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The Role of the Marine Sector in the Irish National Economy: An Input-Output Analysis

Karyn Morrissey and Cathal O'Donoghue

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Abstract

Recent research in Ireland has estimated both the national and regional economic value of the marine sector. However, economic activity does not exist in a vacuum. Activities in the marine sector not only directly affect the industries in the sector but also influence other sectors through inter-sectoral linkages. This paper uses an Input-Output (IO) methodology to examine the linkages and production effects of the Irish marine sector on the national economy. Disaggregating the Irish IO table for 2007 to include ten additional marine sectors, this paper represents the first effort to quantify the inter-industry linkage effects, production-inducing effects and employment multipliers in the marine sector. This analysis found that a number of marine sectors, notably the maritime transportation sector, have an important economic role within the wider Irish economy.

Key Words: Ocean Economy, Input Output Analysis, Industry Linkages, Multipliers, Ireland

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Author Contact Details: Karyn Morrissey, School of Environmental Sciences, University of Liverpool, Email: Karyn.Morrissey@liverpool.ac.uk; Cathal O'Donoghue, SEMRU, NUI Galway

Introduction

An increased understanding of the importance of market (commercial activity) and non-market (climate regulation and food production) value of the marine resource has led to the realisation that empirical evidence at both a national and sub-national level is required to inform public policy, governance and regulation across the sector [1]. Within this context, there has been an increasing interest in the use of economic instruments in the evaluation of the marine resource both at the national and regional level [1, 2]. In Ireland, research on the economic value of the marine sector at both the national and regional level has been historically limited [3]. However, adapting a methodology devised by the National Ocean Economic Programme to value the US marine economy [2], recent research provided a national [3] and regional [1] level value for the Irish marine sector in 2007. At the national level, it was found that the Irish marine sector provided €1.44 billion or 1% of GVA to the Irish economy in 2007 and the sector employed approximately 17,000 [3]. However, regional analysis found that the marine sector makes a greater contribution to the local economy [2]. At the NUTS3 regional level it was found that the marine sector accounted for 2.2% of GVA in the West, 1.3% in both the Border and South West region and it was found that for five of the eight NUTS3 regions, productivity in the marine sector was higher than the overall regional rate.

Research has therefore addressed the direct economic value of the marine resource at both the national and regional level in Ireland. However, sectors do not exist in a vacuum; rather they rely on other sectors for inputs (backward linkages) into their production process, while simultaneously selling their output to sectors (forward linkages) to generate profit. Backward linkage effects are strongly induced by industries with high intermediate input coefficients, such as manufacturing industries [4]. Symmetrically, strong forward linkages are generally induced by the primary and material industries, whose outputs are used by other industries as intermediate goods [4]. The intensity of inter-sectoral linkages between related industry groups has been highlighted as a key determinant of the technical and competitive progress of an economy [5]. As such, the identification of sectors that display strong linkages is believed to be a useful planning tool for stimulating economic growth at the sectoral, regional and national level.

Considering the complexity of inter-sectoral linkages, it would be an enormous task to trace and measure an entire sector's direct and indirect backward and forward relations to other sectors [6]. Developed by the economist Wassily Leontief, IO models may be used to trace the entire backward (or forward) linkages within a sector. However, while the computation of linkages is straightforward within an IO framework and these tables are produced to document the national accounts of most countries, data limitations surrounding marine based sectors [2] have meant that there has been limited use of IO analysis within the sector [2]. Notable exceptions include analyses of the Hawaiian fisheries sector [6, 7, 8], analysis of the Norwegian maritime transportation sector [9] and analysis of the South Korean marine sector (defined as maritime transportation, harbour activity, fishery and marine products and shipbuilding and other marine sectors, including marine tourism) [4].
Using the data contained with the SEMRU marine company database [3], this paper disaggregates the national fifty-two sector Irish IO table to contain ten additional marine sectors. These sectors included fishing and aquaculture, seafood processing, oil and gas extraction and production, marine engineering, marine water construction, boat building, maritime transportation, auxiliary services to maritime transport, marine water-based tourism activities and marine retail. Table 1 provides an overview of these sectors both in terms of direct output and employment in 2007. Utilising the Irish I-O framework, this paper presents the first holistic value, including both direct and indirect effects, of the economic value of the Irish marine sector.

Table 1 Overview of Marine Sub-Sectors Disaggregated in the 2007 Irish IO Table

Sector	Output (€'000)	Employment (FTE)	Sector	Output (€'000)	Employment (FTE)
Water Transport	693	1070	Boat Building	40	224
Marine Auxiliary Transport Services	196	773	Oil & Gas	197	790
Water Based Activities	74	1058	Marine Retail	96	253
Fisheries & Aquaculture	356	2200	Marine Engineering	96	686
Seafood Processing	395	2090	Marine Construction	127	444

The paper continues as follows; Section 2 provides an overview of the data requirements and data used within this paper. Section 3 provides a formal overview of the IO methodology and the derivation of backward and forward linkages. Section 4 presents the results of the IO analysis in terms of linkages, production inducing effects and employment multiplier for the marine sector. Section 5 discusses the results presented in section 3, and examines their usefulness in terms of policy formulation and investment decisions for the marine sector. Sector 6 offers some concluding comments on the analysis.

1. Data

Disaggregating a national IO table to encompass a new sector requires detailed sectoral data on intermediate consumption (input coefficients), output, compensation of employees and final demand. Given the fragmented nature of the marine sector (references), to collect and collate the necessary data to disaggregate the national IO a variety of data types or collection methods must be employed [10]. These data types may be broken down into three broad categories. Type 1 data is data that is in the public domain. Such estimates are generally confined to those sectors whose connection to the sea is clear (i.e. commercial fisheries, coastal transportation). Type 2 data is data that is publicly collected but is not released into the public domain. This data is at a lower industrial or geographical classification and is therefore considered confidential. Type 3 data is data that is not available in the public domain. The sectors where there is no publicly available data are those that are generally not easily recognisable as marine based [3]. These sectors are often indistinguishable from their land based counterparts within economic datasets. For example, one cannot difference between water based recreational activities and land based recreational activities. As such, to disaggregate the Irish national IO table to include a marine component, public data was not sufficient to estimate the full value of the Irish marine sector.

In terms of collating non-public data (Type 2 data), the Irish Central Statistics Office (CSO) provides data on turnover, intermediate consumption, gross value added, exports, and employment for each sector within the Irish economy. This data is collected across a number of censuses and surveys. The censuses and surveys used for the collation of the data on the marine sector include; the Census of Industrial Production (CIP), the Annual Services Inquiry (ASI) and the Census of Buildings and Construction (CBC). These three micro datasets provide detailed firm and enterprise level information on the economic activities for each company at the four digit NACE code. In order to assure consistency of treatment across different datasets, the industry estimates should operate within an established measurement of economic activity, such as the national income and production accounts [10]. The CIP, ASI and CBC data sets collected by the CSO form the basis for the calculation of Ireland's

national income and production accounts. Access may be granted to researchers interested in examining the data, through the CSO officer of statistics facility.

With regard to marine based sectors where no data was available (Type 3 data) a survey was administrated to each company within each sector [3]. The survey was prepared in line with the CSO surveys used to obtain data for the CIP, ASI and CBC datasets. This ensured that the necessary data to disaggregate the national IO table; intermediate consumption, output, final demand and compensation of employees, compiled between public and non-public data was consistent. Companies that provided both land-based and marine-based goods and services were specifically asked about their commercial marine-based activity (i.e. what percentage of their turnover was derived from marine-based activity). The central year for the study was 2007. To ensure temporal consistency, public datasets that were from earlier or later years were not included in the estimates. Data collected via survey specifically asked for company accounts for the year ending the 31st of December, 2007. Table 2 indicates the data type and the data sources for each sector of interest.

Table 2 Overview of Marine Sub-Sectors and Data sources used to compile the Disaggregated Marine Input-Output Table

Marine Sector	Data Type	Data Source
Ship Owners & Maritime Logistics	Type 2 Data	ASI
Water Based Activities	Type 3 Data	Company Survey
High Tech Services	Type 3 Data	Company Survey
Other Services	Type 3 Data	Company Survey
Fisheries & Aquaculture	Type 1 Data	SFPA/CSO/BIM Report
Seafood Processing	Type 2 Data	CIP
Oil & Gas	Type 2 & 3 Data	CIP & Company Survey
Marine Engineering	Type 2& 3 Data	CIP & Company Survey
Construction	Type 2 Data	CBC
Marine Retail	Type 3 Data	Company Survey

2. Methodology

Input-output analysis

Standard approaches to assessing inter-industry linkages begin with a conventional representation of Input–Output relations in an economy [5]:

$$x = X_{e-} + f$$

$$\Rightarrow x = A\,x + f$$

$$\Rightarrow x = (I - A)^{-1} f \quad (1)$$

Where matrix X represents the transaction flows between sectors of activities and is the sum of gross outputs, matrix I is an identity matrix, vector x is the sum of gross outputs, vector f represents the part of gross output sold to final demand, and A is a matrix of input coefficients defined as;

$$A = a_{ij} = \frac{z_{ij}}{x_j} \quad (2)$$

Where z_{ij} is intermediate demand for inputs between sector i and the supply sector j and x_j is the final output for sector i. $(I-A)^{-1}$ (eq. 1) is known as Leontief's inverse matrix and represents the total direct and indirect outputs in sector i per unit of exogenous final demand, d for sector j [11].

However, this standard demand model cannot exactly assess the effects of new production activity in an industry on all other sectors of the economy because changes in the final demand come about as a result of forces outside the model, for example, changes in consumer tastes or increased government purchases. For this purpose, the individual maritime sector needs to be handled as exogenous and put into the final demand group [4, 6]. Decomposing final demand into marine based final demand fi and non-marine final demand fj, and outputs xj and xi and direct input coefficient matrix respectively, one can derive a variant of the Leontief input-output model as follows:

$$\begin{pmatrix} x_i \\ x_j \end{pmatrix} = \begin{pmatrix} A_{ii} & A_{ij} \\ A_{ji} & A_{jj} \end{pmatrix} \begin{pmatrix} x_i \\ x_j \end{pmatrix} + \begin{pmatrix} f_i \\ f_j \end{pmatrix} \quad (3)$$

where i denotes the marine sector and j denotes the rest of the economy. Thus

$$x_j = A_{ji} x_i + A_{jj} x_j + f_j$$

$$x_j = \left(I - A_{jj}\right)^{-1} . A_{ji} x_i + \left(I - A_{jj}\right)^{-1} f_j \quad (4)$$

The additional output for sectors j generated by final demand for those sectors is $\left(I - A_{jj}\right)^{-1} f$. The contribution made by the marine sector to other sectors Δx_j is;

$$\Delta x_j^{'} = x_j - \left(I - A_{jj}\right)^{-1} f_j = \left(I - A_{jj}\right)^{-1}.A_{ji}x_i$$

(5)

Based on this partitioned I-O model, the backward linkage from one unit of output change in the marine sector *i* can be calculated by;

$$\Delta x_j = \left(I - A_{jj}\right)^{-1}.A_{ji}$$

(6)

Summing these elements and the initial unit output change in the marine sector i would give a measure of the sectors backward linkage impacts (6, 7). Thus, the marine sectors, i Leontief supply driven (LSDi) multiplier is given by;

$$LSD_i = 1 + e'\left(I - A_{jj}\right)^{-1}.A_{ji}$$

(7)

where 1 represents the initial unit output change in the marine sector *i*, and **e** is the summation vector used to aggregate the elements in Δx_j, that is, the impacts of this initial output change on the rest of the economy through the marine sectors *i*'s backward linkages. To facilitate linkage comparison among the industries, one may calculate a backward linkage index by using the following formula [15]:

$$BLI_i = \frac{LSD_i}{\left(\frac{\sum_k LSD_k}{K}\right)}$$

(8)

where *K* is the number of industries within the IO table. Capturing the inter-sectoral backward linkages of the marine sector, Eq. (8) can be used to evaluate the impact of a change in marine activity across the ten marine sectors on the output of all other sectors, that is, the production-inducing effect [4].

In terms of using this information as a policy tool, the backward linkage effect is the power of dispersion, calculated as the average of *n* elements in column *j* of the Leontief inverse matrix divided by average of all n^2 elements [6]. A backward-linkage index higher than one implies that the sector has strong backward linkage relative to other sectors in the economy. An industry with high backward linkages than other industries indicates that expansion of its production is more beneficial to the economy in terms of inducing productive activities.

With regard to forward linkages, the use of Leontief row sums are controversial as they calculate measures of forward linkages based on the strength of backward linkages [6, 7]. As such, the forward oriented Ghoshian model, although criticised itself [12], is a popular alternative [6, 7, 12]. In contrast to the Leontief model which relates multiple inputs to each

output, the Ghoshian model relates multiple outputs to each input. As such the Ghoshian model uses fixed exogenous intermediate coefficients, β, derived from the rows of the IO table such that;

$$\begin{pmatrix} x_i' & x_j' \end{pmatrix} = \begin{pmatrix} x_i' & x_j' \end{pmatrix} \begin{pmatrix} B_{ii} & B_{ij} \\ B_{ji} & B_{jj} \end{pmatrix} + \begin{pmatrix} w_i' & w_j' \end{pmatrix} \quad (9)$$

Where i represents the marine sector and j all other sectors and x denotes output. B is the direct output coefficient matrix and w represents primary inputs. Utilising a similar derivation as with the backward linkage, one can define the impact of a one unit output change in the marine sector on the output of other sectors as:

$$\Delta x_j = B_{ij}\left(I - B_{jj}\right)^{-1} \quad (10)$$

Summing and expressing as a ratio of all other forward linkages, one can produce the Ghoshian supply driven (GSD) multiplier:

$$GSD_i = 1 + B_{ij}\left(I - B_{jj}\right)^{-1} e \quad (11)$$

Capturing the inter-sectoral forward linkages of the marine sector, Eq. (11) can be used to evaluate the impact of a price or supply change across the ten marine sectors on the output of all other sectors, that is, the supply-inducing effect.

The forward linkage effect is expressed as the sensitivity of dispersion, which is the average of n elements in row i of the Leontief inverse matrix divided by all n^2 elements [6]. A forward-linkage index higher than one implies that the sector has strong forward linkage relative to other sectors in the economy [6]. In terms of policy application, an industry with higher forward linkages than other industries means that its production is relatively more sensitive to changes in other industries output. Backwards and forward linkages provide a quantitative measure of the relationship among industries that can be organised into a rank-sized hierarchy. This therefore provides policymakers and practitioners with a quantitative measure of the each industry's' structural relationship within the wider economy. Thus, allowing policy decisions on investment to be based on the relative importance of a sector within an economy. The usefulness of the IO framework in policy making is discussed more fully in Section 5.

On disaggregating the Irish IO model for 2007 to include ten additional marine sectors the next section presents the first empirical analysis of the backward and forward linkages and production and employment inducing effects of the Irish marine sector. Such an analysis will provide a deeper understanding of the economic value of the Irish marine resource and thus

provide policymakers with the relevant information to inform public policy and both public and private investment in the area. [1]

3. **Results**

Linkages within the marine sector

Table 3 presents the backward linkages for each sector within the Irish economy. A broad examination of the linkages within the Irish economy indicates that 'mining and quarrying' has the highest backward linkage score (134), followed by 'seafood processing' (126), 'water transport services' (109), 'research and development services' (109) and 'sewage and refuse disposal services'(107). However, what is of interest is that within the wider Irish economy, three marine sectors are ranked within the top ten sectors with the strongest backward linkages – seafood processing (126), maritime transportation (109) and water construction (106). Each of these sectors has a backward linkage greater than one, implying that these sectors are important input suppliers to other sectors.

Examining the magnitude of the linkages for these three sectors in more detail, water construction is 1.06. This implies that for every €1 produced within the water construction sector, €0.06 is backward linked to its direct and indirect upstream suppliers. The magnitude of the water transportation sectors backward linkage is €1.09. This implies that for every €1 produced within the water transportation sector, €0.09 is backward linked to its direct and indirect upstream suppliers. Four cents of this €0.09 belongs to the water transportation sectors direct suppliers and €0.05 belongs to its indirect suppliers (e.g. the suppliers of its direct suppliers). Seafood processing has the strongest backward linkage, €1.26, within the marine sector. This implies that for every €1 produced within the seafood processing sector, €0.26 is backward linked to the sectors direct and indirect upstream suppliers. Two cents of this €0.26 belongs to the seafood processing sectors direct suppliers and €0.24 belongs to its indirect suppliers (e.g. the suppliers of its direct suppliers).

Overall, the average backward linkage for the Irish economy was 58. This indicates that the sectors in the wider Irish economy had low (less than one) backward linkage effects. Ireland is a small open economy and many of its inputs into the process of production are imported from outside the country. Indeed further analysis of the Irish IO table found that on average imports for each of the sixty-two sectors as a percentage of inputs was 60%. In contrast, within the marine sector, the ratio of imports to exports in three sectors, seafood processing, water construction and water transportation sectors are 0.06%, 15% and 16%, respectively.
Further examining these linkages, it was found that the high backward linkage within the seafood processing sector is due to the strong links between the sector and the fishing sector (41), the seafood processing sector itself (9) and wholesale trade (8). The high backward linkage within the water transportation sector is due to the strong links between the indigenous water transportation sector itself (47), auxiliary marine transport service sector (e.g. liner and port services, 18) and computer services (8). The high backward linkage within the water construction sector is due to the strong links between the wider construction sector (46), wholesale trade (8) and other non-metallic mineral products (8). This indicates the key linkages between these three marine sectors and indigenous companies within the Irish economy.

[1] The revised IO table is available from the authors on request.

Table 3 Backward Linkages within the Irish Economy 2007

Sector	Backward Linkages & Rank	Sector	Backward Linkages
Other mining and quarrying	134	Public administration and defence	52
Seafood Processing	126	Leather and leather products	51
Water transport services	109	Wholesale trade	51
Research and development services	109	Air transport services	51
Sewage and refuse disposal services	107	Pulp, paper and paper products	49
Water Construction	106	Rubber and plastics	47
Post and telecommunication services	103	Medical, precision and optical instruments	47
Forestry	96	Other services	47
Construction work	94	Motor fuel and vehicle trade and repair	46
Membership organisation services	90	Oil & Gas Extraction	44
Water collection and distribution	87	Auxiliary Transport Marine	44
Electricity and gas	81	Textiles	39
Wood and wood products (excl furniture)	80	Machinery and equipment	37
Fishing	77	Motor vehicles and trailers	37
Basic metals	77	Real estate services	36
Agriculture	76	Renting services of machinery and equipment	36
Other non-metallic mineral products	76	Fabricated metal products	32
Boat Building	73	Extraction of coal, peat, petroleum and metal ores	29
Auxiliary transport services and travel agencies	73	Petroleum and other manufacturing products	29
Services auxiliary to financial intermediation	72	Financial intermediation services	29
Electrical machinery and apparatus	71	Education	29
Marine Engineering	69	Insurance and pension services	27
Hotel and restaurant services	68	Radio, television and communications apparatus	26
Land transport services	65	Health and social work services	26
Marine Retail	63	Other business services	24
WBA	62	Other transport equipment	23
Computer and related services	61	Printed matter and recorded media	16
Recycling	58	Wearing apparel	13
Recreation	57	Office machinery and computers	13
Food and beverages	56	Chemical products and man-made fibres	12
Retail trade and repair of household goods	55	Private Households	0

Forward linkages

Table 4 presents the sectors that are most strongly forward linked within the Irish economy. A broad examination of the linkages within the Irish economy indicates that 'forestry' has the highest backward linkage score (199), followed by 'other mining and quarrying' (185), 'recycling' (176), 'other non-metallic mineral products' (148) and 'post and communications' (139). Overall, the average forward linkage for the Irish economy was 62. From table 3, one can see that that only one marine sector; maritime transportation has a forward linkage greater than one (120). This implies that every €1 produced by the maritime transportation sector is forward linked to €0.20 to the production of the sectors direct and indirect downstream demanders. In detail, for €1 of the production of water transportation services, €0.49 is sold directly for final consumption, including €0.08 for local consumption and €0.41 for exports. The rest €0.20, are bought by the water transportation sectors downstream demanders.

Within the wider Irish economy the water transportation sector has the seventh highest forward linkage. Placing the high forward linkage demonstrated by the water transportation sector in context to the other nine marine sectors, Ireland is a small, open economy and its island status means that sectors in the wider economy rely on water transportation as a means of importing and exporting goods. Thus, given the structure and geo-economic status of the country, maritime water transportation is an important intermediate service in the production process of Irish industrial and manufacturing sectors. This is particularly true of the wholesale trade and post and communications sectors which display forward linkages of 15 and 10 to the water transportation sector, respectively. The small forward linkages of the other nine marine based sector, particularly the marine retail, boat building, seafood processing, water based activities and water construction reflects the fact that for these sectors almost all of their goods and services are sold for final consumption.

Table 4 Forward linkages in the Irish economy and the Irish marine sector

Sector	Forward Linkages	Sector	Forward Linkages
Forestry	199	Construction work	54
Other mining and quarrying	185	Water Construction	53
Recycling	176	Recreation	52
Other non-metallic mineral products	148	WBA	52
Post and telecommunication services	139	Petroleum and other manufacturing products	46
Electricity and gas	137	Renting services of machinery and equipment	45
Water transport services	120	Membership organisation services	41
Wood and wood products (excl furniture)	116	Medical, precision and optical instruments	39
Services auxiliary to financial intermediation	114	Insurance and pension services	34
Fabricated metal products	111	Real estate services	32
Sewage and refuse disposal services	110	Textiles	30
Agriculture	109	Seafood Processing	28
Auxiliary transport services and travel agencies	103	Hotel and restaurant services	25
Land transport services	99	Food and beverages	24
Auxiliary Transport Marine	95	Leather and leather products	20
Other business services	95	Radio, television and communications apparatus	14

Marine Engineering	95	Education	12
Pulp, paper and paper products	93	Health and social work services	12
Research and development services	93	Public administration and defence	11
Computer and related services	84	Printed matter and recorded media	9
Financial intermediation services	78	Chemical products and man-made fibres	8
Motor fuel and vehicle trade and repair	74	Basic metals	8
Rubber and plastics	72	Motor vehicles and trailers	6
Water collection and distribution	72	Office machinery and computers	4
Air transport services	72	Machinery and equipment	1
Fishing	69	Other transport equipment	1
Other services	64	Boat Building	1
Extraction of coal, peat, petroleum and metal ores	62	Wearing apparel	0
Oil & Gas Extraction	62	Retail trade and repair of household goods	0
Wholesale trade	60	Marine Retail	0
Electrical machinery and apparatus	59	Private Household	0

Production Inducing Effects of the Irish Marine Sector

Further to allowing an analysis of inter-sectoral linkages within an economy, IO analysis also makes it possible to quantify all the repercussions generated by an increase in demand in a sector or group of sectors, which might not, at first sight, seem connected with it [11]. The impacts of a €1 change in marine investment on the wider Irish economy for the ten marine sectors are presented in table 5. From Table 5 one can see that the total production inducing effect for the marine sector is €6.31. The marine sector has the largest impacts on the construction, other business services and financial intermediate service sector. To place these results within the context of the wider Irish economy, Table 6 presents the five sectors with the highest turnover/output in 2007. Comparing Table 5 and 6, one can see that increased investment in the marine sector would have the strongest production inducing impact on three of the five sectors with the highest turnover in 2007 (financial intermediation services, wholesale trade and construction work). This would therefore indicate that stimulating investment in the marine sector would positively affect sectors that have the greatest impact on the Irish economy.

Table 5 Production Inducing effect of the Irish marine sector

Sector	**Production Multiplier**	**Sector**	**Productio Multiplie**
Construction work	0.700	Printed matter and recorded media	0.046
Other business services	0.676	Rubber and plastics	0.041
Financial intermediation services	0.631	Wood and wood products	0.040
Insurance and pension services	0.397	Membership organisation services	0.038
Wholesale trade	0.372	Other mining and quarrying	0.035
Computer and related services	0.355	Research and development services	0.032
Auxiliary transport services and travel agencies	0.354	Chemical products and man-made fibres	0.028
Electricity and gas	0.289	Pulp, paper and paper products	0.024

Real estate services	0.270	Electrical machinery and apparatus	0.023
Post and telecommunication services	0.265	Health and social work services	0.023
Land transport services	0.189	Agriculture	0.023
Hotel and restaurant services	0.176	Education	0.016
Services auxiliary to financial intermediation	0.134	Recycling	0.010
Renting services of machinery and equipment	0.133	Water collection and distribution	0.009
Other non-metallic mineral products	0.113	Forestry	0.008
Petroleum and other manufacturing products	0.113	Textiles	0.007
Air transport services	0.106	Other transport equipment	0.005
Extraction of coal, peat, petroleum and metal ores	0.095	Radio, television and communications apparatus	0.005
Motor fuel and vehicle trade and repair	0.094	Motor vehicles and trailers	0.001
Fabricated metal products	0.079	Basic metals	0.001
Sewage and refuse disposal services	0.071	Office machinery and computers	0.000
Medical, precision and optical instruments	0.070	Retail trade and repair of household goods	0.000
Public administration and defence	0.063	Machinery and equipment	0.000
Other services	0.058	Leather and leather products	0.000
Food and beverages	0.051	Wearing apparel	0.000
Recreation	0.047	Total Impact	6.31

Table 6 Top five sectors (turnover) in Ireland 2007

Sector	Turnover (€'000)
Food and beverages	19,176
Financial intermediation services	20,218
Wholesale trade	20,855
Chemical products & man-made fibres	33,592
Construction work	47,587

To continue the analysis, Table 7 provides a breakdown of the production multipliers by (a) individual marine sector and (b) the sectors it has the greatest impacts on within the wider economy. From Table 7, one can see that an €1 investment in water construction has the largest impact on the Irish economy and generates €1.01 additional spending in the economy. Marine auxiliary transport services have the lowest (€0.39). In terms of individual downstream sectoral impacts, examining Table 7 as a whole, one can see that the sectors receiving the largest downstream impacts are financial intermediation services (marine engineering; oil and gas extraction, 0.1; processing 0.08), insurance and pension services (Fishing, 0.7; Boat Building, 0.14) and other business services (WBA, 0.2; Marine retail, 0.1). Thus, whilst the marine sector is often seem as a 'traditional' primary production oriented sector, these results indicate that the sector has the strongest linkages with the service-based sectors.

Table 7 Marine production multipliers and the downstream sectors greatest impacted

Marine Sector Total Impact (€)	**Sub-Sectors receiving the greatest impact by individual marine sector** (€)		
Fishing	Insurance and pension services	Electricity and gas	Construction work
0.57	0.07	0.06	0.05
Oil & Gas	Financial intermediation services	Electricity and gas	Other business services
0.43	0.11	0.05	0.04
Seafood Processing	Financial intermediation services	Other business services	Wholesale trade
0.74	0.08	0.08	0.08
Boat Building	Insurance and pension services	Financial intermediation services	Construction work
0.73	0.14	0.08	0.06
Water Construction	Construction work	Other non-metallic mineral products	Wholesale trade
1.06	0.46	0.08	0.08
Water Transport	Auxiliary transport services and travel agencies	Computer and related services	Financial intermediation services
0.58	0.18	0.08	0.04
Auxiliary Marine Transport Services	Computer and related services	Other business services	Auxiliary transport services
0.39	0.06	0.06	0.06
Marine Engineering	Financial intermediation services	Other business services	Post & telecommunication
0.68	0.14	0.07	0.06
Marine Retail	Other business services	Real estate services	Financial intermediation services
0.62	0.12	0.10	0.05
WBA	Other business services	Extraction of coal, peat, petroleum and metal ores	Financial intermediation services
0.51	0.15	0.06	0.04

Employment-inducing Effects of the Marine Sector

Policymakers are frequently preoccupied with the employment-creating effects of industrial expansion. The marine sector is specifically believed to be of high employment benefit to local and coastal communities [13, 14], particularly within the marine resource sectors,

fishing, aquaculture and seafood processing. For this reason, it is important to be able to derive employment multipliers as well as production multipliers from the I-O model. Table 8 presents the ranked employment inducing effects of all sectors in the Irish economy in 2007. From Table 8, one can see that the agricultural (2.3), real estate (2) and construction (1.7) sectors had the highest employment inducing effect in 2007. Within the marine sector, the water construction sector (0.9) has the highest employment inducing effect and is the fifth highest sector across the whole Irish economy. This means that for every €100,000 invested in the water construction sector 0.9 individuals are employed (as full time equivalents, FTE). Taking the ten marine sectors together, the total impact of the marine sector on employment is 2.9 (water construction, 0.9; oil and gas extraction, 0.5; seafood processing 0.4; marine engineering 0.2; WBA, 0.2; boat building, 0.2; fishing 0.2; retail, 0.1; water transport services, 0.1; marine auxiliary transport services, 0.1). That is for every €100,000 invested in the marine sector as a whole approximately 3 individuals, FTE, will be employed.

Table 8 Employment Multipliers

Sector	Multiplier	Sector	Multiplier
Agriculture	2.3	Water collection and distribution	0.3
Real estate services	2.0	Sewage and refuse disposal services	0.3
Construction work	1.7	Other non-metallic mineral products	0.3
Food and beverages	1.0	Membership organisation services	0.2
Water Construction	0.9	Wood and wood products	0.2
Renting services of machinery and equipment	0.8	Education	0.2
Recycling	0.7	Machinery and equipment	0.2
Computer and related services	0.7	Leather and leather products	0.2
Retail trade and repair of household goods	0.7	Radio, television and communications apparatus	0.2
Chemical products and man-made fibres	0.7	Services auxiliary to financial intermediation	0.2
Research and development services	0.7	Marine Engineering	0.2
Other business services	0.7	Petroleum and other manufacturing products	0.2
Hotel and restaurant services	0.6	Post and telecommunication services	0.2
Wholesale trade	0.6	Water Based Activities	0.2
Office machinery and computers	0.5	Boat Building	0.2
Other mining and quarrying	0.5	Fishing	0.2
Oil & Gas Extraction	0.5	Marine Retail	0.1
Printed matter and recorded media	0.5	Rubber and plastics	0.1
Seafood Processing	0.4	Pulp, paper and paper products	0.1
Financial intermediation services	0.4	Water transport services	0.1
Auxiliary transport services and travel agencies	0.4	Extraction of coal, peat, petroleum and metal ores	0.1
Basic metals	0.4	Motor vehicles and trailers	0.1
Health and social work services	0.4	Auxiliary Transport Marine	0.1

Electrical machinery and apparatus	0.4	Forestry	0.1
Insurance and pension services	0.4	Fabricated metal products	0.1
Public administration and defence	0.3	Textiles	0.1
Electricity and gas	0.3	Motor fuel and vehicle trade and repair	0.1
Land transport services	0.3	Other services	0.1
Medical, precision and optical instruments	0.3	Other transport equipment	0.02
Recreation	0.3	Wearing apparel	0.01
Air transport services	0.3	Private Households	0.0

To continue the analysis, Table 9 provides a breakdown of these employment multipliers by (a) individual marine sector and (b) the sectors they have the greatest impacts on within the wider economy. In terms of water construction, the sector with the largest impact on employment, the sector generates the largest downstream impacts to the construction sector (0.8 FTE), other business services (0.07 FTE) and wholesale trade (0.05 FTE). Examining the ten marine sectors individually the sectors receiving the largest downstream FTE employment impacts are other business services (Processing 0.1; Marine Engineering, 0.03; Water Transport, 0.06; Marine Retail, 0.07; WBA, 0.1; Marine Auxiliary Transport Services, 0.05) and construction (Fishing, 0.05; Boat Building, 0.1; water construction, 0.8). Similar to the analysis on marine production effects, the employment multiplier presented in this paper indicate that the sector has the strongest impacts with the Irish service sectors.

Table 9 Marine employments multipliers and the downstream sectors greatest impacted

Sector (Total Multiplier)	**Sub-Sectors receiving the greatest impact by individual marine sector** (FTE)		
Fishing (0.2)	Construction work	Other business services	Wholesale trade
	0.05	0.03	0.02
Oil & Gas (0.5)	Financial intermediation services	Other business services	Wholesale trade
	0.13	0.13	0.06
Seafood Processing (0.4)	Other business services	Wholesale trade	Construction work
	0.12	0.07	0.07
Boat Building (0.2)	Construction work	Hotel and restaurant services	Financial intermediation services
	0.06	0.03	0.02
Water Construction (0.9)	Construction work	Other business services	Wholesale trade
	0.8	0.07	0.05
Water Transport (0.1)	Other business services	Auxiliary transport services and travel agencies	Construction work
	0.035	0.025	0.02
Marine Engineering (0.2)	Other business services	Financial intermediation services	Construction work

	0.06	0.04	0.03
Marine Retail (0.1)	Other business services	Construction work	Hotel and restaurant services
	0.07	0.02	0.02
Water Based Activities (0.2)	Other business services	Construction work	Financial intermediation services
	0.11	0.01	0.01
Auxiliary Water Transport (0.1)	Other business services	Construction work	Computer and related services
	0.05	0.02	0.01

4. **Using the I-O Framework for Policy Analysis**

The marine IO framework presented in this paper may be used for policy and investment targeting within the Irish marine sector. With regard to policy recommendations, comparing the strength of inter-industry linkages as presented in section 4 can provide one mechanism for identifying strategic sectors for government investment. In terms of identifying key sectors within an economy, the results of the linkage analysis indicate that three marine sectors, water transport, seafood processing and water construction, have backward linkages greater than 1. With regard to forward linkages, only one sector, water transport, has a forward linkage greater than 1. These results indicate that the Irish marine sector has more strength in absorbing products of related industries (higher backward linkages), rather than being used as an input by other industries (lower forward linkages). This implies that the marine industry has greater impacts in terms of investment expenditures on the national economy than other sectors as it has a relatively strong capacity for pulling or 'spending' within other downstream industries.

Production multipliers derived from the IO analysis may also be used to guide public investment decisions. The magnitude of production multipliers from the demand driven model can be interpreted as the direct and indirect benefits which would ensue from future marine based development projects. Using these multipliers, policy decisions on whether or not to conduct a proposed marine development project could be deduced by examining the magnitude of the marine sectors production inducing effect (Table 4). In terms of the production inducing effects presented in section 4, one can see that a marine-based investment would have the largest impact on the service based industries, particularly the financial and insurance sectors. This indicates the proportionally higher costs of services sectors in the production costs of the marine sector [4]. However, as noted in Section 4, increased investment in the marine sector would have the strongest impact on three of the five sectors with the highest turnover in 2007 (financial intermediation services, wholesale trade and construction work). Thus, stimulating investment in the marine sector would positively affect sectors that have the greatest impact on the Irish economy.

To continue, IO analysis may also be used to provide empirical evidence for the development of spatial clusters [15]. Research in the early nineties [18] found that internationally competitive industries usually occur in the form of specialised clusters of 'home-based' industries, which are linked together through vertical relationships (buyers/suppliers) or horizontal relationships (common customers, technology, skills, distribution channels, etc). Competitive advantage arises as result of these linkages and the Marshallian idea that geographic proximity creates the type of collaborations, knowledge spillovers, and positive externalities that firms can use and exploit [17]. These externalities are based on the presence

of qualified labour, production inputs (for example, support services), and benefits stemming from industrial technological advancement [17, 18, 19].

Within this context, the results presented within this paper indicate that maritime transportation sector had the third highest backward linkage and seventh highest forward linkage in the Irish economy in 2007. In terms of backward linkages the analysis found that in 2007 the sector had high backwards linkages with a number of professional and technology based services, such as the computer, insurance and banking sectors. Symmetrically, with regard to forward linkages the analysis showed that the maritime transportation sector was an important input into three of the most economically valuable sectors in the Irish economy – the food and beverages sector, the construction sector and wholesale trade. In line with the cluster theory, the input-output methodology presented above would indicate that given the strong linkages to a number of key service sectors already in place, and the large forward linkages to a number of key economic sectors, the future development of a maritime transportation cluster could potentially have large effects on the rest of the economy.

With regard to employment, traditionally marine employment was believed to centre on the natural resource sector. However, the employment multipliers presented in section 4 demonstrates that employment in the sector is actually linked to more knowledge and technology intensive sectors in Ireland. Thus, these results would indicate that the promotion of policies that focus on knowledge-based marine sectors, for example marine education and marine R&D, have the potential to have high employment impacts. In Ireland, similar to the experience noted in Malaysia [20], a select few marine sectors including water transportation, oil and natural gas extraction, sea- fishing and aquaculture have dominated policy in the Irish marine sector. However, as noted in the introduction, recent time has seen an increased realisation of the technological potential embedded in the marine resource, particularly in the areas of biotechnology and functional foods and marine renewable energy. Within this context, the Sea Change Strategy 2007-2013 [21] encompassing both the National Marine Technology Programme and the National Marine Biotechnology Programme aims to create a sustained marine technology and marine biotechnology industry around relevant multi-disciplinary, knowledge based sectors within Ireland. However, to estimate the impact of these programmes, a coherent set of indicators detailing the economic impact on the Irish national and regional economy is required [2]. This paper has demonstrated the potential usefulness of the IO framework in examining key sectors within the marine sector and developing policies to ensure sustainable development of the marine sector within the wider Irish economy.

5. Discussion

Given the role the marine resource has in climate change and food production, coupled with the widely acknowledged technological potential embedded in the marine resource has meant that there has been an increased focus on marine policy both in Ireland and abroad [1, 3, 20, 21]. However, to estimate the impact of these programmes, a coherent set of indicators detailing the economic impact on the Irish national and regional economy is required [1, 2]. Thus, in order to examine the role of the marine sector in the national economy and cope with the growing concerns about the need for a new paradigm for Irish marine policy, this paper disaggregates the national IO table to analysis the direct and indirect impact of the Irish marine sector in 2007.

Although the marine sector had a low share of national GVA in 2007 [3], this paper found that as a whole the marine industry has a low forward linkage effect, a relatively high backward linkage effect, a high production-inducing effect and a high employment-inducing effect. There are few studies in which an IO model has been used for analysing the marine

sector [4]. Given that a holistic description of a marine sectors relationship with the wider economy is required to guide policy and investment, this paper demonstrates the feasibility and value of extending a country's IO table to include marine sectors of interest.

In terms of future research, given the importance of the marine economy to the Irish regions [1] and the increased acknowledgement of the importance of the regions in providing a foundation for national economic growth [22], a future extension of the framework presented here will involve regionalising the model. Thus, allowing a more localised analysis of the direct and indirect impacts of the marine sector.

Building on recent research that examined the direct value of the marine at the national [3] and regional level [1] the main outcomes of this analysis has been to increase the number of tools, data and economic indicators that may be used formulate policy for the Irish marine economy. This data may now be used to better inform future marine planning and investment decisions for the Irish regions at both the national and EU level.

5. References

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