

On macroeconomic impact of fishing effort regulation: Measuring bottom-up fish harvesters' economy-wide contribution

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Abstract: Capture fisheries contribute vitally to the coastal or island fisheries economy, not only directly, but also by their influence on the rest of the economy. An increase or decrease in fish capture can produce an economy-wide multiplier effect through fish production chains and sector linkages - and a better understanding of these multiplier effects can aid fisheries management and policy making. This research proposes a fish chain and sector linkage approach to structurally identify the role of capture fisheries in the fisheries economy. Combining input-output techniques and industrial evolutionary theory, we develop a new input-output model to quantify the economy-wide impact of capture fisheries on the fisheries economy. The method regards capture fisheries to be the “carrier branches” whose products, the fish, are the “core inputs” that can drive the other fisheries sectors in the Ghosh supply-driven input-output model. These fisheries sectors all are linked with the rest of the economy and can affect it through backward linkage in the Leontief demand-driven input-output model. An application of the method to the fisheries in the Gulf of Thailand is made to measure impact multipliers of capture fisheries on the rest of the economy, analyze impact of regulation on fishing effort, and identify the economic importance of fisheries.

Key words: Capture fisheries, fish chain, sector linkage, input-output modeling, macroeconomic impact

JEL classifications: C68, O13, Q22, Q56, Q57

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Introduction

Capture fisheries have historically been an important contributor to the coastal or island economy, particularly in developing countries, but currently concerns are expressed about the overexploitation of important fish stocks and the industry's sustainability. In order to reconcile short-run economic benefit, resource conservation, and fisheries sustainability, fisheries management and policy making need to identify heterogeneous fish harvesters' different economic contribution so that current fishing practices can be better justified and regulated.

The harvesters are bottom-up fish producers whose economic contribution is traditionally assessed in term of the value added, particularly profit or rent, generated at microeconomic level. Typically, the fisheries economics takes harvesters' individual profit or private rent as economic goal and maximizes it to analyze bio-economic interactions between harvester's fishing behaviour, stock regulator and one or two commercially important species (Gordon, 1954; Shaeffer, 1957; Clark and Munro, 1975; Bjørndal and Conrad, 1987). While this tradition allows clear focus on particular fisheries issues, mainly on efficient utilization of commercial fish stocks, it limits itself in the partial equilibrium analysis of capture fisheries only and thus loses insights into macroeconomic consequence (Failler and Pan, 2007).

Recently, as fisheries regulation moves towards alleviating social and ecological problems, there is a growing need to assess the full impact of the regulation on the economy in a scope much beyond the fisher's profit or rent. In this sense, the full economic contribution of capture fisheries, or more specifically the economy-wide value added induced by fish harvesting activity, needs to be understood and measured. By theories on economic structure and linkage, the economic contribution of capture fisheries lies not only in the industry itself, but also, perhaps more importantly, in its effects on secondary activities such as fish processing and fish marketing, and in its indirect impact upon non-fisheries sectors. Although there is no official data directly showing these spreading effects, some studies estimate that, for example, globally each employment in capture fisheries and aquaculture production can bring about four employments in the secondary activities in the whole fisheries industry (FAO, 2008). In Béné (2005), small-scale fisheries sector can typically contribute around 0.5–2.5% of GDP in developing countries where fisheries are a significant sector.

In the economics literature, the disaggregate computable general equilibrium (CGE) models are a popular tool to empirically conduct economy-wide analysis, as these are able to summarize the full structural responses of the economy to a change in an economic component like capture fisheries. However, the CGE models are dependent upon the restrictive constraints of standard neoclassical economic theory, involve complicated construction procedures, and have not yet been widely used in fisheries economic analysis (Pan, Failler and Floros, 2007). A conventional alternative to the CGE models is the input-output method. This describes the general quantitative interdependence of an economic system and has the simplicity in mathematics and operation.

Seung and Waters (2006) and Placenti (2001) reviewed the input-output methods used for fisheries management in the U.S and in Europe respectively. The majority of the applications date from the 1970s and 1980s in the US and up to the late 1990s in Europe. They were all based on the traditional Leontief demand-driven input-output model, where final demands in the fisheries sectors were taken as exogenous variables driving the input-output economic system. Following input-output analysis, these researches normally can account three types of effects of fishing activity, namely direct, open-complete and closed-complete effect. The direct effect is measured in term of the value added directly contributed by fish harvesting activity, which basically also is classical fisheries economists' primary interest – individual profit or private rent. The open-complete effect is measured in term of the value added generated in all sectors due to their response to the demand or supply of capture fisheries. This effect is modelled in standard Leontief demand-driven input-output model and captured through the Leontief inverse, which measures total direct and indirect impacts of a change in final demands on total outputs of the sectors. The closed-complete effect is measured in term of the value added generated in all sectors due to their response to the demand or supply of capture fisheries as well as response to the change in household consumption induced by income generation. This effect is modelled in extended Leontief demand-driven input-output model, where household consumption is transformed from exogenous to endogenous variables, and captured through the extended Leontief inverse that measures total direct, indirect and induced impacts of a change in final demands (excluding household consumption) on total outputs of the sectors.

The economy-wide impact analysis of capture fisheries based on the demand-driven input-output models now has become unsatisfactory, partly because of its inconsistency with fisheries regulation schemes. Conventionally, fisheries regulation focuses on supply side controls with a

variety of regulatory instruments such as gear and fleet control, entry limitation, seasonal closing, capacity buy-back, total allowed catch (TAC), individual transferable quota (ITQ), marine protect area (MPA), etc. While the TAC or ITQ targets at output control, majority of the others target at fishing effort control.

Considering allocated quotas on catch of some important species, recent researches tend to use an “output supply-driven” input-output method to measure the economic impact of catch or quota regulations on capture fisheries. The “output supply-driven” method typically partitions the input-output structure into two blocks, one representing the fisheries under output control and another representing the rest of the economy driven by conventional final demands. In the model the final demands of the fisheries block are endogenous and the final demands of the rest block are often assumed to be zero in order to separate the impact of fisheries output control. The model is not completely based on either the Leontief or the Ghosh model¹, but it relies on the Leontief production or the Ghosh allocating coefficients to measure backward or forward linkage effects, respectively (Cai and Leung, 2004).

The “output supply-driven” method was initially proposed to study impacts of different farm types in agriculture (Johnson and Kulshreshtha, 1982). Leung and Pooley (2002) and Cai et al. (2005) adopted the method to study the economic linkage impact of the longline fisheries in Hawaii. At the same time in Europe, within the PECHDEV project, a group of researchers in France, United Kingdom, Denmark, Italy and Spain extended the analysis from input-output into a SAM (Social Accounting Matrix) framework in order to measure the regional economic consequences of coastal ecosystem changes (Failler 2004). In that context, Fernandez-Macho et al. (2008) used the SAM of the Region of Galicia (one of the main fishing region in Europe) to measure the economic impacts of TAC regulation of hake on the regional economy. The advantage of their research is that it internalized the income distribution, consumption and employment factors. Seung and Waters (2009) subsequently followed the approach of Fernandez-Macho et al. (2008) in studying the economic linkages of Alaska fisheries.

In contrast to the traditional interest of fisheries economics in microeconomic consequence of fishing effort regulation and the recent applications of the “output supply-driven” method for macroeconomic impact of fish output regulation, there is a gap in studying macroeconomic impact of fishing effort regulation. In this paper, we attempt to fill in this gap by developing a

method to measure the economy-wide impact of fishing effort control. Combining input-output techniques with industrial evolutionary theory, we take capture fisheries as the “carrier sector”, which produces the “core inputs” - the fish - that constitutes one of the fundamental forces driving the fisheries economy. Instead of using exogenous fisheries outputs, we follow the Ghosh supply-driven model and take primary inputs in capture fisheries as exogenous driving variables. By this method, the forward linkage impact of capture fisheries on the other fisheries sectors can be measured. We view the non-fisheries sector to be the backward linkage sector of the fisheries sector and employ the Leontief demand-driven model to measure the backward linkage impact of the fisheries sector on the non-fisheries sector. Thus, the model developed in this research is a combination of the Ghosh supply-driven model and the Leontief demand-driven model.

This paper is organised as follows. Section 2 discusses the structure of a fisheries economy, based on a fish chain and sector linkage approach. Section 3 deals with methodological issues, discussing the existing studies in the area - and then presents the proposed model. Section 4 provides an application of the model to the Thai fisheries in the Gulf of Thailand. Finally, Section 5 concludes.

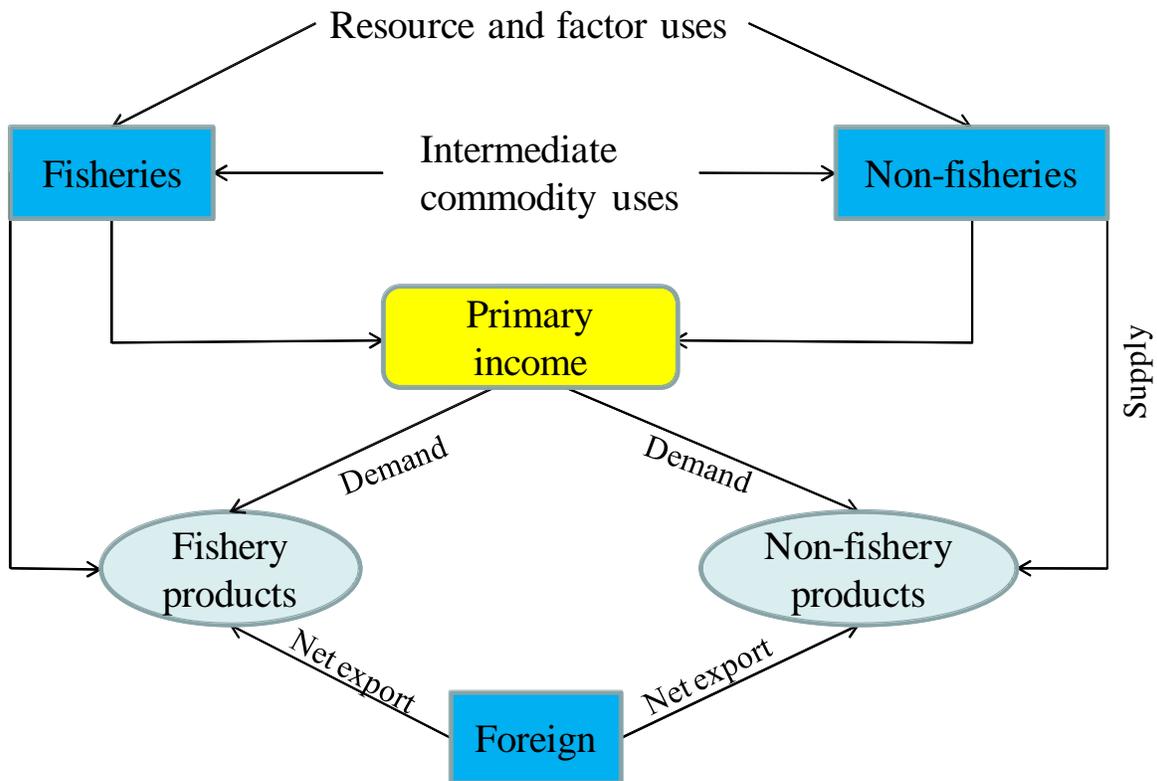
1. The structure of a fisheries economy: a fish chain and sector linkage approach

A fisheries economy basically refers to the coastal or small island economy in which the fisheries sector constitutes a base industry and where changes therein could have dramatic implications for the whole economy (Agnarson and Arnason, 2007). Nowadays, as the relative importance (in terms of GDP, employment, contribution to exports etc.) of the marine fisheries industry is diminishing in developed countries, the ‘fisheries economy’ mainly refers to the coastal or small island economies in developing countries where reliance on the fisheries remains strong. Figure 1 depicts the macroeconomic structure of a fisheries economy where the fisheries sector is treated separately in parallel to the rest of the economy, as well as to the foreign economy. Both fisheries and non-fisheries sectors require resource, factor and commodity inputs to produce fisheries and non-fisheries products, respectively. The direct link between the fisheries and non-fisheries sector is the intermediate commodity use. While production in the fisheries sector clearly needs to use non-fisheries product inputs such as food, tools, energy, etc., fisheries products are also needed in production of some non-fisheries sectors such as animal

feeding, the food industry, the pharmaceutical industry, etc. Fish products are normally final products for human consumption.

In input-output literature on industrial linkages, sectors are interlinked each other; a sector is referred to be the backward linkage (or upstream) sector of another if its product is used in another sector's production – with the sector that uses its product referred to be its forward linkage (or downstream) sector (Hirschman, 1958). By this definition, a sector can be another sector's backward or forward linkage sector (or both). The sectors that have larger than average linkage indices are referred as the “key sectors” (Hazari, 1970; Schulz, 1977). This approach relies largely on the quantitative data showing industrial interrelationships (typically the input-output coefficients), but ignores the real causal relationship behind the numbers. In real cases, a sector can affect another but may not, in turn, be affected by change in the other. According to industrial evolutionary theory (Perez, 1983; Freeman and Luca, 2001), different sectors may play different roles in industrial formation and development; there are some “core inputs” that trigger industrial evolution and the sectors producing these core inputs are the “carrier sectors or branches”. Thus, only the “carrier sectors” can affect the sectors that use the “core inputs” and not vice versa.

Figure 1 Macroeconomic structure of fishery economy



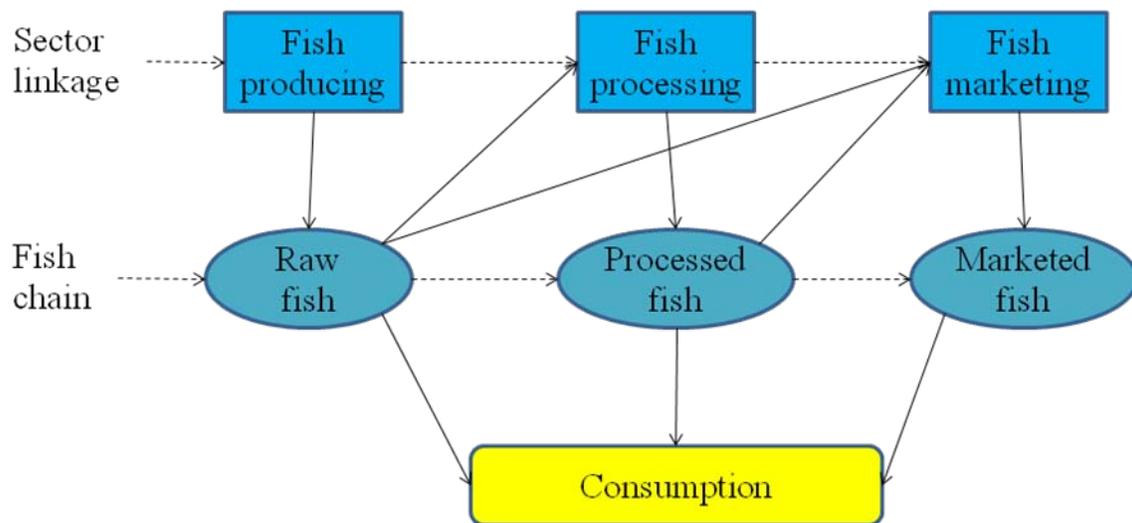
In the case of fisheries, Figure 1 shows that fisheries affect the rest of the economy in three main ways. First, fisheries require the direct use of intermediate non-fisheries products and thus stimulate the rest of the economy, by creating a backward linkage effect. Second fisheries provide employment and generate primary income, which in turn finances consumption and investment, and thus indirectly stimulates the rest of the economy by creating a base-sector effect. Finally, fisheries products can be exported and thus increase local export revenues by creating a trade effect.

Fisheries production may be stimulated in the demand side - intermediate demand of non-fisheries sectors and final demand of consumers for fisheries products. However, fisheries are a primary industry that depends basically on the aquatic resources available or the abundance of certain fish stocks, its production cannot be fully flexible to meet whatever demands for fish, and most of current fisheries regulation set out stock constraints for fisheries production. Thus, it is

better to view that the current fisheries practices are principally determined in supply side, depending on situation of fish stocks.

Within fisheries industry, fisheries constitute a number of sub-sectors such as fish producing, processing and marketing. These sectors are linked through their products, with Figure 2 illustrating the linkage among the fisheries sub-sectors and the fish chain flows among different fish products for human consumption. Fish production includes capture fisheries and aquaculture – and the products are raw and fresh fish part of which will directly go to households for consumption, part of which will go to the fish market for sale, and the rest of which will go to the fish processing sub-sector for processing. Following the industrial evolutionary theory, we can regard the raw and fresh fish to be the “core inputs” of the fish processing and marketing sub-sectors, and so we can regard capture fisheries and aquaculture as the “carrier sectors or branches”. Fish processing produces processed fish part of which will directly go to households for consumption, part of which will go to the fish marketing sub-sector for sale. Finally, raw and/or fresh and/or processed fish will be supplied to the consumers.

Figure 2 The structure of fishery industry



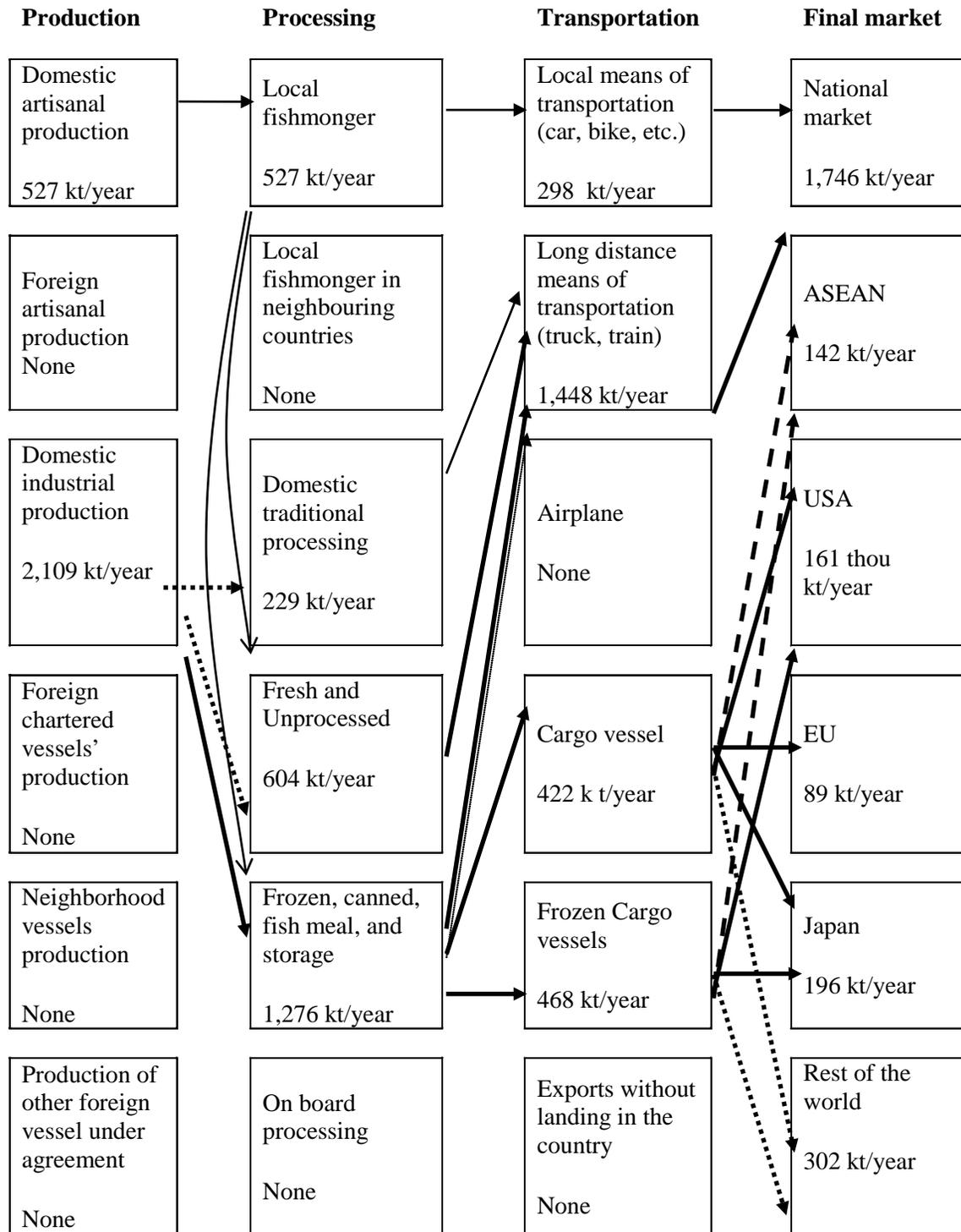
The analysis above reveals that the fish producing sub-sector drives the whole fisheries sector through its forward linkages with the other fisheries sub-sectors. Figure 2 shows that the fish processing sub-sector is the forward linkage sector for the fish producing sub-sector, while the fish marketing sub-sector is both the forward linkage sub-sector for the fish producing and

processing sub-sectors. As the fish passes from one sub-sector to another, they are transformed from raw and fresh to processed, and to marketed fish.

The fisheries sub-sectors can be further disaggregated. The capture fisheries can be subdivided by type of fish harvesters, for example artisanal and industrial harvesters, by scale, by type of boat and/or gear, or by metier, a combination of boat, gear and targeted species; while aquaculture firms can be distinguished by size and/or the species they farm. Within the fish processing sub-sector, fish processing firms can be divided according to processing methods used such as frozen, smoking, canned, salted, etc. Finally, the fish marketing sub-sector can be split into different types of traders such as international traders, wholesalers, fishmongers/retailers, or into different sales chains, or into domestic, regional and international destinations, etc. In reality, the linkages among the different fisheries sub-sectors can be complex, as Figure 3 shows in the case of the Gulf of Thailand fisheries sector (ECOST, 2009).

The flow chart describes the process of fish going from production to process and to distribution. Since there is not any foreign fleet fishing in Thai waters, about 80% of the total landings come from domestic industrial/commercial fisheries. For the 20% domestic artisanal landings, most of them are for local consumption and traditional processing (fish sauce, salted, steamed/smoked, shrimp paste and others including fish ball/cracker). These catches are sold through local fish mongers. About one-third of commercial catches directly go to domestic consumer markets through long-distance transportation, and the rest go to processing sector. Over 50% of commercial catches are frozen and canned and mainly for exported through cargo vessels or long distance transportation. Over 10% of commercial catches are sold to domestic markets after traditional processing.

Figure 3 Thai fish chain and fishery linkage in 2004 (live weight equivalent)



2. Methodology

Consider a fisheries economy with a general economic structure that includes a fish harvesting sector (fh) which consists of n harvesters, a fish processing sector (fp), a fish marketing sector (fm), and a non-fisheries sector (nf). Following fisheries economic theory, fish harvesters make production decisions based on fishing effort, which can be represented in various terms within primary inputs. Assume that fish harvesters' production follows the Ghosh supply-driven model, where exogenous primary inputs determine total inputs (through the Ghosh intermediate allocating coefficients). Then the supply and demand balances of the harvesting products are as follows

$$B_{n,j} \cdot X_j + a_{n,nf} \cdot X_{nf} + V_n = X_n, \quad j \in (n, fp, fm) \quad (1)$$

where j indicates fisheries sectors, $B_{n,j}$ is a parameter matrix of the Ghosh intermediate allocating coefficients with elements $b_{n,j}$ that states the proportion of sector j 's product allocated to harvester n , X_j is a column vector of all economic sectors' inputs, $a_{n,nf}$ is the Leontief intermediate use coefficients that states the proportion of non-fisheries sector's product used by harvester n for fishing, X_j is a column vector of all economic sectors' inputs, V_n is a column vector of exogenous primary inputs or value added of harvesters, and X_n is a column vector of endogenous total inputs of harvesters that equal the sum of intermediate inputs plus primary inputs or value added.

The primary input of the fish processing sector depends on the amount of fish harvested. The more raw and fresh fish that needs to be processed, the more primary inputs that are needed in the fish processing sector. As a result, the production of the fish processing sector will also follow the Ghosh supply-driven model with the following supply and demand balance:

$$B_{fp,j} \cdot X_j + a_{fp,nf} \cdot X_{nf} + V_{fp} = X_{fp} \quad (2)$$

where $B_{fp,j}$ is a row vector of the Ghosh intermediate allocating coefficients of all fisheries sectors for the fish processing sector. Its element $b_{fp,j}$ indicates the proportion of sector j 's product allocated to the fish processing sector (reflecting the forward linkage effect). $a_{fp,nf}$ is the Leontief intermediate use coefficient indicating the proportion of non-fisheries sector's product

used by fish processing. The primary input or value added of the sector is endogenously determined through the ‘pushing’ effect of capture fisheries.

The primary input of the fish marketing sector depends on both the amount of fish harvested and processed. The more raw or processed fish that needs to be distributed in the market, the more the primary input needed in the fish marketing sector. As a result, the production of the fish marketing sector also follows the Ghosh supply-driven model, with the following supply and demand balance:

$$B_{fm,j} \cdot X_j + a_{fm,nf} \cdot X_{nf} + V_{fm} = X_{fm} \quad (3)$$

where $B_{fm,j}$ is a row vector of the Ghosh intermediate allocating coefficients of all sectors for the fish marketing sector. Its element $b_{fm,j}$ indicates the proportion of sector j 's product allocated to the fish marketing sector (reflecting the forward linkage effect). $a_{fm,nf}$ is the Leontief intermediate use coefficient indicating the proportion of non-fisheries sector's product used by fish marketing. The primary input or value added of the sector is endogenously determined through the ‘pushing’ effect of both fish harvesting and fish processing.

Contrary to the supply-driven fisheries sectors, the non-fisheries sector is demand-driven. It must meet both the intermediate requirements of the fisheries sectors and the final demand of society. The production of the non-fisheries sector follows the Leontief demand-driven model and has the following material balance:

$$A_{nf,j} \cdot X_j + a_{nf,nf} \cdot X_{nf} + D_{nf} = X_{nf} \quad (4)$$

where $A_{nf,j}$ is a row vector of the Leontief intermediate use coefficients of the non-fisheries sector. Its element $a_{nf,j}$ indicates the proportion of the non-fisheries sector's product used in fisheries sector j 's production (reflecting the backward linkage effect). $a_{nf,nf}$ is the Leontief intermediate use coefficient indicating the proportion of non-fisheries sector's use of its own product. D_{nf} is exogenous final demand for non-fisheries product. The first and second items on the left hand side of this equation describe the total intermediate demand by the fisheries sectors for products from the non-fisheries sector, while the third item is total final demand by fisheries society for non-fisheries products.

The value added generated by the fish processing sector is ‘pushed’ by the harvesting sub-sector:

$$c_{fp} \cdot BA_{fp,j} \cdot X_j = V_{fp} \quad (5)$$

where c_{fp} is the ratio of value added to total core input in the fish processing sector, representing the effect of per unit core input use on value added generation. $BA_{fp,j}$ is a row vector of the Ghosh intermediate allocating coefficients of fish harvesters for the fish processing sector. It differs from $B_{fp,j}$ in that its elements $b_{fp,fp}$, $b_{fp,fm}$ and $b_{fp,nf}$ are all zero.

The value added generated by the fish marketing sector is ‘pushed’ by both the fish harvesting and fish processing sub-sectors:

$$c_{fm} \cdot BA_{fm,j} \cdot X_j = V_{fm} \quad (6)$$

where c_{fm} is the ratio of value added to total core input in the fish marketing sector, representing the effect of per unit of core input use on value added generation. $BA_{fm,j}$ is a row vector of the Ghosh intermediate allocating coefficients of the fish harvesting and fish processing sectors. It differs from $B_{fm,j}$ in that its elements of $b_{fm,fp}$ and $b_{fm,nf}$ are all zero.

Since the non-fisheries production follows the Leontief demand model, its value added will be determined endogenously by total output or input:

$$v_{nf} \cdot X_{nf} = V_{nf} \quad (7)$$

where v_{nf} represents the share of value added in total input in the non-fisheries sector.

Finally all sectors’ value added should be summed to produce total economy-wide value added, which is equivalent to the total final demand of society and normally called GDP.

$$\sum_j V_j + V_{nf} = V \quad (8)$$

Combining equations (1) - (8), and let A , Y and X denote coefficients matrix, exogenous and endogenous variable vectors, respectively, a consolidated matrix presentation of them is obtained:

$$A \cdot X + V = X \quad (9)$$

with

$$A = \begin{pmatrix} B_{j,j} & A_{j,nf} & I_{j,8} \\ A_{nf,j} & a_{nf,nf} & O_{nf,8} \\ O_{n,j} & O_{n,nf} & O_{n,8} \\ BA_{fp,j} & O_{fp,nf} & O_{fp,8} \\ BA_{fm,j} & O_{fm,nf} & O_{fm,8} \\ O_{1,j} & v_{1,nf} & O_{1,8} \\ O_{1,j} & O_{1,nf} & V_{1,8} \end{pmatrix}, X = \begin{pmatrix} X_j \\ X_{nf} \\ O_4 \\ V_{fp} \\ V_{fm} \\ V_{nf} \\ V \end{pmatrix} \text{ and } Y = \begin{pmatrix} V_n \\ O_2 \\ D_{nf} \\ O_7 \\ \sum_n V_n \end{pmatrix}$$

where

$$B_{j,j} = \begin{pmatrix} B_{n,j} \\ B_{fp,j} \\ B_{fm,j} \end{pmatrix}, A_{j,nf} = \begin{pmatrix} A_{n,nf} \\ A_{fp,nf} \\ A_{fm,nf} \end{pmatrix}, V_{1,8} = (0, 0, 0, 0, 1, 1, 1, 0), \text{ and}$$

$$I_{j,8} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

The solution of this linear equation system can be solved with

$$X = (I - A)^{-1} \cdot Y \quad (10)$$

This equation describes an economic system where exogenous primary inputs of fish harvesting (or fishing effort in the terminology of fisheries economics) determines fish production, these acting as core inputs to generate value added in the (linkage sectors) fish processing, fish trading and non-fisheries sectors. In addition, the overall value added generated in the fisheries sectors will be linked to the total final demand of fisheries society. Thus, an overall economic effect - that includes both production and consumption side effects of capture fisheries - can be obtained.

3. An application to the fisheries in the Gulf of Thailand

The fisheries sector plays an important role in the Thai economy. It directly contributes about 2% of GDP to the economy. Fishing grounds within Thailand's EEZ are located in the Gulf of Thailand (GoT) and in the Andaman Sea. Thai fisheries like other tropical fisheries are multi-fleet, multi-gears and multi-species. Main fleets can be grouped into eight groups; i.e. trawlers, purse seiners, gill netters, falling netters, other mobile netters, hook and liners, stationary fishing, and miscellaneous. In 2004 total catches exceeded eight billion US\$, about half of that was value added, among which total catches by trawlers accounted for 63% while those of purse seiners were 29%, and those by other fleets were 8%. Total number of registered vessels was 16,432, of which 39% or 6,439 vessels were trawlers and 10% purse seiners or 1,699 vessels. Other fishing vessels in the rest six fleets are small comparing to these two.

In trawler fleet, there are three fishing gears i.e. otter board trawl, pair trawl, and beam trawl. For the otter-board trawl, small otter-board trawl being 18m and less long, had a limited capacity and cannot fish outside Thai waters, thus fish mainly in Thai waters. This fishing gear is the most important gear in Thai fisheries. Larger otter-board trawls could fish outside Thai waters. Pair trawls are usually larger commercial fishing gear. Most of them have been fishing outside Thai fishing grounds. Beam trawl is small fishing gear. Some of them used to be small otter board trawl, suffering from fishing loss thus turned into beam trawl. For purse seiner fleet there are two main gears: purse seines targeting at various pelagic fish and anchovy purse seines specifically fish for anchovy. Most of purse seines are large fishing vessels and some have been fishing outside Thai waters. Anchovy purse seine fishes only in Thai fishing grounds. Gill netter fleet uses various types of gill nets such as king mackerel gill net, Indo-Pacific mackerel encircling gill net, crab gill net, shrimp gill net, squid trammel net, Indo-Pacific mackerel gill net, mullet gill net, and other gill nets. Falling netter fleet uses two main gears i.e. squid falling net and anchovy falling net. These are light luring nets. Other mobile netter fleet consists of cast net, acetes scoop net, lift net, other net, and push net. There are two main gears in hook and liner fleet, i.e. long line and hand line/ pole line. For stationary fishing fleet, the gears are set bag net, fish trap, crab trap, squid trap, shrimp trap, ivory shell trap, and bamboo stake trap. These gears are usually for small scale fishing. In 2004 catches by these fishing gears are as follows: otter board trawl catches accounted for 52%, followed by 23% purse seine catches, 11% pair trawl catches, and 6% anchovy purse seine catches. Catches by other fishing gears accounted for 1% or less.

Recently total marine catches has been around two and a half million ton annually in Thailand. More than two third are from the Gulf of Thailand and the rest from the Andaman Sea. Thai fisheries in the Gulf of Thailand covers an area of approximately 304000 km² and accounted for 53% of total catch value and 69% of total catch volume in 2004. The catches included 33% pelagic fish (mainly anchovies, Indo-Pacific mackerel, sardine and scad), 18% demersal fish (mainly big-eyes, threadfin breams, lizard fish and crocker), 7% food fish, 29% trash fish, 3% shrimp, 2% crabs, 6% squid and cuttlefish, and 1% mollusks. While 29% of the harvested was trash fish, the next highest volume was anchovies (6%). The leading catch volume has been pelagic fish (33%), followed by trash fish (29%) and demersal fish (18%). Other catches such as other food fish, squid and cuttlefish, shrimp, crab, mollusc and other (mainly jellyfish) are small volume. Due to over fishing and fisheries resource degradation, the catches have been stagnant. Fisheries resource degradation especially in the Gulf of Thailand has resulted in lower fishing effort in the Gulf. Large vessels of 18 meter long and over have been fishing in non-Thai fishing ground, in nearby coastal states and others including EEZ of those coastal states along Indian Ocean Coastlines and the Atlantic Ocean in the south.

The multiple dimensions of Thai fisheries in terms of fleet, gear and species create numerous heterogeneous fishing activities. Laloe (2009) summarized Thai fisheries into a number of metiers in the Pech Diagram (Pech et al, 2001). Following their work, we define a harvesting metier or a harvester to be a particular fleet equipped with a particular gear and targeting a particular species as main catch, although other species may be ensnared as by-catch. For convenience, we focus on the two most typical metiers or harvesters employed in the Gulf of Thailand – “Otter board trawler” and “Anchovy purse seiner” – to study, and categorise all the other vessel and gear types as “Other harvesters”.

Trawler is the main fishing fleet in Thailand. Otter board trawl is the main fishing gear in this fleet as well as in Thailand. In term of total registered vessels, otter board trawl shared 30%. In term of catch in the Gulf of Thailand otter board trawl shared 44%, highest among the fishing gears in Thailand. Otter board trawl is a demersal fishing gear. 36% of the catches are demersal fish (mainly big eyes, threadfin bream, lizard fish, crocker, red snapper, and ray). 33% are trash fish including low quality catches not for human consumption and juveniles of economic species caught as by catches. 10% are pelagic fish (mainly Indo-pacific mackerel, king mackerel, and

trevally) 9% are cephalopod (mainly squid and cuttlefish), 7% other food fish, 4% shrimp, and 1% crab.

Purse seiner is the main fishing fleet for pelagic catches. Fishing gears in this fleet are purse seines for various pelagic fish and anchovy purse seine targeted only for anchovy, thus using fine mesh size to catch small fish. Among pelagic catches by this fleet, anchovy catch is the highest. In 2004, it was 129 thousand tons or about 22% of purse seiner catches from the Gulf of Thailand. Other catches by purse seines are other 15 pelagic species and other food fish. Anchovy catches from the fishing ground other than Gulf of Thailand was only 24 thousand tons in 2004. Thus the main fishing ground for anchovy is the Gulf of Thailand.

In order to connect the metiers with macroeconomic structure, we combine fisheries data, national accounting data and input-output table for Thailand in 2004 to compile a compact input-output table with details of the fisheries sector (Table 1). It can be seen from the table that capture fisheries in the Gulf of Thailand contribute 0.077% of GDP, slightly higher than the share (0.069%) from capture fisheries in areas other than the Gulf of Thailand and from aquaculture. The fish processing and fish trading sectors contribute 4.36% and 4.71% to GDP, respectively, while the non-fisheries sector contributes nearly 90% of GDP. The shares of total output are similar to the GDP shares, suggesting that the capture fisheries sector in the Gulf of Thailand (and indeed elsewhere) contribute only negligibly to the Thai national economy. However, when the sector's linkage effects are considered, we see fisheries exerting a more important role in the economy. Fish processing and trading sectors completely depend on capture fisheries and aquaculture and each of them contributes nearly 5% of GDP, reflecting multiplier effect of fisheries.

Table 1 Thai input-output table: Fisheries (2004).

Transposed Thai Input-output table (million US\$ at 2004 price)	Otter board trawler	Anchovy purse seiner	Other harvesters	Other fishing	Fish processing	Fish trading	Non-fishery	Sum of intermediate use	Value added	Total input	Share of value added (%)
Otter board trawler in GOT	0	0	0	7	7	0	53	67	67	133	0.02%
Anchovy purse seiner in GOT	0	0	0	1	1	0	12	15	15	29	0.01%
Other harvesters in GOT	0	0	0	205	205	0	1641	2051	2051	4102	0.74%
Other fishing	0	0	0	191	191	0	1532	1915	1915	3830	0.69%
Fish processing	80	1	2225	2549	1214	0	6070	12140	12140	24280	4.36%
Fish trading	19	10	558	626	12950	0	12889	27052	13111	40164	4.71%
Non-fishery	0	0	0	0	0	0	244888	244888	249117	494004	89.48%
Sum of intermediate product	99	11	2784	3581	14568	0	267084	288127	278415	566542	100.00%
Final product	34	18	1318	249	9712	40164	226920	278415			
Total output	133	29	4102	3830	24280	40164	494004	566542			
Output share (%)	0.02%	0.01%	0.72%	0.68%	4.29%	7.09%	87.20%	100.00%			

In empirics, besides BAU case we design 12 scenarios to examine how different levels of fishing effort would affect the economy. In scenarios 1-4 each scenario assumes fishing effort of each of the four harvesters to be increased by one million US\$ and measures corresponding changes in value added in fish processing, fish trading and non-fisheries sectors. The results would reveal multiplier effect of fishing effort on those sectors. Scenarios 5-8 consider impact of fishing regulation on the economy and each of them assumes fishing effort of each harvester to be reduced by 10%. Scenarios 9-12 explore extreme cases when fisheries are completely removed out of the economy. This would reveal economic importance of fisheries.

Table 2 and 3 show the resulted value added of 12 scenarios in value and percentage, respectively. It is clear from scenarios 1-4 in Table 2 that a one million dollar increase in the primary input of Otter board trawler in GoT will induce a nearly three million dollar increase in primary inputs for fish processing, a three million dollar increase in primary inputs for fish marketing, and a five million dollar increase in primary inputs for the non-fisheries sector. In total it can contribute about 12 million dollar to GDP. In terms of employment, one employment in Otter board trawler can generate around three employments in each of the fish processing and fish marketing sectors, and five employments in the non-fisheries sector. Overall, it can generate a multiplier effect of 12 jobs economy-wide. Anchovy purse seiner operations in the GoT has the smallest multiplier effect – 3.5, other harvesters in GoT have a similar multiplier effect to that of the Otter board trawler; while other fishing activities (aquaculture and fishing outside the Gulf of Thailand) has the largest multiplier effect - 15. In each case, the backward linkage effect on non-fisheries sector is larger than the forward linkage effect on fish processing and trading probably because the backward linkage effect combines all effects of fish harvesting, processing and trading as well as society's final demand. Table 3 shows that a one million dollar increase in fishing effort of each capture fisheries in GoT will affect GDP negligibly.

Table 2 Scenario analysis on impact of fishing effort regulation on the Thai economy (value)

Changes in value added (million US\$ at 2004 price)	Exogenous change in value added				Endogenous change in value added			Change in GDP
	Otter board trawler in GOT	Anchovy purse seiner in GOT	Other harvesters in GOT	Other fishing	Fish processing	Fish trading	Non-fishery	
Scenario 1	1.00	0.00	0.00	0.00	2.76	2.97	5.03	11.75
Scenario 2	0.00	1.00	0.00	0.00	0.22	0.75	1.52	3.48
Scenario 3	0.00	0.00	1.00	0.00	2.49	2.69	4.61	10.78
Scenario 4	0.00	0.00	0.00	1.00	3.58	3.86	6.47	14.91
Scenario 5	-6.65	0.00	0.00	0.00	-18.34	-19.74	-33.45	-78.19
Scenario 6	0.00	-1.46	0.00	0.00	-0.32	-1.09	-2.21	-5.07
Scenario 7	0.00	0.00	-205.08	0.00	-509.95	-550.91	-945.61	-2211.55
Scenario 8	0.00	0.00	0.00	-191.48	-685.41	-739.41	-1238.36	-2854.66
Scenario 9	-66.54	0.00	0.00	0.00	-183	-197	-335	-782
Scenario 10	0.00	-14.56	0.00	0.00	-3	-11	-22	-51
Scenario 11	-66.54	-14.56	-2050.81	0.00	-5286	-5717	-9813	-22948
Scenario 12	-66.54	-14.56	-2050.81	-1914.82	-12140	-13111	-22196	-51495

Scenarios 5-8 in Table 2 show that 10% limitation in fishing effort of each harvester will result in multiplier reduction in fish processing, fish trading and non-fisheries sectors. Table 3 shows that 10% limitation in fishing effort of Otter board trawler in GoT will reduce GDP by 0.03%, the effect from Anchovy purse seiner is negligible, the effect from the other harvester in GoT by 0.8%, and the effect from other fishing by 1%.

What would happen if some of harvesters are completely removed from action? Scenario 9 in Tables 2 and 3 tells that if Otter board trawler ceases all operation, it will induce a loss in value added in fish processing, fish trading and non-fisheries sectors by 0.15%, 0.15% and 0.13%, respectively. Overall, it will result in 0.28% loss in GDP. In scenario 10 if Anchovy purse seiner ceases all operation, its effects on value added will be very little. The losses are 0.03%, 0.08% and 0.03% for fish processing, fish trading and non-fisheries sectors, respectively. And, GDP loss will be only 0.02%. However, in scenario 11 when all fisheries in GoT are assumed to take inaction, fish processing and trading sectors will be affected mostly, losing value added by over 43% each. Impact on non-fisheries sector will be relatively small, slightly less than 4%. Startlingly, GDP will get lost by over 8%. In the most extreme case, scenario 12, if all Thai fisheries are assumed to be moved out of the economy, both fish processing and trading sectors will correspondingly cease all operation, and non-fisheries sector's value added will be lost by nearly 9%. Most startlingly, GDP will get lost by over 18.5%. This indicates the ultimate economic importance of fisheries industry in Thailand.

Table 3 Scenario analysis on impact of fishing effort regulation on the Thai economy (%)

Changes in value added (%)	Exogenous change in value added				Endogenous change in value added			Change in GDP
	Otter board trawler in GOT	Anchovy purse seiner in GOT	Other harvesters in GOT	Other fishing	Fish processing	Fish trading	Non-fishery	
Scenario 1	1.50%	0	0	0	0.023%	0.023%	0.002%	0.004%
Scenario 2	0	6.87%	0	0	0.002%	0.006%	0.001%	0.001%
Scenario 3	0	0	0.05%	0	0.020%	0.020%	0.002%	0.004%
Scenario 4	0	0	0	0.05%	0.029%	0.029%	0.003%	0.005%
Scenario 5	-10%	0	0	0	-0.15%	-0.15%	-0.01%	-0.03%
Scenario 6	0	-10%	0	0	0.00%	-0.01%	0.00%	0.00%
Scenario 7	0	0	-10%	0	-4.20%	-4.20%	-0.38%	-0.79%
Scenario 8	0	0	0	-10%	-5.65%	-5.64%	-0.50%	-1.03%
Scenario 9	-100%	0	0	0	-1.51%	-1.51%	-0.13%	-0.28%
Scenario 10	0	-100%	0	0	-0.03%	-0.08%	-0.01%	-0.02%
Scenario 11	-100%	-100%	-100%	0	-43.54%	-43.61%	-3.94%	-8.24%
Scenario 12	-100%	-100%	-100%	-100%	-100.00%	-100.00%	-8.91%	-18.50%

4. Conclusion

This research bridges the gap between fisheries microeconomic regulation and its macroeconomic impact. It has elaborated the sector linkage between fisheries and non-fisheries sectors and the fish chain from harvesting to processing and marketing fisheries to connect bottom-up capture fisheries to top-down economic structure. Based on this approach a new input-output linkage model has been developed to measure the multiplier effect of a change in fishing effort of bottom-up harvesters on the whole economy. By the fact that fisheries sector is a primary industry whose production critically depends on aquatic resource, we use industrial evolutionary theory to qualitatively specify causal relationships among the sectors and define that fisheries sectors follow the Ghosh supply-driven model and non-fisheries sector follows the Leontief demand-driven model. This differs greatly from conventional input-output linkage models where interrelationships among sectors are mechanically identified completely relying on input-output account data. We believe in this way the economy-wide impact of capture fisheries can be better measured.

The model innovatively combines both the Ghosh supply-driven mode and the Leontief demand-driven model into a unique model framework. To our knowledge this appears new in input-output economics literature. The model is constructed in concise and operational mathematical format and to be readily applied with qualitative specification on industrial interrelations and moderate data requirement on a fisheries input-output table. However, because the required table normally does not exist, one needs to insert fisheries microeconomic data into formally published input-output table to compile it. This involves a considerable effort in disaggregating the fisheries sector, connecting it to the other economic accounts, and making all consistencies.

The empirical findings based on the Thai fisheries confirm other literature's results that capture fisheries normally have a multiplier effect on fish processing and trading sectors by 4. However, our results also reveal that capture fisheries make a much greater contribution to the economy than is traditionally thought. Specifically one million US\$ increase in fishing effort of most fisheries can bring about as many as ten times of the value in GDP. On the other hand, if particular fisheries such as Otter board trawler and Anchovy purse seiner are regulated to protect fish stocks, the economic loses will not be considerably high, unless the whole fisheries industry is removed out of the economy where GDP will drop by one-fifth.

The present research may be carried out further in several directions. One suggestion is to study dynamic change in impact multipliers of capture fisheries in response to change in fish stock so that fisheries can be managed efficiently and effectively. Another direction may be to analyse the economic respond of better fishing practices and policies that put up front the quality of the fish instead of the quantity and the value addition along the fish chain. In that way, it can be possible to extend considerably the economic outcomes of the fisheries and their impact on the economy.

References

- Agnarson and Arnason, 2007. The role of the fishing industry in the Icelandic economy, in Bjorndal et al (eds), *Advances in fisheries economics*. Blackwell Publishing.
- Bjorndal, T. and J. Conrad, 1987. Capital dynamics in the North Sea herring fishery. *Marine Resource Economics* 4(1), 63–74.
- Cai, J. and P. Leung, 2004. Linkage measures: a revisit and a suggested alternative. *Economic System Research* 16, 65–85.
- Cai, J., Leung, P., Pan, M., Pooley, S., 2005. Economic linkage impacts of Hawaii's Longline Fishing Regulations. *Fisheries Research* 74, 232–242.
- Cella, G., 1984. The input-output measurement of inter-industry linkages. *Oxford Bulletin of Economics and Statistics* 46, 73–84.
- Chenery, H. and Watanabe, T., 1958. International Comparisons of the Structure of Production. *Econometrica*, No. 4, pp. 487-521.
- Clark, C. and G. Munro, 1975. The economics of fishing and modern capital theory: a simplified approach. *Journal of Environmental Economics and Management* 2, 96-106.
- Dietzenbacher, E. and M. Lahr, 2009. *Expanding Extractions*, draft.
- Failler P. (ed.), 2001. *Research orientations for the development of new tools and models to evaluate the contribution of aquaculture and fishing activities to the development of coastal areas and their socio-economic interactions with other sectors*. European Union Accompanying measure n°Q5AM-2000-00076 A X E S, 171 p.
- Failler P. (ed.), 2003. *Assessment Method Reviews; Economics, Ecology and Biology Frameworks; Regional expectancies; Case Study Presentations*. PECHDEV Report n° 1, European Union Research Project QLRT-2000-02277, CEMARE, University of Portsmouth, UK, pp. 40-82.
- Failler, P. (ed.), 2004. *Static CGEM, biological model and SAM presentations*. PECHDEV Report N. 2, European Union Research Project QLRT-2000-02277, CEMARE, University of Portsmouth, UK. 231p.

- Failler P. and H. Pan, 2007. *A Computable General Equilibrium (CGE) Model in Fisheries: Policy Analysis with Evidence from Five European Regions*. Final Scientific Report, EU Funded RTD Project QLRT-2000-02277 PECHDEV, 72 p.
- Fernandez-Macho, J., C. Gallastegui, and P. Gonzalez, 2008. Economic impacts of TAC Regulation: a supply-driven SAM approach. *Fisheries Research* 90, 225–234.
- Gordon, H. (1954). The economic theory of a common-property resource: the fishery. *Journal of Political Economy*, 62, pp. 124-42.
- Goulding I., et al, 2000. *Regional Socio-economic Studies on Employment and the Level of Dependency on Fishing Lot*. No.23: Coordination and Consolidation Study, Final Report, European Commission,
- Ghosh, A., 1958. Input-output approach to an allocation system. *Economica* 25, 58-64.
- Gruver, G., 1989. On the plausibility of supply-driven input-output model: a theoretical basis for input-coefficient change. *Journal of Regional Science* 29, 441-450.
- Hirschman, A., 1958. *The Strategy of Economic Development*. New Haven: Yale University Press.
- Johnson, T. and Kulshreshtah, S., 1982. Exogenizing Agriculture in an Input-Output Model to Estimate Relative Impact of Different Farm Types. *Western Journal of Agricultural Economics*, 7,187-198.
- Laleo, F., 2009. *Conceptual model of the ecosystem-society interactions*. ECOST project report D2.3, www.ecostproject.org.
- Leontief, W., 1941. *The Structure of American Economy, 1919–1929*. Harvard University Press, Cambridge, MA.
- Leontief, W. et al, 1953. *Studies in the structure of the American economy*. Oxford University Press.
- Leung, P. and S. Pooley, 2002. Regional economic impacts of reductions in fisheries production: a supply-driven approach. *Marine Resource Economics* 16, 251–262.
- Miller, R. and P. Blair, 1985. *Input-Output Analysis: Foundations and Extensions*. Englewoods Cliffs, New Jersey: Prentice-Hall.

- Miller, R. and M. Lahr, 2001. A taxonomy of extractions, in M. Lahr and R. Miller (eds), *Regional science perspectives in economic analysis* (Amsterdam: Elsevier Science), pp. 407-441.
- Oosterhaven, J., 1988. On the plausibility of the supply-driven input-output model. *Journal of Regional Science* 28, 203-217.
- Pan, H., 2006. Dynamic and endogenous change of input–output structure under specific layers of technology. *Structural Change and Economic Dynamics* 17 (2), 200–223.
- Pan, H., P. Failler and C. Floros, 2007. A regional computable general equilibrium model for fisheries. CEMARE Research Paper P163, 46 p.
<http://www.port.ac.uk/research/cemare/publications/researchpapers>
- Pech, N. et al, 2001. Fitting a model of flexible multifleet–multispecies fisheries to Senegalese artisanal fishery data. *Aquatic Living Resource* 14, 81-98.
- Placenti V., 2003. Input/output method presentation, in Failler, P. (eds), *Assessment Method Reviews; Economics, Ecology and Biology Frameworks; Regional expectancies; Case Study Presentations*, Report n° 1, European Union Research Project QLRT-2000-02277, CEMARE, University of Portsmouth, UK, pp. 40-82.
- Schaefer, M., 1957. Some considerations of population dynamics and economics in relation to the management of the commercial marine fisheries. *Journal of the Fisheries Research Board of Canada*, 14, pp. 669-81.
- Seung, C. and E. Waters, 2009. Measuring the economic linkage of Alaska fisheries: A supply-driven social accounting matrix (SDSAM) approach *Fisheries Research* 97, 17–23.
- Seung, C. and E. Waters, 2006. A review of regional economic models for fisheries management in the U.S. *Marine Resource Economics* 21 (1), 101–124.
- Ten Raa, T., 2005. *The economics of input-output analysis*. Cambridge University Press.

¹ The Ghosh supply-driven input-output model is constructed in a way completely reversing the Leontief demand-driven input-output model, originally developed by Ghosh (1958).