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Title Page

Maritime transport in the French economy and its impact on air pollution: an input-output analysis

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Abstract

This article studies the role of maritime transport in France on the domestic economy with respect to output and employment-inducing effects through an Input-Output approach. This is the first study ever made in this country for this industry, whereas the same approach has been applied in the past to many other countries (Korea, Ireland, China, Spain...) having a significant maritime industry, thus giving a basis for comparison. In addition, an original contribution to the literature is provided through the assessment of the environmental impact of shipping on air pollution through various greenhouse gas emissions (SO₂, NO_x, CO₂, PM_{2.5}, PM₁₀). This assessment of direct and indirect gas emissions caused by water transport is particularly important at a time of more stringent regulations being implemented by the International Maritime Organisation and the European Union (i.e. within and beyond the SECA –*Sulphur Emission Control Areas*- limits) to reduce the sulphur emissions of ships.

Key-words: maritime transport, input-output analysis, air pollution, France

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Abstract

This article studies the role of maritime transport in France on the domestic economy with respect to output and employment-inducing effects through an Input-Output approach. This is the first study ever made in this country for this industry, whereas the same approach has been applied in the past to many other countries (Korea, Ireland, China, Spain...) having a significant maritime industry, thus giving a basis for comparison. In addition, an original contribution to the literature is provided through the assessment of the environmental impact of shipping on air pollution through various greenhouse gas emissions (SO₂, NO_x, CO₂, PM_{2.5}, PM₁₀). This assessment of direct and indirect gas emissions caused by water transport is particularly important at a time of more stringent regulations being implemented by the International Maritime Organisation and the European Union (i.e. within and beyond the SECA –*Sulphur Emission Control Areas*- limits) to reduce the sulphur emissions of ships.

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1. Introduction

The European integrated maritime policy was first launched in 2007¹ following the recommendations of the Green Book (2006) and the Blue Book (2007), and later adopted in 2012² by the Ministers in charge of the maritime policy and the European Commission. It emphasized the potential contribution of maritime sectors to the European economic growth and employment, inviting Member States to define their own “blue growth” strategy for the sustainable development of their sea-related activities.

With 12,840 km of coastline³ and 11 km² of Exclusive Economic Zone (EEZ), France possesses the second largest EEZ in the world, just behind the USA. Historically more focused on land activities, France has recently realised that the “blue economy” represents a tremendous growth potential⁴. It encompasses a large number of interconnected sub-sectors: marine renewable energy, extraction of minerals from the seabed, offshore oil and gas production, ports, shipbuilding and repair, short and long-distance shipping, fishing, aquaculture, marine bioprospecting, etc. Maritime transport is a key player of the blue economy in France. In 2016, exports and imports represented around 30% of the French GDP⁵, 40% of French exports and 52% of French imports being seaborne trade⁶. Marseille-Fos and Le Havre are two important ports in Europe and the French Group CMA CGM is the fourth largest shipping firm worldwide. However, even if the French maritime industry has achieved good results in 2016, much more could be done to increase its competitiveness.

Promoting a sustainable blue economy first requires good empirical knowledge about its economic importance and linkages. This may provide policy-makers with accurate information about the potential of this industry for future economic growth. One of the main objectives of this research is therefore to assess the impact of water transport services on the French economy over the period 2010-2016, by using an input-output (I-O) approach. This has never been done so far for the French domestic economy, compared with similar studies applied to other countries.

Some recent articles have measured the economic role of maritime sectors in China [1], South Korea [2,3,5], Ireland [6], Spain [7] or Taiwan [4]. Kwak *et al.* [5] studied the economic impact of five maritime industries⁷ in South Korea using an I-O longitudinal approach between 1975 and 1998. They have pointed out that the Korean maritime industry had high backward linkage effects, low forward linkage effects and a high employment-inducing effect. Lee and Yoo [3] also used a comprehensive I-O model for Korea in a longitudinal approach to analyse the economic weight of four transportation industries⁸ on the domestic economy. The economic impact was found higher for rail and road transportation than for the two other transportation sectors (water and air). Morrissey and O’Donogue [6] adopted a similar approach and reached identical conclusions as Kwak *et al.* [5] for Ireland, but they

¹ The European Union’s Integrated Maritime Policy: <http://ec.europa.eu/maritimeaffairs/policy/documents/>

² Declaration of the European Ministers responsible for the Integrated Maritime Policy and the European Commission, on a Marine and Maritime Agenda for growth and jobs the “Limassol Declaration”, 7 Oct. 2012, https://ec.europa.eu/maritimeaffairs/sites/maritimeaffairs/files/docs/body/limassol_en.pdf

³ 5,500 of which is in mainland France.

⁴ France has implemented its national strategy for the sea and coastal areas by decree n°2017-222 of February 23rd, 2017 (http://www.dirm.sud-atlantique.developpement-durable.gouv.fr/IMG/pdf/decret_2017-222_du_23fevrier2017-snml.pdf).

⁵ OECD (2018), Trade in goods and services (indicator). doi: 10.1787/0fe445d9-en (Accessed on 07 June 2018)

⁶ Eurostat trade database. <http://ec.europa.eu/eurostat/web/international-trade-in-goods/data/database>

⁷ Marine transportation, construction and harbor services, fishery and marine products, shipbuilding and other marine sectors.

⁸ Rail, road, water and air.

disaggregated the Irish I-O table to include ten additional marine sectors for one year only, using both public and non-public data. They showed that the water transport industry presented the highest backward linkage of the ten marine sectors included in the article. Chang *et al.* [4] distinguished nine marine sectors⁹ in the Taiwan I-O Table (554 sub-sectors) over the period 1996-2011. They reported that the magnitude of the Taiwanese marine sectors in the domestic economy had increased significantly during the covered period. Transportation support services appeared to have one of the highest forward and backward linkages, and the strongest wealth-inducing and employment-inducing effects. Since 2014, the European Community Shipowners' Associations (ECSA), with the assistance of Oxford Economics, regularly publishes a report concerning the economic value of the EU shipping industry, still using an I-O approach. According to this literature, maritime industries, and particularly maritime transport [8,9,10], have major economic impacts for the studied countries. China has also a fast-growing maritime industry across many activities (aquaculture and fisheries, shipbuilding, transportation, offshore oil and gas, marine engineering...) and authors recently reported an impressive number of 46 million jobs (i.e. 6% of the working population) directly or indirectly linked with marine and marine-related industries [1]. The authors also used a mixed I-O model, making marine sectors exogenous, and have been looking at production-inducing, sectoral supply-shortage and employment-inducing effects with a disaggregation in 12 marine sectors. **They found that the three key production-inducing marine sectors were coastal tourism, maritime transport and shipbuilding. Any \$1 investment in the marine industry creates a \$1.65 effect which is distributed among various marine industries (tourism, shipping, shipbuilding, fisheries, oil & gas, offshore mining, marine chemicals, marine pharmaceutical, offshore engineering...). The backward linkage effect was also found to be far greater than the forward linkage effect in their Chinese study.**

A comprehensive synthesis proposed by Jacobsen *et al.* [11] has surveyed a great number of economic multipliers (808 in overall) of maritime sectors in a meta-analysis. These authors have reported data issued by the oceaneconomics.org website on eight marine or maritime sectors (aquaculture, fisheries, marine renewable energy, fish processing, shipping, recreational fisheries, shipbuilding and tourism) in more than 180 countries, resulting in 189 income multipliers, 164 job multipliers, 90 GDP multipliers, etc. The estimated average output multiplier was 1.82, meaning that any US Dollar created by the maritime industry would increase the domestic output by an additional amount of 82 cents into the rest of the economy. In this study, the output (or Leontief) multipliers were found higher than others such as employment, GDP or income multipliers. In other terms, it was shown that marine sectors have many backward linkages across their production process, purchasing inputs from many different suppliers, but they somehow do not create as much added value or as many jobs as other industries, presumably because they remain capital-intensive activities.

Interestingly, we have not found any study using the same I-O basis to calculate the environmental impacts of maritime transport. However, this is of major importance at a time when the International Maritime Organization (IMO) attempts to reduce the greenhouse gas impact of shipping which has been left outside the Paris agreement on Climate Change, by imposing emission control areas [12,13].

The present research aims at providing a basis for comparison with the magnitude of water transport multipliers in the French economy throughout several years (2010-2016) to account for potential inter-annual variability. Our approach is original by splitting up the water transport service activity in two separate branches: freight and passenger transport, showing distinct results in terms of employment-inducing effects. Moreover, on the basis of environmental data issued from the National Accounting Matrix including Environmental Accounts (NAMEA), we introduce environmental multipliers of

⁹ Classified in three sectors: marine fishery, marine contraction and marine transportation.

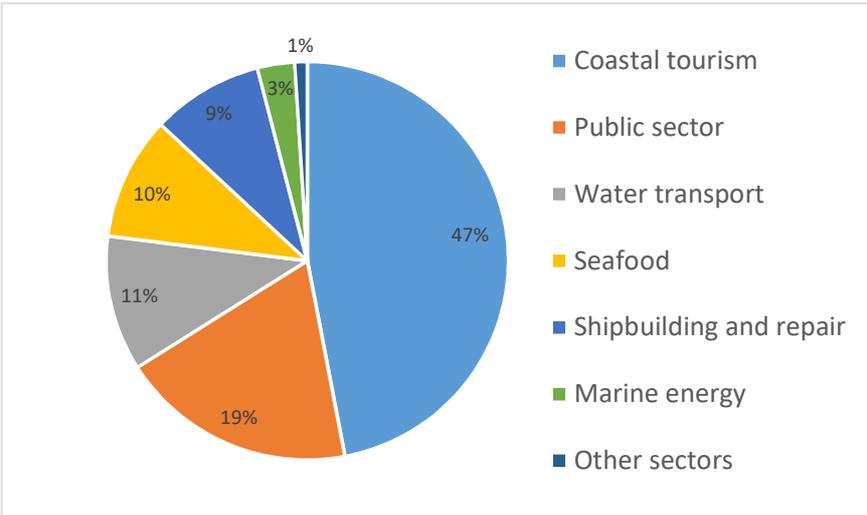
maritime transport for CO₂, SO₂, NO_x, CH₄ emissions and suspended particulate matter (PM₁₀ and PM_{2.5}) to stress the major role played by shipping and seaborne trade on air pollution emissions. **Our study therefore contributes to the literature by applying a standard I-O model for the first time to the French maritime transport industry, and by extending this empirical work to several types of air pollution multipliers and effects by using the European database NAMEA.** After some stylized facts reported in Section 2, the I-O model is introduced in Section 3, including the development of environmental multipliers. Section 4 presents the major results before drawing some conclusions in Section 5.

2. Current status of maritime transport in France: some stylized empirical facts

In 2015, the EU shipping industry directly employed 640,000 people and generated a 57 billion euro contribution to GDP. Maritime freight accounted for 57% of the EU shipping industry’s total contribution to GDP [10].

In France, in 2013, some 450,000 people, equivalent to 2% of overall national employment are employed in the maritime economy as a whole (from fishing to ocean biotechnologies, [14]) and produce an output value of €104 billion for an added value of €35 billion according to Ifremer [15]. Coastal tourism accounts for half of the jobs (227,600). Public works, maritime and river transport and seafood products represent 19%, 11% and 10% of French maritime jobs, respectively (Fig 1). In its contribution to GDP, tourism represented 43%, offshore oil & gas 17%, maritime transport 13%, seafood (fisheries, aquaculture, fish processing) 10%, shipbuilding 10%, and the remaining contribution to GDP (7%) being shared between ports, offshore equipment, R&D, renewable energy, telecommunications and biotechnology [13]. In overall, the blue economy contributed to 1.7% of the domestic GDP in 2013. The share of maritime transport services is fairly low and largely dominated by one single company (CMA-CGM). Being a global carrier, this company employs international seafarers, orders ships in Korea or China, and purchases inputs from all over the world (bunkering, shipchandling, stevedoring, manning, etc.). The estimation of the domestic share of added value created by such global companies remains a challenge for economists [16].

Fig. 1. Structure of employment in the French maritime industry



Source: INSEE 2015.

3. Material and methods

3.1 The Input-Output mixed model

The I-O approach proposes a multi-linear, inter-sectoral model that displays explicitly the relationships between the productive industries of a given economy [17]. In the standard open demand model, the direct and indirect output effects of an economy are determined by the exogenous final demand [17]. However, if one wishes to estimate the impact of a change in one industry's output on the economy as a whole, it is necessary to consider this output as exogenous, and include it in the final demand vector [5,6]. The so-called mixed model allows to assess the effects of the change in the production of water transport activities on all other industries without considering the endogenous effects of these industries on the water transport activity itself [18]. The basic balance equations of the I-O model consisting of N industry sectors can be expressed as:

$$X_i = \sum_j^N x_{ij} + x_i^D = \sum_j^N a_{ij}X_j + x_i^D \quad (\text{Eq. 1})$$

where X_i is the total output in industry $i = 1, 2, \dots, N$. x_i^D represents the final demand vector for products i and $a_{ij} \left(= \frac{x_{ij}}{X_j} \right)$, are the technical coefficients that give the proportion of input i needed to produce one unit of product j . X_j denotes the total output vector for industry j .

The abbreviated matrix form of the model is

$$X = AX + X^D \quad (\text{Eq. 2})$$

$$X^D = (I - A)X \quad (\text{Eq. 3})$$

$$X = (I - A)^{-1}X^D \quad (\text{Eq. 4})$$

In the mixed model, the first K branches of the model have an exogenous final demand and an endogenous production. The production the $(n-k)$ exogenous (e.g. maritime) industries needs to be treated exogenously and left into the final set of industries. Eq. 1 must thus be rewritten as:

$$X_i = \sum_j^K x_{ij} + \sum_{k+1}^N \bar{x}_{ik+1} + x_i^D = \sum_j^K a_{ij}X_j + \sum_{k+1}^N a_{ik+1}\bar{X}_{k+1} + x_i^D \quad (\text{Eq. 5})$$

In an abbreviated matrix form of the mixed model, it gives:

$$X_M = M^{-1}N\bar{x}_M^D \quad (\text{Eq. 6})$$

With

$$M = \begin{bmatrix} (1 - a_{11}) & -a_{1k} & 0 & 0 \\ -a_{k1} & (1 - a_{kk}) & 0 & 0 \\ -a_{k+1,1} & -a_{k+1,k} & -1 & 0 \\ -a_{n1} & -a_{nk} & 0 & -1 \end{bmatrix} \quad N = \begin{bmatrix} 1 & 0 & a_{1,k+1} & a_{1n} \\ 0 & 1 & a_{k,k+1} & a_{kn} \\ 0 & 0 & -(1 - a_{k+1,k+1}) & a_{k+1,n} \\ 0 & 0 & a_{n,k+1} & -(1 - a_{nn}) \end{bmatrix} \quad (\text{Eq. 7- 8})$$

$$\text{And } \bar{x}_M^D = \begin{bmatrix} x_1^D \\ x_k^D \\ \bar{x}_{k+1} \\ \bar{x}_n \end{bmatrix} \quad (\text{Eq. 9})$$

Using the Leontief matrix of technical coefficient (A), we obtain:

$$M = \begin{bmatrix} (I - A_{12}) & 0 \\ A_{21} & -1 \end{bmatrix} \text{ and } N = \begin{bmatrix} I & A_{12} \\ 0 & -(1 - A_{22}) \end{bmatrix} \quad (\text{Eq.10})$$

3.2. Output multipliers and linkage indices

Output multipliers are used to estimate the effects of a change of an exogenous variable (household, firms' investment, external or public consumption, or even production in water transport services) on the rest of the economy. The algebraic expression of the output multiplier is:

$$O_j = \sum_i^N \alpha_{ij} \quad (\text{Eq.11})$$

Where, α_{ij} are the elements of the modified reverse matrix ($M^{-1}N$). These effects can be decomposed considering the direct output effect (i.e. the intermediate inputs purchased by the maritime industries to their suppliers ($\sum_i^n a_{ij}$), and the indirect output effects (i.e. purchases of the maritime industries' suppliers to their own suppliers ($\sum_i^n \alpha_{ij} \sum_i^n a_{ij} - 1$)).

In the framework of an I-O model, two indices of economic effects stemming from the maritime industries and directed toward other industries can be calculated: the Backward Linkage Index (BLI) ($B_j = \frac{1/n \sum_i^n \alpha_{ij}}{1/n^2 \sum_j^n \sum_i^n \alpha_{ij}}$) and the Forward Linkage Index (FLI) ($B_j = \frac{1/n \sum_j^n \alpha_{ij}}{1/n^2 \sum_j^n \sum_i^n \alpha_{ij}}$). The BLI means that an increasing activity in water transport services may induce greater use of other industries' products as intermediate inputs. FLI shows the extent to which water transport services are used as inputs by other industries for their own production. These two effects are then useful to assess the overall impact of water transport activities onto the domestic economy.

3.3 Employment multipliers

In the paper we also seek to assess the effects of maritime industries' activities on the employment of the associated industries. In order to integrate the differences in employment structures, we have split up the water transport industry into two branches, freight and passenger water transport. First, the employment diagonal vector (\widehat{W}_i) has been constructed:

$$\widehat{W} = \begin{bmatrix} \frac{E_1}{X_1} & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \dots & \frac{E_n}{X_n} \end{bmatrix} \quad (\text{Eq. 12})$$

Where E_i is the number of jobs in industry i and X_i , the output of industry i . Multiplying \widehat{W}_i by the modified reverse matrix ($A_M = M^{-1}N$), we obtain the employment multipliers generated by a change in maritime industries' final uses of exogenous industries and productions of endogenous industries (ΔX_D):

$$\frac{\Delta E_i}{\Delta X_D} = [\widehat{W}_i * (I - A_M)^{-1}] \quad (\text{Eq.13})$$

3.4 Environmental multipliers

For the period 2007-2012, the International Maritime Organization (IMO) estimated that shipping is responsible for approximately 3.1% of annual global CO₂ and 2.8% of annual Greenhouse gas (GHG, including CO₂, CH₄ and N₂O) emissions on a CO₂-equivalent basis [22]. It represents nearly 1 billion tonnes of GHG emissions. This is a major concern for IMO while striving to mitigate the impact of shipping on climate change, since CO₂ emissions are expected to grow by 50% to 250% in 2050 according to some IMO scenarios [22]. Many authors have studied the global CO₂ emissions of the shipping industry in order to stress the overall reduction of emissions [19,20] or the expected impact of some specific mitigating measures [21]. Most of them are doing so by estimating the fuel consumption of ships through different variables: the total number of active ships by size and type, the annual number of days at sea, the time spent by ships at various speeds, the travelled distance, the time at port calls, the main and auxiliary engine power, the Specific Fuel Oil Consumption (SFOC, in grams per kW), etc. Fuel consumption is converted thereafter into CO₂-equivalent emissions by using emission factors (e.g. in g per tonne of fuel; IMO 2014).

One may consider that all GHG emissions are not included in such estimations which do not account for the indirect (backward and forward effects) of the shipping industry on the whole economy. Input-Output analysis can be useful in that regard by integrating environmental extensions to form what is called an environmentally-extended input-output (EE-IO) approach [23]. The basic equation (Eq. 14) underlying EE-IO models has been defined by the United Nations [24]:

$$E_{ghg} = \hat{B} * (I - A_M)^{-1} * \hat{Y} \quad (Eq. 14)$$

Where E_{ghg} is the matrix of direct and indirect GHG emissions, \hat{B} is the diagonal vector of emission intensity coefficients (GHG emission per unit of output, industry by industry), I is the unit matrix, A_M is the matrix of input coefficients obtained from the mixed model and \hat{Y} is the diagonal vector for final use.

This approach allows assessing the domestic direct and indirect carbon dioxide emissions for the production of shipping services and other related activities. However, it should be noticed that such a result is far from estimating the comprehensive carbon footprint of this production, since it does not include input emissions imported by the domestic industry, nor extracted raw materials which remain unused by the production process. More global EE-IO tables through inter-country input-output (ICIO) models must be used to take global emissions into consideration [25], although this type of modelling goes beyond the scope of the present research.

In the above emission equation, the components of the \hat{B} -vector are obtained from a Physical supply-use table which describes the magnitude (measured in physical units such as Mega-grams, i.e. tonnes, or Giga-grams, i.e. thousand tonnes) and the nature of residuals flowing between the economy and nature (UN 2018), following the international standards of the UN System of Environmental-Economic Accounting (SEEA) Central Framework (2012)¹⁰. Since the 1990s, within the SEEA framework, the European Statistical Office (EUROSTAT) has developed its own environmental accounting system called NAMEA (national accounting matrix with environmental accounts), which is a conceptual tool linking conventional (monetary) national accounts and environmental (physical) accounts [23]. The physical satellite accounts include the energy consumption broken down by industry and household categories,

¹⁰ https://unstats.un.org/unsd/envaccounting/seearev/seea_cf_final_en.pdf

as well as waste and air, soil and water polluting emissions. Most EU countries, including France, have now built their own NAMEA-air pollution data collection system¹¹.

3.5 Data

The symmetrical input-output tables (IOT) product by product published by EUROSTAT between 2010 and 2014 were used in order to build the I-O model¹². The input-output tables (IOT) combine both supply and use into a single table with identical classification of industries, applied to both rows and columns. Employment data are provided by the national account scheme and published by the National Institute of Statistics and Economic Studies [14].

The physical air emission data are available in France for 14 chemical substances between 2008 and 2014¹³, including those usually associated with shipping: carbon dioxide (CO₂), methane (CH₄), sulphur dioxide (S₂O), Nitrous oxides (NO_x), suspended particulate matter (PM_{2.5} or PM₁₀, with diameters of 2.5 or 10 micron, respectively). They can also be extracted from the same Eurostat source¹⁴.

4. Results

4.1 Backward and forward linkage effects

Table 1 and Table 2 show the backward and forward linkage indices of the top ten national industries ranked by decreasing order of Backward Linkage Index (BLI) in 2016. From Table 1, one can see that the backward linkage of water transport services is between 1.21 and 1.30 in regular years. The significantly lower value at the beginning of the period is clearly caused by the decreasing demand which has followed the financial crisis of 2008. In 2016, water transport services reached the second highest backward linkage of all 64 industries (1.30). In other words, the maritime transport industry displays a certain capacity to pull other industries upwards by its high level of intermediate consumptions.

Table 1. Backward Linkage Index (BLI).

Industry	2010		2011		2012		2013		2014		2015		2016	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank
Insurance, reinsurance and pension funding services	1.34	1	1.32	1	1.36	1	1.34	1	1.37	1	1.37	1	1.37	1
Water transport services	1.11	13	1.27	3	1.21	5	1.23	4	1.21	5	1.27	3	1.30	2
Wood and of products of wood and cork,	1.24	5	1.23	5	1.22	4	1.22	5	1.27	2	1.22	5	1.27	3
Food, beverages and tobacco products	1.26	3	1.27	4	1.27	3	1.27	2	1.27	3	1.26	4	1.27	4
Travel agency, tour operator and other reservation services	1.27	2	1.30	2	1.29	2	1.26	3	1.25	4	1.30	2	1.24	5

¹¹ <https://ec.europa.eu/eurostat/web/environment/emissions-of-greenhouse-gases-and-air-pollutants/air-emissions-accounts>

¹² Table [naio_10_cp1700] extracted from <https://ec.europa.eu/eurostat/fr/data/database>

¹³ <https://www.citepa.org/fr/activites/inventaires-des-emissions/namea>

¹⁴ Table [env_ac_ainah_r2] extracted from <https://ec.europa.eu/eurostat/fr/data/database>.

Electricity, gas, steam and air conditioning	1.25	4	1.22	6	1.18	6	1.16	7	1.16	6	1.16	6	1.16	6
Other non-metallic mineral products	1.15	8	1.17	7	1.17	7	1.16	6	1.16	7	1.14	7	1.16	7
Basic metals	1.14	9	1.13	10	1.14	8	1.14	10	1.14	8	1.13	8	1.14	8
Legal and accounting services; mgt consultancy services	1.08	18	1.10	15	1.11	15	1.12	13	1.14	9	1.11	13	1.14	9
Products of agriculture, hunting and related services	1.11	14	1.11	12	1.12	10	1.15	8	1.13	10	1.12	10	1.13	10

Note: sectors are ranked by decreasing order of BLI in 2016.

By contrast, the forward linkage (Table 2) of water transport services is the lowest of all sectors. When the economy is growing, water transport services are therefore less stimulated than other industries by the rest of the economy.

Table 2. Forward Linkage Index (FLI)

Industry	2010		2011		2012		2013		2014		2015		2016	
	Value	Rank	V	R	V	R	V	R	V	R	V	R	V	R
Legal and accounting services; services of head offices; management consult. services	2.80	1	2.91	1	2.94	1	3.03	1	3.10	1	3.14	1	3.11	1
Wholesale trade services, except of motor vehicles and motorcycles	2.47	2	2.40	2	2.42	2	2.45	2	2.47	2	2.47	2	2.47	2
Financial services, except insurance and pension funding	2.14	3	2.03	4	2.09	4	2.13	3	2.21	3	2.17	3	2.21	3
Electricity, gas, steam and air conditioning	2.11	4	2.09	3	2.11	3	2.08	4	2.03	4	1.98	4	2.03	4
Security and investigation services; services to buildings and landscape; office admin., etc.	1.92	5	1.87	5	1.88	5	1.86	5	1.77	5	1.70	5	1.78	5
Warehousing and support services for transportation	1.73	7	1.61	7	1.62	7	1.63	7	1.65		1.65	7	1.67	6
Real estate services excluding imputed rents	1.59	6	1.67	6	1.69	6	1.67	6	1.65	6	1.66	6	1.65	7
Rental and leasing services	1.35	8	1.33	8	1.34	8	1.32	8	1.33	7	1.33	9	1.33	8
Services auxiliary to financial services and insurance services	1.28	11	1.26	11	1.30	10	1.28	10	1.31	8	1.34	8	1.31	9
Food, beverages and tobacco products	1.24	13	1.26	12	1.27	11	1.29	9	1.30	9	1.27	10	1.30	10
.../...														
Water transport services	0.56	64	0.58	64	0.59	64	0.60	64	0.56	64	0.61	64	0.60	64

Note: sectors are ranked by decreasing order of FLI in 2016.

However, this result is largely caused by the way input and output data are registered in I-O tables. In the national accounts, final demand and exports are registered as FOB (Free On Board) value and imports as CIF (Cost-Insurance-Freight) value. In water transport services, exports thus represent about 98% of the total uses, and intermediate uses only 2%. Water transport is therefore nearly excluded of the input-output table rows and its intermediate uses by other domestic industries cannot be

estimated. Consequently, even if the water transport industry seems to be poorly supportive of other industries by the forward linkage effects, it plays a significant role in the French economy by boosting other activities through its backward linkage effects. This result is totally in line with what has been observed in other domestic economies [1,5,6].

4.2 Output-inducing effects

Table 3 shows the twenty domestic industries with the highest output multipliers and therefore showing the inter-industrial impact of water transport services. In 2016, the output multiplier of water transport services was 2.16 (the second highest). This number shows that a 1 million euro increase of the final demand for water transport services would generate a 1.16 million increase of output value (in addition to the water transport output itself) in the whole economy¹⁵. The total output-inducing impact result from both direct and indirect effects. Actually, a change in the final demand for water transport services generates a rise in production of related industries (direct effects) which in turn buy more from their own suppliers (indirect effects) and so on and so forth.

The output multiplier of water transport services sector remains relatively stable between 2011 and 2016, with a much lower value in 2010 when the impact was found lower that particular year (1.88) due to a slow economic recovery, thus showing the strong sensitivity of the shipping sector to international business conditions.

Table 3. Output multipliers (direct + indirect impacts)

Industry	2010		2011		2012		2013		2014		2015		2016	
	Value	Rank	V	R	V	R	V	R	V	R	V	R	V	R
Insurance, reinsurance and pension funding services	2.26	1	2.21	1	2.27	1	2.23	1	2.28	1	2.25	1	2.28	1
Water transport services	1.88	13	2.14	3	2.04	5	2.06	4	2.02	5	2.08	3	2.16	2
Wood and of products of wood and cork,	2.09	5	2.07	5	2.04	4	2.04	5	2.11	2	2.01	5	2.11	3
Food, beverages and tobacco products	2.13	3	2.13	4	2.13	3	2.13	2	2.11	3	2.08	4	2.11	4
Travel agency, tour operator and other reservation services	2.14	2	2.15	2	2.16	2	2.11	3	2.07	4	2.15	2	2.07	5
Electricity, gas, steam and air conditioning	2.11	4	2.05	6	1.99	6	1.94	7	1.93	6	1.91	6	1.94	6
Other non-metallic mineral products	1.94	8	1.96	7	1.96	7	1.94	6	1.92	7	1.87	7	1.92	7
Basic metals	1.93	9	1.89	10	1.91	8	1.90	10	1.90	8	1.86	8	1.90	8
Legal and accounting services; management consultancy services	1.82	18	1.85	15	1.86	15	1.88	13	1.90	9	1.83	13	1.90	9
Products of agriculture, hunting and related services	1.87	14	1.87	12	1.88	10	1.92	8	1.89	10	1.84	10	1.88	10
.../...														
Services of households as employers;	1.00	64	1.00	64	1.00	64	1.00	64	1.00	64	1.00	64	1.00	64

¹⁵ Because input coefficients can fluctuate from year to year, a Monte Carlo approach based on random values drawn from a Normal law (with a standard-deviation of 20%, which is tremendous) was used for the main 13 input coefficients. With 1000 random trials, the output multiplier of water transport has a 90% probability of being found between 1.90 and 2.13 over the full period).

Note: sectors are ranked by decreasing order of output multipliers in 2016.

The final demand of water transport services industry has grown from 12 billion euros in 2010 to **14 billion euros in 2016**. Consequently, the total output effect created by the domestic maritime transport industry has increased from €23 billion in 2010 to **€30 billion in 2016**¹⁶ (Table 4). Only four industries cumulated **68%** of the maritime transport's output-inducing effects, of which primarily the branch itself with 49%. Warehousing and support services for transportation, **legal and accounting services** and the sector of **coke and refined** petroleum products have also benefitted from the boom of maritime transport, but to a much lesser extent. This indicates that the costs of these four industries make the largest share of production costs for the maritime transport industry.

Table 4. Output-inducing effects of maritime transport by industry between 2010 and 2016 (in billion euros and percentage of maritime transport's total production-inducing effects).

	2010		2011		2012		2013		2014		2015		2016	
Total output-inducing effect (in billion €)	23.0		27.1		29.1		29.1		29.2		32.0		29.8	
	Bn €	%												
Water transport services	11.8	51	12.5	46	14.2	49	14.1	49	14.4	49	15.3	48	13.7	46
Warehousing and support services for transportation	2.67	12	3.3	12	3.4	12	3.5	12	3.5	12	4.1	13	4.0	13
Legal and accounting services; management consultancy serv.	1.32	6	1.7	6	1.8	6	1.9	6	1.9	7	2.3	7	2.2	7
Coke and refined petroleum services	0.62	3	1.0	4	1.2	4	1.1	4	1.0	3	0.6	2	0.6	2
Cumulated share of the top-4 industries	16.4	71	18.5	68	20.5	71	20.5	71	20.8	71	22.3	70	20.5	68

4.3 Employment-inducing effects

Maritime industries offer many employment opportunities. In 2016, the world maritime economy has generated 31 million jobs according to OECD [26]. In France, the admitted figure is around 400,000 jobs [27].

In 2014, the Freight water transport industry had a job multiplier of 7, but the value of the passenger water transport industry was nearly twice higher (13)¹⁷. In other words, per million euro of additional demand for water transport services, 7 jobs are created in freight and 13 jobs in passenger transport. This difference makes sense when the distinct nature of jobs in these two activities is observed: more services (catering, accommodation, gift shops,...) are included onboard passenger ferries crossing the English channel or sailing to Corsica or Algeria for instance. These two branches rank respectively 19th and 53rd among the 64 branches of the economy by their multiplier, and could be considered as poorly job-creating. However, in 2014, some 105,259 jobs were directly or indirectly created by the final

¹⁶ In 2016, the direct output effect was 9.6 billion euros and the indirect effect was 20.3 billion euros.

¹⁷ The employment effects have been calculated after splitting the maritime transport industries into two sub-sectors, freight water transport services and passenger water transport services.

demand for water transport services within the whole domestic economy (of which 18,862 jobs concentrated in the two maritime transport industries). The Warehousing and support services for transportation industry is another industry taking advantage of the demand for water transport (Figure 2).

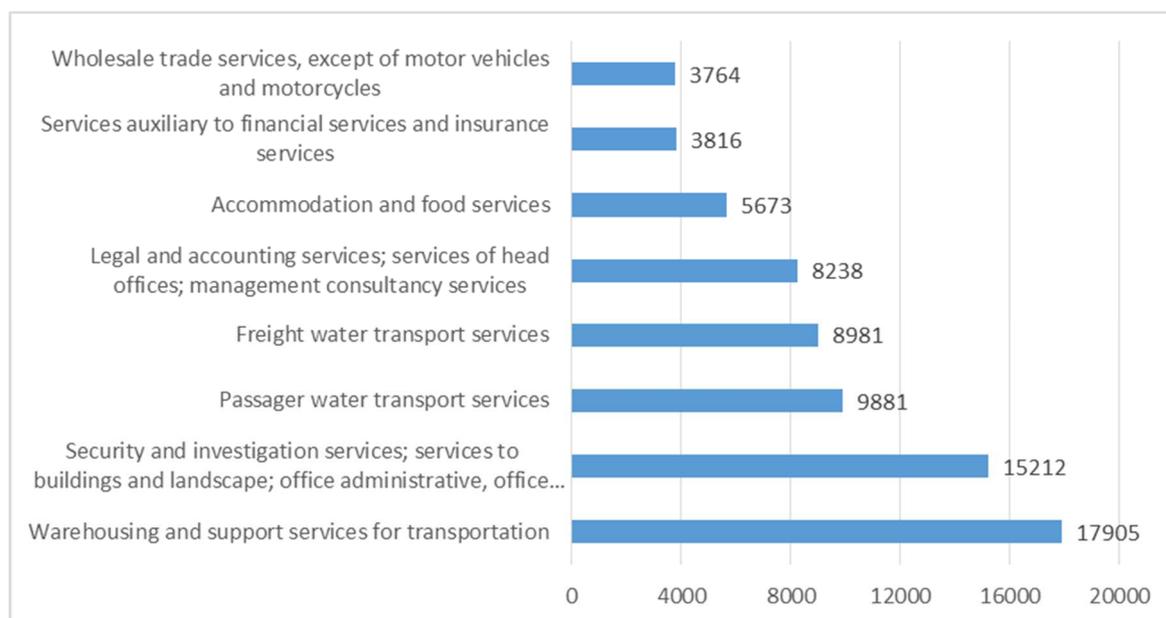


Figure 2. Main industries benefitting from an increased demand for water transport in 2014 (in terms of employment); own calculation from authors

4.4 Environmental effects

Environmental multipliers and total effects of air chemical pollutions have been computed for the French shipping industry. As explained in the methodological section, multipliers are obtained by the product of the B diagonal vector of emission intensity coefficients (i.e. the physical amount of substance per M€ of output; CO₂ is expressed in thousand tonnes per M€, the other chemical compounds in tonnes per M€) and the inverse Leontief Matrix of the mixed model ($M^{-1} \cdot N$). The total effects are obtained by the matrix product of the emission multipliers and the diagonal vector of final demand. By doing so, the air polluting emissions are re-allocated throughout their indirect backward effects on upstream activities. For instance, water transport is not only responsible for its own CO₂ emissions, but also for the CO₂ emissions of the whole chain of suppliers, of which those emitted by the coke and refined petroleum product industry.

Table 5. Air pollution multipliers and total emissions from water transport

a) in 2014

	CO ₂	CH ₄	NO _x	PM ₁₀	PM _{2.5}	SO ₂
Multiplier	0.30	0.34	4.95	0.46	0.42	2.60
(Rank/64)	(9)	(20)	(2)	(5)	(3)	(1)

Total effect	3,342	4,935	71,445	6,683	6,040	37,543
(Rank/64)	(16)	(34)	(2)	(5)	(4)	(1)

b) in 2016

	CO₂	CH₄	NO_x	PM₁₀	PM_{2.5}	SO₂
Multiplier	0.26	0.31	4.02	0.32	0.29	1.87
(Rank/64)	(12)	(20)	(2)	(4)	(3)	(1)
Total effect	3,567	4,677	54,335	4,295	3,880	25,244
(Rank/64)	(20)	(32)	(4)	(7)	(5)	(1)

Note: Multiplier units are in thousand tonnes per M€ for CO₂ and in tonnes per M€ for other compounds. Total emission effects are measured in thousand tonnes for CO₂ and in tonnes for other compounds. The figure in brackets represents the rank out of the 64 French industries, i.e. by decreasing order of polluting emissions.

By its final use magnitude, the water transport industry (€13.5 Bn) is only ranked at the 42nd level out of the 64 national industries in 2016. As a result, this activity contributes to only 1% of the domestic CO₂ emissions, i.e. less than the worldwide average share which is above 3% [28]. However, the role played by shipping in the domestic air pollution is far from being negligible with regard to several chemical compounds. The intensity of emission per monetary unit of final use reaches 260 tonnes per M€ for carbon dioxide, 4 tonnes for nitrogen oxides and 1.9 tonnes for sulphur dioxide. For the two latter pollutants, water transport is even ranked fourth and first out of 64 in terms of total pollution effects, with 54,335 tonnes and 25,244 tonnes in 2016, respectively.

Interestingly, a comparison between two close dates (2014 and 2016) show how different multipliers per monetary unit can be. For sulphur dioxide (SO₂), one of the major pollutants emitted by the shipping industry, a significant gap is observed between 2.60 and 1.87 tonnes per M€, representing a 28% decline between the two dates. The same observation goes for fine particulate matters, whose multipliers have decreased by 30% for both PM₁₀ and PM_{2.5}. Demand and the domestic supply have slightly decreased over this short period of time (-6%), nonetheless causing a significant decline of the major pollutants (-24% for NO_x, -33% for SO₂, -36% for PM₁₀ and PM_{2.5}). Because the multipliers are set in relative terms, the lower emissions cannot be fully explained by the decreasing demand for transport in France, but may simply mean that companies are now paying greater attention to environmental issues. When the oil price skyrocketed in 2007-08, before the financial bubble burst out, shipping companies have selected slow steaming strategies by reducing their commercial speed so as to gain a double dividend with lower bunker costs and GHG emissions [28]. The price of Brent oil was more than halved since the crisis and particularly during the 2014-16 period (falling from €80 to €40-50 per barrel). Saving fuel costs was no longer a priority but companies have also invested in new technologies and fuels (scrubbers, LNG, SCR,...) to mitigate their impact on the environment and anticipate the changing regulations.

NO_x and SO₂ are responsible for ocean acidification and eutrophication of waters. In particular, sulphur dioxide is produced by the diesel engines of ships and represents a major risk for human health [29]. The International Maritime Organization has set a new limit for sulphur oxides in fuel oil used by ships outside Emission Control Areas defined by the MARPOL Convention (Annex VI) that comes into force from 1 January 2020¹⁸. The past limit is 3.50% m/m (mass by mass) and becomes 0.50% m/m since then, which should result in a decreasing pollution effect from the shipping industry. Suspended particulate matter is also a major risk for human health, especially fine particles like PM_{2.5} [29,30].

¹⁸ <http://www.imo.org>

Water transport stands in the top five most polluting industries concerning particulate matter effects which have major harmful consequences for lung and heart diseases.

5. Some conclusions and policy implications of the results

France is one of the most important maritime countries globally by its large Exclusive Economic Zone which is the second largest in the world with 11 million km². However, the maritime economy is still largely ignored by the French government and the economic interest of developing the blue economy has only started to be considered very recently. For the first time, this study estimates the role and relative influence that maritime transport has on the French economy by using an input-output approach. Such an analysis offers the interest to produce some results that can be compared with previous works achieved in other countries [1,2,3,4,5,6,7], of which many were published in *Marine Policy* and grounded in a similar conceptual (Input-Output) framework. Obviously, the output multipliers estimated in the present study for one specific maritime industry are found smaller than national studies cumulating several sectors [1,5,6]. In particular, the employment multipliers [5 jobs per M€ of final demand on average] is far below the same value found for Ireland (29 jobs per M€ created by the 10 marine industries). However, the BLI and FLI are very consistent with those shown by these research works, with a much greater than average backward index and a much lower than average forward index, this latter low value being caused by the FOB registration of exports. With one major global carrier (CMA-CGM) ranking at the third or fourth position of the worldwide top liner shipping companies, France appears as an important maritime country, which is also revealed by the direct and indirect employment depending on the water transport activity. However, France is not amongst the major European nations involved in this activity (Germany, Denmark, United Kingdom...), although the output multiplier is found greater than the average European figure of 1.6 for maritime transport [8-10].

Another interest of this study relates to the concept of 'blue growth' and the need to follow the development of the European maritime industry by referring to a well-established initial point. Indeed, we now have a starting basis for the number of jobs or the wealth-inducing effects of maritime transport in France. As long as this country, through its national Blue growth strategy¹⁹, claims for greater investment in maritime sectors and the development of water transport, it is now possible to evaluate the outcomes of such a blue growth policy from the dynamics of economic effects produced by the maritime industry in the years to come in France.

From the results, we can see that passenger water transport services are more labour-intensive than maritime freight services and should be encouraged for their employment-inducing effects. Water transport services appear to be relatively less job-creating than many other French industries, particularly the freight services. For any million euro spent on the demand side, the freight industry creates 7 full-time equivalent (FTE) jobs, meanwhile the passenger transport activity creates 13 FTE jobs. However, because the demand for freight (€13 bn) exceeds by far that of passenger services (€1.4 bn in 2014), the combined direct and indirect effects of the demand for water transport (for both passenger and freight) in the economy result in a cumulated creation of 105,259 jobs in 2014 (of which 18,862 jobs for the mere water transport), i.e. 0.4% of total domestic employment. Although the ferry lines are not always profitable for private companies, they may produce significant spillover effects for the economy through the number of direct and indirect jobs which are created, not even mentioning the induced impact on local economies through the household expenditures²⁰ for the workers of this

¹⁹ http://www.dirm.sud-atlantique.developpement-durable.gouv.fr/IMG/pdf/decret_2017-222_du_23fevrier2017-snml.pdf

²⁰ Such an impact on regional consumptions stems from the Keynesian (income) multiplier effect which has not been estimated in the present analysis but could represent an interesting extension of this work.

sector. Actually, sailors working aboard of passenger ferries are rather nationals and live near the domestic harbours, unlike the international market of seafarers where multinational freight companies hire their crew members through global manning agencies, resulting in a negative remittance balance because wages are usually spent abroad [31].

The results of inter-industry linkages indicate that water transports services have more power in consuming services and products of related upstream industries rather than being used as an essential input by other downstream activities. Indeed, the water transport industry plays a significant role in the French economy by boosting other industries through its backward linkages. With an output multiplier of **2.16 in 2016 (the second highest among 64 industries)**, water transport services have a significant production-inducing effect in the economy, well above the average multiplier of 1.82 reported in a meta-analysis of maritime multipliers all over the world [11]. Three sectors associated as major suppliers of the water transport services really matter: warehousing and support services for transportation, legal and accounting services, coke and refined petroleum products. Altogether with the branch of water transport itself, these 4 sectors cumulate **68%** of all backward economic effects of the shipping industry. If the last branch is poorly job-creating domestically and would rather tend to increase the trade deficit of the country, the first two sectors remain interesting to develop a public policy supporting the use of maritime transport because their job basis remains local and weakly re-deployable internationally.

As far as the forward linkage index is concerned, the results are just opposite, water transport being ranked at the very bottom of the 64-industry list. This can be considered as a statistical artefact caused by the FOB registration of national exports. For this reason, whatever the domestic or foreign incurrence of freight costs, the sales of domestic water transport services are reported in the export column (i.e. as though all services were purchased by the rest of the world), i.e. representing a final use rather than an intermediate input consumed by other domestic industries. More information is needed to make a clearer interpretation of the results.

Finally, when compared to the strand of research works based on I-O models and dealing with the marine and maritime industries, **this study contributes to the empirical IO literature applied to the maritime industry by introducing an original look at the direct and indirect air pollution effects that shipping produces on the environment, in connection with the ongoing discussion about the reduction of greenhouse gas emissions by the International Maritime Organisation (IMO 2014)**. Considering the environmental impact of water transport on air pollution, we show that water transport stands in the top five most polluting industries out of 64 concerning several pollutants ($PM_{2.5}$, NO_x and SO_2). In terms of emission intensities (tonnes per M€ of final use), CO_2 emissions is also a major concern, water transport belonging to the **top-12** most polluting industries, despite the fact that shipping has only the **42nd most** important final use level out of the 64 national industries.

Since 2015, IMO and thereafter the European Parliament stipulated that all ships in SECA (*Sulphur Emission Control Areas*, set in 2005 and 2012) should use low sulphur marine fuel not exceeding 0.1% [22]. It will be interesting to monitor the intensity coefficients shown and total direct and indirect emissions of NO_x and SO_2 in this article after the new reduction adopted on January 1st 2020 beyond the SECA limits, where a standard of 0.50% sulphur rate is now imposed instead of the past 3.50% (MARPOL Annex VI). A debate has followed the announcement of the new rule to compare the disadvantage of affected companies which have to comply with stringent regulation compared to their competitors in non-SECA who are not subject to this regulation. Two years after the IMO regulation, the effect has not been as intense as originally expected for both shipowners and ports [13,32]. However, the new sulphur reduction that is imposed will have a larger impact and push companies to invest in scrubbers, SCR or LNG technology or take other mitigating measures. From our results, most of the GHG emissions, whatever the compound, are concentrated in the water transport activity itself, and more weakly in other industries through the cascading effects. Policy efforts should therefore

focus on this particular activity to further reduce the overall emissions rather than spreading the efforts over various industries [19]. However, because forward linkages are imperfectly measured (due to the FOB registration of exports), it should be outlined that other industries might also be partly responsible for such emissions because of their long and global logistic supply chains consuming intermediate services of transport, which are not visible in the present domestic I-O framework [21]. Nonetheless, the same EE-IO exercise as the one developed in this article remains an interesting preliminary approach to assess and follow throughout time the coming achievements regarding the reduction of GHG emissions by the shipping industry.

We hope that other studies will attempt to replicate a similar methodology for some other countries. We also believe that this type of research would benefit from being developed in a multi-regional or inter-country input-output framework for such a global industry [25]. By doing so, the GHG footprint and other types of footprints (e.g. water, energy, materials, residuals...) would be re-affected to the countries where the demand for shipping services originates, instead of estimating an inventory based on the domestic output only. Such a study would probably require an international research endeavour to re-allocate the shipping services between importing and exporting countries.

References

- [1] Wang Y., Wang, N., 2019. The role of the marine industry in China's national economy: an input-output analysis. *Marine Policy* 99: 42-49.
- [2] Jun W.K., Lee M.-K., Choi J.Y., 2018. Impact of the smart port industry on the Korean national economy using input-output analysis, *Transportation Research Part A* 118: 480-493.
- [3] Lee M.-K., Yoo S-H, 2016. The role of transportation sectors in the Korean national economy: An input-output analysis. *Transportation Research Part A*, p. 13–22
- [4] Chang S-M, Huang Y-Y, Cheng T-S. 2015. The Role of the Taiwan Marine Sectors in the National Economy: An Input-output Analysis. Proceedings of the International Forum on Shipping, Ports and Airports (IFSPA) 2015.
- [5] Kwak, S.-J., Yoo, S.-H., Chang, J.-I., 2005. The role of the maritime industry in the Korean national economy: an input-output analysis. *Marine Policy* 29 (3), p.371–383.
- [6] Morrissey K., O'Donoghue C., 2013. The potential for an Irish maritime transportation cluster: An input-output analysis. *Ocean & Coastal Management* 71: 305-313.
- [7] Fernández-Macho, Murillas A., Ansuategi A., Escapa M., Gallastegui C., González P., Prellezo R., Virto J. 2015. Measuring the maritime economy: Spain in the European Atlantic Arc. *Marine Policy* 60: 49-61.
- [8] Oxford economics, 2014. The economic value of the EU shipping industry. Report for the European Community Shipowner' association (ECSA).
- [9] Oxford economics, 2015. The economic value of the EU shipping industry. Update report for the European Community Shipowner' association (ECSA).
- [10] Oxford economics, 2017. The economic value of the EU shipping industry. Update report for the European Community Shipowner' association (ECSA).

- [11] Jacobsen K.I., Lester S.E., Halpern B.S., 2014. A global synthesis of the economic multiplier effects of marine sectors. *Marine Policy* 44: 273-278.
- [12] Endresen Ø., Sjørgård E., Sundet J.K., Dalsøren S.B., Isaksen I.S.A., Berglen T.F., Gravir G., 2003. Emission from international sea transportation and environmental impact. *Journal of Geophysical Research* 108(D17), <https://doi.org/10.1029/2002JD002898>.
- [13] Cullinane K., Bergqvist R., 2014. Emission control areas and their impact on maritime transport. *Transportation Research Part D: Transport and Environment* 28: 1-5.
- [14] INSEE, 2015. L'économie maritime : des activités diverses et localisées. *Insee Première* 1573, November 2015, 4 pp.
- [15] Ifremer, 2017. Données de l'économie française maritime, Report of the Département d'Economie Maritime, Ifremer, Paris.
- [16] Miossec J.-M., 2016. Le conteneur et la nouvelle géographie des océans et des rivages de la mer. Dans le sillage de la CMA-CGM. L'Harmattan, Paris, 722 pp.
- [17] Leontief W., 1966. Input-Output Economics. Oxford University Press, New York.
- [18] Hambÿe C., 2012. Analyse entrées-sorties, modèles, Multiplicateurs, Linkages. *Bureau fédéral du plan, analyse et prévisions économiques*, Brussels, Belgium, WP 12-12.
- [19] Bouman E. A., Lindstad E., Riolland A. I., Strømman A. H., 2017. State-of the-art technologies, measures, and potential for reducing GHG emissions from shipping—A review. *Transportation Research Part D* 52: 408-421.
- [20] Olmer N., Comer B., Roy B., Mao X., Rutherford D., 2017. Greenhouse gas emissions from global shipping, 2013-2015. Report of the International Council on Clean Transportation (ICCT), 38 pp.
- [21] Cariou P., Parola F., Notteboom T., 2018. Towards low carbon global supply chains: a multi-trade analysis of CO₂ emission reductions in container shipping. IAME2018 Conference, Mombasa, Kenya, Paper ID 54, 26 pp.
- [22] IMO, 2014. Third IMO Greenhouse Gas Study. International Maritime Organization (IMO), London, UK, 327 pp.
- [23] Gajos E., Prandecki K., 2016. National Accounting Matrix with Environmentally Extended IO analysis. *Oeconomia* 15(4): 65-74.
- [24] United Nations, 2018. Handbook on Supply, Use and Input-Output Tables with extensions and applications. *Studies in Methods, Series F* 74, Rev.1, New York, 628 pp.
- [25] Tukker A., 2011. EXIOPOL and CREEA: Towards a global Multi-Regional Economic and Physical Supply and Use tables with Environmental Extensions (ESA/STAT/AC.238). Department of Economic and Social Affairs Statistic Division United Nations, New York.
- [26] OECD, 2016, The ocean economy in 2030, OECD, Paris.
- [27] Colas S., 2019. Les emplois de l'économie maritime – données 2015. Observatoire National de la Mer et du Littoral, Ministère de la Transition Ecologique et Solidaire and INSEE.
- [28] Cariou P., 2011, Is slow steaming a sustainable means of reducing CO₂ emissions from container shipping? *Transportation Research Part D* 16: 260-264.
- [29] Pandey J.S., Kumar R., Devotta S., 2005. Health risks of NO₂, SPM and SO₂ in Delhi (India). *Atmospheric Environment* 39(36): 6868-6874.
- [30] Englert N., 2004. Fine particles and human health—a review of epidemiological studies. *Toxicology Letters* 149(1-3): 235-242.

[31] Bagoulla C., Guillotreau P., 2016. Shortage and labor productivity on the global seafaring market. In P. Chaumette (ed.), *Seafarers: an international labour market in perspective*, ERC project Human Sea. Gomylex Editorial, Chapter 1: 37-49.

[32] Omolola Olaniyi E., 2017. Towards EU2020: an outlook of SECA regulations implementation in the Baltic Sea region. *Baltic Journal of European Studies* 7(2): 182-2017.