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Economic contributions of wild fisheries and aquaculture: A social accounting matrix (SAM) analysis for Gyeong-Nam Province, Korea

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ABSTRACT

This study quantifies and compares the economic contributions of two alternative methods of producing raw fish – wild fisheries and aquaculture – in Gyeong-Nam (GN) province, Korea. This study departs from most previous studies in several important ways. First, this study employs a social accounting matrix (SAM) model to overcome the inability of input-output (IO) models to address the distributional effects. Second, this study conducts a regional-level analysis rather than a national-level analysis. Third, this study uses an adjusted demand-driven SAM modeling framework to avoid double-counting problem with the conventional Leontief demand-driven model and the problem with Ghosh (1958) approach. Results indicate that the contributions *per unit* of output from the two different fish producing industries to total provincial employee compensation and total provincial business surplus are substantially different, but that the contributions (per unit of output) to total provincial output, total household income, and provincial government revenue are not significantly different between the two different fish producing industries. Results also reveal that the non-seafood industries that benefit most from wild fisheries are starkly different from those that gain most from aquaculture.

1. Introduction

Globally, fish is an important source of food, providing a large percentage of animal protein to people. People have traditionally relied on wild-caught fish for their food source. However, human demand for fish as a food source has dramatically increased due to the fast growing human population. To meet the increasing human demand for fish, fishermen increased harvest of fish. This resulted in a rapid depletion of fish resources, making the sustainable production of wild-caught fish increasingly difficult. Because the supply of wild-caught fish cannot catch up with the ever-increasing human demand for fish, aquaculture (fish farming), as an alternative method of producing fish, has grown fast to meet the increasing demand. Over the past 30 years, globally, fish farming has increased on average 689% while the total production of wild-caught fish has not increased as dramatically, growing only 7% on average over the same period (Fig. 1).

Similar trend is observed in Korean fisheries. While fish harvest from wild fisheries has generally decreased (on average 37% from 1990 to 2017, Fig. 2), fish production from aquaculture has increased by 199%. Since year 2006, the quantity of the farm-raised fish has surpassed the quantity of fish harvested from wild fisheries. In year 2017, the fish production from aquaculture is 149% larger than that from wild fisheries. In 2017, the total amount of fish produced in aquaculture was 2.3 million metric ton (or 2,952 billion KRW in value). Major species produced in aquaculture in Korea include seaweeds, shellfish, and finfish, accounting for 76%, 18.5%, and 3.7%, respectively, in quantity (MOF, 2018).

Countries have laws governing fishery resources. These laws mandate that the economic impacts of fishery management actions (or environmental shocks) be formally taken into account. For example, for U.S. fisheries, Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) requires that the economic importance of fishery resources to the fishing-dependent communities be considered. For fisheries in Korea, Fisheries Resources Management Act (FRMA, MOF, 2015) states, "The purpose of this Act is to contribute … to the income growth of fisherman …" (Article 1, Purpose) and "… The term "fishery resources" … are resources useful to the national economy and people's living …" (Article 2, Definition). These statements clearly indicate the importance of efficient management of fishery resources to fishermen's income and the economy depending on fisheries resources.

Therefore, fishery managers in Korea, whether they are at national level or regional level, are interested in the economic contribution of

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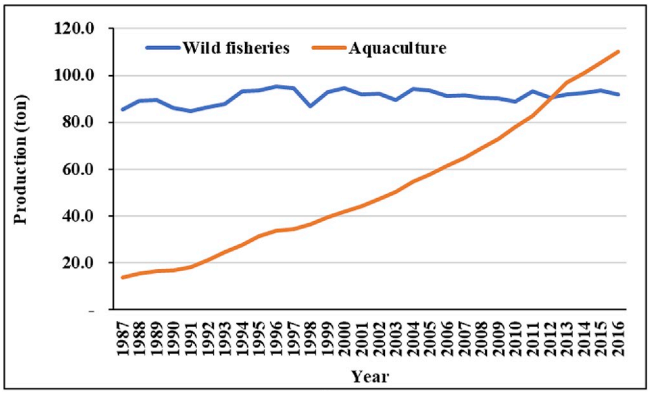

Fig. 1. Global trend of fish production from wild fisheries and aquaculture Source: FAO. Fishery and Aquaculture Statistics. 2018.

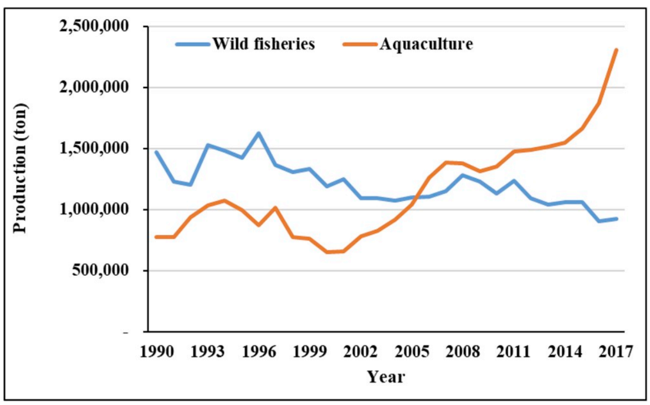

Fig. 2. Trend of fish production from wild fisheries and aquaculture in Korea Source: MOF. Fisheries Production Statistics. 2018.

Korean fisheries in general as well as the economic impacts of a fishery-related policy. With the rapid growth of aquaculture, they are also concerned with the relative economic contributions of aquaculture vs. wild fisheries and the economic impacts of various fishery management policies for, or exogenous shocks to, the wild capture and aquaculture industries. We chose Gyeong-Nam (GN) province in Korea as the study region because the province is substantially dependent on both wild fisheries and aquaculture. One main interest of regional (provincial) policy-makers and fishery managers alike is how much wild fisheries and aquaculture contribute to the provincial economy.

As shown below, aquaculture industry uses strikingly different mix of intermediate inputs from that used in wild captures. The difference in the input mix for producing raw fish between the two fish producing industries implies that the economic impacts (or contributions) of the two industries will be generated through considerably different paths, and may lead to different magnitudes of the impacts.

Several previous studies (e.g., Garcia-Negro et al., 2004; Murray, 2014; Lee and Yoo, 2014; and Garza-Gil et al., 2017) examined the relative contributions or impacts of wild capture fisheries and aquaculture using input-output (IO) models. However, no previous studies have utilized a social accounting matrix (SAM) model to compare the contributions of the two different methods of raw fish production.

More specifically, the present study improves on the previous studies in the following two ways. First, the present study uses a social accounting matrix (SAM) model due to its advantage that the model can investigate the distributional effects of a policy. Using a SAM model is important when measuring the contribution of an industry. This is because, by endogenizing value added sectors (factors of production), household sectors, and regional government sector, the SAM model captures the monetary flows from producing sectors to value added sectors, then on to institutions such as households and regional government which purchase goods and services. In contrast, an IO model cannot capture these distributional effects due to not accounting for these monetary flows, considering only the effects occurring among industry sectors. This makes the economic impacts (contributions) from an IO model generally understated compared to a SAM model. Nonetheless, many previous studies rely on an IO model to measure the contributions or impacts of a seafood industry. Applications of SAM approach to the assessment of economic impacts of fisheries are found, for example, in Seung and Waters (2009), Seung (2017), and Morrissey et al. (2019).

Second, and most importantly, this study made an adjustment the SAM model before running the model. The adjusted model is called "adjusted demand-driven SAM model" where the regional purchase coefficients (RPCs) are set equal to zero for all the directly impacted industries such as fish harvesting and aquaculture industries and their forward-linked industry (seafood processing industry). The RPCs are set to zero to avoid (i) the problem of the overestimated contributions of the seafood industries, typically encountered when using an unadjusted Leontief demand-driven model and (ii) the problem with Ghosh (1958) approach that is frequently (and wrongly) used to determine forward-linked impacts notwithstanding its theoretical fallacy.

This paper is structured as follows. The next section (Section 2) provides a brief description of fisheries in GN province. Section 3 reviews previous studies of economic contributions of seafood industries, followed by Section 4 which describes the GN SAM model, and discusses the problems with previous approaches to economic impact modeling for dealing with supply (output) constraints. Section 5 describes the data used. Section 6 reports and Section 7 discusses the results from the economic contribution analysis. The final section concludes.

2. Fisheries in GN province

GN province is located in Southeastern part of the Korean peninsula, and accounts for an enormous share of total fish production in Korea. In 2017, fishermen in the province harvested about 220,000 metric tons of wild fish (or 663.5 billion KRW in value) and produced 377,880 metric tons of farmed fish (568.4 billion KRW in value). In terms of quantity, GN ranks second in catch of wild fish as well as in production of farmed fish, among 16 Korean provinces. In GN province, major species caught in wild fisheries include anchovy, spanish mackerel, chub mackerel, conger, and hairtail while the major species farmed in aquaculture in the near-shore waters include oyster, sea squirt, Korean rockfish, gray mullet, and red seabream. Fig. 3 depicts the annual production of fish from both wild fisheries and aquaculture for GN region from 1990 to

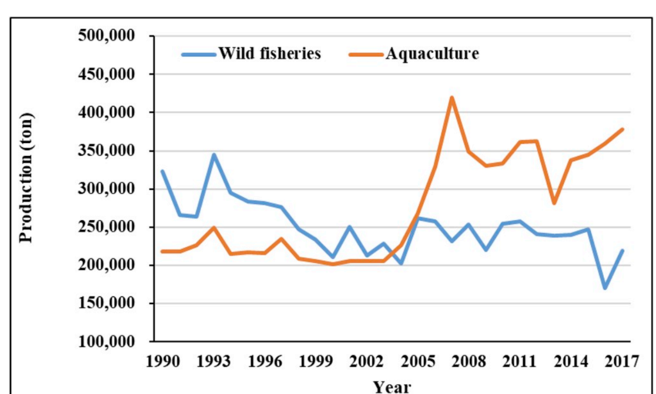

Fig. 3. Trend of fish production from wild fisheries and aquaculture in GN Province
Source: MOF. Fisheries Production Statistics. 2018.

2017. As the figure shows, the amount of fish caught in wild fisheries has decreased since 1994 while the production of farmed fish has increased dramatically since year 2004. Since year 2004, the production from aquaculture has exceeded the fish harvest from wild fisheries.

A large portion of the raw fish produced in GN province is sold to processors which process the fish, and supply the processed fish to consumers in GN, rest of Korea (ROK), or the rest of the world (ROW). The remainder of the raw fish is either consumed directly by households or used in restaurants in GN province. In 2013, 93% (1,615 billion KRW) of fish processed in GN was exported to non-GN regions with 74% (1,285 billion KRW) exported to ROK and 19% (329 billion KRW) to ROW (Bank of Korea, 2015). The top three countries to which the GN-processed fish is exported include USA, Japan, and China. The money from the sales of fish to non-GN provinces in Korea and ROW represent an important export base for GN economy, and generate multiplier effects throughout the GN economy.

3. Previous studies

There are a few number of studies that examined the economic importance or contribution of seafood industries (mostly focusing on wild capture fisheries). The economic importance of fisheries of different regions within Finland was investigated in Virtanen et al. (2001). The study used the absolute values and shares of employment and production in seafood industries in the regions. The study also utilized location quotients to measure the economic importance of fisheries across different regions. Seung and Waters (2005) constructed a SAM model for the state of Alaska in US in order to estimate the total contribution of commercial fish harvesting sector to the economic base of the state. To examine the role of seafood industries in the state, the study developed employment dependency index and labor earnings dependency index.

Watson and Beleiciks (2009) developed a SAM for each of the two fishing-dependent communities on the US West Coast (Westport, Washington and Newport, Oregon). The study developed indices of economic dependence for these two communities which depend on marine resources including fisheries. Morrissey et al. (2011) quantified the value of marine services sector, marine resources sector (including fish harvesting and seafood processing sectors), and marine manufacturing sector. An important finding is that the gross value added of the whole seafood industry (which includes sea-fisheries, aquaculture, and seafood processing) was 230 million Euros or about 0.12% of the GDP of Ireland in 2007.

Sigfusson et al. (2013) examined the economic contribution of fisheries and associated industries to Iceland, and found that the total contribution (direct, indirect and induced effects) of the cluster of fish harvesting, processing and the related industry was more than 17% of national GDP. Most recently, Waters et al. (2014) assessed the multi-regional economic contribution of the Alaska head and gut (H&G) fishing fleet on three regions of US – Alaska, West Coast, and the rest of US. The study used a multi-regional SAM model, and found that more than 50% of the impacts of the head and gut (H&G) fleet on total industry output and about 80% of the impacts on household income fall on the two non-Alaska US regions.

As mentioned, a number of studies measured the economic contributions of wild fisheries and aquaculture. Garcia-Negro et al. (2004) measured the economic importance of extractive fishing and marine aquaculture for Galacia, Spain while Murray (2014) assessed the economic impacts of shellfish aquaculture and commercial fishing in Northampton County, Virginia. Lee and Yoo (2014) conducted a comparative analysis of the contributions of capture fishery and aquaculture to the national economy of Korea. An innovative feature of this study is that, unlike many previous IO studies of fisheries, this study used longitudinal data (1995–2010) to trace and compare the temporal changes in the contributions of the two raw fish production industries. Garzia-Gil et al. (2017) carried out a study that investigates the economic effects of fishing and aquaculture for Galacia, Spain. The present study is the first to use a SAM framework that evaluates the relative contributions of wild fisheries and aquaculture.

4. Methods

4.1. Gyeong Nam (GN) social accounting matrix model

IO models have been used extensively in economic impact analysis because the model considers explicitly the inter-industry transactions of intermediate inputs when computing the economic impacts using multipliers, and therefore captures an important economic linkage in an economy.

However, the model suffers from some limitations. One of the most critical limitation is that the model cannot capture the income flowing from industry production sectors to factors of production (such as labor and capital), and then on to institutional sectors such as households and various levels of governments. A SAM model overcomes this limitation. Because the SAM model captures these flows in detail, the model can examine the distributional effects of a policy or an exogenous shock on non-industry sectors such as value added sector and various types of institutions. Also, because the model captures the endogenous demand by these institutions (governments and households) for goods and services, the resulting multipliers can include the effects that an IO model fails to capture. More detailed discussion of a SAM and SAM models can be found in, for example, King (1985), Holland and Wyeth (1993), and Adelman and Robinson (1986).

This section presents a 2013 SAM model for GN province. Table A.1 in Appendix A shows the structure of the GN SAM. The SAM has a total of forty-six accounts (or sectors). Forty-two of these accounts are endogenous accounts with the other four accounts being exogenous accounts. The endogenous accounts include thirty-three industry accounts, two value added accounts, one enterprise account, five household accounts (distinguished by income levels), and a regional government account (which is a combined account including the provincial government and the sub-provincial governments such as *Kun* and Cities). Exogenous accounts are non-tax revenue account for the regional government, national government, capital, and the rest of the world (ROW).

The matrix of direct SAM coefficients in the GN SAM model, denoted S, is derived as follows:

$$\boldsymbol{S} = \begin{bmatrix} A & 0 & 0 & 0 & C & G \\ L & 0 & 0 & 0 & 0 & 0 \\ K & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & E & 0 & 0 & 0 \\ 0 & Lh & 0 & Kh & 0 & TR \\ Tb & 0 & 0 & 0 & Th & 0 \end{bmatrix} \tag{1}$$

where:

$\boldsymbol{S}$ = matrix of SAM direct coefficients
$\boldsymbol{A}$ = matrix of technical coefficients
$\boldsymbol{L}$ = matrix of labor income payments coefficients
$\boldsymbol{K}$ = matrix of capital income payments coefficients
$\boldsymbol{Tb}$ = matrix of coefficients representing business tax payments by industries to provincial government
$\boldsymbol{Lh}$ = matrix of coefficients representing distribution of labor income to households
$\boldsymbol{E}$ = matrix of coefficients representing distribution of capital income to enterprise income
$\boldsymbol{Kh}$ = matrix of coefficients representing distribution of enterprise income to households
$\boldsymbol{C}$ = matrix of coefficients representing household consumption demand for commodities
$\boldsymbol{Th}$ = matrix of coefficients representing household payments of income tax to provincial government
$\boldsymbol{G}$ = matrix of provincial government demand coefficients

TR = matrix of coefficients representing provincial government transfers to households

The SAM model can be represented as:

$$\begin{bmatrix} X \\ VA \\ E \\ H \\ PG \end{bmatrix} = S \begin{bmatrix} X \\ VA \\ E \\ H \\ PG \end{bmatrix} + \begin{bmatrix} ex \\ ev \\ ee \\ eh \\ eg \end{bmatrix}$$

or

$$\begin{bmatrix} X \\ VA \\ E \\ H \\ PG \end{bmatrix} = \left(I - S \right)^{-1} \begin{bmatrix} ex \\ ev \\ ee \\ eh \\ eg \end{bmatrix} \quad (2)$$

where:

X = vector of industry regional output (endogenous)
VA = vector of total primary factor payments (endogenous)
E = vector of total enterprise earnings (endogenous)
H = vector of total household income (endogenous)
PG = total provincial government income or revenue (endogenous)
ex = vector of exogenous demand for provincial output
ev = vector of exogenous factor payments
ee = exogenous enterprise earnings
eh = vector of exogenous income to households
eg = exogenous income to provincial government including national government transfers and provincial government non-tax revenue
$(\mathbf{I–S})^{-1}$ = SAM multiplier matrix or matrix of SAM inverse coefficients.

The endogenous variables in the SAM model (Equation (2) above) include ***X***, ***VA***, ***E***, ***H***, and ***PG***. The exogenous variables are ***ex***, ***ev***, ***ee***, ***eh***, and ***eg***. The final demand vector ***ex*** has elements including investment demand, national government demand, and export demand. The elements of ***eg*** include the national government transfers to the regional government and non-tax revenue to the regional government.

4.2. Calculating impacts of exogenous change in production activities

Leontief demand-driven economic impact models (such as conventional IO and SAM models) have often been used to analyze the economic impacts of exogenous change in productive capacity or output. However, if these demand-driven models are used to estimate the economic impacts of exogenous change in productive capacity without any adjustment to the model, the models can generate biased results. This led to some studies (e.g., Leung and Pooley, 2002; Johnson and Kulshreshtha, 1982; Eiser and Roberts, 2002) using mixed endogenous-exogenous (MEE) model (Miller and Blair, 1985). These studies argue that an MEE model is more appropriate tool than a Leontief demand-driven model that can be used when the level of production activity is directly changed and the associated change in demand is not usually known.

In studies using MEE models (whether they are implemented within IO or SAM framework), the forward-linkage effects are ignored if the effects are negligible. The forward-linkage effects are sometimes estimated, if the effects are nontrivial, using the Ghosh approach (Ghosh, 1958) (e.g., Eiser and Roberts, 2002; Leung and Pooley, 2002). However, economists have criticized the Ghosh approach because of its serious theoretical problem. In particular, the approach has been criticized because the Ghosh model assumes that sales from industry *i* to industry *j* are proportional to the industry *i*'s output (i.e., fixed output allocation coefficient assumption). However, this assumption seems neither intuitive nor economically valid. More detailed discussion of the plausibility and implausibility of the approach, see Oosterhaven (1988, 1989), Dietzenbacher (1997, 2005), and De Mesnard (2009).

To overcome the weaknesses of the approaches above, some studies (e.g., Seung and Waters, 2013; Waters et al., 2014) used an adjusted demand-driven SAM model when calculating the economic impacts of exogenously altered level of productive capacity (e.g., seafood industry output in analysis of fisheries). The present study does not calculate the economic impacts from a specific fishery management policy, but rather attempts to measure the contribution of the seafood industries in the GN region. But these two problems (calculating economic impacts vs. measuring the contribution) are essentially the same problem with both requiring consideration of the backward and forward linkage effects when the initial shock is applied to a fish harvesting industry. Therefore, we utilize the adjusted-demand driven SAM approach in our study.

4.3. Adjusted demand-driven approach

To implement the adjusted demand-driven SAM model in our study, we (i) treat the base-year output levels for the directly impacted industries (wild capture and aquaculture industries) and their forward-linked industry (seafood processing industry) as exogenous, final demand shocks, and (ii) set to zero the RPCs for the outputs of all these industries, when we run our SAM model.[1] Note that we specify the base-year levels of these industries as exogenous, *before* running the model, and apply these levels as final demand shocks to the model.

With the RPC for the directly impacted industries set to zero, our model prevents the industries within the region from buying inputs from the directly impacted industries, and thereby effectively avoids the double-counting or biased results that are typically obtained when using Leontief demand-driven models. This means in our study that the zero RPC for a raw fish production industry (either wild fisheries or aquaculture) prevents the seafood processing industry from buying more raw fish from the fish production industry (arising from indirect and induced effects) than the amounts needed to achieve the specified direct shocks.

Within a single-region model (as in our GN SAM model), the zero RPC for a raw fish production industry *technically* means that the seafood processing industry's demand for the raw fish (which is used as an intermediate input in the processing industry) is met by the raw fish imported from outside of the region instead of being supplied by regional production. This technicality, however, is not relevant for the analysis because the model already incorporates the base-year level of output of the regional raw fish production industry into the direct impact vector.

Additionally, by specifying the output level of the forward-linked industry as exogenous and running the model with zero RPCs for this industry, we avoid the problem with the Ghosh approach. Because the output level of the forward-linked industry is exogenously specified as an initial shock before running the model, the analyst does not have to rely on the Ghosh model which suffers from its theoretical problem discussed above.

Setting RPCs for the directly impacted industries (seafood industries) to zero is equivalent to setting the row elements for the industries to zero in the *S* matrix above (matrix of direct SAM coefficients). For the other industries (non-seafood industries), we use the non-zero RPCs given by the original model. Therefore, demand by seafood industries for the inputs from these other industries is satisfied in the standard way by regional production and/or imports. For more details about the adjusted demand-driven modeling approach, see Seung and Waters (2013), Seung (2014), and Waters et al. (2014).

5. Data

To develop our GN SAM, we start with 30-sector multi-regional

[1] Tanjuakio et al. (1996) and Steinback (2004) are among the earlier studies that applied this approach. However, these studies used IO models while the present study uses a SAM model.

input-output (MRIO) data for 2013 (Bank of Korea, 2015) which contain transactions within each of sixteen regions (intra-regional transactions) and among different regions (multi-regional transactions) in Korea. We used the MRIO data as the source for the information on (i) inter-industry transactions, (ii) employee compensation, (iii) operations surplus, (iv) indirect business taxes paid by GN firms to the regional government (GN government) and the national government, and (v) trade flows among the sixteen provinces. We combine all non-GN regions into the rest of the world (ROW) which includes ROK and all foreign countries, and estimated the trade flows between GN and ROW based on the MRIO data.

The aggregate household sector in the MRIO data is divided into five different household sectors depending on income levels as defined in Household Income and Expenditure Survey (HIES, Statistics of Korea, 2014a) data for 2013. Specifically, we first split the whole household sector in the MRIO data for GN province into five different household sectors consistent with five different income levels in HIES data using the ratios estimated from the HIES data. Next, for each of the five different household sectors, we calculate the ratios of household expenditures on different commodities using the HIES data. Then, for each household sector, we multiply the household expenditure ratios thus obtained by the income of the household sector to derive the sector's expenditure on each commodity. Household savings are similarly estimated. We use the household savings rates for the five different household sectors derived from HIES data to estimate the each household sector's savings. Information on household tax payments to the national and regional governments is from the HIES data, National Tax Service Annual Report (NTSAR, National Tax Service of Korea, 2014, for 2013 data), and Annual Local Tax Statistics Report (ALTSR, Ministry of the Interior, 2014, for 2013 data).

For private investment data, we use the 2013 MRIO data. To calculate total government demand, we first combine government expenditure with government investment for each commodity in the MRIO data. Next, the single government sector in the MRIO data is split into two government sectors, the national government and the regional government. Here the regional government is combination of the provincial government and all the lower-level governments (e.g., Cities, *Kuns*). When allocating the total government demand for goods and services between the national and regional governments, we subtract the regional government expenditures, which are estimated based on the information from Jae-Jung-Go (http://lofin.moi.go.kr/portal/main.do), from the total government demand estimated above, to obtain the national government demand for goods and services. The data on the national government revenues (taxes) and expenditures on items other than goods and services purchased by the government (e.g., transfer payments) are estimated using NTSAR data. Regional government revenue and expenditure information is based on ALTSR and Jae-Jung-Go (http://lofin.moi.go.kr/portal/main.do), respectively.

The 30-sector MRIO data set does not have a separate fish harvesting industry and a fish processing industry. Therefore, we rely on 161-sector MRIO data set (for the same year) where these two industries are separately identified. However, the 161-sector version of the data does not identify the aquaculture industry as a separate industry. This makes us to use 2005 regional IO data for GN region which contain the two raw fish production industries (i.e., wild fisheries and aquaculture) as two separate industries. We apply the intermediate input use ratios for the two industries obtained from the 2005 data to the industries' base year (2013) revenues for GN region based on Fish Production Survey for 2013 (Statistics of Korea, 2014b). Using the 2005 information about the two raw fish producing industries' use of intermediate input ratios may produce some bias in the results from this study in which all the other data elements are for year 2013. However, since the production technology of the raw fish production industries does not seem to have changed drastically over the past 8-year period, the bias is not expected to be significantly large.

Using the data thus estimated as above, we construct GN SAM. The structure of the GN SAM is shown in Table A1 in Appendix A. When balancing the SAM, we adjust the elements in the exogenous accounts until the column sums equal the row sums.[2]

6. Results

To conduct the contribution analysis, we estimate the economic impacts that would occur if all the economic activities related to a raw fish producing industry (wild fisheries or aquaculture) suddenly ceased to occur. This is done within the model by computing the total impacts (direct, indirect, and induced) of *hypothetically* eliminating the whole wild-capture related activity (i.e., fish harvesting and processing activities) or the whole aquaculture-related activity (i.e., fish farming and processing activities). This approach involves giving demand shocks (equal in magnitudes to the baseline levels of outputs from a raw fish producing activity and the activity of processing the fish) to the model with RPCs set to zero for all seafood industries. An example that used this approach is Waters et al. (2014). This study quantifies the contribution of each of two different raw fish producing industries to the economy of GN province in terms of output, employment, value added, household income, and regional government revenue.[3]

Prior to carrying out the contribution analysis, this study first compares the production functions of the two alternative raw fish producing industries. Table 1 presents the top ten industries (determined by the SAM coefficients) that supply the largest amounts of inputs to wild capture industry and aquaculture, respectively. As shown in the table, aquaculture industry uses significantly different mix of intermediate inputs from that used in wild fisheries. For example, the top three backward-linked industries for wild fisheries are Wood, Paper, and Printing, Finance and Insurance, and Transportation while the top three industries for aquaculture are Textile and Leather Products, Agriculture and Forestry, and Finance and Insurance.[4] The stark difference in the production functions (or input mixes) between the two raw fish producing industries implies that the economic impacts of the two industries will be generated through considerably different paths, and potentially lead to different magnitudes of the impacts. For details on each seafood industry's purchase of intermediate inputs, see Table A2 in the appendix, which is from 2013 GN SAM.

[2] We chose this method of balancing the SAM over bi-proportional adjustment techniques (e.g., RAS technique). That is, we wanted to keep the original parameter values (e.g., production functions and other key behavioral and endogenous share parameters) implied in the SAM, but allowed the peripheral elements in the exogenous accounts to be adjust when necessary to balance row and column totals.

[3] In our study, the contribution of a raw fish producing industry to its backward-linked industries is calculated endogenously within the model. Similarly, the contribution of the seafood processing industry, which is an important downstream industry purchasing raw fish from the fish producing industry, to its backward-linked non-seafood industries is computed endogenously within the model with the baseline level of output of the seafood processing industry applied as a shock. For other downstream industries such as Food and Drinking and Food Services (restaurants) and Lodging, it is difficult to separate out that portion of the industries' sales which is attributable to seafood. In addition, it is likely that the reduction in seafood supply in these industries will be met by imports of seafood or by increased use of other types of meat such as beef and chicken. For these reasons, we assume that the gross revenues of these downstream industries do not change. Steinback and Thunberg (2006) adopted similar assumption.

[4] Examples of specific products supplied by Wood, Paper, and Printing industry to wild capture fisheries include wooden box for fish storage and transportation, wooden goods for fishing vessel, and so on. Examples of Transportation services for wild capture fisheries are land and sea transportation of caught and processed fish, etc. Products from Textile and Leather Products industry sold to aquaculture include netting of fish cage, etc. Agriculture and Forestry industry supplies products such as feed ingredient (soybean) for fish to aquaculture.

Table 1
Top ten backward-linked industries determined by the SAM coefficients.

Wild fisheries			Aquaculture		
Industry	SAM coefficients	ranking	Industry	SAM coefficients	ranking
Wood, paper, and printing	0.039103	1	Textile and leather products	0.033282	1
Finance and insurance	0.022427	2	Agriculture and forestry	0.025364	2
Transportation	0.021293	3	Finance and insurance	0.020186	3
Chemical products	0.016591	4	Electricity, gas, and steam	0.018159	4
Textile and leather products	0.015041	5	Wholesale and retail	0.013883	5
Machinery and equipment	0.010423	6	Chemical products	0.013829	6
Agriculture and forestry	0.009832	7	Health and social services	0.007443	7
Business support	0.009199	8	Food and drinking	0.007359	8
Wild capture fishery	0.007513	9	Transportation	0.005428	9
Transport equipment	0.007375	10	Wood, paper, and printing	0.003381	10

Next, the SAM multipliers are computed with zero and non-zero RPCs for seafood industries, respectively (Table 2). In the present study, multiplier is defined as the change in a variable (total provincial output, total employee compensation, total business surplus, total household income, or total provincial government revenue) occurring when the output (or final demand in case of non-zero RPCs) of a seafood industry (wild capture, aquaculture, or seafood processing industry) changes by one unit. Table 2 shows that the SAM total output multipliers with non-zero RPCs for the two raw fish producing industries are 1.442 and 1.413, respectively, for wild capture and aquaculture. With zero RPCs, the multipliers are only slightly smaller – 1.430 and 1.406, respectively. Results indicate, however, that the total output multiplier for seafood processing with zero RPCs (1.251) is substantially smaller than that computed with non-zero RPCs (1.547). This result is obtained because the total output multiplier with zero RPCs (1.251) accounts for the backward-linkage effects on non-seafood industries only, excluding the backward-linkage effects on the raw fish producing industries to avoid the double-counting problem discussed above, whereas the multiplier with the non-zero RPCs (1.547) takes into account the backward-linkage effects on both the raw fish producing industries and non-seafood industries.

Similar results are obtained for the multipliers for the other variables (Table 2). As an example, the SAM multipliers for total employee compensation with non-zero RPCs (0.377 and 0.187, respectively, for wild capture and aquaculture) are only slightly larger than those calculated with zero RPCs (0.374 and 0.186, respectively), whereas the employee compensation multiplier for seafood processing industry with non-zero RPCs (0.182) is much larger than that calculated with zero RPCs (0.117).

Comparing the contributions of the two raw fish producing industries computed with zero RPCs, the contribution per unit (i.e., one KRW) of wild-caught fish to the GN economy is larger than that of farm-raised fish. One KRW's output in wild capture fisheries generates 1.430 KRWs in the total GN output while one KRW's output in aquaculture produces slightly smaller total provincial output, 1.406 KRWs. It is noteworthy that wild capture fisheries have much larger contribution (per unit output) to total employee compensation than aquaculture (0.374 vs. 0.186), but have much smaller contribution to the total business surplus compared to aquaculture industry (0.150 vs. 0.438).

This study also computes the total output multipliers for the three seafood industries from an IO-version of the model where only production industries are endogenous (last row, Table 2). The IO-based multipliers are much smaller, 1.236, 1.211, and 1.427, respectively, for the three seafood industries, when compared to the SAM multipliers obtained with non-zero RPCs.

Table 3 presents the results for the contributions to the GN economy with respect to several different economic variables. The contribution of wild fisheries to the total industry output in the province is estimated to be 1,106,926 (in million KRWs)[5] (second column) while the contribution of aquaculture to the output is less than half of the contribution of wild fisheries (472,604 million KRWs). This result is not surprising because the raw fish production from wild fisheries is much larger than the farm-raised production in the base year (774,142 million KRWs vs. 336,033 million KRWs). The total contributions of the two raw fish producing industries to total regional employment are, respectively, 8,453 and 3,911 (in FTEs).

The contribution of wild fisheries to total employee compensation in the province (289,229 million KRWs) is more than three times larger than the aquaculture's contribution to the same variable (62,602 million KRWs). One obvious reason is the substantial difference in the base-year output levels of the two industries. Another reason is that the employee compensation per worker in wild capture fisheries is significantly larger than in aquaculture (34.2 million KRW vs. 16.0 million KRW per year). As mentioned above, a policy change encouraging an expansion of farm-raised fish production but discouraging wild fisheries will reduce the total labor income in the province. It is also worth noting that the contribution of aquaculture to total business surplus (147,336 million KRWs) is larger than that of wild capture (116,481 million KRWs), although the base-year level of output of aquaculture (336,033 million KRWs) is much smaller than that of wild fisheries (774,142 million KRWs).

The combined wild capture sector (fish harvesting and processing, Table 3, Column 6) and the combined aquaculture sector (fish farming and processing, Column 7) contribute, respectively, 2,893,579 million KRWs and 863,594 million KRWs to the total industry output. These are equivalent to 1.11% and 0.33%, respectively, of the base-year level of total provincial industry output. The contributions of the two combined sectors to total regional employment are 16,403 FTEs and 5,651 FTEs, respectively, for wild capture and aquaculture. The contributions to

Table 2
SAM multipliers with non-zero and zero RPCs and IO multipliers.

	Wild capture	aquaculture	Processing
SAM multipliers with non-zero RPCs			
Total provincial output	1.442	1.413	1.547
Total employee compensation	0.377	0.187	0.182
Total business surplus	0.152	0.440	0.112
Total household income	0.470	0.451	0.252
Provincial government revenue	0.035	0.035	0.033
SAM multipliers with zero RPCs			
Total provincial output	1.430	1.406	1.251
Total employee compensation	0.374	0.186	0.117
Total business surplus	0.150	0.438	0.073
Total household income	0.466	0.449	0.162
Provincial government revenue	0.034	0.035	0.025
IO multipliers			
Total provincial output	1.236	1.211	1.427

[5] Yearly average exchange rate (KRW/dollar) for 2013 was 1,143 KRW per dollar. (https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates). Applying this rate, the contribution of wild fisheries in 2013 is estimated to be $968.4 million.

Table 3
Economic Contributions of Wild Capture Fisheries and Aquaculture (million KRWs for all non-employment variables; FTEs for employment).

	Raw fish production		Fish processing		Raw fish production plus processing	
	Wild capture	Aquaculture	Wild capture	Aquaculture	Wild capture	Aquaculture
Base-year level of output	774,142	336,033	1,428,113	312,528	2,202,255	648,561
Contribution to GN's Economy						
Total industry output	1,106,926	472,604	1,786,653	390,990	2,893,579	863,594
Total employment (FTEs)	8,453	3,911	7,950	1,740	16,403	5,651
Total employee compensation	289,229	62,602	166,526	36,443	455,755	99,045
Total business surplus	116,481	147,336	103,872	22,731	220,353	170,067
Household income						
Household 1	17,792	8,735	12,148	2,659	29,940	11,394
Household 2	45,932	20,959	30,166	6,602	76,098	27,561
Household 3	65,391	29,384	42,614	9,326	108,006	38,710
Household 4	89,266	37,030	57,105	12,497	146,371	49,527
Household 5	142,454	54,769	89,692	19,628	232,146	74,398
TOTAL HOUSEHOLD INCOME	360,834	150,878	231,726	50,711	592,560	201,589
Regional gov't revenue	26,663	11,595	36,380	7,961	63,043	19,556

total regional household income are 592,560 million KRWs and 201,589 million KRWs, respectively.

Table 4 presents the contributions of the seafood industries to the outputs of the individual industries in the province whereas Table 5 shows similar information for employment. Table 6 summarizes the information in Tables 4 and 5 Finance and Insurance is the top non-seafood industry to which both wild fisheries and aquaculture make the largest contributions. The contributions of the two raw fish production industries to the non-seafood industry output are 35,770 million KRWs and 14,270 million KRWs, respectively (Table 4).

The next four non-seafood industries that benefit most from wild fisheries are Wood, Paper, and Printing, Transportation, Real Estate and Leasing, and Health and Social Services. In contrast, the next four non-seafood industries for aquaculture are Agriculture and Forestry, Textile and Leather Products, Electricity, Gas, and Steam, and Health and Social Services.

Three of the top five industries (Finance and Insurance, Wood, Paper, and Printing, and Transportation) to which wild capture fisheries make the biggest contributions (Table 6), are also included in the list of top ten backward-linked industries for the wild capture fisheries (Table 1). In other words, the three industries supplying the largest amounts (in KRWs) of inputs to wild capture industry (Table 1) are also among the industries that gain most from wild fisheries when direct, indirect, and induced contributions are accounted for (Table 6). Although two industries, Chemical Products and Textile and Leather Products, are among the top five industries that supply the largest amounts of inputs

Table 4
Contributions to industry output (million KRWs).

	Harvesting		Processing		Harvesting and processing	
	Wild capture	Aquaculture	Wild capture	Aquaculture	Wild capture	Aquaculture
Agriculture and forestry	13,553	11,846	5,802	1,270	19,355	13,116
Wild capture fishery	774,142	–	–	–	774,142	–
Aquaculture	–	336,033	–	–	–	336,033
Mining	56	26	479	105	536	131
Food and drinking	9,678	6,899	11,202	2,451	20,880	9,351
Seafood processing	–	–	1,428,113	312,528	1,428,113	312,528
Textile and leather products	12,548	11,698	1,350	296	13,898	11,994
Wood, Paper, Printing	33,065	1,629	8,486	1,857	41,551	3,486
Coal and petroleum products	478	120	313	69	791	188
Chemical products	15,616	5,689	17,420	3,812	33,036	9,501
Non-metallic mineral products	806	364	1,082	237	1,888	601
Primary metal products	1,103	329	1,938	424	3,042	753
Metal products	2,633	1,007	26,198	5,733	28,831	6,740
Machinery and equipment	10,717	1,498	9,975	2,183	20,692	3,681
Electric and electronic equipment	5,700	1,347	3,830	838	9,530	2,185
Precision instruments	854	154	553	121	1,407	275
Transport equipment	7,514	1,732	2,303	504	9,817	2,236
Other manufacturing	2,175	863	18,739	4,101	20,914	4,964
Electricity, gas, and steam	14,703	11,515	24,938	5,457	39,641	16,973
Water supply, sewerage, and waste mgt.	4,088	1,842	8,124	1,778	12,212	3,620
Construction	4,505	2,537	6,079	1,330	10,583	3,868
Wholesale and retail	11,616	7,289	33,967	7,433	45,583	14,723
Transportation	23,650	4,459	41,172	9,010	64,822	13,469
Food service and lodging	12,254	5,086	11,595	2,537	23,849	7,624
Telecommunications and broadcasting	9,292	4,724	11,249	2,462	20,542	7,186
Finance and insurance	35,770	14,270	22,256	4,871	58,026	19,140
Real estate and leasing	21,599	7,720	14,694	3,216	36,292	10,936
Professional, scientific, and tech. serv.	6,942	1,929	9,057	1,982	15,999	3,911
Business support	11,371	1,711	13,268	2,904	24,639	4,615
Public administration and defense	7,137	3,100	9,718	2,127	16,855	5,226
Educational services	17,406	7,334	12,943	2,832	30,349	10,166
Health and Social Services	18,161	9,880	15,030	3,289	33,190	13,169
Cultural and other services	17,794	7,974	14,779	3,234	32,574	11,208
TOTAL	1,106,926	472,604	1,786,653	390,990	2,893,579	863,594

Table 5
Contributions to industry employment (FTEs).

	Harvesting		Processing		Harvesting and processing	
	Wild capture	Aquaculture	Wild capture	Aquaculture	Wild capture	Aquaculture
Agriculture and forestry	435	380	186	41	622	421
Wild capture fishery	4,832	–	–	–	4,832	–
Aquaculture	–	2,293	–	–	–	2,293
Mining	0	0	1	0	1	0
Food and drinking	25	17	28	6	53	24
Seafood processing	–	–	4,054	887	4,054	887
Textile and leather products	58	54	6	1	64	55
Wood, Paper, Printing	121	6	31	7	152	13
Coal and petroleum products	1	0	0	0	1	0
Chemical products	43	16	48	11	92	26
Non-metallic mineral products	3	1	4	1	6	2
Primary metal products	2	1	3	1	5	1
Metal products	5	2	54	12	59	14
Machinery and equipment	26	4	25	5	51	9
Electric and electronic equipment	13	3	9	2	22	5
Precision instruments	2	0	2	0	4	1
Transport equipment	15	3	5	1	19	4
Other manufacturing	10	4	86	19	96	23
Electricity, gas, and steam	7	5	11	3	18	8
Water supply, sewerage, and waste mgt.	16	7	31	7	47	14
Construction	35	20	48	10	83	30
Wholesale and retail	247	155	721	158	968	313
Transportation	410	77	714	156	1,125	234
Food service and lodging	238	99	226	49	464	148
Telecommunications and broadcasting	52	26	62	14	114	40
Finance and insurance	279	111	173	38	452	149
Real estate and leasing	157	56	107	23	263	79
Professional, scientific, and tech. serv.	76	21	99	22	175	43
Business support	253	38	296	65	549	103
Public administration and defense	70	30	95	21	165	51
Educational services	268	113	199	44	467	156
Health and Social Services	303	165	251	55	554	220
Cultural and other services	451	202	374	82	825	284
TOTAL	8,453	3,911	7,950	1,740	16,403	5,651

Table 6
Top five non-seafood industries benefiting from wild fisheries and aquaculture.

Harvesting		Processing		Harvesting and processing	
Wild capture	Aquaculture	Wild capture	Aquaculture	Wild capture	Aquaculture
Output					
Finance and Insurance	Finance and Insurance	Transportation	Transportation	Transportation	Finance and Insurance
Wood, Paper, Printing	Agriculture and Forestry	Wholesale and Retail	Wholesale and Retail	Finance and Insurance	Electricity, Gas, and Steam
Transportation	Textile and Leather Products	Metal Products	Metal Products	Wholesale and Retail	Wholesale and Retail
Real Estate and Leasing	Electricity, Gas, and Steam	Electricity, Gas, and Steam	Electricity, Gas, and Steam	Wood, Paper, Printing	Transportation
Health and Social Services	Health and Social Services	Finance and Insurance	Finance and Insurance	Electricity, Gas, and Steam	Health and Social Services
Employment					
Cultural and Other Services	Agriculture and Forestry	Wholesale and Retail	Wholesale and Retail	Transportation	Agriculture and Forestry
Agricultural and Forestry	Cultural and Other Services	Transportation	Transportation	Wholesale and Retail	Wholesale and Retail
Transportation	Health and Social Services	Cultural and Other Services	Cultural and Other Services	Cultural and Other Services	Cultural and Other Services
Health and Social Services	Wholesale and Retail	Business Support	Business Support	Agriculture and Forestry	Transportation
Finance and Insurance	Educational Services	Health and Social Services	Health and Social Services	Health and Social Services	Health and Social Services

to wild capture industry (Table 1), they are not among the top five beneficiaries (Table 6) of the wild capture industry, taking account of direct, indirect, and induced effects. Instead, the Real Estate and Leasing and Health and Social Services (Table 6) are in the list of the top five industries gaining most from wild fisheries.

In addition to Finance and Insurance, Health and Social Services is included in the lists of the top five non-seafood industries for both wild fisheries and aquaculture (Tables 4 and 6). This result is in contrast to the finding that Health and Social Services is not in the list of top ten industries supplying the largest quantities of inputs to the wild capture fisheries, and is ranked seventh in the list of top ten industries for aquaculture (Table 1).

Table 4 also shows that Transportation and Wholesale and Retail are the top two primary beneficiaries of the existence of the seafood processing industry (see also Table 6). These industries are followed by Metal Products, Electricity, Gas, and Steam, and Finance and Insurance. The top two non-seafood industries to which the combined wild capture sector (harvesting and processing) makes the largest contribution are Transportation and Finance and Insurance (Column 5, Table 6) whereas the top two industries for the combined aquaculture sector (fish farming and processing) are Finance and Insurance and Electricity, Gas, and Steam (the last column, Table 6). Four non-seafood industries (Transportation, Finance and Insurance, Wholesale and Retail, and Electricity, Gas, and Steam) are included in the two lists of the top five non-seafood industries for the combined wild capture sector and the combined aquaculture sector (the last two columns, Table 6).

Comparing the results in Tables 4 and 5, one can see that contributions of seafood industries to non-seafood industries can be different depending on which variables (output vs. employment) are used. A non-seafood industry may benefit most in terms of output from the existence of a seafood industry, but the same industry may not necessarily be the industry that receives the largest benefit, in terms of employment, from the seafood industry. As shown in Table 6, in case of wild capture fisheries, the top five industries determined based on output level are Finance and Insurance, Wood, Paper, and Printing, Transportation, Real Estate and Leasing, and Health and Social Services while the top five industries with respect to employment generation are Cultural and Other Services, Agricultural and Forestry, Transportation, Health and Social Services, and Finance and Insurance.

7. Discussion

This study found that the contribution per unit of output of wild capture fisheries to the total employee compensation in GN province is significantly larger than that of aquaculture (Table 2). Fishery managers and provincial policy-makers, who are concerned with the income of the workers in the GN industries, may find this finding useful in their decision-making. For instance, suppose that they implement a policy that reduces the allowable fish harvest in wild fisheries due to a low level of the fish stock, and encourages instead an increase in production of farmed fish in the province, equal in quantity to the amount of fish reduced in wild fisheries. In this case, they may want to know that the policy change will lower total labor income substantially in the GN economy. However, this policy change will not lower the total household income by a large magnitude in the province. The reason is that the contributions of the two raw fish producing industries to total household income are not significantly different from each other (0.466 vs. 0.449, Table 2).

The large divergence in seafood processing industry multipliers obtained from the two approaches (i.e., with and without zero RPCs) is worth further discussion (Table 2). The processing industry multipliers calculated with non-zero RPCs include the effects on all non-seafood processing industries (i.e., the two raw fish producing industries and all the non-seafood industries such as Finance and Insurance) as well as the direct effect on the seafood processing industry. Compared to these multipliers, the multipliers estimated with zero RPCs do not include the effects on the two raw fish producing industries. Thus, all the zero-RPC-based multipliers for the processing industry in Table 2 measure the total effects of the processing industry on the non-seafood industries only. In addition to avoiding the double counting problem mentioned above, the zero-RPC-based multipliers will be able to answer the question of how much a new fish processing plant in the province will contribute to the growth of non-seafood industry sector as a whole in the province.

This study clearly showed that the IO-based multipliers underestimate the economic impact or contribution of the seafood industries, due to IO models' ignoring the distributional effects on the non-industry endogenous sectors (value added, households, and provincial government) and the ensuing induced effects generated by the additional expenditures made by the non-industry endogenous sectors. Nevertheless, many previous studies rely on IO models to measure the economic contribution of seafood industries and provide results that understate the importance of these industries (or the economic impacts of a fishery management policy). If the policy-makers are provided with the extent of the economic contribution evaluated within an IO framework, their decisions may be distorted.

Finance and Insurance is not the top backward-linked industry that provides the largest amount of input (in value) to the two raw fish producing industries (Table 1). But the same industry gains most from the two fish producing industries (Table 4). This means that the industry, although not the top backward-linked industry, plays a critical role in the sense that the multiplier effects originating from a fish production industry transpire through a myriad of different paths, many of which go through Finance and Insurance.[6]

The two raw fish production industries do not purchase a significant amount of input directly from Health and Social Services (Table 1). But the contributions of these two fish producing industries to Health and Social Services are immense, when the direct, indirect, and induced effects are accounted for. This result points to the importance of using a SAM model. Health and Social Services is an important expenditure item for households, whose income consists mainly of employee compensation and business surplus from the two fish production industries and non-seafood industries. An IO model cannot compute the effects of the change in the factor income from a change in an industry activity (here, fish harvesting or fish farming) on household income, and its subsequent effects on household expenditures on goods and services, including Health and Social Services. Our SAM model captures these effects.

From the perspective of direct input provision (Table 1), the direct effects of the two fish production industries on some non-seafood industries (e.g., Chemical Products in case of wild fisheries) are strong (Table 1). But the total effects (direct, indirect, and induced effects) of the fish production industries on these same industries are not as strong. On the contrary, Real Estate and Leasing and Health and Social Services are not shown to be important input providers to the fish production industries, but are among the top five industries that the two fish production industries have the largest multiplier effects. If fishery managers are given only the information on the direct input use (Table 1) or the multipliers from an IO model, they may not be able to identify those non-seafood industries on which the fish production industries have the largest multiplier effects. Results point out that the industries (such as Real Estate and Leasing and Health and Social Services), which are ostensibly unrelated to the fish production industries, can be identified neither from direct SAM coefficients in Table 1 nor from an IO model.

It is notable that Cultural and Other Services is among the top five industries that receive the largest benefit, in terms of employment, from the two fish production industries. In case of processing, Business Support industry is ranked fourth in the list (Table 6). The large contributions of the fish production industries to these two non-seafood industries are explained by the base year data. The base year data shows that, for the two non-seafood industries, the ratios of employment to total output are, respectively, the second (Cultural and Other Services) and the third (Business Support) highest among the 30 industries in the model; Cultural and Other Services and Business Support hire, respectively, 0.025 FTEs and 0.022 FTEs per one million KRW's worth of output. Since these two non-seafood industries play a vital role in changing the total provincial employment when there is a change in fishery management policy, both fishery managers and provincial policy makers may want to pay attention to these non-seafood industries.

8. Conclusion

Wild-caught fish has been an important food source for people around the world. The limited supply of wild-caught fish, however, cannot be able to meet the fast increasing human demand for fish due to the rapidly increasing human population. As an alternative that meets the increasing demand, the fish farming has grown in many countries including Korea. One of the concerns of fishery managers and policy-makers is the extent of the economic contribution that fish farming will make to a country or a region. They may also want to compare the relative contributions of wild fisheries and fish farming. A number of previous studies examined the importance of wild capture and

[6] Analysis identifying the different paths (connecting different poles or industries in an economy) through which economic impacts occur is called structural path analysis (SPA). See, for example, Defourny and Thorbecke (1984).

aquaculture to a national or a regional economy using an IO model. However, no studies have measured the relative contributions of the two fish producing industries using a SAM model. The present study filled this void. The present study developed a SAM model for GN province in Korea, accounting for the distributional effects of seafood industries, and used an approach that avoids the double-counting problem with conventional Leontief demand-driven model and the problem with the Ghosh approach.

This study found that the contribution of *the whole* wild fisheries industry to the total provincial output is substantially larger than that of *the whole* aquaculture industry because of the enormous difference in the base-year output levels of the two industries. On the other hand, this study found that the contribution *per unit* (i.e., one KRW) of output from wild capture fisheries is only slightly larger than that of aquaculture. In contrast, the contributions of raw fish producing activity to total employee compensation and total business surplus in the province are dramatically different between the two fish producing industries. Wild capture fisheries have a far larger contribution per unit of output (KRW) to total regional employee compensation, but have much smaller contribution (per unit of output) to the total regional business surplus, compared to aquaculture.

An interesting result is that the contribution of aquaculture to total business surplus (capital income) is larger than that of wild capture, although the base-year level of output from aquaculture is much smaller than that of wild fisheries. This is so whether the contribution is measured in terms of the total regional output from a raw fish production industry or is gauged per unit of output from the industry. The contributions of the combined wild capture sector (harvesting and processing) and the combined aquaculture sector (fish farming and processing) to total regional output are about 1.11% and 0.33%, respectively, of the base-year level of total regional output.

This study also found that, among the non-seafood industries, Finance and Insurance is the top beneficiary of the existence of each of the two raw fish producing industries. Other non-seafood industries that gain most include Wood, Paper, and Printing and Transportation (for wild fisheries) and Agriculture and Forestry and Textile and Leather Products (for aquaculture). Transportation, Finance and Insurance, Wholesale and Retail, and Electricity, Gas, and Steam are among the top five industries to which the combined wild capture sector and the combined aquaculture sector make the biggest contributions.

While the expansion of farm-raised fish production has met a large fraction of increasing demand for fish, and generated positive economic impacts, it has brought about negative consequences on environment, contaminating seawaters. This may have resulted in an adverse impact on the level of wild fish stock available for both commercial wild capture fisheries and sport angling in some areas. Additionally, the expansion of aquaculture may have had economic effects on the market for raw fish where the aquaculture industry competes with the wild fisheries. One such effect is the lowered fish prices due to an increased supply of fish from aquaculture, which benefits the consumers of the fish. It appears that the effects of increased farm-raised fish supply on the price of wild-caught fish vary among different species. Additionally, economists have not reached any consensus yet regarding the responses of the fish market to increased supply of farm-raised fish. While these issues are important, they are beyond the scope of the present study.

One of the limitations of this study is that the single-region SAM model used in this study does not account for a large portion of the contributions that occur in non-GN regions. Base-year data indicate that GN region relies to a large extent on the economies of other regions, implying that the contributions of GN seafood industries are not limited to the GN region. Therefore, a future study can take account of these multiregional contributions using a multi-regional SAM model such as the one in Waters et al. (2014).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocecoaman.2019.105072.

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