need to compute endogenously the effects on the forward-linked industry's output from a change in the directly impacted industry's output, thereby avoiding the problem of the Ghosh approach.

Setting RPCs for the seafood commodities to zero is equivalent to setting the row elements for the commodities to zero in the S matrix above (matrix of direct MRSAM coefficients). Zero RPCs prevent the seafood processing industry from buying more raw fish from the fish harvesting industry than the amount required to attain the pre-determined direct change in the harvesting industry output. This avoids effectively the biases in economic impact estimates often obtained when the Leontief demand-driven model is used to estimate the impacts from an exogenous change in productive capacity. RPCs can be applied to either commodities or industries. In MRSAM model, the RPCs are set to zero for all the commodities produced by all seafood industries.

Zero RPC for the raw fish applied to a single-region model (e.g., for Alaska) would mean technically that a change in demand by the fish processing industry for the intermediate input (i.e., raw fish), due to a change in output of the processing industry, is not met by regional production but by the imports of the raw fish from the outside of the region. However, this technicality is irrelevant for the analysis because the anticipated effect of the change in the processing industry's output on the fishing industry is already specified exogenously as the direct impact on the fishing industry. The (intermediate) demand by fish harvesting and processing industries for the output from the non-seafood industries, however, is satisfied in the standard way by regional production and/or imports, because the RPCs for the output from the non-seafood industries are non-zero numbers.

A similar technicality applies to the multiregional model. In the MRSAM model, RPCs are set to zero for output produced by all the seafood industries in all three regions. This means technically that the change in Alaska's import demand for the two commodities (raw salmon and processed salmon in this study), which occurs due to the exogenous shocks in Alaska, is satisfied by imports from ROW, rather than by the additional production of these commodities in the other two regions in US. With zero RPCs for these commodities produced in the other two US regions as well as in Alaska, the MRSAM model prevents the output of a seafood industry in the two non-Alaska regions from changing at all due to the shocks in Alaska. This assumption is reasonable because the annual harvest levels of most species in US fisheries are exogenously set at their total allowable catches (TACs),[10] and therefore, an exogenous change in catch of a species caught in Alaska waters will not affect the harvest levels of the other species (commodities) in Alaska and those of all the species caught in the other two regions.

2.5. Direct, Indirect and Induced Effects in MRSAM Model

There are two different types of regional economic effects that a policy or an exogenous shock engenders – backward linkage effects and forward-linkage effects. Leontief demand-driven model calculates only backward-linkage effects in response to a final demand change. A Ghosh-type model attempts to calculate the forward-linkage effects. In this study, the direct effects (initial shocks) are the reductions in production of the two commodities (raw salmon and processed salmon) which are given exogenously.

The direct effects (initial shocks) produce backward linkage effects, which include both indirect and induced effects engendered not just in the region (Alaska) where the direct effects originate but also in the other two regions (spillover effects). Indirect effects refer to the effects generated due to a change in intermediate demand for non-seafood industries' output caused by the direct shocks. However, in the adjusted demand-driven MRSAM model, the indirect effects do not include the additional change in the output of the salmon harvesting industry (and harvesting industries catching other species) from the exogenous change in processed seafood. This is because the impacts on salmon harvest (a negative number) and harvest of other species (zeroes) are already specified as exogenous as above.

In the MRSAM model, induced effects refer to the additional regional expenditure impacts resulting from the direct and indirect changes in household income and state and local government revenue. More specifically, a decrease in fish harvesting and processing output (direct effect) will lead to a reduction in the industries' use of goods and services from non-seafood industries (indirect effect). The direct and indirect effects, in turn, will decrease value added, indirect business taxes, household income, and state and local government revenue. The

[8] Most of the fisheries impacted by this salmon disaster are salmon set gillnet fisheries, which are included in Salmon harvesting industry. This industry also includes a small salmon fishwheel fishery on the upper Yukon River.

[9] The commercial fisheries that were impacted by the salmon disaster include the Yukon River Chinook salmon setnet and fishwheel fisheries, the Kuskokwim River Chinook salmon setnet fishery, and the Upper Cook Inlet setnet fisheries for all salmon species.

[10] Alaska salmon is not managed by TACs but by escapement.

Table 1
Baseline (2008) values of output ($ million).

Industry sector	Alaska	West Coast	Rest of US
Fish harvesting industry			
Catcher-Processors (harvesting)	287.4	10.1	0.0
Trawlers	232.3	64.3	226.8
Longliners	247.7	22.3	0.0
Crabbers	145.5	136.1	95.5
Salmon Netters	179.8	18.0	0.0
Other Harvesters	124.1	178.5	1002.5
Fish processing industry			
Catcher-Processors (processing)	902.4	46.3	0.0
Motherships	227.7	32.3	0.0
Shorebased processors	1749.1	2883.8	7903.6
Seafood industry total	4096.0	3391.7	9228.4
Non-seafood industry total	47,143.6	3,781,915.7	20,664,328.8
TOTAL ALL INDUSTRIES	51,239.6	3,785,307.4	20,673,557.2

Table 2
Baseline (2008) values of value added, household income, and state and local government revenue ($ million) (total federal relief funds paid = $7.6 million).

	Alaska	West Coast	Rest of US
Value added			
Labor income	17,788.5	1,155,478.6	5,999,015.5
Capital income	10,707.1	754,136.5	4,067,330.9
Indirect business tax	2080.1	151,950.3	778,993.4
TOTAL VALUE ADDED	30,575.7	2,061,565.4	10,845,339.7
Household income			
Low income households	2154.7	198,187.8	974,913.2
Medium income households	9515.2	714,172.9	3,433,828.1
High income households	10,942.2	852,913.7	4,840,387.9
TOTAL HOUSEHOLD INCOME	22,612.2	1,765,274.4	9,249,129.3
STATE AND LOCAL GOVERNMENT REVENUE	7787.9	466,024.7	2,765,307.5

decrease in household income and state and local government revenue implies that their consumption of goods and services will decrease (induced effect). In the MRSAM model, because the economies of the three regions are all connected to each other, the indirect and induced effects are generated in all the three regions. The total impacts are the sum of all direct, indirect and induced effects.

2.6. Estimating Effects of Federal Disaster Relief

To calculate the economic impacts of salmon failures only without considering the effects of federal relief payments, the adjusted demand-driven MRSAM model is used as above. In addition, the economic impacts of federal relief payments are calculated using a Leontief demand-driven version of the MRSAM model. It is appropriate to use a Leontief demand-driven model version in this case because the federal relief funds received by the permit holders (households) will most likely be spent on purchasing final consumption goods. The "net economic impacts" of salmon failures are calculated by subtracting the impacts from federal relief payments from those from salmon failures only.

This study first identifies the amounts of federal payments to (i) Alaska-resident, (ii) WC-resident, and (iii) RUS-resident permit holders separately using data from Pacific States Marine Fisheries Commission (PSMFC, 2015). This is because the non-Alaska permit holders are expected to spend most of their relief funds outside the State of Alaska. Next, the federal relief payments made to each of the three groups (by residency) of permit holders are allocated to the three household sectors based on the baseline ratios of distribution of the combined proprietary income and other property income in the MRSAM across the three types of households for each region. Then, the estimated relief payments received by the three types of households in each region are administered as direct shocks to the Leontief type demand-driven model.

3. Data

The Alaska portion of the MRSAM was generated using 2004 data and software from IMPLAN (Minnesota IMPLAN Group, Inc., 2004). Since IMPLAN data for fish harvesting and processing sectors are not reliable, the sectors were constructed using government data along with information obtained from informal interviews with key industry contacts. The information from the informal interviews were used to ground-truth the industry cost estimates (i.e., the fish harvesting and processing sectors' expenditures on the inputs they used). More detailed information about the seafood industries' data for the Alaska portion of the MRSAM model are found in The Research Group (2007).

To build the WC portion of the MRSAM, this study used the data from the IO model for Pacific Coast Fisheries (IO-PAC) developed by the Northwest Fisheries Science Center (NWFSC). The IO-PAC model is based on IMPLAN data supplemented with detailed data about fishery-related industries and commodities. The fishery data for the IO-PAC model are for year 2006, and were obtained from economic surveys of vessels engaging in WC fisheries (Leonard and Watson, 2011). Data on industry, commodity, and employment in IO-PAC were incorporated into the WC portion of the MRSAM.

The RUS portion of the MRSAM was compiled based on 2008 IMPLAN data. However, because the IMPLAN data for RUS contained only rudimentary information about RUS commercial fishery sectors, these data had to be supplemented with 2008 National Marine Fisheries Service (NMFS) landings data.[11] In addition, it is assumed that the expenditure functions for the RUS fisheries sectors were identical to those for corresponding Alaska and WC fisheries sectors. Specifically, this study applied the expenditure distributions for the corresponding fishery sectors in the Alaska and/or WC SAMs to RUS landings revenue aggregated by major species group from the NMFS data.

Due to different data years for the three different regional dataset (2004 for Alaska, 2006 for WC, and 2008 for RUS), the date years were matched by adjusting the WC and RUS SAMs to 2004 levels using the GDP price deflator series.[12] This study used IMPLAN version 3 to estimate the commodity trade flows among the three regions based on 2008 IMPLAN data. Since the Alaska and WC data were not for 2008, the trade flows were estimated by constructing additional IMPLAN models for the WC and Alaska regions for 2008. This study performed the interregional trade flow estimation within IMPLAN version 3. In addition to the commodity trade flows, this study estimated non-commodity flows (factor income, transfer payments, and financial flows) among the three regions, and with respect to ROW. The Alaska SAM has information about non-resident labor in seafood and other Alaska industries. However, there was no information on the origin or destination of interregional transfer payments and financial flows. So this study had to estimate these interregional flows based on fairly crude assumptions and the analyst's knowledge.

The MRSAM was built by assembling the three price-deflated SAMs as above. The baseline MRSAM was balanced via adjusting exogenous accounts until row totals equaled column totals across the three regions.[13]

4. Results

Table 1 displays the baseline values of output for seafood industries and for non-seafood industries combined, by region while Table 2 presents baseline values of other variables including value added income, household income, and state and local government revenue. This study calculates the combined economic effects from salmon

[11] http://www.st.nmfs.noaa.gov/st1/commercial/landings/annual_landings.html.

[12] An alternative method of adjusting the SAMs is to use nominal GDP ratios to deflate 2006 and 2008 levels to 2004 levels. This may better adjust for both scale as well as the price effects.

[13] This method of balancing was selected over bi-proportional adjustment techniques such as "RAS" in order to retain the original integrity of the estimated values for key behavioral and endogenous share parameters in the SAM, while allowing the peripheral elements in the SAM to be adjusted as needed to balance row and column sums.

Table 3
Total impacts on output and employment (% change in parentheses).

	Alaska	West Coast	Rest of US
Output ($ million)			
Fish harvesting industry	−16.80 (−1.38)	0.00 (0.00)	0.00 (0.00)
Fish processing industry	−25.10 (−0.87)	0.00 (0.00)	0.00 (0.00)
Seafood industry total	−41.90 (−1.02)	0.00 (0.00)	0.00 (0.00)
Non-seafood industry total	−24.03 (−0.05)	−8.82 (−0.0002)	−30.39 (−0.0001)
TOTAL ALL INDUSTRIES	−65.93 (−0.13)	−8.82 (−0.0002)	−30.39 (−0.0001)
Employment (number of jobs[a])			
Fish harvesting industry	−167 (−0.96)	0.00 (0.00)	0.00 (0.00)
Fish processing industry	−216 (−0.77)	0.00 (0.00)	0.00 (0.00)
Seafood industry total	−382 (−0.84)	0.00 (0.00)	0.00 (0.00)
Non-seafood industry total	−223 (−0.05)	−64 (−0.0002)	−213 (−0.0001)
TOTAL ALL INDUSTRIES	−605 (−0.13)	−64 (−0.0002)	−213 (−0.0001)

[a] To calculate employment impacts in this study, the base-year ratio of employment-to-output for each industry is multiplied by the change in total output for that industry.

fishery failures in the four Alaska salmon setnet fisheries and one small fishwheel fishery.[14] The lost ex-vessel revenue of the salmon harvesting industry from the salmon fishery failures was about $16.8 million while the resulting loss in the wholesale revenue from reduced salmon production in the processing industry was $25.1 million. These numbers (−$16.8 million and −$25.1 million) are applied to the model as direct impacts. Tables 3 and 4 present the impacts that were calculated using the adjusted demand-driven MRSAM model, accounting for only the effects of salmon failures. Table 5 compares the impacts from only salmon failures with those from both salmon failures and federal relief payments.

Total Alaska seafood industry output and non-seafood industry output decrease, respectively, by $41.9 million and $24.0 million when the salmon harvest is reduced due to salmon failures (Table 3). The MRSAM model can calculate the impacts on the two non-Alaska regions; the total non-seafood industry output for WC and RUS, respectively, decreases by $8.8 million and $30.4 million. The decreases in the non-seafood industry output in the two non-Alaska regions are caused by the spread effects (indirect and induced effects) occurring in the two non-Alaska regions because the Alaska salmon harvesting and processing industries use a large amount of inputs imported from the two regions. Total Alaska output decreases by $65.9 million while the total regional employment[15] (in jobs) decreases by 605 jobs. The total economic impacts on output generated in two non-Alaska regions combined are −$39.21 million [= (−$8.82 million) + (−$30.39 million)], which account for as large as 37.3% of the total US economic impacts amounting to $105.14 million. Table 4 presents results for economic impacts on value added, household income, and state and local government. As in Table 3, the impacts occurring in the two non-Alaska regions are significant. For example, the loss of the value-added income by the two non-Alaska regions combined ($7.66 million + $16.63 million) is about 42.1% of the loss of the total US value added. The combined Alaska state and local government revenue decreases by $2.5 million, which includes impacts to state of Alaska fish tax receipts and other state and local government revenues. The revenues for the other two regions decrease, respectively, by $0.8 million and $2.1 million.

While this study used the adjusted demand-driven MRSAM model to estimate the adverse impacts of the salmon failures, this study used the Leontief demand-driven MRSAM model to estimate the effects of the federal relief payment only. In the first round of federal relief for the fishery disaster, the federal government paid a total of about $7.6 million to the commercial fishermen (permit holders) who suffered from the disaster (PSMFC, 2015). The available funds were divided evenly among permit holders in the Yukon-Kuskokwim regions; in Cook Inlet, each set-net permit holder received a base payment of $2000, plus a percentage of their estimated revenue loss. About $6.5 million (or 86% of the total of $7.6 million) was paid to Alaska resident permit holders while the other $1.1 million was paid to WC-resident ($0.4 million) and RUS-resident ($0.7 million) permit holders. These three numbers ($6.5 million, $0.4 million, and $0.7 million) were applied to the Leontief demand-driven version of the model as exogenous shocks to household accounts for the three regions.[16] Next, the impacts from this Leontief demand-driven model were subtracted from the impacts of the salmon disaster (in Tables 3 and 4) in order to estimate the "net" economic impacts (columns 3, 5, 7, and 9 in Table 5).

Table 5 compares the results obtained when considering only the effects of the salmon disaster (columns 2, 4, 6, and 8) with those obtained when taking into account both the effects of salmon disaster and the effects of federal relief payment (columns 3, 5, 7, and 9). The results in columns 2, 4, 6, and 8 are from Tables 3 and 4. The impact on the total US output is -$105.1 million without relief funds payment while the impact is only -$86.3 million with the relief payments. It is shown that, when the federal relief funds are paid to the permit owners in the amount of $7.6 million, the *decreases* in the impacts from the salmon disaster on the total US output, total US value added income, and total US household income will be, respectively, $18.8 million ($105.1 million minus $86.3 million), $10.7 million ($57.7 million minus $47.0 million), and $14.0 million ($36.0 million minus $22.0 million) (the last two columns in Table 5). The decrease in the impacts on the total US household income ($14.0 million) is much larger than the initial impact of $7.6 million. A single-region model would calculate the impacts on Alaska only, failing to provide policymakers any information on the multi-regional impacts.

Although the federal relief payments partially countervail the adverse economic impacts from the salmon failures, results indicate that the net economic impacts are still significant. Furthermore, there may be a number of commercial fishery stakeholders who do not receive any relief payments. The permit holders who received the payments may not have shared the payment with other fishery participants who are affected by the salmon failures. These participants include non-permit holding crew, vessel owners, suppliers of fishing inputs, and owners, employees, and suppliers of fish processing firms.[17]

This study examines the economic impacts from fishery disasters, in particular, Alaska salmon fishery disasters. In the real world, non-fishery natural disasters also occur. Often federal policy makers are required to

[14] These are commercial setnet fishery failures from 2010 to 2012 for Yukon River Chinook salmon, for 2011 to 2012 for Kuskokwim River Chinook salmon, and in 2012 for Upper Cook Inlet all salmon and Northern District Cook Inlet all salmon.

[15] To calculate employment impacts, the base-year ratio of employment-to-output for each industry is multiplied by the estimated change in total output for that industry.

[16] To calculate the impacts, the federal payment to the permit holders in each region are allocated among the three types of households in the model based on the baseline household distribution of the combined proprietary income and other property income in the MRSAM.

[17] In the second round of relief fund payments, the government was supposed to make $700,000 available to "commercial buying stations and salmon buyers." Of the $700,000, $573,886 was disbursed in July 2015 (PSMFC, 2015). However, as of the time that this study was conducted, this payment had not been made. Therefore this study did not analyze the effects of the second relief payments including the payment to the commercial buying stations and salmon buyers.

Table 4
Total impacts on value added, household income, and state and local government revenue ($ million; % change in parentheses).

	Alaska	West Coast	Rest of US
Value added			
Labor income	−20.94 (−0.12)	−4.86 (−0.0004)	−8.95 (−0.0001)
Capital income	−11.05 (−0.10)	−2.40 (−0.0003)	−6.45 (−0.0002)
Indirect business tax	−1.44 (−0.07)	−0.40 (−0.0003)	−1.24 (−0.0002)
TOTAL VALUE ADDED	−33.43 (−0.11)	−7.66 (−0.0004)	−16.63 (−0.0002)
Household income			
Low income households	−0.97 (−0.04)	−0.31 (−0.0002)	−0.56 (−0.0001)
Medium income households	−8.28 (−0.09)	−2.13 (−0.0003)	−3.77 (−0.0001)
High income households	−10.84 (−0.10)	−2.82 (−0.0003)	−6.31 (−0.0001)
TOTAL HOUSEHOLD INCOME	−20.09 (−0.09)	−5.27 (−0.0003)	−10.65 (−0.0001)
State and local government revenue			
STATE AND LOCAL GOVERNMENT REVENUE	−2.49 (−0.03)	−0.75 (−0.0002)	−2.09 (−0.0001)

estimate the amounts of federal relief payments to those who suffer from the disasters. This study indicates that the type of data and model used is important to policy makers in identifying different stakeholder groups that may be eligible to receive relief funds and in making decisions on the distribution of relief funds among these different groups.

The data set used in this study (MRSAM data) identifies the different affected stakeholder groups. These groups include permit holders and crew members in the fish harvesting industry, owners and employees in the fish processing industry, and input suppliers to the affected fish harvesting and processing businesses. The data set provides baseline information about the magnitude of sales and income losses incurred by stakeholders. For example, the baseline data set in this study shows that the income lost by crew members in the salmon harvesting industry was $7.1 million, and the lost sales by local input suppliers to the industry was $6.5 million (not reported in a table). This type of information can guide federal policy makers in determining the distribution of federal relief payments to the stakeholder groups affected by natural disasters.

Additionally this study demonstrates that the MRSAM model is capable of indicating the economic impacts of natural disasters occurring not only in the region where the initial impact (e.g., the fishery disaster in this study) occurs but also in places that have economic linkages with that region. Thus the type of model used in this study overcomes a limitation of single region models by providing federal policy makers with the magnitudes of economic impacts occurring simultaneously among different stakeholder groups in several different geographic regions.

5. Concluding Remarks

Fishery managers care about the regional economic impacts of fishery management actions or exogenous environmental shocks (such as climate change or a salmon disaster as in this study). Often, however, the economic impacts are not limited to the region where the initial shocks originate, but they are spread across the regions that have economic linkages with the originating region. This is particularly true for Alaska fisheries. The present study calculates the net economic impacts of the salmon disasters, accounting for both the adverse impacts of decreased salmon harvests from the fishery disaster and the offsetting effects of federal relief payments. This study used a multiregional modeling framework to compute the multi-regional economic impacts that a single-region model would not be able to estimate.

This study used two different versions of the MRSAM model – adjusted demand-driven MRSAM model with zero RPCs to estimate the effects of the exogenous reduction in salmon harvest and Leontief demand-driven MRSAM model to calculate the positive effects of federal relief payments. The important advantage of using the adjusted demand-driven MRSAM model is to avoid double counting in estimating the economic impacts from exogenous changes in output and to overcome the weakness in the Ghosh (1958) approach in calculating the forward-linkage effects. This type of model is particularly useful for economic impact analysis for fisheries in which many management actions involve placing constraints to the level of fish harvest in the form of TAC due to environmental alterations or other management actions.

This study finds that the salmon fishery failure has significant adverse economic impacts that include not only the intra-regional (Alaska) but also the inter-regional (West Coast and the rest of US) impacts. This study also finds that, although federal relief funds mitigate the adverse economic impacts to some extent, the distribution of federal relief funds only to permit owners is not sufficient to compensate for the losses incurred by other stakeholders.

OMB Disclaimer

The findings and conclusions in the paper are those of the author and do not necessarily represent the views of the National Marine Fisheries Service, NOAA.

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Table 5
Total impacts on key variables with and without relief funds.

	Alaska		West Coast		Rest of US		All US	
	Without relief funds	With relief funds	Without relief funds	With relief funds	Without relief funds	With relief funds	Without relief funds	With relief funds
Total output ($ million)	−65.9	−59.3	−8.8	−6.2	−30.4	−20.7	−105.1	−86.3
Total employment (jobs)	−605	−540	−64	−45	−213	−144	−882	−729
Total value added ($ million)	−33.4	−29.5	−7.7	−5.9	−16.6	−11.6	−57.7	−47.0
Total household income ($ million)	−20.1	−11.5	−5.3	−3.8	−10.7	−6.8	−36.0	−22.0
State and local government revenue ($ million)	−2.5	−1.8	−0.8	−0.5	−2.1	−1.4	−5.3	−3.8

Appendix A

Table A.1
Structure of two-region social accounting matrix.

		Region 1					Region 2					Exogenous accounts	TOTAL
		Activity	Commodity	Value-added	Households	State & local govt	Activity	Commodity	Value-added	Households	State & local govt		
Region 1	Activity		MAKE matrix										Total value of output
	Commodity	USE matrix			Household purchase	SL govt purchase		Imports from Region 1 to Region 2				Fed govt purchase. Investment demand. Foreign exports	Total value of commodity (regional use, exogenous demand, and exports)
	Value-added	Value added payments							Leakage of factor income from Region 2 to Region 1				Total value added received in the region
	Households			Net factor income		SL govt transfers to households						Fed govt transfers to households. Remittances from ROW	Total household income
	State & local govt			SL govt factor taxes. Indirect business tax	SL govt personal income tax	SL govt transfers						Fed govt transfer to SL govt	Total SL govt revenue
Region 2	Activity							MAKE matrix					Total value of output
	Commodity		Imports from Region 2 to Region 1				USE matrix			Household purchase	SL govt purchase	Fed govt purchase. Investment demand. Foreign exports	Total value of commodity (regional use, exogenous demand, and exports)
	Value-added			Leakage of factor income from Region 1 to Region 2			Value added payments						Total value added received in the region
	Households								Net factor Income		SL govt transfers to households	Fed govt transfers to households. Remittances from ROW	Total household income
	State & local govt								S&L govt factor taxes and indirect business tax	SL govt personal income tax	SL govt transfers	Fed govt transfer to SL govt	Total SL govt revenue
Exogenous accounts			Foreign imports	Social security tax, capital tax, and indirect business tax to Fed govt. Business savings	Fed govt personal income tax. Household savings	SL govt savings		Foreign imports	Social security tax, capital tax, and indirect business tax to federal govt. Business savings	Federal govt personal income tax. Household savings	SL govt savings	Fed gov savings. Negative foreign savings. Foreign borrowings.	
TOTAL		Total value of output	Total value of commodity (production and imports)	Total value added generated in the region	Total household expenditure	Total SL govt expenditure	Total value of output	Total value of commodity (production and imports)	Total value added generated in the region	Total household expenditure	Total SL govt expenditure		

Table A.2
Industry aggregation scheme for the MRSAM model.

IMPLAN SECTORS	INDUSTRIES in MRSAM
Sector 16 (Replaced with estimated data)	Catcher-Processor (CPs, harvesting)
Sector 16 (Replaced with estimated data)	Trawlers
Sector 16 (Replaced with estimated data)	Longliners
Sector 16 (Replaced with estimated data)	Crabbers
Sector 16 (Replaced with estimated data)	Salmon Netters
Sector 16 (Replaced with estimated data)	Other Harvesters
Sector 71 (Replaced with estimated data)	Catcher-Processor (CPs, processing)
Sector 71 (Replaced with estimated data)	Mothership (MS)
Sector 71 (Replaced with estimated data)	Shorebased processor
Sectors 1–15, 17, and 18	Agriculture
Sector 19	Oil and Gas Extraction
Sectors 20–26	Other Mining
Sectors 27–29	Mining services
Sectors 30–32, 495, and 498	Utilities
Sectors 33–45	Construction
Sectors 112–123	Wood products
Sectors 46–70 and 72–84	Other Food Manufacturing
Sectors 85–111, 124–141, and 143–389	Other Manufacturing
Sectors 142 and 396	Refined Petroleum
Sector 390	Wholesale Trade
Sector 391	Air transportation
Sector 393	Water transportation
Sectors 392, 394, 395, and 397–400	Other transportation
Sector 405	Food and Beverage Stores
Sectors 401–404 and 406–412	Other Retail
Sectors 413–424	Information
Sectors 425–430	Finance and Insurance
Sectors 431–436	Real Estate, Renting, and Leasing
Sectors 437–450	Professional- scientific and technical serv.
Sector 451	Management of Companies
Sectors 452–459	Administrative Support Services
Sector 460	Waste Management and Remediation Serv.
Sectors 461–463	Educational Services
Sectors 464–470	Health Service and Social Assistance
Sectors 471–478	Arts, Entertainment, and Recreation
Sectors 479–480	Accommodations
Sector 481	Food Services and Drinking Places
Sectors 482–486	Repair and Maintenance
Sectors 487–494	Other Services
Sectors 496, 497, 499–502, and 507–509	Government and non-NAICS
Sectors 503 and 504	State and local government services
Sectors 505 and 506	Federal government services

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