

Regional Economic and Environmental Analysis as a Decision Support for Strategic Marine Planning in Xiamen

—a comparative study of port and shipping industry and waterfront tourism by using environmental input-output approach

1. Introduction

Since ancient times, oceans have been regarded as pristine and unknown areas for human activities. As cognitive level improves and science and technology advances, the development and exploitation of the oceans by human beings today come to an unprecedented level (Charles Ehler & Douvere, 2007). Shipping, fishing, military use, sea mining, recreation, energy use, aquaculture etc., all these human uses increasingly make the sea a prosperous and crowded area (Douvere & Ehler, 2009). With increasing intensity of existing uses as well as diversification of use pattern on the oceans, traditional sector-based regimes have been recognized as inadequate to account for the interactions of various human activities as well as their cumulative effects (Ardron, Gjerde, Pullen, & Tilot, 2008; Cicin-Sain & Knecht, 2000; C. Ehler, 2008; Flannery, Cinneide, & Nixon, 2010; Interagency Ocean Policy Task Force, 2009; Mengerink, 2010; Slater, 2004; Tyldesley, 2004). Over the past few decades, Marine Planning (MP) has been widely used all over the world to overcome the inadequacies of sectoral approach and manage human activities in ocean and coastal areas, with significant results achieved and valuable lessons learned (C. Ehler, 2008). This approach provides a comprehensive framework to address environmental, economic and social objectives, thus facilitating the fulfillment of sustainable development (Charles Ehler & Douvere, 2009; Gilliland & Laffoley, 2008; Gubbay, 2005; MSPP Consortium, 2006; Tyldesley, 2004).

The MP system in China has developed for sea use management under national jurisdiction for more than 20 years (Fang, Zhang, Zhang, & Hong, 2011). It was first proposed by Chinese central government in 1988 and two rounds of practices were carried out during the period of 1989-1993 and 1998-2001 (Dong, 2002). However, a

majority of planning schemes developed in these periods merely compiled and pieced together the existing information and spatial designations of various relevant sectors, rather than taking into account socioeconomic attributes of human uses and their interactions with biophysical ecosystem (Douvere & Ehler, 2009; P. E. Wang, Hong, & Zhang, 2004). Since 2009, with the adoption of an innovative concept—‘Principal Functional Zoning (PFZ)’—by Ministry of Land and Resources of China, State Oceanic Administration (SOA) has initiated the research and development of ‘National Marine Principal Functional Zoning’, which provides a great opportunity to direct exploitation and utilization activities in marine and coastal areas from a strategic perspective (<http://www.soa.gov.cn/soa/index.htm>). PFZ guides regional development by prioritizing principal function and selecting development intensity, in accordance with carrying capacity of natural resources, current situation of utilization, and prospective development potential (State Oceanic Administration, 2011). Although there are increasing number of studies attempting to discuss its nature, theory, and approach in a relatively conceptual sense, very limited experiences and lessons on decision analysis can be drawn from existing practices throughout the nation, particularly for real life cases (He, Wang, Zhao, Xu, & Song, 2010; Li, Zhao, & Song, 2010; R. Zhang, Zhang, & Fang, 2011). Therefore, it is meaningful to carry out theoretical and application researches on decision analytical approach in the context of marine principal functional zoning.

2. Purpose

This analytic paper explores the applicability of environmental input-output (EIO) approach as a decision support analytical framework in the context of marine principal functional zoning in China. Using Xiamen as a demonstration case, the research is going to conduct a comparative analysis between two of this southeastern coastal city’s leading marine functional uses—‘port and shipping’ versus ‘waterfront tourism’. The study investigates 1) economic impacts and 2) selected resource and environmental implications associated with these two marine functional uses from a region-wide perspective, under both baseline and simulated scenarios.

Two primary outcomes are achieved. Practically, quantitative assessment of tradeoffs between two marine functional uses provides local government with necessary decision support in terms of principal functional orientation in marine and coastal areas. Methodologically, EIO analysis offers a useful decision analysis approach to assess economic, environmental and social impacts of different human uses on the oceans, thus providing valuable reference for MP practices.

3. Research Context

Xiamen is located in the southeastern part of Fujian Province, China and endowed with abundant marine and coastal resources. Oceans have been playing an important role in Xiamen city's social, economic and cultural development. 'Sea within the city and the city on the sea', this well-recognized description vividly characterizes the inseparable connection between the city and the oceans. During the period of '11th Five-Year-Plan', the annual growth rate of value added of marine economy in Xiamen was 13.21%, and in 2010, the value added from marine economy amounted to 24.681 billion Yuan, taking up 12.02% of the GDP of the city (Xiamen Municipal Government, 2011b).

However, with human demands of the oceans expanding, anthropogenic activities in marine and coastal areas are increasing to an unprecedented level in terms of both intensity and frequency, which results in three types of issues: (1) these activities bring about a sequence of environmental and ecological problems. Lin et al. (2007), Zhang et al. (2010), Lin and Zuo (2006), and Wang et al. (2007) discussed comprehensively resource exploitations and utilizations in Xiamen Bay and resulting cumulative effects such as loss of coastal wetlands, pollution of nearshore areas, degradation of representative ecosystems, decline of marine biodiversity and risks of catastrophic events; (2) different activities can result in use conflicts. Yu et al. (2005) elaborated prominent incompatibilities among port and shipping industry, marine aquaculture, and waterfront tourism, while he discussed the challenges faced by marine ecosystem services of Xiamen. Wang et al. (2004) also identified significant resource use conflicts between port and shipping industry and waterfront tourism; (3) resources and environmental restraints

in bay area are not negligible and in turn hinder the further developments of promising sea uses. The limited marine area (only 390 km²) brings an inevitable bottleneck effect in fully accommodating expanding spatial demands of all potential uses such as port and shipping industry, waterfront tourism and coastal industries (Xiamen Municipal Government, 2011b). Coastal reclamation alters the hydrodynamics of Xiamen Bay, which accelerates sedimentary processes in the shallow sea and causes a severe threat to navigation (Fang, Zhang, Jiang, Yang, & Hong, 2006; T. Lin, et al., 2007). Degradation of natural environment could adversely impact those industries that are highly dependent upon environmental and ecological amenities, like waterfront tourism (Xiamen Municipal Government, 2011b; X. Yu, et al., 2005).

In order to prevent disordered and excessive development activities, prioritize the allocation of limited marine/coastal resources, direct long-term vision for marine economy, and facilitate the sustainable development of marine/coastal areas, it is highly suggested that the municipal government develop the orientation of functional use in marine and coastal areas (P. Wang, et al., 2004; P. E. Wang, et al., 2004; X. Yu, et al., 2005). Historically, sea use conflicts forced local government to make some significant adjustments of use functions in Xiamen Bay area. A very typical representation was the gradual retreat of marine aquaculture from the bay area from 2002 to 2006, making place for three other major functional uses which are ecological conservation, port and shipping, and waterfront tourism (Xiamen Municipal Government, 2006). According to Xiamen Municipal Government (2011b), the current sea use pattern of Xiamen Bay is composed of two leading industries for marine economy, which are ‘port and shipping industry’ and ‘waterfront tourism’, along with other emerging industries such as marine biotechnology, yacht industry, and marine modern services.

Although a series of planning documents (e.g. ‘12th Five-Year’ Specific Plan for Marine Economic Development of Xiamen, Sea Area Use Plan of Xiamen, and Marine Environmental Protection Plan of Xiamen) have been enacted during recent years, there is still lack of explicit policy guidance regarding functional orientation in the whole bay area. Which industry has greater economic impacts to the region? Which industry develops in a way that is more environmentally friendly, meaning consuming less natural

resources and causing less externalities? What are the tradeoffs? How will the economic and environmental performance associated with these two industries change over time under anticipated policy scenarios? Answers to such questions are not yet clear to decision makers.

In 2009, Xiamen was selected as one of first several demonstration sties to develop marine and coastal PFZ by SOA (National Marine Environment Monitoring Center, 2012). Building upon this platform, this work addresses one aspect of relevant decision analysis and provides local government with necessary decision support in terms of marine/coastal functional orientation. As marine principal functional zoning by its very nature is one of several paradigms in the domain of MP (Douvere, 2008; R. Zhang, et al., 2011), appendix A reviews various decision-making analytical approaches to MP practices all around the world and sheds light on Xiamen specific research. As the review identifies, the development of decision analysis approach or methodology for strategy-led MP is still in its early stage, with relatively few real life practices dealing with how to put specific policy analysis into workable practice.

4. Methodology

The research content comprises three following aspects.

(1) Based on macroeconomic statistical data in the base year (2007), the research assesses the regional economic impacts generated by the two leading marine industries that affect marine/coastal development: port and shipping industry and waterfront tourism, respectively.

(2) Linking local economic system with environmental data, the research investigates selected resource and environmental implications associated with port and shipping industry and waterfront tourism respectively to local area in the base year.

(3) Simulating alternative policy scenarios on functional use orientation in Xiamen Bay, the research conducts scenario analysis for the growth of specified marine industry in

terms of its regional economic impacts as well as resource and environmental implications in the planned year set as 2015.

This analysis applies an environmental input-output (EIO) framework as the fundamental approach to conduct the analysis for the following reasons.

(1) Input-output (IO) analysis, developed by Wassily Leontief in the 1930s, is a powerful tool in estimating the economy-wide effects of an initial change in economic activities on a regional economy, which offers an inter-industry method for solving important problems that are macroeconomic in scope (Bess & Ambargis, 2011; Christ, 1955). It is a quantitative economic technique that represents the interdependencies and equilibriums among different branches of the regional economy (Raa, 2010). Its structural and large-scale features make this tool reasonably applicable to the research context which requires a comparison between different branches of a local economy. Especially from a regional development standpoint, it is not always adequate to merely measure the direct performance of the industries concerned; in a regional context, it makes better sense in policy decision support to examine their interrelations with other sectors in the economy and spread effects on the region as a whole. IO analysis has been used to analyze the structure of a regional economy, evaluate the potentials of different industries and development programs, and thus inform regional even national economic planning (Blaylock & Jones, 1973; Loehman & McElroy, 1976; Nelson, Hardy, & Flynn, 1980).

(2) Input-output analysis has been extended to incorporate environmental considerations, called EIO analysis, associated with economic production system since the 1960s (Cumberland, 1966; Daly, 1968; W. Leontief, 1970). The approach estimates the quantity of resources required for and environmental emissions resulting from activities in economy by appending the traditional IO model with additional information of non-economic data (W. Leontief, 1970). Since established, EIO has become a useful tool for analyzing the structure of environmental loads especially on a macroscopic scale, and has been widely adopted for investigating environmental footprints triggered by economic development and trade (Duchin & Lange, 1994; Hubacek & Sun, 2001; Hubacek & Sun, 2005; Juliá & Duchin, 2007; Marcotullio, Williams, & Marshall, 2005; Okadera, Watanabe, & Xu, 2006). Such an integrated analytical tool presents as a promising

framework to bridge socioeconomic system with environmental system, and to represent heterogeneous dimensions of human activities at an inter-sectoral level. This can also advance strategy-led MP from being rather a conceptual framework into operational practices to a certain extent.

(3) Notwithstanding that input-output analysis has been criticized because of its inherently static and linear assumptions, this approach allows coping with discrete and explicit variation in structures, so as to simulate various large-scale policy scenarios and direct discussion on the points of interest (Duchin, 1998). The structural changes usually include composition and volume of final demand, technology relationship in production system, and the availability of natural resources and environmental quality (Hubacek et al., 2009). The applicability of input-output analysis to represent different policy scenarios in the foreseeable future turns out to be a suitable fit for MP which requires a proactive approach.

4.1. Assessment of economic contribution

Based on the theory and method developed by Leontief (1986), the IO analysis for marine industries in Xiamen Bay is constructed as follows.

(1) Impact analysis

This section of analysis measures the impact of final demand as an exogenous factor on the economy as a whole. The basic IO equation is:

$$\mathbf{AX} + \mathbf{Y} = \mathbf{X}, \quad (1)$$

where \mathbf{A} is the technical coefficient matrix, \mathbf{X} is the column vector of gross output, and \mathbf{Y} is the column vector of final demand. \mathbf{A} is an $n \times n$ matrix representing the interrelationships of n sectors within the economy of concern. In this matrix, each element a_{ij} (called direct input coefficient) is defined as:

$$a_{ij} = z_{ij} / X_j, \quad (2)$$

where z_{ij} denotes the transaction from sector i to sector j , and X_j denotes the total output of sector j . Values for these two parameters can be drawn from ‘Input-Output Tables of Xiamen (2007)’ (Xiamen Municipal Statistics Bureau, 2007).

By using matrix algebra, the economic effects of any given final demand can be calculated as:

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1} \mathbf{Y}, \quad (3)$$

where \mathbf{I} is an $n \times n$ identity matrix. Here, the Leontief inverse matrix $(\mathbf{I} - \mathbf{A})^{-1}$ functions as a multiplier that measures the total regional impact of final demand change. The total impact here captures both direct effect which comes from direct sales of business activities/developments, and indirect effect which is caused by inter-industry purchases.

In China, the compilation of IO table generally include seven following categories as final demand, namely household (both urban and rural) consumption, government consumption, fixed investment, inventory change, export, import, and others as an error term to represent different reported data (particularly on trade) and balance the table. This study uses the lump sum of all these categories to represent total final demand as an initial input into the model.

(2) Inter-industry linkage analysis

The inter-industry linkage analysis is another widely used technique in IO analysis to distinguish the roles and natures of various industries in the economy (Kwak, Yoo, & Chang, 2005; S. J. Lin & Chang, 1997). It is able to quantify the strength of causation among industries and identify those sectors whose economic activities impose greater than average influences on the whole economy (Guitton & Rasmussen, 1957). Therefore, it makes reasonable sense to appeal to policy makers who have interests in industrial targeting.

The inter-industry linkage for any given sector consists of backward linkage (BL_j) and forward linkage (FL_i), which are defined as Eq. (4) and Eq. (5) respectively:

$$BL_j = \frac{\frac{1}{n} \sum_{i=1}^n b_{ij}}{\frac{1}{n^2} \sum_{i,j=1}^n b_{ij}}, \quad (4)$$

$$FL_i = \frac{\frac{1}{n} \sum_{j=1}^n b_{ij}}{\frac{1}{n^2} \sum_{i,j=1}^n b_{ij}}, \quad (5)$$

where b_{ij} , called total requirement coefficient, is the element of Leontief inverse matrix. BL_j , also called power of dispersion, indicates the degree to which the production activity of the j th sector pulls other sectors as inputs for its production; while FL_i , also called sensitivity of dispersion, indicates the degree to which the product of the i th sector is needed by all other sectors as an input for their own productions. Those industries with both backward and forward linkages larger than one have greater potential in boosting other industries as well as supporting other industries, and are generally interpreted as key sectors (S. J. Lin & Chang, 1997).

4.2. Investigation of environmental implication

The basic idea of the EIO method can be described as follows (Carnegie Mellon University Green Design Institute, 2008; W. Leontief, 1970).

First, one can determine the direct external (environmental) effect coefficient (or intensity) for each sector within economy by calculating:

$$r_i = e_i / X_i, \quad (6)$$

where e_i is the direct external effect of the i th sector measured in corresponding physical unit; X_i is the total output of the i th sector in monetary term.

Second, to obtain the total external effect throughout the economy, the direct external effect coefficient is combined with traditional economic IO model. Here, a vector of total external effect, \mathbf{E} can be defined as the following equation:

$$\mathbf{E} = \hat{r}_i (\mathbf{I} - \mathbf{A})^{-1} \mathbf{Y}, \quad (7)$$

where \hat{r}_i denotes the diagonal matrix of direct external effect coefficient r_i ; $(\mathbf{I} - \mathbf{A})^{-1}$ is Leontief Inverse matrix; \mathbf{Y} denotes the final demand in economic system. A variety of external effects can be included in this calculation such as material and energy resources as well as environmental emissions.

To account for the data availability of the study area and make expected modeling results policy-relevant, the research is going to investigate environmental effects incurred by economic production in four following categories: energy consumption, air emission, freshwater consumption and water pollutant discharge. Several general principles need to be noted here so as to guide the research of this section:

- existing China-based studies (nationally, regionally or locally) are extensively reviewed as the first source to derive input parameters (basically r_i) for the EIO model constructed for this research;
- although parameters for different categories of environmental effects are inevitably derived from diverse studies with different context and temporal references, such differences will not have significant impacts on the expected results of this research as long as the comparison of alternatives in terms of each category is based on an identical benchmark;
- to apply parameters to the Xiamen research context, a bold assumption has to be made that, environmental effect intensities by sector at the municipal level are the same as their counterparts drawn from relevant studies. Additionally, it is necessary to map such derived coefficients into 144-sector specification, with the assumption that those more disaggregated sectors (from Xiamen IO table) corresponding to the same aggregated sector (from relevant studies) have identical environmental effect intensity as suggested by Peters et al. (2007);
- wherever possible, use local specific data to modify or adjust the parameters drawn from previous researches.

(1) Energy consumption

Energy is one of the most important strategic resources for urban sustainable development; meanwhile, energy use and energy structure have a lot do with urban

carbon footprint and other air pollutions (Liang, Wang, & Zhang, 2010a). For Xiamen as a pilot city of low-carbon economy listed by National Development and Reform Commission in 2010, energy conservation and emission reduction are considered as important as economic development (J. Lin, Meng, Cui, Yu, & Zhao, 2012).

In terms of energy consumption footprints, this research proposes to primarily refer to the Economic Input-Output Life Cycle Assessment (EIO-LCA) model results developed by the Green Design Institute of Carnegie Mellon University (CMU) for China (Carnegie Mellon University Green Design Institute, 2012). For details with regard to how to construct energy consumption inventory from the perspective of final energy use by sector and energy balance, please refer to previous researches by Peters et al. (2006; 2007). Several reasons favoring the CMU model as a reasonable reference are as follows:

- a. to the best of my knowledge, the most comprehensively authoritative statistical data concerning energy balance, final energy consumption by industry sector and net calorific value are compiled on a national scale in China;
- b. the China 2002 EIO-LCA model has 122 industry sectors, which mostly corresponds to the industry classification (with 144 sectors) from 2007 IO table of Xiamen that this research is dependent upon for marine industry analysis;
- c. the model covers a wide range of energy sources such as coal coke, petroleum, natural gas, electricity, and other energy, which is able to measure the energy footprint more comprehensively at an economy-wide level.

(2) Air emission

As to air pollution, this study is going to examine the Greenhouse Gases (GHGs), sulfur dioxide (SO₂) and nitrogen oxide (NO_x) emissions resulted from economic production, since these air pollutants are widely recognized as the major sources of concern with regard to climate change and acid rain. While from the perspective of marine/coastal ecosystem management, their emissions contribute to ocean acidification and nitrogen loading in water body through atmospheric deposition. As the results from 'Environmental effect assessment of human activities in Xiamen Bay' indicated, for Western Sea and Tong'an Bay, atmospheric deposition contributed to about 10.05% of

the nitrogen loading from non-point source pollutions in these two sea areas (L. Zhang, et al., 2010).

The calculation of GHGs, SO₂ and NO_x emissions generated by economic system (primarily from fuel combustion and industrial processes) basically takes an ‘emission factor’ approach. Two types of data are required to operationalize the calculation: the feedstock data (e.g. energy consumption and production volume) extracted from various official statistics, and the emission factor for each fuel type or each production process adopted from context-specific studies where available or the generic Intergovernmental Panel on Climate Change (IPCC) guidelines (IPCC, 1996, 2006). Peters et al. (2006; 2007), Liang et al. (2010a; 2010b), and Chen and Zhang (2010) gave in-depth explanations on the methodology of constructing air pollutant inventory.

For consistency concern, again, the CMU model is consulted to draw corresponding emission coefficients from for similar reasons as mentioned above in the evaluation of energy consumption footprints.

(3) Freshwater consumption

Water scarcity is an intrinsic problem for Xiamen city. By household registration population, per capita water availability is 871 m³, which is about 40% of the national average level and 25% of Fujian provincial average level; by permanent population, per capita water availability is only 526 m³, which is far below the internationally acknowledged alarm level of 1700 m³ (B. Yu, Yang, Huang, & Yuan, 2006). Currently, over 80% of water supply relies on trans-regional water diversion program (J.-h. Lin, 2010). This research refers to the study by Guan and Hubacek (2007) and examine the freshwater footprints incurred by different marine functional uses. As claimed by Guan and Hubacek (2007), Fujian, Guangdong, Guangxi and Hainan provinces, which were categorized as South China, have similar situations with regards to economic conditions, water availability and water use patterns. Since Xiamen is located in Fujian Province, it is reasonable to apply sectoral direct freshwater coefficients for the region of South China from that study to this research context.

(4) Water pollutant discharge

Historically, the principal pollutants of seawater for Xiamen Bay are inorganic nitrogen (IN) and labile phosphate (LP); meanwhile, nutrients persist as a major concern in terms of seawater quality and the majority of them exist in organic form in the ocean (L. Zhang, et al., 2010). As we know, chemical oxygen demand (COD) is an important indicator to represent the concentration of organic pollutants comprehensively and related to nutrients level to some extent. Taking all of these into account, this research designates COD, total nitrogen (TN) and total phosphorous (TP) as the main focus in assessing water pollution footprint.

Previous research exists as useful sources for generating model parameters or providing estimation methods: Guan and Hubacek (2008) presented an integrated hydro-economic accounting and analytical framework and calculated the discharged wastewater (with average COD concentration) by 40 economic production sectors for North China (including six provinces) in 1997; Okadera et al. (2006) developed a methodology of constructing water demand and water pollutant inventories and applied it to estimate carbon, nitrogen and phosphorous discharges in wastewater associated with socio-economic activities (with 28 industrial sectors) in Chongqing, China. The basic approach to these studies is that:

- the priority is to obtain and calibrate water quantity/quality data by economic sector directly from various authoritative statistics, where available;
- when data are non-existent for certain water pollutants in question, there are usually two ways to proceed. Pollutants discharge can be estimated based on a mass balance approach, according to the amount of feedstock as input into production process and corresponding emission factors like the ones discussed for air emissions above (e.g. estimation of nitrogen discharge from cultivation by chemical fertilizer usage and its surface runoff ratio); or they can also be estimated by using conversion coefficients between elements from other empirical studies, such as CNP ratio for various types of industrial wastewater.

As water quantity/quality data with sector-specific details are not available at such a decentralized level as Xiamen city, pollution coefficients derived from relevant studies

described above will be referred to in estimating the water pollution footprint in this research.

4.3. Representation of marine functional use at the municipal level

In order to analyze and compare two marine functional uses in Xiamen Bay area by using the EIO approach, it is necessary to figure out the way in which these marine functional uses are represented by the municipal IO table.

According to the statistical approach of local government (2011b), port and shipping industry encompasses ocean transportation, loading, unloading, portage and other transport services. This industrial scoping is ideally corresponding to the one for ‘Water Transport’, an individual branch of 144-sector classification in 2007 IO table, which is defined as waterborne passenger transport, freight transport, port and other auxiliary services (State Statistical Bureau of China, 2009). While for waterfront tourism, the 2007 IO table does not have any specific sectors exactly corresponding to this sea use pattern. However, several facts regarding the tourism of Xiamen city deserve being taken into consideration here to account for the mismatch issue: (1) as a typical bay city, Xiamen’s tourism products are featured by coastal landscape sightseeing, waterfront resorts and water-approaching recreations to a large extent; (2) there is no an easy way to distinguish between waterfront tourism and other types of water-irrelevant tourism from any existing official documents; (3) according to Zhang (2010), waterfront tourism takes up around 90% of the whole tourism industry of Xiamen in terms of value added. Based on the situations mentioned above, it is acceptable to assume that waterfront tourism in Xiamen Bay can be approximately represented by the ‘Tourism’ sector as surveyed in the municipal IO table. As defined by State Statistical Bureau of China (2009), ‘Tourism’ sector in the IO table refers to the activities of travel agencies, including various tourism services provided to business travel, organized groups and independent travelers.

4.4. Scenario analysis for the growth of marine industry

As Eq. (7) shows, anticipatory regional economic contributions as well as corresponding resource and environmental implications resulting from the growth of specified marine industry over time have to do with a variety of factors: (1) increase in final demands

represented by \mathbf{Y} ; (2) change in production structure represented by $(\mathbf{I} - \mathbf{A})^{-1}$; (3) change of environmental effect intensity (resource consumption and environmental discharge intensities) represented by r_i . Given availability of time and resources, this study will only organize scenario analysis around first two factors.

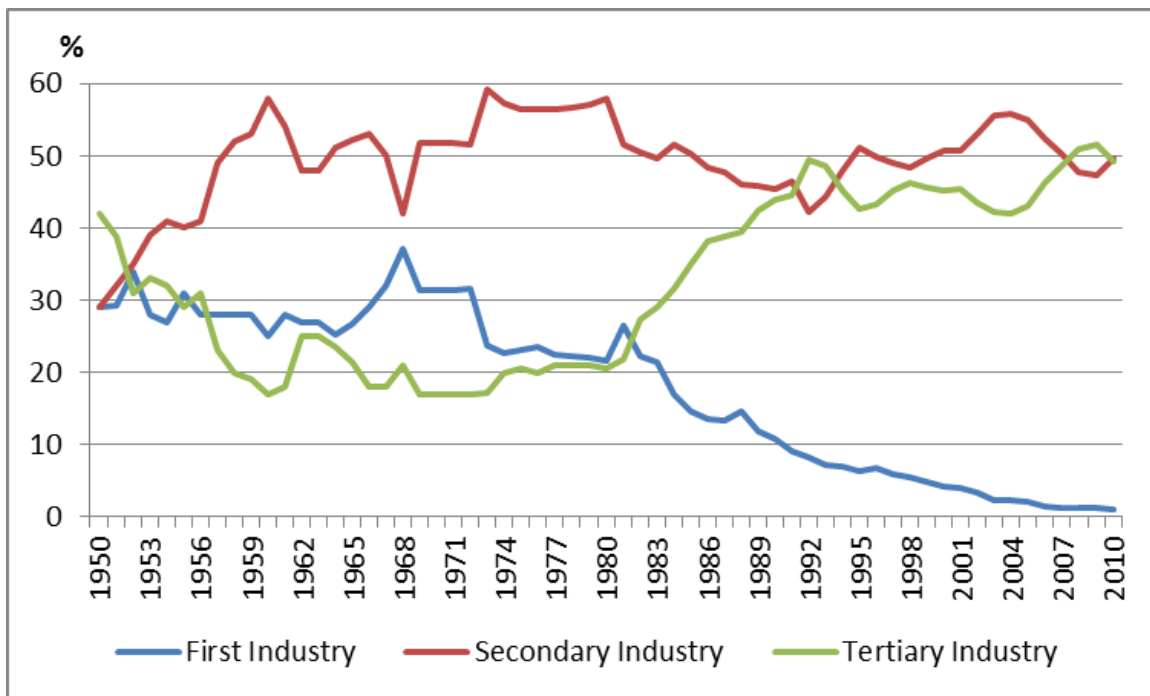
For the purpose of prioritizing two leading marine functional uses, a comparative approach is adopted that analytically treats them separately. Therefore, the research constructs two fundamental policy scenarios, namely port-and-shipping-oriented or waterfront-tourism-oriented, to simulate alternative determinations of principal functional use in marine/coastal areas. Within each fundamental scenario, two economic growth (volume component) scenarios combined with two economic structure (structural component) scenarios is designated as Table 4.1. For economic growth, high and low indicate different annual growth rates of GDP; for economic structure, business as usual (BAU) means input-output relationships stay the same as the base year, while economic structural change (ESC) refers to a shift in the fundamental structure of the economy which is often linked to technical progress, economic development and changes in consumption patterns.

Table 4.1 Basic scenarios for local economic growth by 2015

Economic growth \ Economic structure	BAU	ESC
High		
Low		

Derived from both historical growth trend of GDP from local statistical source (Xiamen Municipal Statistics Bureau, 2011) and relevant official projections on general socioeconomic development (Xiamen Municipal Government, 2011a), an annual growth rate of 15% is designated for the high economic development scenario. Taking into account the influences of a stagnating labor force, diminishing marginal returns, and lower gains from structural change (World Bank, 1997), 12% of annual growth is selected arbitrarily to represent the low economic development scenario. Historically, the variation of economic structure of Xiamen (in terms of share of local GDP among first,

secondary and tertiary industries) is shown as Figure 4.1. On one hand, the important role of secondary industry in local economic development would not change fundamentally, and it is still profitable for the secondary industry to increase investment and scale-up production (Economic Development Bureau of Xiamen, 2011a); on the other hand, the municipal government looks forward to promote the development of service sector, increasing its proportion to local GDP (Xiamen Municipal Development and Reform Commission, 2011). As corroborated by Xia and Zhang (2011), Xiamen is experiencing the transition from later stage of industrialization to post-industrialization. In this regard, the BAU scenario is going to represent an economic structure as what it was in the base year, with the proportion of first, secondary and tertiary industry equaling 1.3: 53.1: 45.6 in terms of value added; while the ESC scenario is going to simulate a prospective situation where tertiary industry outweighs secondary industry and takes the lead in driving economic development, with the proportion designated as 1: 45: 54 hypothetically.



Source: Xiamen Municipal Statistics Bureau (2011)

Figure 4.1 Variation of economic structure in Xiamen

4.4.1. Final demand change

In port-and-shipping-oriented scenario, as suggested by Peng et al. (2006) in a local study, cargo throughput—a major indicator of productivity in port and shipping industry—serves as a proxy to represent the growth of this industry, given the availability of historical statistical data and relevant development plans. This research proposes to use GDP as an explanatory variable to forecast the cargo throughput of Xiamen by developing a linear regression model, basically because:

- in economic sense, the GDP of port hinterland has close relationship with its cargo throughput as verified by a series of studies by using Chinese data (Huang, Li, & Gu, 2004; Mao & Chen, 2011; Ou, 2003; Yang & Shao, 2005);
- a consistent approach with the basic scenario design (as Table 4.1) is achieved by both using GDP as a benchmark indicator.

Figure 4.2 illustrates this relationship by using the statistical data from ‘Yearbook of Xiamen Special Economic Zone’. Based on the regression function, the cargo throughput of Xiamen Port is predicted to be 255 million ton and 206 million ton under high and low growth scenarios respectively. According to Xiamen ‘12th Five-Year’ Specific Plan for Marine Economic Development (Xiamen Municipal Government, 2011b) and General Plan for Xiamen Port (Xiamen Port Authority, 2011), cargo throughput is projected to reach 200 million ton in 2015, which is pretty close to the forecast under low growth scenario. Besides, according to an empirical estimation by Zhang et al. (2012), based on the carrying capacity of marine/coastal resource, the maximum volume of cargo throughput that can be handled in Xiamen Bay area would be 284 million ton. Thus, before coming to the maximum capacity, the projections in this research under both scenarios appear reasonable.

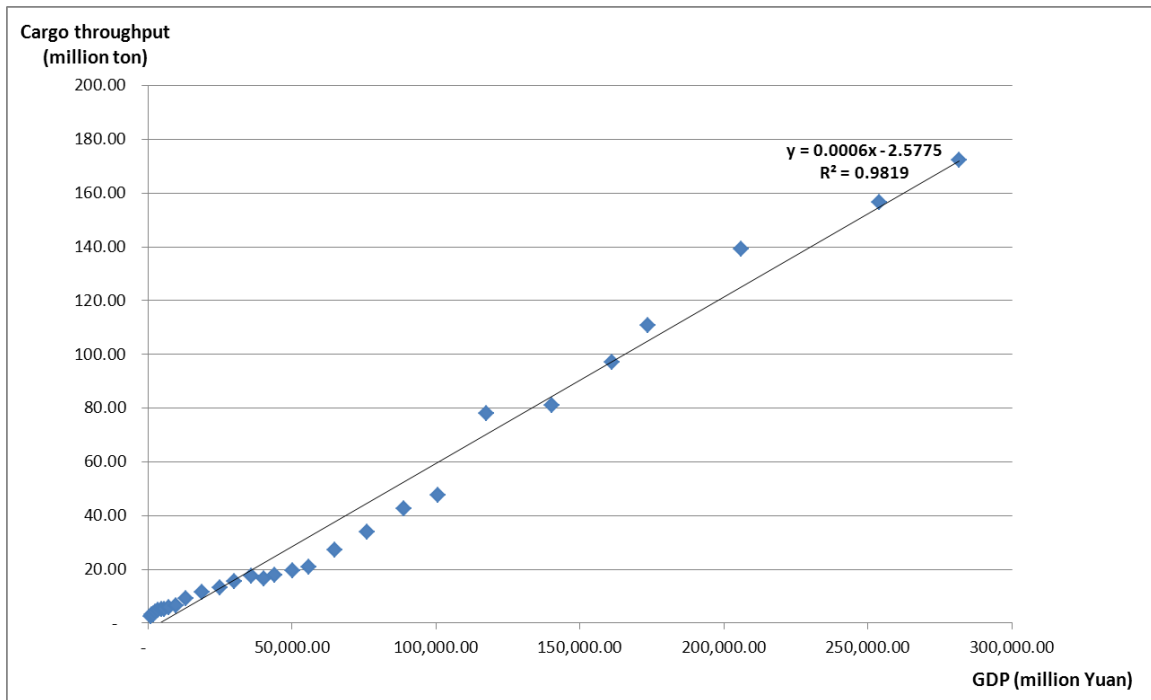


Figure 4.2 Historical cargo throughput and local GDP from 1983 to 2012

In order to link cargo throughput in physical unit with final demand in monetary unit, two assumptions have to be made here:

- the gross output of port and shipping industry can be estimated by the product of cargo throughput and its unit price;
- there is a fixed ratio of final demand to gross output for port and shipping industry.

With these assumptions, the final demand of port and shipping industry for the year 2015 (under both high and low scenarios) can be estimated by using 2007 constant unit price calculated from the base year IO table, which is shown as Table 4.2.

Table 4.2 Final demand for port and shipping industry in 2015

	High	Low
Cargo throughput (million ton)	255	206
Final demand (million Yuan)	14,300	11,600

Note: all numbers are rounded off to 3 significant figures.

In waterfront-tourism-oriented scenario, a similar approach is taken by using annual person-trip (including both domestic and oversea tourists) as a proxy to indicate the magnitude of this industry, based on two following considerations that:

- as the type of tourism product is relatively unitary (predominantly sightseeing), tourism revenue in Xiamen mainly comes from transportation, accommodation, catering, and tour fees which can be estimated from the number of person-trip, residence time and average daily expenditure (People's Government of Siming District (Xiamen), 2011a);
- person-trip is a commonly used statistical index obtainable from publicly available sources (U.S. Travel Association, 2012).

According to Xiamen '12th Five-Year' Plan for Tourism (Xiamen Tourism Bureau, 2011), the objective for 2015 is to receive 56.88 million person-trips. While according to Xiamen '12th Five-Year' Specific Plan for Modern Services Development (Xiamen Municipal Development and Reform Commission, 2011), the objective for annual person-trips in 2015 is set as 68 million. Since no additional evidence is available to verify these estimations, this study refers to the later value as a radical projection under high growth scenario and to the former value as a conservative projection under low growth scenario. To anticipate the final demand of waterfront tourism, some further assumptions have to be made as follows:

- as detailed information regarding proportions of different residence time is not available, all person-trips within a specific year would be treated as one-day trip which has a remarkable market share for Xiamen's tourism;
- the gross output (also the gross revenue) approximately equals the product of annual person-trip and its unit price (using 2007 constant price);
- there is a fixed ratio of final demand to gross output for this industry.

In this way, the final demand of waterfront tourism for the year 2015 (under both high and low scenarios) can be estimated in Table 4.3.

Table 4.3 Final demand for waterfront tourism in 2015

	High	Low
Annual person-trip (million)	68	57
Final demand (million Yuan)	6,100	5,100

Note: all numbers are rounded off to 2 significant figures.

4.4.2 Change in production structure

As techniques of production do change over time, it is necessary to update the input-output relationships available from a specific earlier year to reflect the economic conditions for the year of interest (Miller & Blair, 1985). This research employed the RAS technique to adjust the direct requirement coefficients of 2007 IO table. The RAS technique is a partial-survey method which attempts to estimate the technical coefficient matrix for the target year (denoted as $\mathbf{A}(1)$) based on a technical coefficient matrix in the base year (denoted as $\mathbf{A}(0)$), given that only partial information for the target year are known which are: (a) total gross outputs by sector, $X_j(1)$; (b) total intermediate sales by sector, $U_j(1)$ and (c) total intermediate purchases by sector, $V_j(1)$ (Stone, 1961; Stone, Brown, & University of Cambridge. Dept. of Applied, 1962). The basic idea of the RAS technique is to adjust, alternately and sequentially, rows and columns of a given coefficient matrix $\mathbf{A}(0)$ by generating a series of row multipliers \mathbf{R}^k and column multipliers \mathbf{S}^k , where the superscript k means the ‘step’ of adjustment and \mathbf{R}^k and \mathbf{S}^k refer to the diagonal matrices of elements modifying rows and columns respectively, and finally estimate a relatively accurate matrix $\mathbf{A}(1)$ in the sense that the row sums and column sums of the target year inter-industry transactions calculated from $\mathbf{A}(1) \hat{\mathbf{X}}(1)$ correspond to the available information of $\mathbf{U}(1)$ and $\mathbf{V}(1)$. Miller and Blair (1985) gave detailed explanation on the mathematic procedures of the RAS technique. The key to implement the RAS method in this research context is to obtain the estimations of three control variables in the year 2015, namely total outputs $\mathbf{X}(2015)$, total intermediate sales $\mathbf{U}(2015)$ and total intermediate purchases $\mathbf{V}(2015)$. For specific technical procedures, please refer to appendix B. Although there are a number of alternative methods to update the \mathbf{A} matrix, empirical studies found that the RAS technique has some advantages, such as preserving non-negativity of the coefficient a_{ij} and not requiring solution of complex nonlinear programming problems (Allen & Gosling, 1975; Hewings & Janson, 1980), and can be applicable even in an emergent economy (Dobrescu & Gaftea, 2012).

5. Result

5.1. Base year analysis

5.1.1. Economic impact

In 2007, the final demands for port and shipping industry and waterfront tourism were 4,600 and 1,900 million Yuan, respectively. By using Eq. (3) and summing across 144 sectors, it is estimated that the total economic impact (in terms of gross output) on Xiamen municipality induced by port and shipping industry in 2007 was 9,300 million Yuan, as compared to that of 6,100 million Yuan which was induced by waterfront tourism. Looking into these impacts from a structural perspective by using the classification of 42 more aggregated sectors, the results are shown in Table 5.1 and Figure 5.1. Of the economic contribution generated by port and shipping industry, ‘Traffic, Transport and Storage’ (including port and shipping), ‘Processing of Petroleum, Coking, Processing of Nuclear Fuel’, and ‘Extraction of Petroleum and Natural Gas’ were the top three sectors in terms of gross output value; while of the contribution brought by waterfront tourism, ‘Leasing and Business Services’ (including waterfront tourism), ‘Traffic, Transport and Storage’, and ‘Hotels and Catering Services’ took up the first three places in terms of gross output value (formatted as grey shells in Table 5.1). With regard to the indirect effect coming from inter-industry purchases, 74% of that was taken up by secondary industry for the case of port and shipping contribution, while 67% of that was dominated by tertiary industry for the case of waterfront tourism contribution (shown as Figure 5.2).

On an absolute scale, the contribution of port and shipping industry to local economy was larger than that of waterfront tourism in 2007 intuitively. On a relative scale, however, every single Yuan of final demand for port and shipping only generated 2.0 Yuan of gross output for the economy, while every single Yuan of final demand for waterfront tourism generated 3.3 Yuan of gross output for the economy. In this sense, the waterfront tourism functioned in a more efficient way than the port and shipping industry in boosting the local economy.

Table 5.1 Sectoral economic impacts induced by two marine functional uses in 2007

Unit: million Yuan

No.	Aggregated Sector	P&S	WT	No.	Aggregated Sector	P&S	WT
1	Agriculture, Forestry, Animal Husbandry & Fishery	44	47	22	Scrap and Waste	5.3	7.0
2	Mining and Washing of Coal	38	70	23	Production and Supply of Electric Power and Heat Power	54	1.0E+02
3	Extraction of Petroleum and Natural Gas	8.4E+02	1.1E+02	24	Production and Distribution of Gas	4.3	2.3
4	Mining of Metal Ores	22	8.5	25	Production and Distribution of Water	9.3	85
5	Mining and Processing of Nonmetal Ores and Other Ores	1.6	2.4	26	Construction	3.8	8.0
6	Manufacture of Foods and Tobacco	23	72	27	Traffic, Transport and Storage	5.1E+03	1.3E+03
7	Manufacture of Textiles	27	67	28	Post	2.9	13
8	Manufacture of Textile Wearing Apparel, Footwear, Caps, Leather, Fur, Feather (Down) and Its products	8.5	35	29	Information Transmission, Computer Services and Software	29	1.4E+02
9	Processing of Timbers and Manufacture of Furniture	34	16	30	Wholesale and Retail Trades	1.2E+02	40
10	Papermaking, Printing and Manufacture of Articles for Culture, Education and Sports Activities	1.5E+02	2.6E+02	31	Hotels and Catering Services	52	3.8E+02
11	Processing of Petroleum, Coking, Processing of Nuclear Fuel	1.3E+03	1.6E+02	32	Financial Intermediation	2.7E+02	2.6E+02
12	Chemical Industry	3.6E+02	159.31	33	Real Estate	6.0	18
13	Manufacture of Nonmetallic Mineral Products	6.1	9.8	34	Leasing and Business Services	94	2.0E+03
14	Smelting and Rolling of Metals	2.0E+02	53	35	Research and Experimental Development	0.0095	0.022
15	Manufacture of Metal Products	46	23	36	Comprehensive Technical Services	10	0.72
16	Manufacture of General Purpose and Special Purpose Machinery	72	11	37	Management of Water Conservancy, Environment and Public Facilities	5.7	49
17	Manufacture of Transport Equipment	2.0E+02	25	38	Services to Households and Other Services	72	1.3E+02
18	Manufacture of Electrical Machinery and Equipment	16	8.8	39	Education	11	3.6E+02
19	Manufacture of Communication Equipment, Computer and Other Electronic Equipment	21	37	40	Health, Social Security and Social Welfare	11	8.4
20	Manufacture of Measuring Instrument and Machinery for Cultural Activity & Office Work	3.3	3.8	41	Culture, Sports and Entertainment	16	52
21	Manufacture of Artwork, Other Manufacture	7.9	28	42	Public Management and Social Organization	4.5	2.4
					Sum	9,300	6,100

Note: P&S stands for port and shipping; WT stands for waterfront tourism; grey shells mean top three sectors in terms of gross output value induced by either P&S or WT; all numbers are rounded off to 2 significant figures.

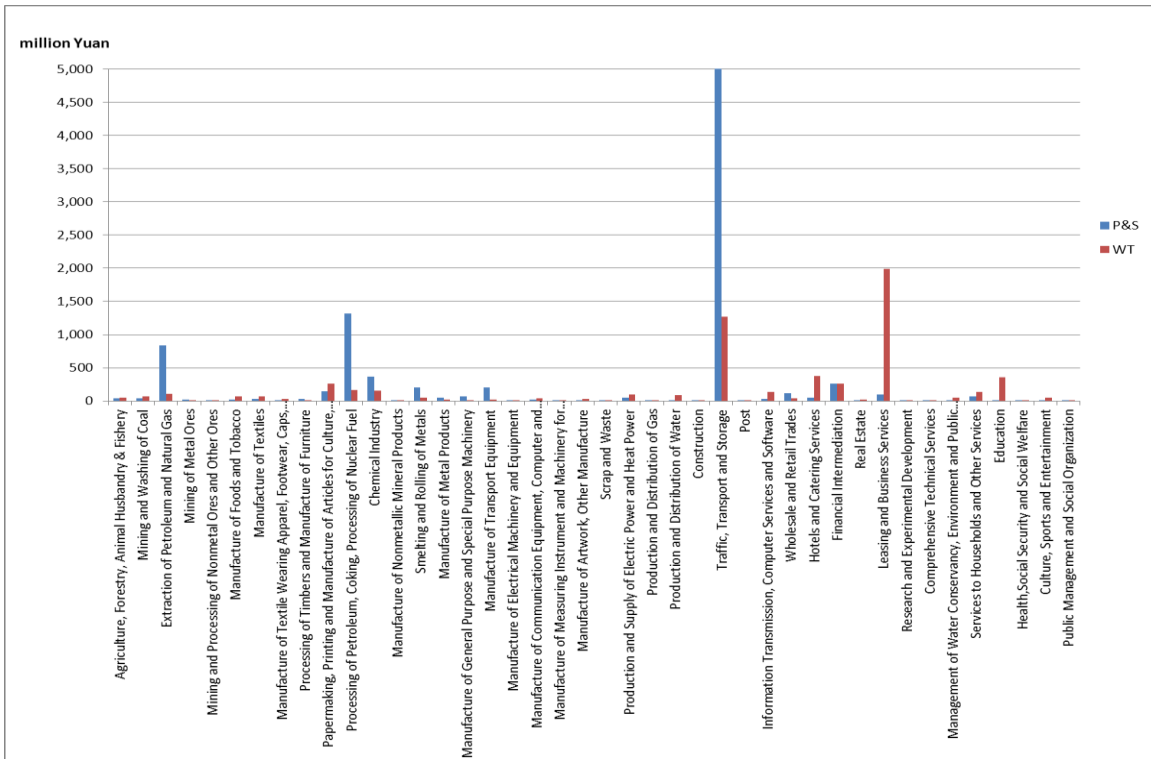
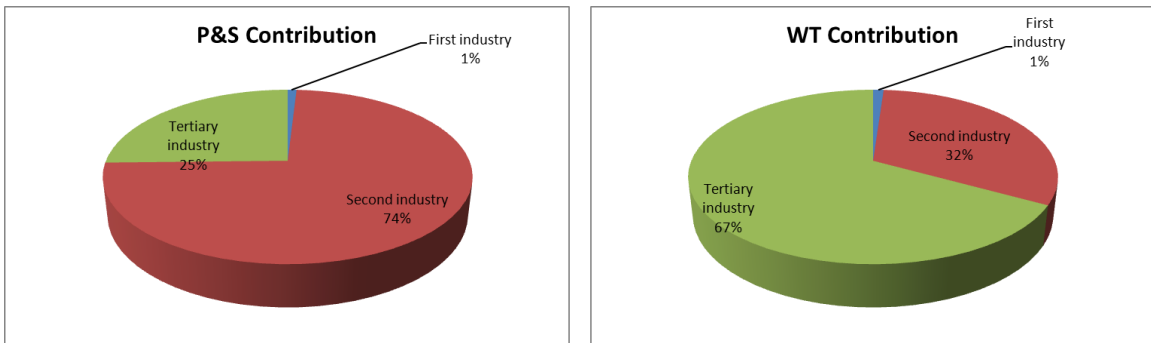


Figure 5.1 Economic impacts induced by two marine functional uses in 2007



Note: measured in million Yuan

Figure 5.2 Share of indirect effect caused by two marine functional uses in 2007

The results from inter-industry linkage analysis are shown in Table 5.2. The backward linkage of waterfront tourism outweighed that of port and shipping by ranking 41st among 144 sectors, meaning that the waterfront tourism has a greater potential than the port and shipping in pulling in production activities of other sectors from which it purchased inputs. This result explains the reason why the waterfront tourism is more efficient than the port and shipping industry as observed above. While in terms of the forward linkage, the port and shipping took a much higher rank than the waterfront

tourism. Although both two values were less than 1, it is still reasonable to claim that the port and shipping plays a relatively important role as an infrastructure in supporting other sectors' production, as compared to the waterfront tourism which tends to stay at the lower stream of industry chain and provide final products. Therefore, the port and shipping industry appears more sensitive to economic fluctuations.

Table 5.2 Inter-industry linkage analysis of two marine functional uses in 2007

	Backward Linkage	Rank	Forward Linkage	Rank
P&S	0.7633	103	0.8477	47
WT	1.2412	41	0.3776	130

5.1.2. Environmental effect

By employing Eq. (7), a series of total external effects induced by 'port and shipping industry' versus 'waterfront tourism' to meet their respective final demands in 2007 can be derived. In terms of energy consumption, the total energy need was 14,000 terajoules (TJ) for the development of port and shipping and 6,200 TJ for waterfront tourism. The top three contributors for port and shipping were 'Traffic, Transport and Storage', 'Extraction of Petroleum and Natural Gas' and 'Processing of Petroleum, Coking, Processing of Nuclear Fuel', taking up 83% of total energy consumption (with port and shipping itself taking 57%); while for waterfront tourism, the top three contributors were 'Production and Supply of Electric Power and Heat Power', 'Traffic, Transport and Storage' and 'Leasing and Business Services', summing up to 74% of total energy consumption (as Figure 5.3 in appendix C). For the economic activities induced by port and shipping, every million Yuan of gross output consumed 1.5 TJ of energy; in contrast, every million Yuan of gross output consumed 1.0 TJ of energy for the case of waterfront tourism, which was more energy efficient.

Looking at the air emissions associated with energy combustion and industrial processes, the results are shown in Figure 5.4-5.6 in appendix C. For the GHGs indicated by CO₂ equivalent (CO₂e), the emission structure looked very similar to the energy use structure, with total CO₂e amounting up to 1,100,000 metric tons (MT) for port and shipping and 490,000 MT for waterfront tourism. From the perspective of emission per unit of output,

the economic activities induced by waterfront tourism had a lower carbon footprint, which was 80 MT/million Yuan, as compared to the one from activities induced by port and shipping, which was 110 MT/million Yuan. As to SO₂, ‘Traffic, Transport and Storage’, ‘Production and Supply of Electric Power and Heat Power’ and ‘Smelting and Rolling of Metals’ were the top three sectors that contributed most to the total emission brought about by either of two leading marine functional uses. Especially for the emission induced by waterfront tourism, 58% of the total SO₂ came from ‘Production and Supply of Electric Power and Heat Power’ alone. Note that the lump sum emission intensity of SO₂ associated with waterfront tourism, valuing 0.45 MT/million Yuan, outweighed the one with port and shipping, valuing 0.41 MT/million Yuan. As to NO_x, ‘Traffic, Transport and Storage’ and ‘Production and Supply of Electric Power and Heat Power’ dominated the contribution from production chain to its emission, with 88% of total emission for port and shipping versus 80% for waterfront tourism. The lump sum emission intensity of NO_x for the development of waterfront tourism, which was 0.47 MT/million Yuan, was lower than that for the development of port and shipping, which was 0.75 MT/million Yuan.

In terms of net freshwater consumption (Figure 5.7 in appendix C), the economic activities pulled by port and shipping industry used 7,000,000 m³ in total, with ‘Agriculture, Forestry, Animal Husbandry & Fishery’, ‘Traffic, Transport and Storage’ and ‘Chemical Industry’ being the first three water-use sectors; and those pulled by waterfront tourism used 6,200,000 m³ totally, with ‘Agriculture, Forestry, Animal Husbandry & Fishery’, ‘Papermaking, Printing and Manufacture of Articles for Culture, Education and Sports Activities’ and ‘Production and Supply of Electric Power and Heat Power’ being the first three consumers. For both cases, ‘Agriculture, Forestry, Animal Husbandry & Fishery’ occurred as the largest water consumer, contributing around 50% of the total freshwater footprints induced by these two functional uses. Viewing from an efficiency perspective, for every million Yuan of gross output associated with port and shipping, 750 m³ of freshwater had to be consumed; while for every million Yuan associated with waterfront tourism, 1,000 m³ had to be used which was more water-consuming.

As to the discharge side (shown as Figure 5.8-5.11 in appendix C), the development of port and shipping industry accounted for 5,100,000 m³ of wastewater discharge, with 2,100 tons of COD, 1,800 tons of TN and 97 tons of TP; while the development of waterfront tourism accounted for 2,900,000 m³ of wastewater discharge, with 1,400 tons of COD, 470 tons of TN and 57 tons of TP. For COD discharge, ‘Traffic, Transport and Storage’, ‘Chemical Industry’ and ‘Papermaking, Printing and Manufacture of Articles for Culture, Education and Sports Activities’ were the top three pollution sources for both cases; for TN discharge, ‘Processing of Petroleum, Coking, Processing of Nuclear Fuel’ and ‘Chemical Industry’ were the primary sources for both cases, with ‘Processing of Petroleum, Coking, Processing of Nuclear Fuel’ dominating the discharge scheme (about 79% of total) for the case of port and shipping; for TP discharge, ‘Processing of Petroleum, Coking, Processing of Nuclear Fuel’, ‘Chemical Industry’ and ‘Traffic, Transport and Storage’ were the top three contributors for the case of port and shipping, whereas ‘Chemical Industry’, ‘Manufacture of Foods and Tobacco’ and ‘Production and Distribution of Water’ were the top three contributors for the case of waterfront tourism. The lump sum discharge intensities of all these three water pollutants were either indiscriminative or lower for the economic activities induced by waterfront tourism as compared to those induced by port and shipping, which were 0.22 t/million Yuan versus 0.22 t/million Yuan for COD, 0.078 t/million Yuan versus 0.19 t/million Yuan for TN, and 0.0093 t/million Yuan versus 0.010 t/million Yuan for TP.

5.2. Planned year analysis

The results of scenario analysis for the year 2015 are presented in Table 5.3. Regarding the BAU scenario, since input-output relationships among sectors keep identical as those of the base year, the Leontief multiplier $(\mathbf{I} - \mathbf{A})^{-1}$ does not change. In determining the total economic impact and environmental footprints resulted from the growth of concerned industries for this case, only the values of final demand matter as exogenous model inputs. This can also be reflected by ‘Relative value’ column under the BAU scenario, which indicates gross output value per unit of final demand from an economic perspective or total external effect per unit of gross output from an environmental perspective. Note that these relative values are the same as their counterparts for the base year, and in most of

the cases waterfront tourism is preferable to port and shipping industry except in terms of SO₂ emission and freshwater consumption (shaded as grey cells in column BAU in Table 5.3).

Table 5.3 Scenario analysis for alternative marine functional uses in 2015

Note: in 2007 constant price

		BAU				ESC				
		Total impact		Relative value (per million Yuan)		Total impact		Relative value (per million Yuan)		
		P&S	WT	P&S	WT	P&S	WT	P&S	WT	
High economic growth	Economic impact (million Yuan)	2.9E+04	2.0E+04	2.0	3.3	3.5E+04	2.3E+04	2.4	3.8	
	Energy consumption (TJ)	4.4E+04	2.1E+04	1.5	1.0	5.5E+04	2.6E+04	1.6	1.1	
	Air emission	GHGs (MT CO ₂ e)	3.3E+06	1.6E+06	1.1E+02	8.0E+01	5.0E+06	2.4E+06	1.4E+02	1.0E+02
		SO ₂ (MT)	1.2E+04	9.1E+03	0.41	0.45	1.9E+04	1.2E+04	0.55	0.50
		NO _x (MT)	2.2E+04	9.5E+03	0.75	0.47	2.7E+04	1.1E+04	0.76	0.48
	Net freshwater consumption (m ³)	2.2E+07	2.0E+07	7.5E+02	1.0E+03	2.0E+07	2.5E+07	5.9E+02	1.1E+03	
	Wastewater discharge (m ³)	1.6E+07	9.4E+06	5.5E+02	4.7E+02	1.9E+07	1.1E+07	5.4E+02	5.0E+02	
	Water pollutant	COD (t)	6.5E+03	4.5E+03	0.22	0.22	7.8E+03	4.8E+03	0.22	0.21
		TN (t)	5.5E+03	1.6E+03	0.19	0.078	5.8E+03	2.6E+03	0.17	0.11
TP (t)		3.0E+02	1.9E+02	0.010	0.0093	4.0E+02	2.7E+02	0.011	0.012	
Low economic growth	Economic impact (million Yuan)	2.4E+04	1.7E+04	2.0	3.3	2.8E+04	1.9E+04	2.4	3.8	
	Energy consumption (TJ)	3.5E+04	1.7E+04	1.5	1.0	4.4E+04	2.2E+04	1.6	1.1	
	Air emission	GHGs (MT CO ₂ e)	2.7E+06	1.3E+06	1.1E+02	8.0E+01	4.0E+06	2.0E+06	1.4E+02	1.0E+02
		SO ₂ (MT)	9.6E+03	7.6E+03	0.41	0.45	1.6E+04	9.6E+03	0.55	0.50
		NO _x (MT)	1.8E+04	8.0E+03	0.75	0.47	2.2E+04	9.3E+03	0.76	0.48
	Net freshwater consumption (m ³)	1.8E+07	1.7E+07	7.5E+02	1.0E+03	1.7E+07	2.1E+07	5.9E+02	1.1E+03	
	Wastewater discharge (m ³)	1.3E+07	7.9E+06	5.5E+02	4.7E+02	1.5E+07	9.5E+06	5.4E+02	5.0E+02	
	Water pollutant	COD (t)	5.3E+03	3.7E+03	0.22	0.22	6.3E+03	4.0E+03	0.22	0.21
		TN (t)	4.5E+03	1.3E+03	0.19	0.078	4.6E+03	2.2E+03	0.17	0.11
TP (t)		2.5E+02	1.6E+02	0.010	0.0093	3.2E+02	2.3E+02	0.011	0.012	

Note: all numbers are rounded off to 2 significant figures.

Should economic structure change, the regional gross output induced by port and shipping would reach an estimated 35,000 million Yuan under high growth scenario or 28,000 million Yuan under low growth scenario, as compared to 23,000 million Yuan under high growth scenario or 19,000 million Yuan under low growth scenario which would be induced by waterfront tourism otherwise. The change of economic structure also blows up the multipliers for these two industries (as compared to those under the

BAU scenario): for port and shipping, every single Yuan of final demand would bring 2.4 Yuan of gross output for the economy; while for waterfront tourism, every single Yuan of final demand would produce 3.8 Yuan of gross output. With regard to environmental implication, a similar trend could be observed that waterfront tourism is more favored over port and shipping on most of the select indicators. However, these results (shaded in grey in column ESC in Table 5.3) are uncertain although useful for comparative insights for policy decisions, the reason for which is left to the discussion below.

6. Discussion

6.1. Policy implication

6.1.1. Implication for marine principal functional orientation

From the base year analysis, although port and shipping industry had a larger economic magnitude relative to waterfront tourism, every unit of final demand for waterfront tourism induced greater economic impact on the region than port and shipping did by pulling more production activities through inter-industry purchases. On a marginal basis, waterfront tourism played a more significant role in the contribution to local economy as compared to port and shipping. In terms of marginal environmental implications incurred by these two functional uses, waterfront tourism generally outperformed port and shipping. Specifically, for every unit of economic output, less resource was consumed and less emission was generated by the activities associated with waterfront tourism than those associated with port and shipping. Therefore, given such conventional environmental indicators as selected in this study, the development of waterfront tourism imposed less environmental burden on the regional ecosystem.

A structural approach is taken to interpret the superiority of waterfront tourism over port and shipping. Through examination of the model parameter r_i (direct external effect coefficient) derived from various empirical studies, in general, sectors categorized as secondary industry tend to be characterized by higher energy and materials consumption as well as heavier pollution than sectors categorized as tertiary industry. As discussed in

section 5.1.1, 74% of production activities (in terms of gross output value) pulled by port and shipping come from secondary industry, while 67% of those pulled by waterfront tourism fall in the category of tertiary industry. This structural difference of pulling effect constitutes a main reason behind differing environmental performance induced by two marine industries. In brief, waterfront tourism pulls in more ‘cleaner’ industries than port and shipping does.

The results from the planned year analysis show that waterfront tourism could still develop in a more economically efficient and environmentally friendly way in the near future, compared with port and shipping industry. Under the economic structure change scenario, the economic impact brought about by either port and shipping or waterfront tourism would be larger than the one under the BAU scenario. The comparison implies that, these two industries are expected to have greater influences on the economy with the adjustment of industrial structure for which tertiary industry overrides secondary industry, probably due to both of them fall into the category of tertiary industry.

From a dynamic point of view, the change of economic growth mode has been established as one of the most important policies for Chinese economy in the near future (Xiamen Municipal Government, 2011a). A national level input-output study (Research Group of 2007 China Input-Output Table, 2011) identified three ways to facilitate optimization of industrial structure and change of economic growth mode: a) reduction of overreliance on investment; b) reduction of overreliance on international export; and c) increase of consumption rate (particularly domestic consumption). Following this trend at a local level, future economic growth of Xiamen city is expected to more likely be driven by expanding domestic demand than increasing investment and export. Through examination of the base year IO table: for port and shipping, over 95% of final demand (4514.60 million Yuan) was concentrated on the sub-category of ‘net export’, implying the export-oriented nature of this industry; while for waterfront tourism, about 52% of final demand (960 million Yuan) came from the sub-category of ‘consumption’ with the remaining 48% (890 million Yuan) relying on ‘net export’. Such a structural difference suggests that, there might be greater potential for the final demand of waterfront tourism to grow than that for the final demand of port and shipping industry.

To sum up, given select economic and environmental indicators, no matter for base year or planned year analysis, waterfront tourism may be generally more preferable to port and shipping on a marginal basis. With adjustment of economic structure and change of growth mode, the prospective policy scenario is apt to be more beneficial for the growth of waterfront tourism. Thereby, it is reasonable to suggest that waterfront tourism, to some extent, has its advantages over port and shipping as the principal functional use in marine and coastal areas of Xiamen.

6.1.2. Implication for improved management

From a policy formulation perspective, this study helps the municipal government with necessary decision support as to the orientation of principal functional use in the whole bay areas, as discussed in section 6.1.1. From a policy implementation perspective, the study could also provide insights into framing of specific management measures to better guide the development of both marine industries.

Despite that waterfront tourism tends to be more favorable for the economic development and environmental protection of the region, it does not outperform port and shipping on every select dimension of assessment in this analysis. In other words, the tradeoffs reported here may still merit some co-existence of both sectors. With regard to SO₂ emission and freshwater consumption, waterfront tourism incurs even greater environmental footprints for every unit of gross output contributed to the region. Besides, the discharges of COD and TP induced by waterfront tourism on a marginal basis are at a level comparative to those induced by port and shipping (less than 10% of difference). By disaggregating these externalities from a sectoral perspective, industries such as ‘Agriculture, Forestry, Animal Husbandry & Fishery’, ‘Production and Supply of Electric Power and Heat Power’, ‘Manufacture of Foods and Tobacco’, ‘Production and Distribution of Water’ and ‘Papermaking, Printing and Manufacture of Articles for Culture, Education and Sports Activities’ usually stand out as leading contributors.

These analytical results basically have two implications: firstly, as waterfront tourism bring people, the accompanying environmental footprints are likely to be more attributed to those industries that provide goods and services (e.g. foods, electricity and water)

regularly consumed by tourists. Therefore, to transform from extensive growth mode that is highly dependent on tourist volume to promotion of diverse, high-end, high value-added and quality tourism products is an acknowledged way to optimize and upgrade tourism industry (People's Government of Siming District (Xiamen), 2011b); secondly, future regulatory measures could be directed against such key sectors to achieve greater abatement potential, for instance, promotion of water-saving irrigation in agriculture (Hubacek & Sun, 2005) and advancement of desulfurization technique in power industry (Liang, et al., 2010a).

Since the recommendation of waterfront tourism as principal functional use does not mean to exclude port and shipping, it still makes sense to discuss how port and shipping industry could develop in a more sustainable way. In comparison with 'waterfront tourism-induced' industry chain, which is dominated by tertiary industry (as Figure 5.2) and can be characterized as labor-intensive (tertiary industry accounting for over 50% of local employment according to Xiamen Municipal Statistics Bureau), port and shipping mainly pulls in secondary industry and appears more resource-intensive. As discussed in section 5.1.2, 'Traffic, Transport and Storage', 'Extraction of Petroleum and Natural Gas', 'Processing of Petroleum, Coking, Processing of Nuclear Fuel', 'Chemical Industry' and 'Production and Supply of Electric Power and Heat Power' are generally the main contributors to the environmental footprints (particularly on energy and air emissions) induced by port and shipping.

Therefore, the focus of 'energy conservation and emission reduction' policy in terms of sustainable port and shipping development is suggested to target these main contributors. This inference is corroborated by some of the policy recommendations from Xiamen '12th Five-Year' Specific Plan for Energy Conservation (Economic Development Bureau of Xiamen, 2011b), such as: (1) to optimize energy structure through the development of new energy and renewable energy; (2) to renovate industrial boilers with clean combustion technologies; (3) to promote the energy conservation of marine transportation and port industry by adopting advanced ship's power system, developing modern transportation modes, optimizing the structure of transport capacity etc.; (4) to enhance

the management of raw material consumption for key sectors such as petrochemical industry.

6.2. Limitation and future work

6.2.1. Validity of model parameters

The robustness of analytical results mainly depend upon three basic components of the model in accordance with Eq. (7), namely final demand \mathbf{Y} , direct input coefficient matrix \mathbf{A} , and environmental effect intensity r_i .

The estimation of final demand is related to a variety of factors such as national income growth and international economic situation. Given limited access to additional relevant information and time availability, a simplified approach was taken in this research by using ‘proxy’ variable to indicate final demand, and some projections (e.g. final demand for waterfront tourism) were drawn directly from pertinent official planning documents without further verification. Estimation of final demand change is suggested to be based on more structural approach by taking into account per capita income growth, population dynamics, urbanization, income elasticity of demand for various goods and services, share of aggregate household consumption in total final demand etc. (Hubacek & Sun, 2005; Wei, Liang, Fan, Okada, & Tsai, 2006).

The uncertainty of the \mathbf{A} matrix basically has both spatial and temporal dimensions. Spatially, as Xiamen 2007 IO table was compiled as ‘competitive import type’ IO table within which imports are included in the intermediate and final uses (Y.-X. Zhang & Zhao, 2009), the production-inducing effect could be overestimated because supply chain activities could depend partially on the outside economy rather than entirely on the local economy. For instance, via in-depth validation of 2007 IO table, it is clear that actually Xiamen does not possess ‘Extraction of Petroleum and Natural Gas’ at all and its ‘Agriculture, Forestry, Animal Husbandry & Fishery’ is highly dependent on import. However, the analysis shows that ‘Extraction of Petroleum and Natural Gas’ is the third largest industry in terms of sectoral contribution to local economy induced by port and shipping, and ‘Agriculture, Forestry, Animal Husbandry & Fishery’ dominates the total freshwater use induced by either port and shipping or waterfront tourism. These results

are not the real cases for Xiamen. To account for such problems caused by regional trade patterns, use of regional supply percentages, which represent the proportion of total regional requirements by sector that could be expected to originate within the region, to adjust the \mathbf{A} matrix is a common approach (Miller & Blair, 1985). Also, caution needs to be borne in interpreting analytical results on induced effects especially for those sectors that have heavy dependence on out-of-region import (United States, 1978).

Temporally, the RAS technique has its own limitations in updating the \mathbf{A} matrix based on partial information for the planned year. As discussed by Miller & Blair (1985) from some empirical studies, the RAS procedure might generate a direct input coefficients matrix that looks differently than a fully survey-based matrix on an element-by-element basis, even though that matrix can perform relatively well in terms of Leontief multiplier (known as ‘holistic’ accuracy). That is to say, the reliability of each individual coefficient of the projected \mathbf{A} matrix and thus its associated $(\mathbf{I} - \mathbf{A})^{-1}$ matrix can be a reason for further study. Note that the direct environmental effect intensity r_i could vary with sector. In this case, the results about environmental footprints (calculated by $\hat{r}_i (\mathbf{I} - \mathbf{A})^{-1} \mathbf{Y}$) under the ESC scenario for which the RAS method was employed are not credible (as shaded in grey in Table 5.3). To reduce the uncertainty in estimating the \mathbf{A} matrix of a future economy, a mixed approach of combining the RAS technique and case studies is suggested, where case studies are used to project key cells in the \mathbf{A} matrix by applying survey or expert elicitation (Hubacek & Sun, 2001; Miller & Blair, 1985; Wei, et al., 2006).

As to the environmental effect intensity r_i , future works can be focused on three following aspects:

(1) to construct local environmental database (e.g. resource consumption and environmental discharge inventory by sector) and derive more context-specific r_i . Assembly of numerous official statistics, extensive literature research and detailed in-field industrial survey could be pulled together to fulfill the task. In addition, consultation of regional ‘energy conservation and emission reduction’ plan, ‘water conservancy’ plan, ‘water pollution control’ plan etc. can help set up future scenarios to simulate the change of r_i . For those ‘key’ sectors whose environmental footprints are relatively high for the

region, sensitivity analysis can be performed on corresponding r_i that seem most likely to change;

(2) to refer to more extensive EIO studies if applicable. This can be a complementary approach while local data are not available, and those researches that are more analogous to the study area contextually and temporally will be more desirable. This can also be used to take into consideration technological advancement, policy shift, scaling issue, regional disparity etc. and update the parameter r_i to obtain more accurate estimation. For example, Liu et al. (2012) explored the energy use from all industrial sectors, although at a highly aggregated level, in China's economy of 2007. Chen and Zhang (2010) created a GHGs (covering CO₂, CH₄ and N₂O) emission inventory for the Chinese economy in 2007 with 26 more aggregated sectors. Ni et al. (2001) conducted a regional study based on IO analysis for Shenzhen, South China, aiming at adjusting the economic structure for minimizing COD level in industrial wastewater;

(3) to verify modeling results with comparable academic researches. For instance, Lin et al. (2012) analyzed the carbon footprint (CO₂, CH₄ and N₂O included) on urban energy use of Xiamen city in 2009 by using a hybrid process-based and EIO approach. Zhang et al. (2010) estimated the pollution loads of COD, TN and TP (including point and non-point sources) into Xiamen Bay with the application of discharge coefficient and empirical modeling. Besides, official statistics such as 'Yearbook of Xiamen Special Economic Zone', 'Xiamen Water Resource Bulletin', and 'China Statistical Yearbook on Environment' can also be used for cross-verification.

In a nutshell, the reliability of future scenario design could be improved through broader literature survey across different research fields, international comparison with those developed countries, and elicitation of expert knowledge (Hubacek & Sun, 1999).

6.2.2. Extension of EIO analysis

The study presents an attempt of adapting the EIO approach to supporting the orientation of marine principal functional use, with some preliminary results achieved which are encouraging. Built upon this first step, further research work can be carried out to explore

the applicability of EIO analysis to this strategic MP context. Two extensions are suggested as follows:

(1) inclusion of social accounts with income and employment multipliers. Social account is one of the common dimensions examined by the IO framework (Loehman & McElroy, 1976; Nelson, et al., 1980). Following the tradition of Miller and Blair (1985), with additional information on employee compensation and number of employment by sectors, it is feasible to identify the impact of industrial growth and expansion on the household income and employment of the study area. Thus, the valuation of social aspect could be more integrated with other trade-off analysis;

(2) consideration of land use change and sea space occupation. Other than the exploitation and utilization of physical resources, one of the major concerns derived from human activities in marine/coastal areas is with the occupation of sea space. Historically in Xiamen, the development of marine economy (e.g. port and warehouse land uses for shipping industry, marine aquaculture etc.) brought about a series of coastal wetland reclamation projects (L. Zhang, et al., 2010). The occupation of marine space resulted from these reclamation projects are considered to have caused significant cumulative effects on the marine ecosystem (Fang, et al., 2006; T. Lin, et al., 2007; Xuan Wang, Chen, Zhang, Jin, & Lu, 2010). Hubacek and Sun (2001) and Ferng (2009) ever discussed land use change and ecological footprints by applying IO analysis. Dalton (2004) presented an integration of IO analysis into evaluating the economic impacts of potential designations of marine protected area. Studies of this kind and their methodologies are worth being reference while considering the spatial resource occupancy and spatial planning for prospective sea uses.

6.2.3. Integration with other decision analysis approach

Even if the proposed approach can provide necessary assessment in facilitating the prioritization of two alternative marine functional uses, this analysis should be complemented by other decision analysis approaches.

Firstly, the IO analysis has its intrinsic assumptions such as static nature (fixed production patterns, no substitution effect, fixed prices etc.) and no supply constraints

(Bess & Ambargis, 2011). These assumptions restrain the IO analysis from better modeling the realistic socio-economic system which is fairly dynamic and with a variety of constraints. In the long run, more advanced modeling approach such as computable general equilibrium (CGE) models can be referred to (Burfisher, 2011; Fossati & Wiegard; Wajzman, 1995).

Secondly, the EIO model developed in this study is limited in depicting a full range of environmental effects. It is mainly because: (1) what the model uses as its input are mostly data sources that are publicly available, and such official statistics are generally restrained in several conventional environmental indicators. Additionally, less-developed monitoring and reporting system, economic burden of large-scale inventory, and entrenched bureaucracy in developing countries such as China could further decrease data accessibility; (2) the inherent linearity of the EIO model makes the approach relatively appropriate to address those routine resource uses or environmental discharges (or so-called 'end-of-the-pipe' effects) that are directly related to economic production process, but not theoretically sound to account for unconventional, secondary or indirect environmental and ecological effects which are also of great concern to decision makers (e.g. variation of hydrodynamics, habitat destruction, change of species composition and community structure, occurrence of catastrophic events such as oil spill and red tide). In addition to improvement of fundamental survey and database construction, combination with other physical oceanography models or ecological models to carry out a more comprehensive assessment is recommended.

Thirdly, the EIO model by itself is limited in handing a complete trade-off analysis. For example, the assessments of economic dimension (in monetary unit) and environmental dimension (in physical unit) in this research are not in the same unit of measurement, which becomes an obstacle for stakeholders to do a straightforward comparison while trade-offs exist. There are two proposed ways to overcome the drawback. One approach is to exercise nonmarket valuation methods (Champ, Boyle, & Brown, 2003), such as stated preference valuation, hedonic valuation, defensive behavior valuation and damage cost valuation, to monetize environmental externalities and measure the social cost associated with economic development. Accordingly, it is possible to investigate: (1) how

well we could make either port and shipping or waterfront tourism more environmentally friendly in a cost-effective way; (2) whether the expansion of waterfront tourism is still preferred to the expansion of port and shipping while including damage abatement cost into account. Another approach is to link the EIO model with multi-criteria decision analysis (Belton & Stewart, 2002; Keeney & Raiffa, 1976) to deal with integrated assessment of heterogeneous dimensions.

7. Conclusion

This study applied the EIO approach to the decision analysis of orientation of marine principal function in Xiamen Bay, prioritizing two of its leading marine functional uses—port and shipping versus waterfront tourism. Based on 2007 Xiamen IO table and empirical coefficients drawn from comparable researches, an EIO model representing local economy as well as its associated environmental footprints was established. The economic output impact and several environmental implications (energy consumption, air emissions, freshwater use, and water pollutant discharges) induced by two marine functional uses mentioned above were investigated with a region-wide perspective. In addition, scenario analysis was conducted to simulate the influence of expected economic growth and structural change on selected economic and environmental performance.

The results indicate that, in the base year 2007, per unit final demand for waterfront tourism generated 3.3 units of gross output for the economy, while per unit final demand for port and shipping only generated 2.0 units of gross output for the economy. In terms of their environmental implication, except for SO₂ emission and freshwater consumption, the economic activities induced by waterfront tourism had smaller environmental footprints associated with every single unit of gross output than those induced by port and shipping. The structural difference of production-inducing effect can best explain the superiority of waterfront tourism over port and shipping with regard to environmental performance, as waterfront tourism pulls in more ‘cleaner’ industries than port and shipping does. For the planned year 2015, the anticipatory analysis presents consistent results on a marginal basis with those in the base year under the BAU scenario, with only

scale differing. Should economic structure change, waterfront tourism would still outperform port and shipping in general both economically and environmentally. This analysis generally finds that waterfront tourism appears preferable to be recommended as principal functional use in marine and coastal areas of Xiamen given selected dimensions of assessment. Furthermore, the analysis can help in framing of regulatory strategies for improved management of both ‘waterfront tourism’-induced and ‘port and shipping’-induced industry chains.

This empirical research has not only a practical significance in providing the municipal government with necessary policy decision support and facilitating the orientation of marine principal functional use, but a methodological significance in advancing the development of decision analytical approach in the context of strategy-led MP to some extent. Through a case application in Xiamen, the EIO analysis presents itself as a promising approach in conducting systematic and structured analysis on a macroscopic scale, bridging socioeconomic with environmental system in an integrated way, and implementing policy evaluation with a proactive perspective. However, the analysis represents an initial exploration of the applicability of the EIO approach in the domain of MP in China. Efforts to improve the validity of model parameters, and integration with other approaches to construct a more comprehensive decision analysis framework is also recommended.

Reference

- Allen, R. I. G., & Gossling, W. F. (1975). *Estimating and projecting input output coefficients*. London: Input-Output Publishing Co.
- Ardron, J., Gjerde, K., Pullen, S., & Tilot, V. (2008). Marine spatial planning in the high seas. *Marine Policy*, 32(5), 832-839. doi: 10.1016/j.marpol.2008.03.018
- Belton, V., & Stewart, T. J. (2002). *Multiple criteria decision analysis : an integrated approach*. Boston: Kluwer Academic Publishers.
- Bess, R., & Ambargis, Z. O. (2011). *Input-Output Models for Impact Analysis: Suggestions for Practitioners Using RIMS II Multipliers*. Paper presented at the the 50th Southern Regional Science Association Conference, New Orleans, Louisiana.
http://www.bea.gov/papers/pdf/WP_IOMIA_RIMSII_020612.pdf
- Blaylock, J. E., & Jones, L. L. (1973). *An analysis of economic-environmental interrelations in the lower Rio Grande region of Texas : final report*. Austin: Office of the Governor, Office of Information Services.
- Boyes, S., Elliott, M., Thomson, S., Atkins, S., & Gilliland, P. (2007). A proposed multiple-use zoning scheme for the Irish Sea. An interpretation of current legislation through the use of GIS-based zoning approaches and effectiveness for the protection of nature conservation interests. *Marine Policy*, 31(3), 287-298. doi: 10.1016/j.marpol.2006.08.005
- Bundesamt für Seeschifffahrt und Hydrographie (BSH). (2009). *Spatial Plan for the German Exclusive Economic Zone in the Baltic Sea - Text section*. Hamburg and Rostock: Retrieved from
http://www.bsh.de/en/Marine_uses/Spatial_Planning_in_the_German_EEZ/documents/2/Spatial_Plan_Baltic_Sea.pdf.
- Burfisher, M. E. (2011). *Introduction to Computable General Equilibrium Models*. New York: Cambridge University Press.
- Calado, H., Ng, K., Johnson, D., Sousa, L., Phillips, M., & Alves, F. (2010). Marine spatial planning: Lessons learned from the Portuguese debate. *Marine Policy*, 34(6), 1341-1349. doi: 10.1016/j.marpol.2010.06.007
- Carnegie Mellon University Green Design Institute. (2008). Theory and Method behind EIO-LCA Retrieved Oct 30, 2012, from <http://www.eiolca.net/Method/eio-lca-method.html>
- Carnegie Mellon University Green Design Institute. (2012). Economic Input-Output Life Cycle Assessment (EIO-LCA) China 2002 (122) model [Internet]. Retrieved Nov 1, 2012
<http://www.eiolca.net/>
- Champ, P. A., Boyle, K. J., & Brown, T. C. (2003). *A primer on nonmarket valuation*. Dordrecht; Boston: Kluwer Academic Publishers.
- Chen, G. Q., & Zhang, B. (2010). Greenhouse gas emissions in China 2007: Inventory and input-output analysis. *Energy Policy*, 38(10), 6180-6193.
- Christ, C. F. (1955). *A Review of Input-Output Analysis* Input-Output Analysis: An Appraisal. Princeton: Princeton University Press. Retrieved from
<http://www.nber.org/chapters/c2866>.
- Cicin-Sain, B., & Knecht, R. W. (2000). *The future of U.S. ocean policy : choices for the new century*. Washington, D.C.: Island Press.
- Crowder, L., & Norse, E. (2008). Essential ecological insights for marine ecosystem-based management and marine spatial planning. *Marine Policy*, 32(5), 772-778. doi: 10.1016/j.marpol.2008.03.012

- Cumberland, J. H. (1966). A regional interindustry model for analysis of development objectives. *Papers of the Regional Science Association Papers of the Regional Science Association*, 17(1), 65-94.
- Daly, H. E. (1968). On Economics as a Life Science. *The Journal of Political Economy*, 76(3), 392-406.
- Day, J., Fernandes, L., Lewis, A., & Innes, J. (2003). *RAP - An ecosystem level approach to biodiversity protection planning*. Paper presented at the ITMEMS, Manila, Philippines. http://www.gbrmpa.gov.au/data/assets/pdf_file/0016/4354/Day-et-al-2003.pdf
- Dobrescu, E., & Gafta, V. (2012). On the accuracy of ras method in an emergent economy. *Amfiteatru Econ. Amfiteatru Economic*, 14(32), 502-521.
- Dong, A. (2002). Seriously establishing the distribution of sea functions and carrying out the laws and statutes on the management of the sea. *Ocean Development and Management*, 19, 42-44.
- Douvere, F. (2008). The importance of marine spatial planning in advancing ecosystem-based sea use management. *Marine Policy*, 32(5), 762-771. doi: 10.1016/j.marpol.2008.03.021
- Douvere, F., & Ehler, C. N. (2009). New perspectives on sea use management: Initial findings from European experience with marine spatial planning. *Journal of Environmental Management*, 90(1), 77-88. doi: 10.1016/j.jenvman.2008.07.004
- Douvere, F., Maes, F., Vanhulle, A., & Schrijvers, J. (2007). The role of marine spatial planning in sea use management: The Belgian case. *Marine Policy*, 31(2), 182-191. doi: 10.1016/j.marpol.2006.07.003
- Duchin, F. (1998). *Structural economics : measuring change in technology, lifestyles, and the environment*. Washington, D.C.: Island Press.
- Duchin, F., & Lange, G.-M. (1994). *The Future of the environment : ecological economics and technological change*. New York: Oxford University Press.
- Economic Development Bureau of Xiamen. (2011a). *Xiamen '12th Five-Year' Specific Plan for Advanced Manufacturing Industry (in Chinese)*.
- Economic Development Bureau of Xiamen. (2011b). *Xiamen '12th Five-Year' Specific Plan for Energy Conservation (in Chinese)*. Retrieved from <http://xmecc.xmsme.gov.cn/2011-10/20111013122701.htm>.
- Ehler, C. (2008). Conclusions: Benefits, lessons learned, and future challenges of marine spatial planning. *Marine Policy*, 32(5), 840-843. doi: 10.1016/j.marpol.2008.03.014
- Ehler, C., & Douvere, F. (2007). *Visions for a Sea Change*. Report of the First International Workshop on Marine Spatial Planning. Paris: Intergovernmental Oceanographic Commission and Man and the Biosphere Programme.
- Ehler, C., & Douvere, F. (2009). *Marine Spatial Planning: a step-by-step approach toward ecosystem-based management IOC Manual and Guides No. 53, ICAM Dossier No. 6*. Paris: Intergovernmental Oceanographic Commission and Man and the Biosphere Programme. UNESCO.
- Energy and Environmental Affairs. (2009). *Massachusetts Ocean Management Plan. Volume 1. Management and Administration*. Retrieved from <http://www.env.state.ma.us/eea/mop/final-v1/v1-complete.pdf>.
- Fang, Q., Zhang, L., Jiang, Y., Yang, X., & Hong, H. (2006). A case study of cumulative effects assessment for harbor planning in China (in Chinese). *Environmental Pollution & Control*, 28(10), 764-767.
- Fang, Q., Zhang, R., Zhang, L., & Hong, H. (2011). Marine Functional Zoning in China: Experience and Prospects. *Coastal Management*, 39(6), 656-667.

- Ferng, J.-J. (2009). Applying inputoutput analysis to scenario analysis of ecological footprints. *Ecological economics : the journal of the International Society for Ecological Economics.*, 69(2), 345.
- Flannery, W., Cinneide, M. O., & Nixon, E. (2010). Preparing the ground for marine spatial planning in Ireland. *Int. J. Sustainable Dev. Plann. International Journal of Sustainable Development and Planning*, 5(1), 57-67.
- Fossati, A., & Wiegard, W. (2002). *Policy evaluation with computable general equilibrium models*, London; New York.
- GBRMPA. Developing the Draft Zoning Plan. *Great Barrier Reef Marine Park Authority* Retrieved October 2, 2011, from <http://www.gbrmpa.gov.au/zoning-permits-and-plans/rap/developing-the-draft-zoning-plan>
- Gilliland, P., & Laffoley, D. (2008). Key elements and steps in the process of developing ecosystem-based marine spatial planning. *Marine Policy*, 32(5), 787-796. doi: 10.1016/j.marpol.2008.03.022
- Guan, D., & Hubacek, K. (2007). Assessment of regional trade and virtual water flows in China. *ECOLOGICAL ECONOMICS*, 61(1), 159-170.
- Guan, D., & Hubacek, K. (2008). A new and integrated hydro-economic accounting and analytical framework for water resources: A case study for North China. *J. Environ. Manage. Journal of Environmental Management*, 88(4), 1300-1313.
- Gubbay, S. (2005). Marine protected areas & zoning in a system of marine spatial planning *a discussion paper for WWF-UK*.
- Guitton, H., & Rasmussen, P. N. (1957). Studies in Inter-Sectoral Relations. *Revue économique* *Revue économique*, 8(6).
- He, G., Wang, X., Zhao, R., Xu, C., & Song, W. (2010). Research on the method of China's marine major function oriented zoning (in Chinese). *Marine Science Bulletin*, 29(3), 334-341.
- Hewings, G. J. D., & Janson, B. N. (1980). Exchanging regional input - output coefficients: a reply and further comments. *Environ. Plann. A Environment and Planning A*, 12(7), 843-854.
- Huang, R.-f., Li, X.-m., & Gu, H.-y. (2004). Research on Port Handling Capacity Forecasting Method by Regression Forecasting Technology (in Chinese). *Port & Waterway Engineering*(4), 24-26.
- Hubacek, K., Guan, D., Barrett, J., Wiedmann, T., Advances in Life-Cycle Approaches to, B., & Resource Management in the Asia-Pacific, R. (2009). Environmental implications of urbanization and lifestyle change in China: Ecological and Water Footprints. *Journal of Cleaner Production*, 17(14), 1241-1248.
- Hubacek, K., & Sun, L. (1999). Land Use Change in China: A Scenario Analysis based on Input-Output Modeling. Laxenburg, Austria: International Institute for Applied Systems Analysis (IIASA).
- Hubacek, K., & Sun, L. (2001). A scenario analysis of China's land use and land cover change: incorporating biophysical information into inputoutput modeling. *Structural Change and Economic Dynamics Structural Change and Economic Dynamics*, 12(4), 367-397.
- Hubacek, K., & Sun, L. (2005). Economic and Societal Changes in China and their Effects on Water Use: A Scenario Analysis. *JOURNAL OF INDUSTRIAL ECOLOGY*, 9(1/2), 187-200.
- . *Integrated Management Plan for the North Sea 2015*. (2005). Interdepartmental Directors' Consultative Committee North Sea. The Netherlands.
- Interagency Ocean Policy Task Force. (2009). *Interim Framework for Effective Coastal and Marine Spatial Planning*. Washington, D.C.: White House Council on Environmental Quality Retrieved from <http://purl.fdlp.gov/GPO/gpo8618>.

- IPCC. (1996). *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*. Retrieved from <http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html>.
- IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Hayama, Japan: IGES Retrieved from <http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html>.
- Juliá, R., & Duchin, F. (2007). World trade as the adjustment mechanism of agriculture to climate change. *Climatic Change Climatic Change*, 82(3-4), 393-409.
- Keeney, R. L., & Raiffa, H. (1976). *Decisions with multiple objectives : preferences and value tradeoffs*. New York: Wiley.
- 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 Marine Policy*, 29(4), 371-383.
- Leontief, W. (1970). Environmental repercussions and the economic structure an input-output approach. *Review of Economics and Statistics*, 52(3), 262-271.
- Leontief, W. (1986). *Input-output economics*. New York: Oxford University Press.
- Li, D., Zhao, R., & Song, W. (2010). Research on the technical method of offshore marine major function oriented zoning (in Chinese). *Marine Environmental Science*, 29(6), 939-944.
- Liang, S., Wang, C., & Zhang, T. (2010a). An improved input-output model for energy analysis: A case study of Suzhou. *Ecological economics : the journal of the International Society for Ecological Economics.*, 69(9), 1805.
- Liang, S., Wang, C., & Zhang, T. (2010b). An improved input-output model for energy analysis: A case study of Suzhou. *Ecological economics : the journal of the International Society for Ecological Economics.*, 69(9), 1805.
- Lin, G., & Zuo, Y. (2006). Cumulative ecological effects assessment on resource exploitation and utilization in bay (in Chinese). *Journal of Natural Resources*, 21(3), 432-440.
- Lin, J.-h. (2010). Assessment of sustainable utilization of urban water resources in Xiamen City (in Chinese). *Water Resources Protection*, 26(6), 51-56.
- Lin, J., Meng, F., Cui, S., Yu, Y., & Zhao, S. (2012). Carbon footprint analysis on urban energy use: A case study of Xiamen, China. *Shengtai Xuebao Acta Ecol. Sin. Shengtai Xuebao/ Acta Ecologica Sinica*, 32(12), 3782-3794.
- Lin, S. J., & Chang, Y. F. (1997). Linkage Effects and Environmental Impacts from Oil Consumption Industries in Taiwan. *Journal of Environmental Management Journal of Environmental Management*, 49(4), 393-411.
- Lin, T., Xue, X. Z., & Lu, C. Y. (2007). Analysis of Coastal Wetland Changes Using the "DPSIR" Model: A Case Study in Xiamen, China. *Coastal Management*, 35(2-3), 289-303.
- Liu, Z., Geng, Y., Lindner, S., Zhao, H., Fujita, T., & Guan, D. (2012). Embodied energy use in China's industrial sectors. *Energy Policy*, 49, 751-758.
- Loehman, E. T., & McElroy, R. (1976). *Input-output analysis as a tool for regional development planning*. Gainesville, Fla.: Food and Resource Economics Dept., University of Florida.
- Maes, F., Batist, M. D., Lancker, V. V., Leroy, D., & Vincx, M. (2005). Towards a Spatial Structure Plan for Sustainable Management of the Sea, SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY (SPSD II): Belgian Science Policy.
- Mao, C., & Chen, J. (2011). Economic Contribution of Chongqing Port Based on Input-output Model (in Chinese). *Journal of Transport Information and Safety*, 29(1), 37-40.
- Marcotullio, P. J., Williams, E., & Marshall, J. D. (2005). Faster, sooner and more simultaneously: how recent road and air transportation CO2 emission trends in developing countries differ from historic trends in the United States. *Journal of Environment & Development*, 14(1).
- Mengerink, K. (2010). Planning for Our Oceans' Future: No individual tool can single-handedly support coastal and marine spatial planning. *The environmental forum.*, 27(4), 42-47.

- Miller, R. E., & Blair, P. D. (1985). *Input-output analysis : foundations and extensions*. Englewood Cliffs, N.J.: Prentice-Hall.
- Ministerie van Verkeer en Waterstaat. (2009). *Policy Document on the North Sea 2009 - 2015*. Dutch central government Retrieved from <http://www.rijksoverheid.nl/bestanden/documenten-en-publicaties/brochures/2010/08/12/beleidsnota-noordzee-2009-2015-engels/12pd2010g202.pdf>.
- Morin Dalton, T. (2004). An approach for integrating economic impact analysis into the evaluation of potential marine protected area sites. *Journal of Environmental Management Journal of Environmental Management*, 70(4), 333-349.
- MSPP Consortium. (2006). Marine Spatial Planning Pilot: Final Report.
- National Marine Environment Monitoring Center. (2012). Technical Study and Demonstration of Coastal Principal Functional Zoning--Special Scientific Research for Marine Public Welfare (in Chinese) Retrieved Dec 6, 2012, from <http://www.nmemc.gov.cn/news/2745.htm>
- Nelson, R. G., Hardy, W. E., & Flynn, J. B. (1980). *The economic and environmental structure of Alabama's coastal region. Part 2 : Environmental structure*. Auburn: Dept. of Agricultural Economics and Rural Sociology, Agricultural Experiment Station, Auburn University.
- Ni, J. R., Zhong, D. S., Huang, Y. F., & Wang, H. (2001). Total waste-load control and allocation based on inputoutput analysis for Shenzhen, South China. *Journal of Environmental Management Journal of Environmental Management*, 61(1), 37-49.
- Okadera, T., Watanabe, M., & Xu, K. (2006). Analysis of water demand and water pollutant discharge using a regional input€“output table: An application to the City of Chongqing, upstream of the Three Gorges Dam in China. *ECOLOGICAL ECONOMICS*, 58(2), 221-237.
- Ou, Y. (2003). On Forecast Method of Port Throughput (in Chinese). *Port & Waterway Engineering*(1), 10-11.
- Peng, B., Hong, H., Xue, X., & Jin, D. (2006). On the measurement of socioeconomic benefits of integrated coastal management (ICM): Application to Xiamen, China. *OCEAN AND COASTAL MANAGEMENT*, 49(3-4), 93-109.
- People's Government of Siming District (Xiamen). (2011a). *Siming District '12th Five-Year' Plan for Tourism*. Retrieved from <http://www.siming.gov.cn/zsy/zxgh/201209/P020120929442363439129.pdf>.
- People's Government of Siming District (Xiamen). (2011b). *Siming District '12th Five-Year' Plan for Tourism (in Chinese)*. Retrieved from <http://www.siming.gov.cn/zsy/zxgh/201209/P020120929442363439129.pdf>.
- Peters, G. P., Weber, C., & Liu, J. (2006). Construction of Chinese Energy and Emissions Inventory. Trondheim, Norway: Norwegian University of Science and Technology.
- Peters, G. P., Weber, C. L., Guan, D., & Hubacek, K. (2007). China's Growing CO2 Emissions--A Race between Increasing Consumption and Efficiency Gains. *Environmental Science & Technology*, 41(17), 5939-5944.
- Raa, T. t. (2010). Input-output economics theory and applications : featuring Asian economies, from <http://site.ebrary.com/id/10422529>
- Research Group of 2007 China Input-Output Table. (2011). A scenario analysis of China's industrial structural change based on input-output analysis (in Chinese).
- Slater, A. M. (2004). Marine spatial planning: implications for the marine environment through examination of the Darwin Mounds and the James T`oxic' Fleet cases. *Environmental law and management.*, 16(6), 287-295.

- State Oceanic Administration. (2006). Technical Directives for the Division of Marine Functional Zonation. Beijing: Standardization Administration of China.
- State Oceanic Administration. (2011). Technical Regulation for Eivision of Marine Major Function Oriented Zone (in Chinese).
- State Statistical Bureau of China. (2009). *2007 Input-Output Tables of China (in Chinese)*.
- Stone, R. (1961). *Input-output and national accounts*. [Paris: Organisation for European Economic Co-operation.
- Stone, R., Brown, A. A., & University of Cambridge. Dept. of Applied, E. (1962). *A computable model of economic growth*. London: Chapman and Hall].
- Symes, D. (2005). *Marine Spatial Planning: A Fisheries Perspective. Report to English Nature. Unpublished*. Retrieved from http://ioc3.unesco.org/marinesp/files/Marine%20Spatial%20Planning_Fisheries%20Perspective.pdf
- Tyldesley, D. (2004). Coastal and Marine Spatial Planning Framework for the Irish Sea Pilot Project: Defra.
- U.S. Travel Association (Producer). (2012). U.S. TRAVEL ANSWER SHEET. Retrieved from http://www.ustravel.org/sites/default/files/page/2009/09/USTravelAnswerSheet_June2012.pdf
- UNESCO. (28 January 2010). Marine Spatial Planning Initiative Retrieved 10 September, 2010, from <http://www.unesco-ioc-marinesp.be/>
- UNESCO. (28 January 2010). The Netherlands. MSP Around the World. *Marine Spatial Planning Initiative* Retrieved November 2, 2010, from http://www.unesco-ioc-marinesp.be/spatial_management_practice/the_netherlands
- United States. (1978). *Regional development and plan evaluation the use of input-output analysis*. Washington. D.C.: U.S. Dept. of Agriculture, Economics, Statistics, and Cooperatives Service Retrieved from <http://purl.fdlp.gov/GPO/gpo29892>.
- Vincent, M. A., Atkins, S. M., Lumb, C. M., Golding, N., Lieberknecht, L. M., & Webster, M. (2004). Marine nature conservation and sustainable development - the Irish Sea Pilot. Report to Defra by the Joint Nature Conservation Committee. Peterborough.
- Wajzman, N. (1995). The Use of Computable General Equilibrium Models in Evaluating Environmental Policy. *Journal of Environmental Management*, 44(2), 127.
- Wang, P., Zhang, L. P., & Hong, H. S. (2004). The case study on ecocity conceptual planning of Xiamen (in Chinese). *Journal of Xiamen University (Natural Science)*, 43(Supplement), 190-194.
- Wang, P. E., Hong, H. S., & Zhang, L. P. (2004). Discussion on the resource-oriented marine functional zoning (in Chinese). *Journal of Xiamen University (Natural Science)*, 43, 205-210.
- Wang, X., Chen, W., Zhang, L., Jin, D., & Lu, C. (2010). Estimating the ecosystem service losses from proposed land reclamation projects: A case study in Xiamen. *ECOLEC Ecological Economics*, 69(12), 2549-2556.
- Wang, X., Zhu, X., Li, Y., Huang, H., & Cai, B. (2007). Dynamic assessment of the cumulative ecological effects from Xiamen Bay city development (in Chinese). *Acta Ecologica Sinica*, 27(6), 2375-2381.
- Wei, Y. M., Liang, Q. M., Fan, Y., Okada, N., & Tsai, H. T. (2006). A scenario analysis of energy requirements and energy intensity for China's rapidly developing society in the year 2020. *Technological Forecasting & Social Change*, 73(4), 405-421.
- World Bank. (1997). *China 2020 development challenges in the new century*. Washington: World Bank.

- Xia, X.-Y., & Zhang, H.-H. (2011). Economic development and its driving force for coastal vice-provincial city in the post-industrialization age: an empirical research on Shenzhen, Xiamen, Qingdao and Ningbo (in Chinese). *Science & Technology Progress and Policy*, 28(18), 21-25.
- Xiamen Municipal Development and Reform Commission. (2011). *Xiamen '12th Five-Year' Specific Plan for Modern Services Development (in Chinese)*.
- Xiamen Municipal Government. (2006). *Report on the Work of the Government Delivered at the Fourth Session of the Twelfth Municipal People's Congress of Xiamen (in Chinese)*. Retrieved from http://www.xm.gov.cn/zfxxgk/xxgkznm/szhch/szfgzbg/201112/t20111201_441210.htm.
- Xiamen Municipal Government. (2011a). *The Outline of Xiamen '12th Five-Year' Plan for Economic and Social Development (in Chinese)*. Retrieved from http://www.fujian.gov.cn/zwgk/zxwj/sqswj/xm/201103/t20110325_347408.htm.
- Xiamen Municipal Government. (2011b). *Xiamen '12th Five-Year' Specific Plan for Marine Economic Development (in Chinese)*. Retrieved from http://www.xm.gov.cn/zwgk/ghfz/bmgh/201109/t20110928_428061.htm.
- Xiamen Municipal Statistics Bureau. (2007). *Input-Output Tables of Xiamen*. (in Chinese).
- Xiamen Municipal Statistics Bureau. (2011). *2011 Yearbook of Xiamen Special Economic Zone (in Chinese)*. Retrieved from <http://www.stats-xm.gov.cn/2011/>.
- Xiamen Port Authority. (2011). *General Plan for Xiamen Port (in Chinese)*. Retrieved from <http://www.portxiamen.gov.cn/xmsgkglj/zhfxxgk/zhfxxgkml/ghjh/shmgfzhghgy/271351.htm>.
- Xiamen Tourism Bureau. (2011). *Xiamen '12th Five-Year' Plan for Tourism (in Chinese)*. Retrieved from <http://www.xmtravel.gov.cn/news/1323658824455.html>.
- Yang, J., & Shao, Z.-p. (2005). Econometrics Forecasting Analysis of Harbor Throughput (in Chinese). *Navigation of China*, 64(3), 54-56.
- Yu, B., Yang, X., Huang, X., & Yuan, L. (2006). Assessment of water resources security in Xiamen (in Chinese). *Xiamen Science & Technology*(3), 28-32.
- Yu, X., Lu, C., Wang, J., & Lin, Z. (2005). Challenges and regulation strategies the nearshore marine ecosystem services faced in Fujian (in Chinese). *Journal of Oceanography in Taiwan Strait*, 24(2), 257-264.
- Zhang, L.-p., Chen, W.-q., Fang, Q.-h., Huang, J.-l., Ricci, P., Mu, R., . . . Cai, Y.-r. (2012). Coastal Principal Functional Zoning in Bay Areas. Xiamen: Coastal and Ocean Management Institute, Xiamen University.
- Zhang, L., Chen, W., Huang, J., Peng, B., Fang, Q., Zhao, Z., . . . Lian, P. (2010). Environmental effect assessment of human activities in Xiamen Bay (in Chinese). Xiamen University.
- Zhang, R., Zhang, L., & Fang, Q. (2011). Review on marine spatial planning and principal functional zoning (in Chinese). *Ocean Development and Management*(11), 16-20.
- Zhang, Y.-X., & Zhao, K. (2009). *China's Input-Output Table Compilation and its Extensions*. Paper presented at the 17th International Input-Output Conference, São Paulo, Brazil. http://www.iioa.org/pdf/17th%20Conf/Papers/492297253_090601_103024_ZHANGYA_XIONG268.PDF

Appendix A. Decision-Making Analytical Approach to Marine Planning

A general, but not exhaustive, list of MP practices all over the world is shown as Table A.1. In MP, decision-making analytical approach refers to the flow path or operation process which helps analyze planning alternatives and formulate decisions as to selection of functional use and distribution of spatial arrangement. Basically, there are two prevailing paradigms of MP according to decision hierarchy: plan-led MP and strategy-led MP.

Table A.1 Global practices of Marine Planning

Country/International Organization	Initiative	Year
Australia	Great Barrier Reef Marine Park (GBRMP)	1978-2005
	Marine Planning Framework for South Australia	2006
Belgium	Master Plan for the Belgian part of the North Sea (GAUFRE)	2003-2005
Germany	Spatial Plan for the North Sea and Baltic Sea	2004-ongoing
	Spatial Plan for the State of Mecklenburg-Vorpommern	2005
The Netherlands	Integrated Management Plan for the North Sea 2015 (IMPNS 2015)	2003-ongoing
United Kingdom (UK)	Irish Sea Pilot Project and Marine and Coastal Access Act 2009	2002-2005
Norway	Ecosystem Management Plan for the Barents Sea	
Sweden	Marine Environment Inquiry	2006-2008
Finland	Towards Marine Spatial Planning in the Baltic Sea	
Denmark, Germany & The Netherlands	Trilateral Wadden Sea Plan	1993-2010
OSPAR Commission	Marine Spatial Management Working Group	
Helsinki Commission (HELCOM)	Marine Spatial Planning Exercise in the Baltic Sea	
European Union (EU)	EU MSP Roadmap	
Canada	Large Ocean Management Area Integrated Management Plans	1998-2007
	Eastern Scotian Shelf Integrated Management Plan	2006-2012
United States (U.S.)	Florida Keys National Marine Sanctuary	1990-2007
	Massachusetts Ocean Management Initiative	2008-2009
	Rhode Island Special Area Management Plan	
Ecuador	Galapagos Marine Reserve Zoning	
China	Territorial Sea Marine Functional Zoning	2002-ongoing

Adapted from Marine Spatial Planning Initiative website (UNESCO)

Plan-led MP aims at separating specific sea use conflicts from a pragmatic perspective. It gets more actively involved in detailed management and regulation; it is inclined to be somewhat narrower, more prescriptive and less flexible with respect to spatial (and temporal) use (Symes, 2005). Generally speaking, it is readily operational and

enforceable to both resource managers and end-users of marine areas by specifying, for example, what activities are allowed to occur where, what activities are prohibited, and what activities require a permit to access. The GBRMP in Australia, Spatial Plan for German EEZ, and Massachusetts Ocean Management Plan belong to this category. In contrast, the main idea of strategy-led MP is to deal with high level of sea use issues. It provides a broader, general sea use framework, primarily indicating strategic and long-term vision; it enables flexible and adaptive design, allowing alternative pathways to the achievement of determined vision; it leaves detailed decision making on the management of different uses to other professional sector-based organizations (Symes, 2005). Representative examples are GAUFRE project in Belgium, Spatial Planning Policy for the DPNS in Netherlands, Irish Sea Pilot Project in UK, MFZ in China, and Spencer Gulf Marine Plan in South Australia. In terms of public policy process, strategy-led MP takes place in the phase of policy formulation, while plan-led MP plays the role of policy implementation in pursuance of strategic and long-term objectives.

A.1. Plan-led decision-making approach

(1) Zoning within the GBRMP

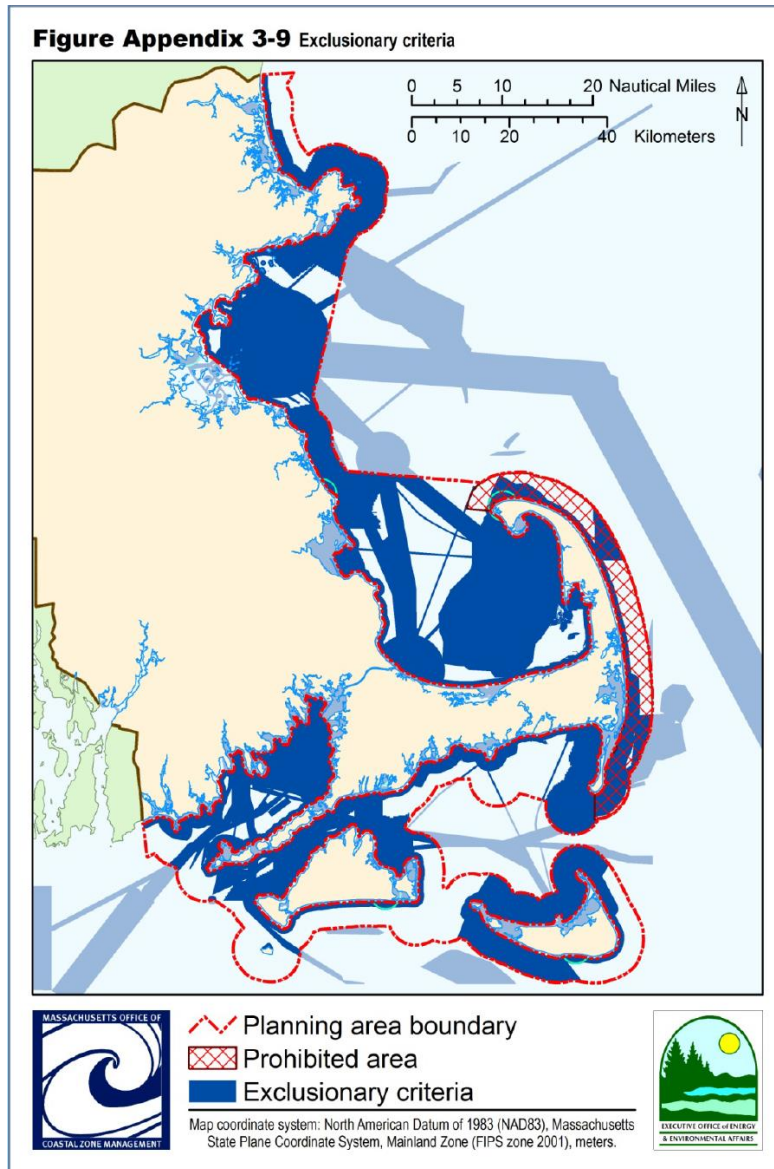
In the GBRMP, bioregion mapping, through which the planning area was classified into 70 ‘bioregions’ by the biological and physical diversity, provided a fundamental basis for subsequent zoning efforts. Then a combination of expert opinion, stakeholder involvement and analytical approaches was used to identify ‘candidate’ area for no-take areas (Day, Fernandes, Lewis, & Innes, 2003). The analytical approaches consisted of marine reserve design software including Marxan and a suite of GIS-based spatial analysis tools, which allowed generating and assessing a number of options based on a series of biophysical, social, cultural and economic principles. Likewise, the placement of the other types of zones followed the approach stated above, aiming at maximizing the protection of the biodiversity whilst minimizing negative social, economic or cultural impacts on the stakeholders of GBRMP (GBRMPA).

(2) Spatial Plan for the North Sea and Baltic Sea

The basic approach to spatial planning for German EEZ was to set targets, principles, and areas for individual function or use, based on applicable laws and policies (internationally and domestically) for relevant sectors; additionally, an associated environmental assessment was carried out in cooperation with the Federal Agency for Nature Conservation to identify and evaluate the likely significant effects of implementing the Spatial Plan on the environment, whose findings have been taken into account in the designations made in the draft plan (Bundesamt für Seeschifffahrt und Hydrographie (BSH), 2009). Other than that, no new research efforts were undertaken in the context of plan development, and the plan was merely developed by means of compilation and synthesis of already existing information and data led by BSH (Douvere & Ehler, 2009).

(3) Massachusetts Ocean Management Plan

According to Energy and Environmental Affairs (2009), the decision-making approach to Massachusetts Ocean Management Plan can be best represented by the process of designating two appropriate wind energy areas. After a baseline assessment to characterize the current situation of the planning area with the creation of 26 spatial data layers, an environmental screening was conducted based upon the presence of suitable targeted resources and the absence of conflict with other uses or sensitive resources (e.g. whale core habitat, navigation areas, areas of commercial fishing, and regulated airspace). Since such a use-by-use compatibility assessment (see Figure A.1) might not be robust enough to elicit scientifically sound decisions, other constraint criteria were also developed to assist in evaluating the relative suitability of potential sites and designating the final sites. These constraint criteria incorporated the consideration of potential cumulative effects, feasibility of wind turbine technology, visual impacts and so forth, as derived through qualitative assessment, stakeholder input and public comment. Combined with the screening results in a comprehensive way, the spatial delineation for commercial-scale offshore wind development was generated.



Source: Energy and Environmental Affairs (2009)

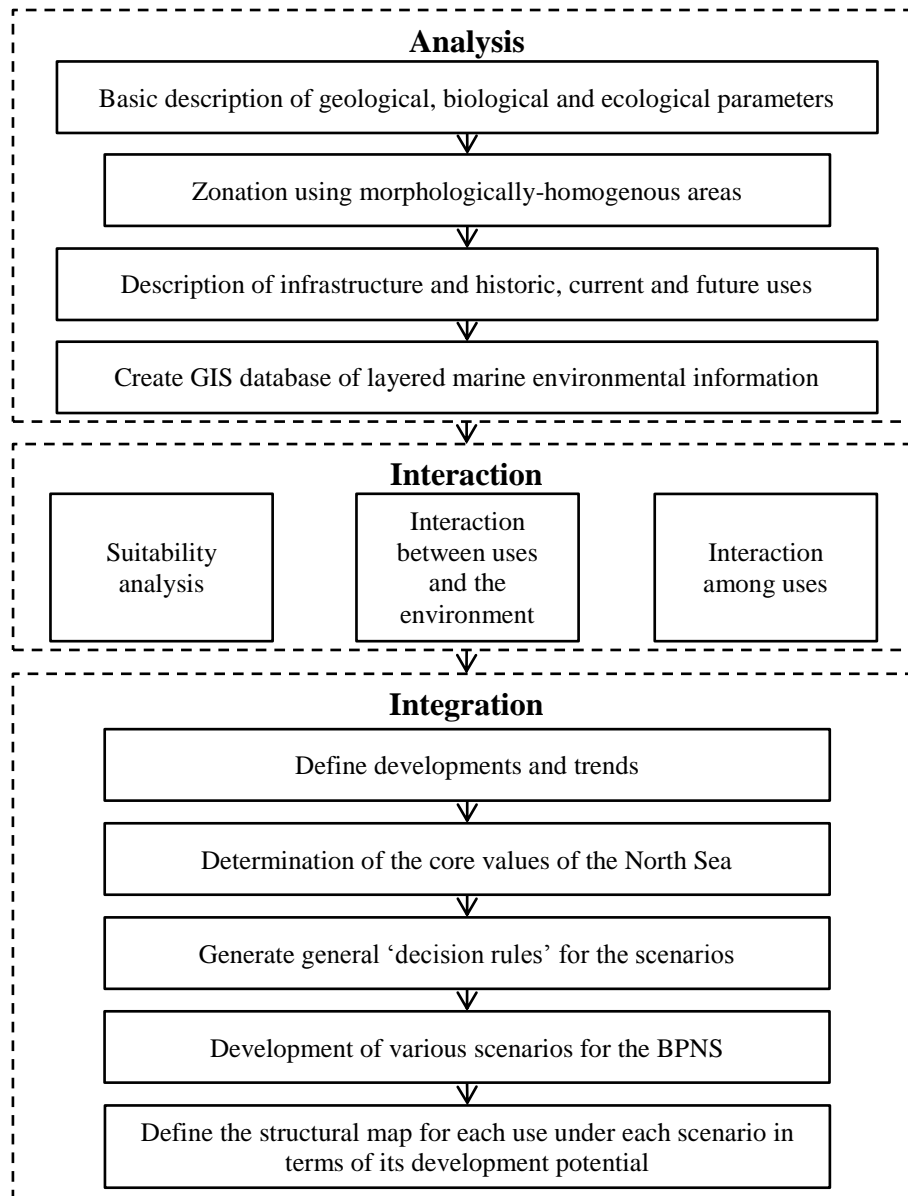
Figure A.1 Wind energy screening in Massachusetts Ocean Management Plan

A.2. Strategy-led decision-making approach

(1) GAUFRE project

According to the report of GAUFRE project in Belgium, the approach can be described as Figure A.2. The ‘Analysis’ section formed the baseline of the study (Maes, Batist, Lancker, Leroy, & Vincx, 2005). Subsequently, the second section allowed an analysis of interactions among the environment, infrastructure and uses, which contributed to the

search for potential scenarios and the feedback on the possible outcome of those scenarios (Douvere, Maes, Vanhulle, & Schrijvers, 2007). Based on the accumulation of basic information and its interaction analysis, the project took a step further, namely 'Integration', to develop concrete future possibilities by applying a structural approach (Maes, et al., 2005). In more specific terms: (1) well-being, ecology and landscape, and economic value were determined as key values to guide the sustainable development, and any future decision towards overall vision and spatial structure for the BPNS would therefore have to be assessed against these key values; (2) varying emphasis was placed on the core values to develop alternative scenarios under which the BPNS might be managed (Douvere, et al., 2007; Maes, et al., 2005). Note that the project was not intended to provide the ultimate spatial structure plan for the BPNS as it is a task of weighting and balancing different values of the society which was seen as a political decision (Maes, et al., 2005).



Adapted from Maes et al. (2005)

Figure A.2 Approach to spatial structural planning for the BPNS

(2) Spatial planning policy for the DPNS

Guided by the overarching objective to foster a healthy, safe and profitable sea, the Dutch spatial policy framework was composed of location-based usage zones, opportunity maps, and several exclusion policies (*Integrated Management Plan for the North Sea 2015*, 2005; UNESCO). According to Policy Document on the North Sea 2009-2015 (2009), the decision-making framework behind this holistic vision in general was to provide

activities of national importance with priority (such as shipping, defense, sand extraction, wind energy and commitment to nature conservation) and designate areas for these activities where other activities must not hinder the defined use. Additionally, a research on the economic valuation of the DPNS in relation to its use of space is ongoing, in which three alternative scenarios have been developed depending on estimated economic growth rates (slow, medium or high) for an anticipatory analysis of potential conflicts and compatibilities, providing better insight into MP in the long term (Douvere & Ehler, 2009).

(3) Irish Sea Pilot Project

After sub-dividing the regional sea according to its marine landscape (Vincent et al., 2004), several key steps in relation to decision analysis were specified as below (MSPP Consortium, 2006): (1) Forecasting, the stage to predict the demands for activities and their spatial manifestations, was dependent on a series of assumptions with regard to the relationship between past change and the future, government policy, the economy, technological change, climate change etc.; (2) Analysis served to identify the conflicts and the uncontested satisfiable demands on space; (3) Generating spatial options was aided by data handling techniques coupling with the weighting of objectives, and each alternative tended to favor one set of values rather than another; (4) Evaluation took account of socio-economic needs and environmental protection requirements, as required by SEA/sustainability appraisal. One of the most frequently used techniques in this stage is the Goals Achievement Matrix, in which the axes of the matrix are constructed by the objectives of the plan and the elements of each option, and each element is assessed against the criteria of each objective and awarded a score. Thus an overall score for individual option can be attained and all generated options can be ranked in order.

(4) Marine Functional Zoning in China

In China, the Technical Directives for the Division of Marine Functional Zonation provides an overall development process of its MP (State Oceanic Administration, 2006). After collecting and collating all available baseline information (with supplementary investigation if necessary), a key step is to define and analyze present and future

situations, the purpose of which is to identify the problems that already exist in current sea uses and predict the conflicts that might occur as a result of prospective human intervention (Fang, et al., 2011; State Oceanic Administration, 2006). Then the most crucial step follows by developing the zoning scheme. In this phase, natural attributes are initially considered as the basis to determine the functions of sea areas (Fang, et al., 2011). For areas that can accommodate multiple functions, different functional uses will be compared with comprehensive consideration of natural and social attributes, requirements of environmental protection, and relevant sectoral plans, and then dominant function will be defined (State Oceanic Administration, 2006).

A.3. Research gap

(1) Limitation of plan-led approach

Plan-led approach can be described as an extrapolation of traditional sectoral approach and thus has limited contribution to the sustainable development of marine and coastal areas.

To deal with specific sea use conflicts, the rationale underpinning plan-led MP is to maximize the interests of desirable uses, whilst minimize negative impacts on all other stakeholders as far as possible. The analytical process generally has preferential sectoral interests (or predetermined objectives in other words) as the first concern and conducts its following analysis based on this premise. In such situations, even though the approach allows taking various human activities into account and examining the impacts of one use on others, it is less likely for final planning results to make a fundamental change, due to concerns for other values, to the principal functional use of those candidate areas identified to meet sectoral interests. The majority of the concern is where to locate targeted uses in such a way that use conflicts could be reduced as far as possible (Boyes, Elliott, Thomson, Atkins, & Gilliland, 2007; Energy and Environmental Affairs, 2009; P. E. Wang, et al., 2004). Once conflicts among various interests occur inevitably, priority would tend to be given to the oriented sector in the decision-making process (Calado et al., 2010; Cicin-Sain & Knecht, 2000).

Therefore, plan-led MP by its nature does not completely get rid of the paradigm of sector-based management and could not fully account for trade-offs, which is still at a management and regulation level. As Calado et al. (2010) observed, the development of MP has been encountering entrenched sectoral views. The decision-making approach to the MP of this category is fairly beneficial for mobilizing specific marine resources and sea use activities, but it could neither guarantee balanced decision analysis nor address sufficiently the cumulative effects of human activities on the marine environment; it helps regulate and manage sectoral conflicts in the short term through analyzing the requirements and characteristics (e.g. compatibility and excludability) of specific use activities from a pragmatic perspective, yet it is incapable of dealing with the optimization of resource use configuration substantively and offering a long-term, strategic and sustainable guidance on sea use priorities on a macroscopic scale. Critiques have been raised about its limitations to contribute to the overall goals of sustainable development (Douvere, et al., 2007; Symes, 2005).

(2) Less-developed strategy-led approach

To deal with high level of sea use issues and facilitate sustainable resource use of marine and coastal areas, strategy-led MP appears to be reasonably needed. However, the development of decision-making approach or methodology for strategy-led MP is in the early stage up till now, and limitations can be identified in following aspects.

First, plan-led paradigms still have strong influences on decision-making approach, although the strategy-led ideology is expected to direct the process. The most apparent representation is that, interactions between uses and the environment as well as among various uses themselves tend to be dealt with in a piecemeal approach (e.g. towards every single piece of marine space or every concrete activity), while effects (especially those cumulative) of different functional uses on recipient ecosystem as a whole, are not adequately and systematically addressed.

Second, trade-off analysis is the most critical stage for comparing and prioritizing alternatives as decision support, whereas it is the most untraceable and intractable for most of the cases though. It is broadly suggested to develop approaches that are able to

integrate natural and social science disciplines on defining and analyzing sea uses, because valuation of social and economic aspects (human dimensions) is not systematically incorporated with ecological valuation for most of MP initiatives (Crowder & Norse, 2008; Douvère & Ehler, 2009; Charles Ehler & Douvère, 2007).

Third, in terms of methodologies, even though there are several classic methods and tools already existing such as feasibility analysis, suitability analysis, cost-benefit analysis and environmental impact assessment, these are rooted in the realm of traditional project appraisal which usually requires elaborated parameters about engineering design, technical process etc. Despite their applicability in analyzing use conflicts or compatibilities, prioritizing siting options and planning spatial use at a project-based level, these methods and tools has limited capability to handle a region-wide analysis on a macroscopic scale. Meanwhile, although policy makers have embraced innovative decision analytical frameworks such as SEA and sustainability appraisal, operational instruments that are able to explicitly represent social, economic and environmental performance of alternatives are still deficient, which makes policy analysis stay more at a conceptual level. In other words, how to measure social, economic and environmental tradeoffs brought about by strategic planning, particularly in a quantitative way, is still an issue needs to be solved. Without appropriate measurement of performance, it is hard to provide various stakeholders with a common benchmark to build their value-based judgments on.

In summary, for strategy-led MP, despite of numerous attempts which tried to define its scope and nature, relatively few dealt with how to put it into workable practice, which stands as an obstacle for the substantive operation of this framework when it comes down to specific policy analysis (Charles Ehler & Douvère, 2009).

Appendix B

Several technical steps are proposed as follows to make the RAS method implementable.

(1) Aggregate the 2007 144-sector IO table into a 41-sector specification. The 2007 IO table with 144-sector classification has several rows and columns completely filled with 0 values, indicating no supply as intermediate demand from those sectors to other sectors or nonexistence of those sectors within the region. To avoid occurrence of any 0 value as denominator in computation process, aggregating sectors within the region is a feasible solution. The aggregation criteria basically follow the hierarchical sectoral classification system of ‘2007 IO tables of China’ (State Statistical Bureau of China, 2009) with only two exceptions. One is to combine sector 6 through 10 into one aggregated sector called ‘Mining’, as sector 6 through sector 9 do not exist in Xiamen; another is to isolate sector 102 ‘Water Transport’ from the aggregated sector ‘Traffic, Transport and Storage’ and isolate sector 125 ‘Tourism’ from the aggregated sector ‘Leasing and Business Services’, as the final demands for these two sectors are regarded as exogenous model inputs. Detailed aggregation information is shown as Table B.1.

(2) Obtain the value added for each of 41 sectors in 2015. Given annual growth rate of GDP and proportion of first, secondary and tertiary industry in GDP predetermined at the beginning of section 4.4, the value added of first, secondary and tertiary industry for 2015 can be attained. Without additional information on the growth of every single sector, the share of each of these 41 sectors to its corresponding major branch of national economy (1 for first industry, 22 for secondary industry, and 18 for tertiary industry) in 2015 is assumed to be the same as what it was in 2007. In this way, the value added of each of the 41 sectors for 2015 is derived.

(3) Estimate the gross output and final demand for each of 41 sectors in 2015. Here, this study follows the manipulation from Hubacek et al. (2009) by assuming that, for each sector the share of value added to gross output as well as the share of final demand to gross output in 2015 are the same as their counterparts in 2007. In order to further verify this assumption, seven IO tables of China (containing 1990, 1992, 1995, 1997, 2002, 2005 and 2007) drawn from Chinese Input-Output Association (<http://www.iochina.org.cn/>) are used to test the variation of two above-mentioned ratios respectively and statistically. The results are shown in Figure B.1 for the ratio of value added to gross output and B.2 for the ratio of final demand to gross output. Each

individual chart is a scatter plot with the ratios across various sectors for an earlier year as x-values and the corresponding ratios for a next available year as y-values (note that the IO tables were compiled into 33-sector specification for 1990, 1992 and 1995 and into 38-sector specification for 1997, 2002, 2005 and 2007). If the assumption that both ratios keep invariable over time holds true, for each chart all spots would line up and the straight-line would go through the origin with slope equaling 1. According to the regression equation and R-squared value of each chart, the presumption could be deemed as acceptable. With such ratios derived from the aggregated 41-sector IO table, the gross output and final demand for each of 41 sectors in 2015 can be estimated, and then the three control variables **X(2015)**, **U(2015)** and **V(2015)** are obtained.

Table B.1 Information on aggregation of IO table

Disaggregated Sector No.	Aggregated Sector No.	Aggregated Sector Name
[1, 2, 3, 4, 5]	1	Agriculture, Forestry, Animal Husbandry & Fishery
[6, 7, 8, 9, 10]	2	Mining
[11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24]	3	Manufacture of Foods and Tobacco
[25, 26, 27, 28, 29]	4	Manufacture of Textiles
[30, 31]	5	Manufacture of Textile Wearing Apparel, Footwear, Caps, Leather, Fur, Feather (Down) and Its products
[32, 33]	6	Processing of Timbers and Manufacture of Furniture
[34, 35, 36]	7	Papermaking, Printing and Manufacture of Articles for Culture, Education and Sports Activities
[37, 38]	8	Processing of Petroleum, Coking, Processing of Nuclear Fuel
[39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49]	9	Chemical Industry
[50, 51, 52, 53, 54, 55, 56]	10	Manufacture of Nonmetallic Mineral Products
[57, 58, 59, 60, 61, 62]	11	Smelting and Rolling of Metals
[63]	12	Manufacture of Metal Products
[64, 65, 66, 67, 68, 69, 70, 71, 72]	13	Manufacture of General Purpose and Special Purpose Machinery
[73, 74, 75, 76]	14	Manufacture of Transport Equipment
[77, 78, 79, 80, 81]	15	Manufacture of Electrical Machinery and Equipment
[82, 83, 84, 85, 86, 87]	16	Manufacture of Communication Equipment, Computer and Other Electronic Equipment
[88, 89]	17	Manufacture of Measuring Instrument and Machinery for Cultural Activity & Office Work
[90]	18	Manufacture of Artwork, Other Manufacture
[91]	19	Scrap and Waste
[92]	20	Production and Supply of Electric Power and Heat Power
[93]	21	Production and Distribution of Gas
[94]	22	Production and Distribution of Water
[95, 96, 97, 98]	23	Construction
[99, 100, 101, 103, 104, 105, 106]	24	Traffic, Transport and Storage (excluding water transport)

[102]	25	Water Transport
[107]	26	Post
[108, 109, 110]	27	Information Transmission, Computer Services and Software
[111, 112]	28	Wholesale and Retail Trades
[113, 114]	29	Hotels and Catering Services
[115, 116, 117, 118]	30	Financial Intermediation
[119, 120, 121, 122]	31	Real Estate
[123, 124]	32	Leasing and Business Services (excluding tourism)
[125]	33	Tourism
[126]	34	Research and Experimental Development
[127, 128, 129]	35	Comprehensive Technical Services
[130, 131, 132]	36	Management of Water Conservancy, Environment and Public Facilities
[133, 134]	37	Services to Households and Other Services
[135]	38	Education
[136, 137, 138]	39	Health, Social Security and Social Welfare
[139, 140, 141, 142, 143]	40	Culture, Sports and Entertainment
[144]	41	Public Management and Social Organization

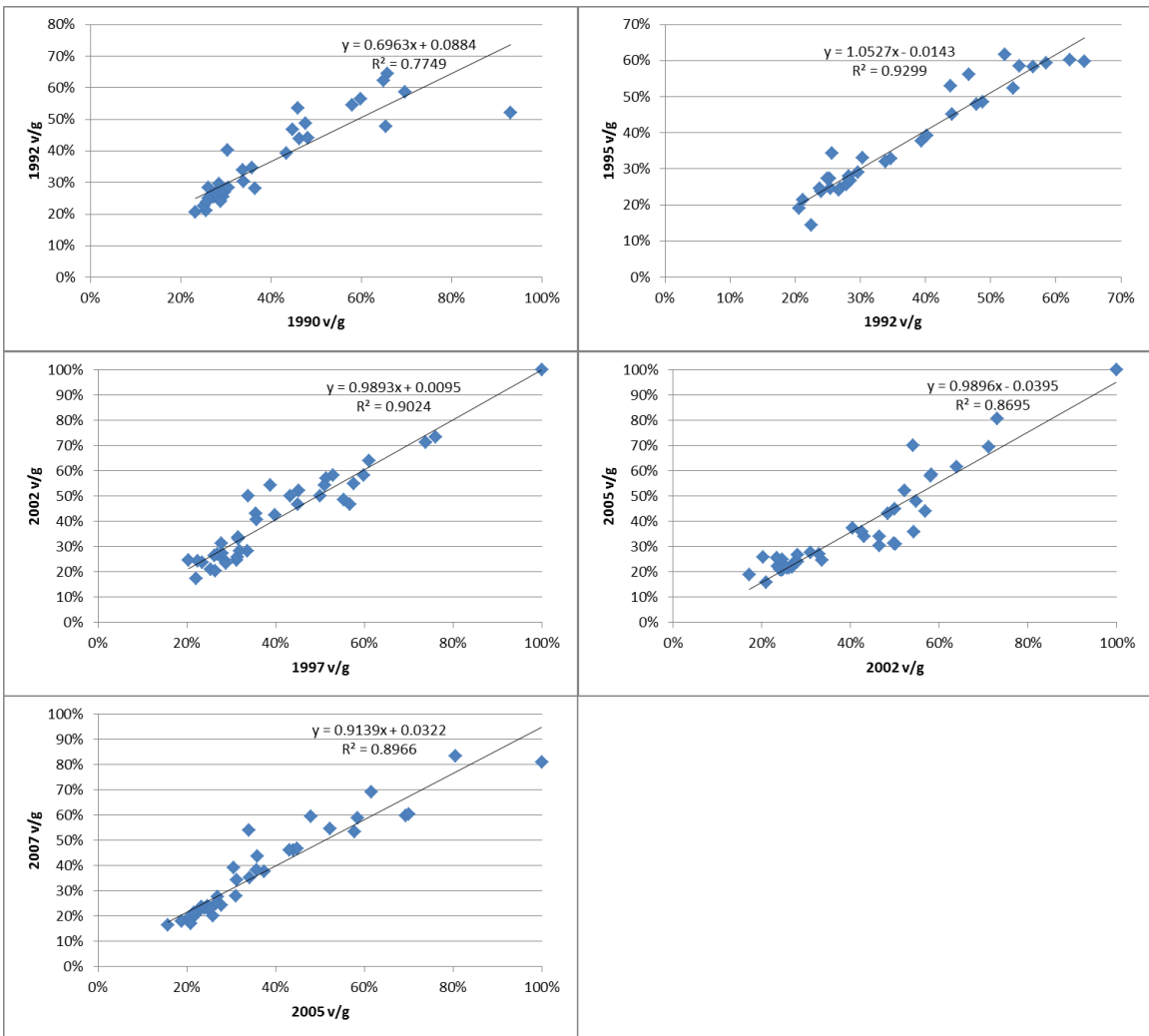


Figure B.1 Variation of the ratio of value added to gross output

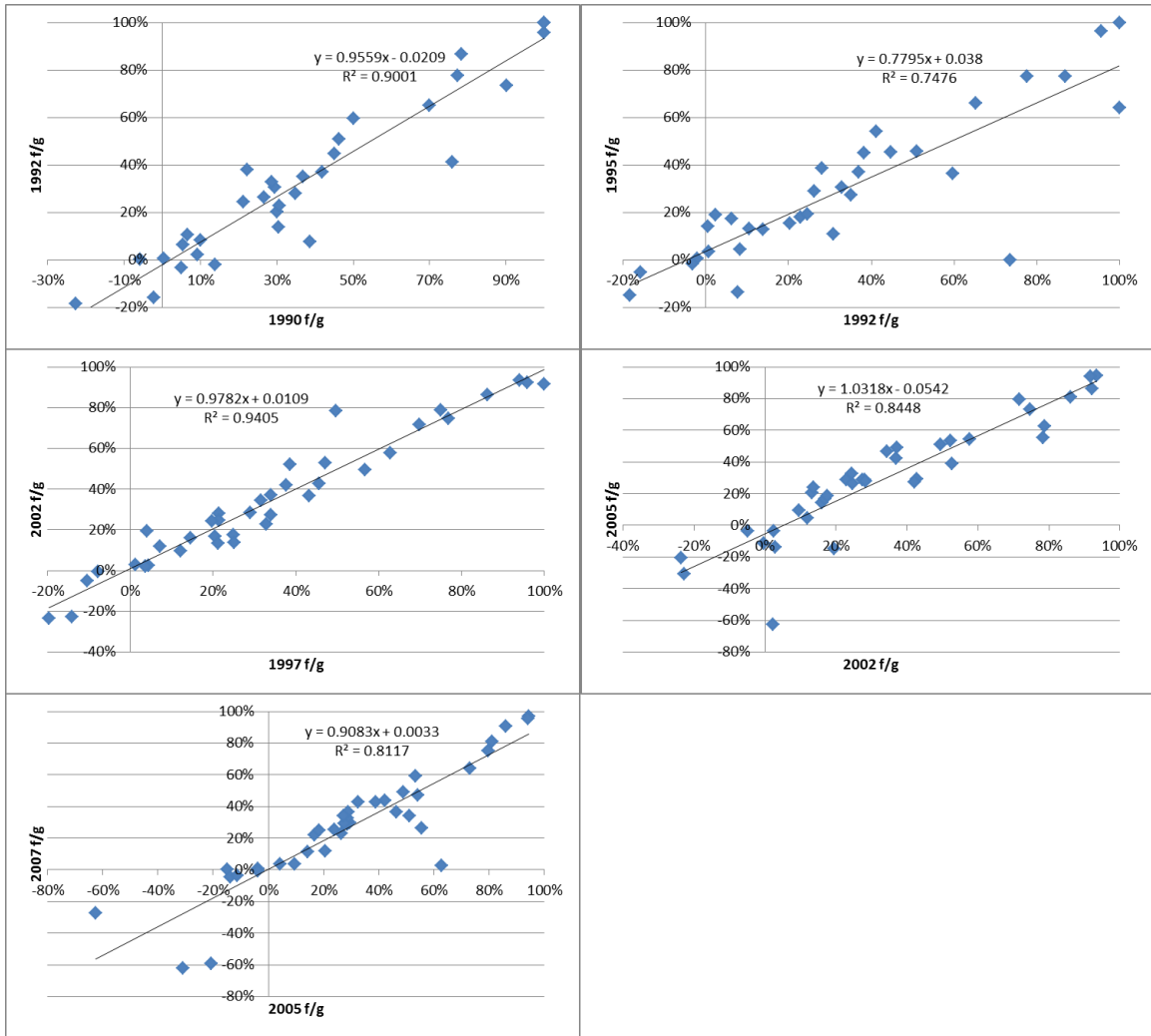


Figure B.2 Variation of the ratio of final demand to gross output

Given the updating procedure as described above, the EIO analysis for 2015 under the ESC scenario is carried out with a 41-sector specification. In this case, the environmental effect intensity r_i (originally mapped into 144-sector specification) might vary across some disaggregated sectors which fall into the same aggregated sector. If this happens, a weighted average approach (by using sectoral economic outputs calculated from $(\mathbf{I} - \mathbf{A})^{-1} \mathbf{Y}$ as weights) will be taken to derive a new r_i for that aggregated sector.

Appendix C

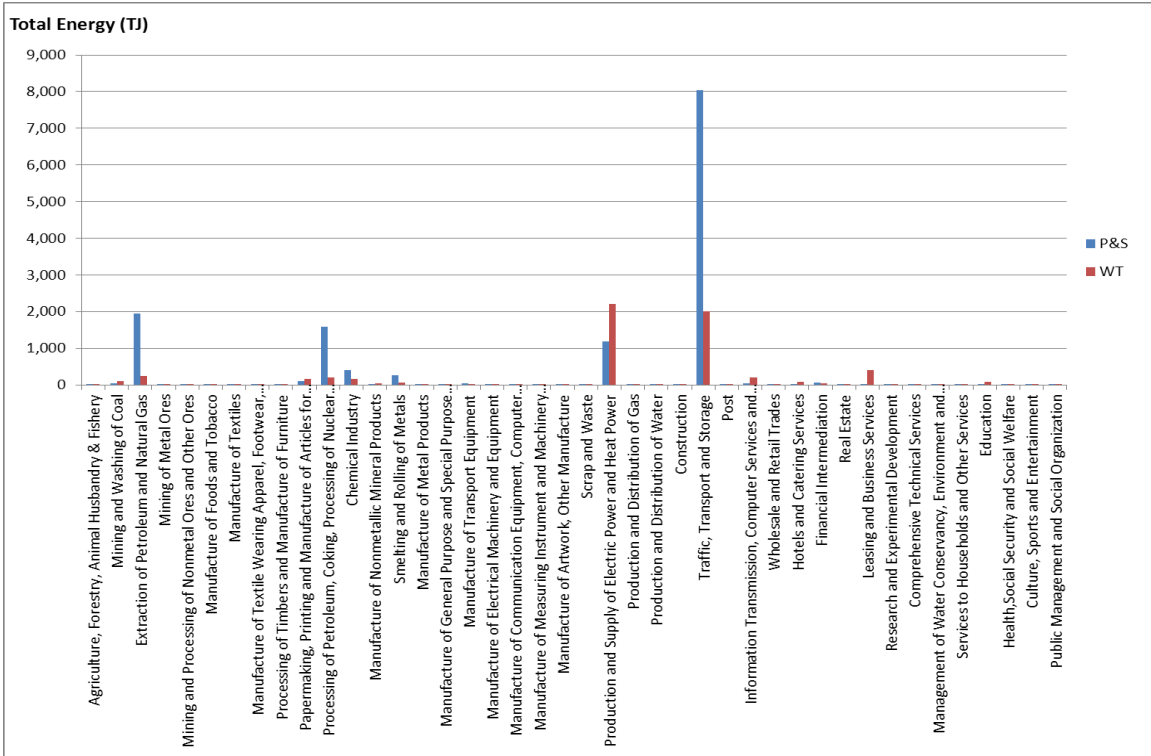


Figure 5.3 Energy use induced by two marine functional uses in 2007

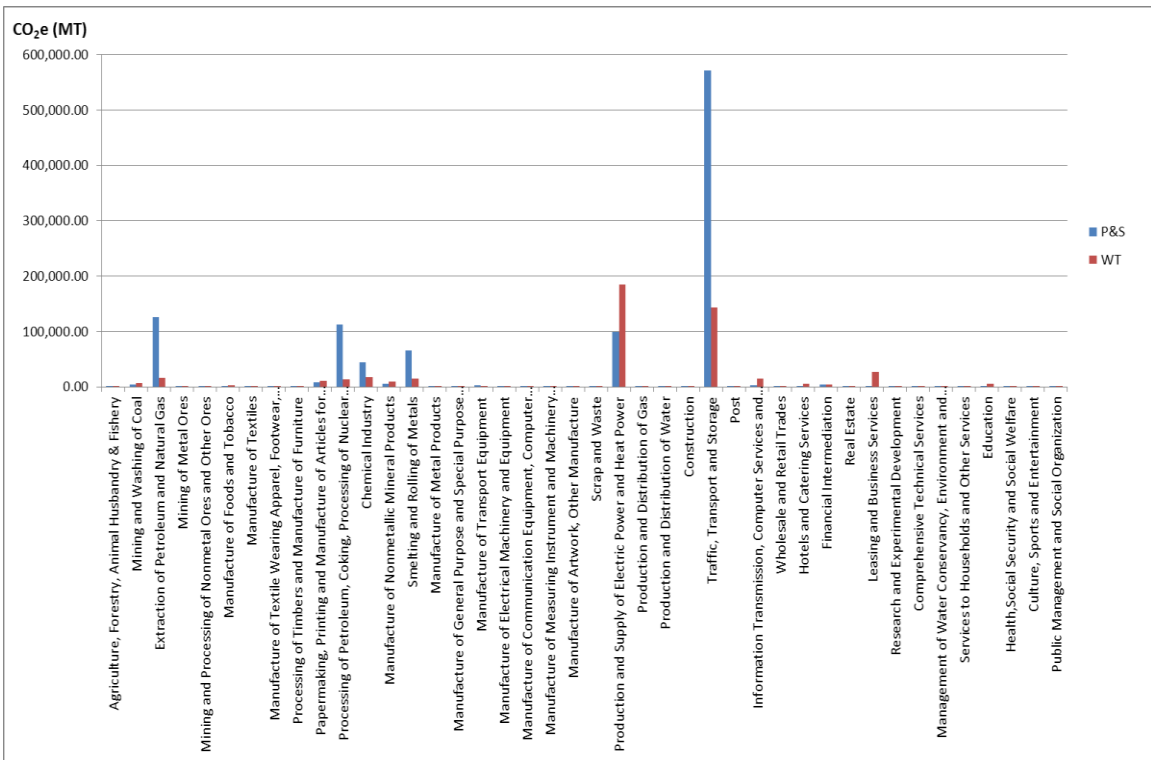


Figure 5.4 CO₂e emission induced by two marine functional uses in 2007

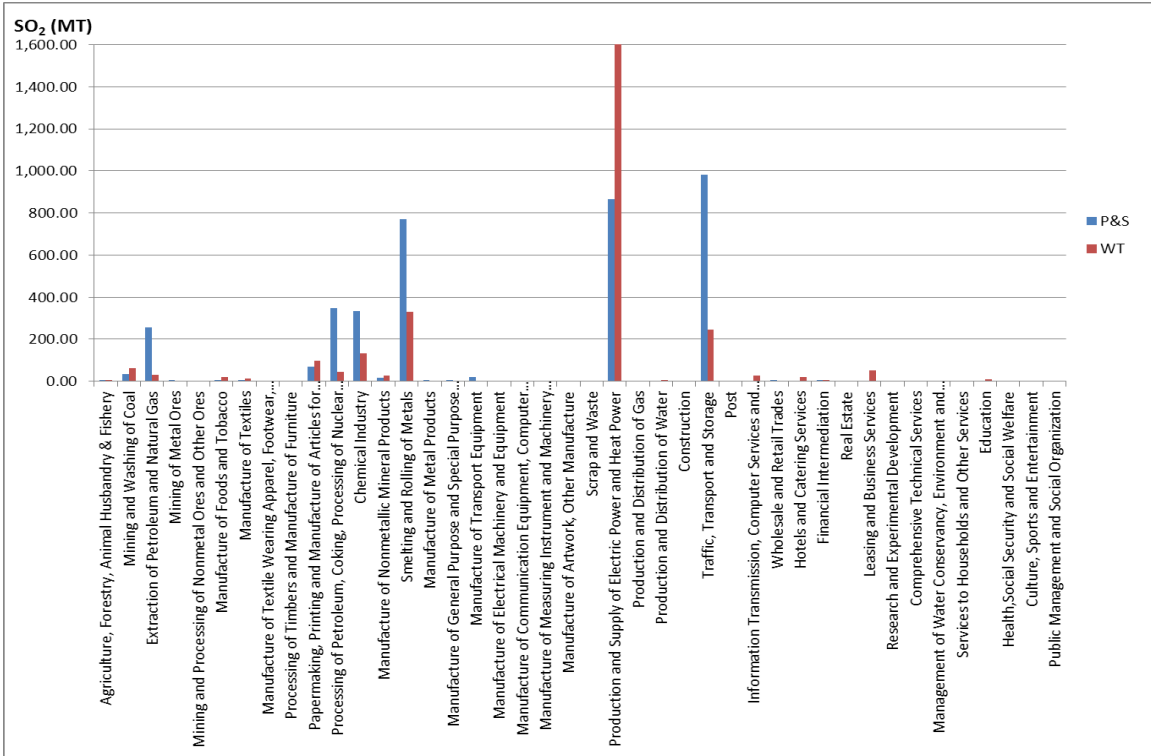


Figure 5.5 SO₂ emission induced by two marine functional uses in 2007

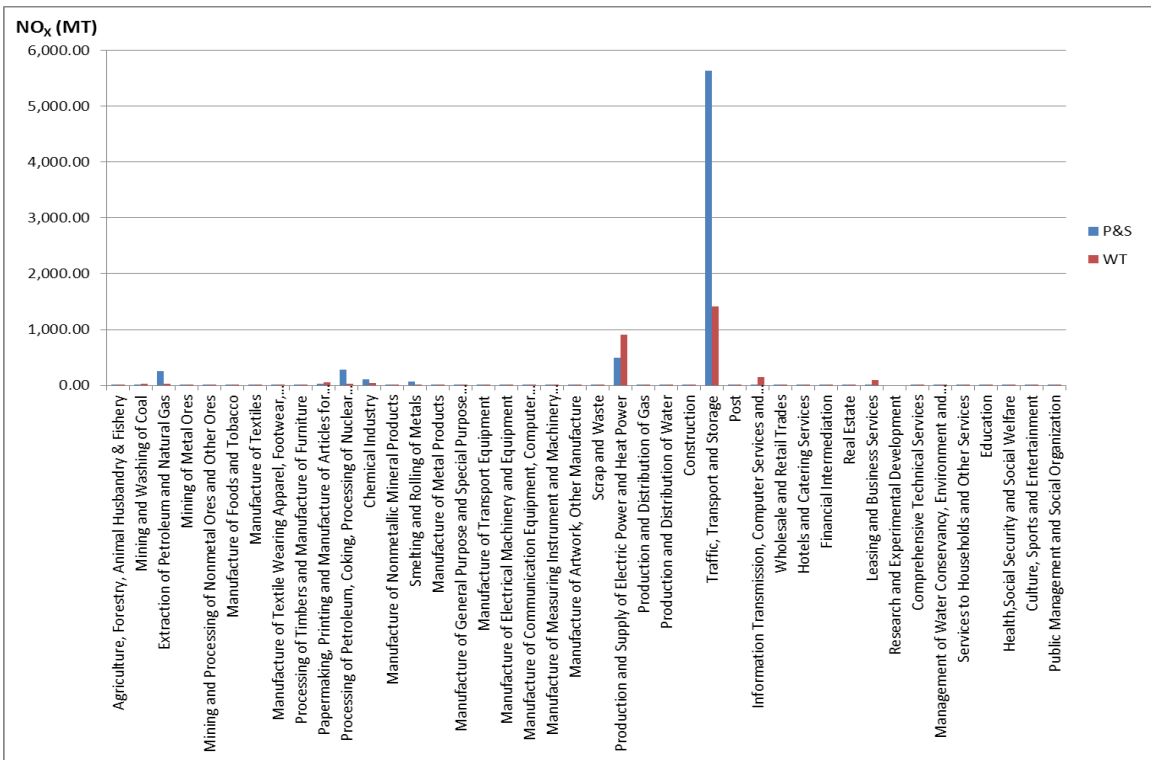


Figure 5.6 NO_x emission induced by two marine functional uses in 2007

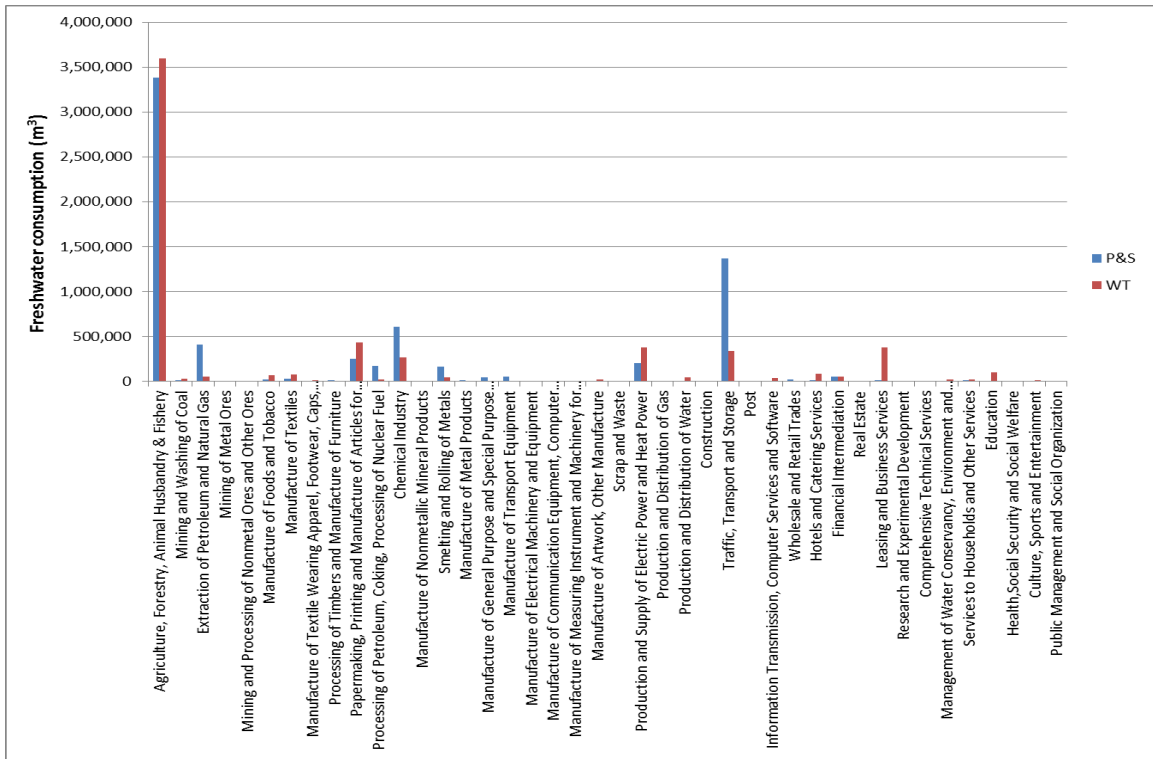


Figure 5.7 Net freshwater use induced by two marine functional uses in 2007

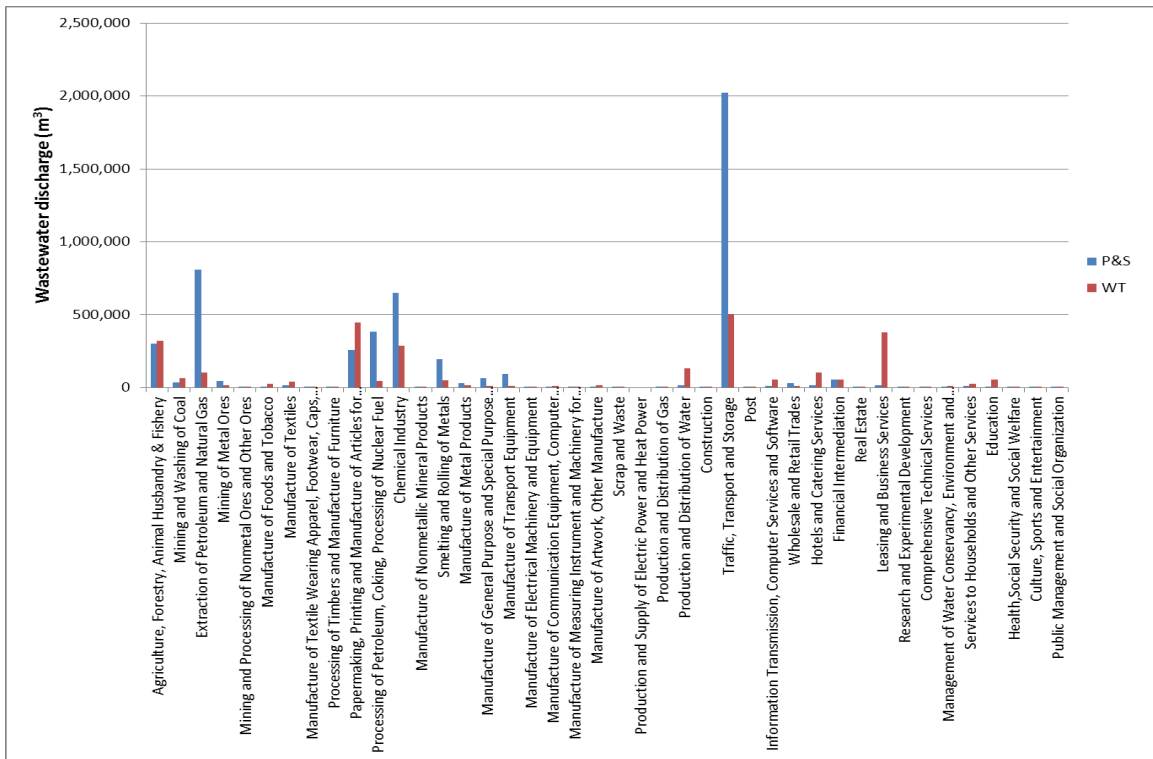


Figure 5.8 Wastewater discharge induced by two marine functional uses in 2007

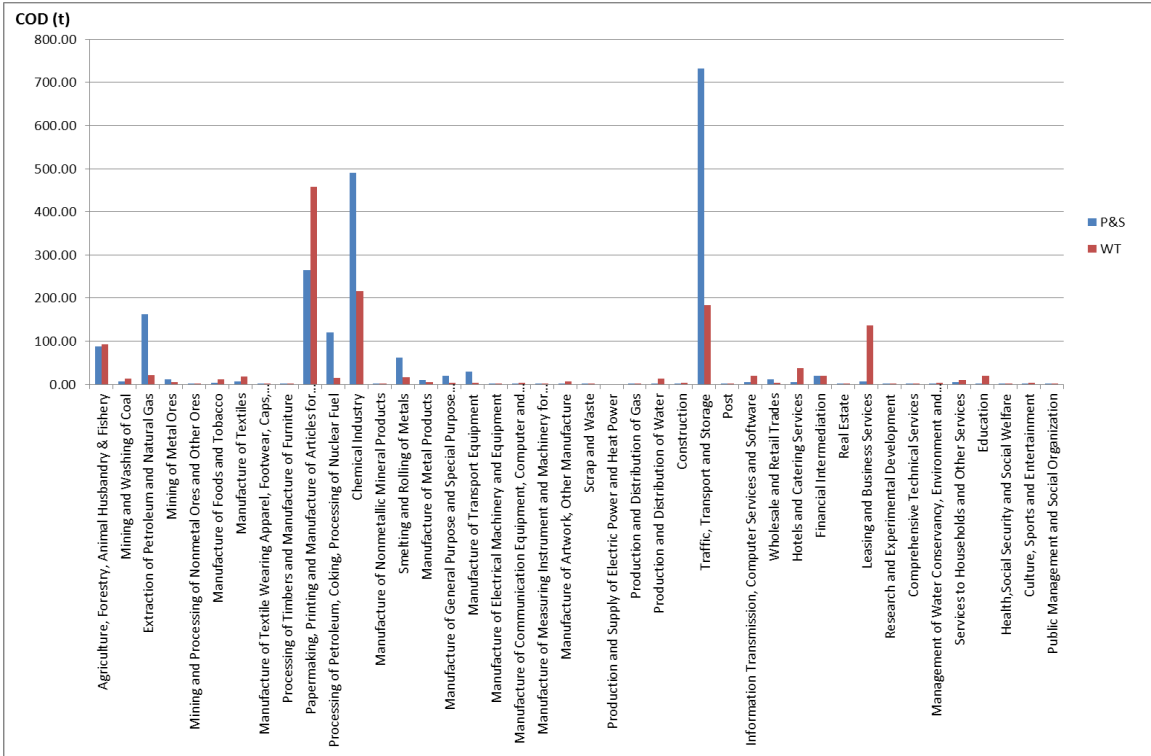


Figure 5.9 COD discharge induced by two marine functional uses in 2007

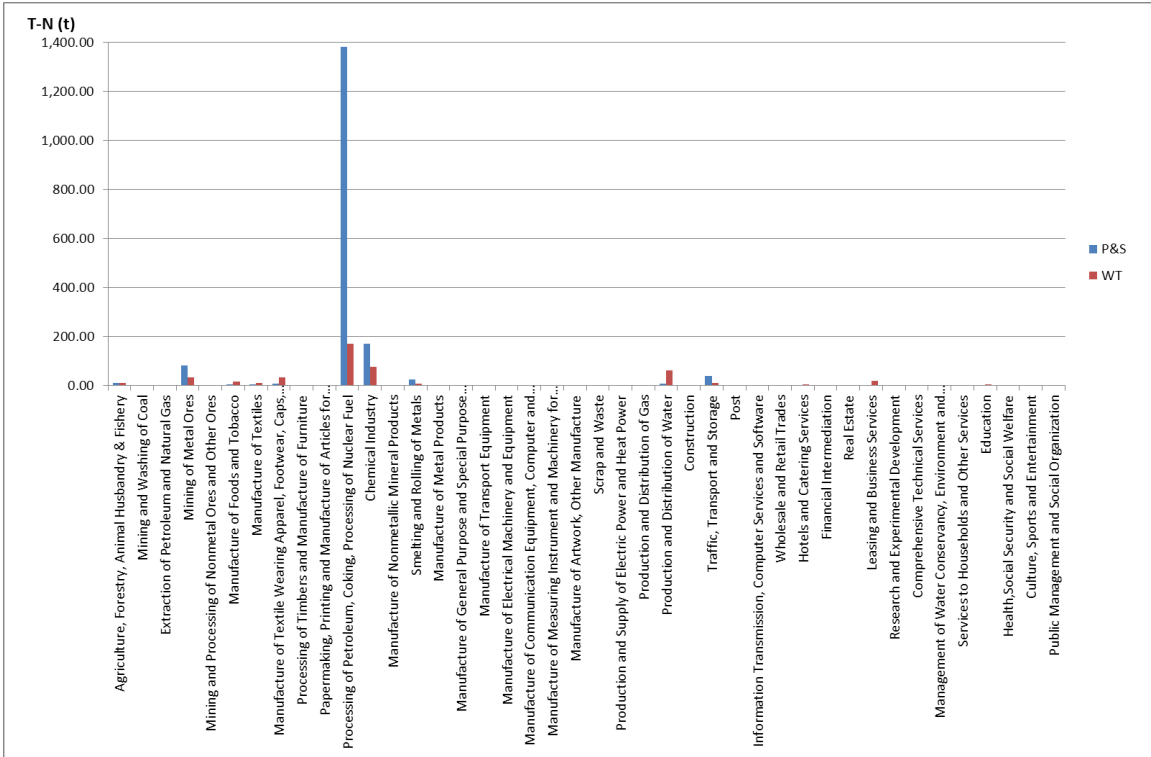


Figure 5.10 TN discharge induced by two marine functional uses in 2007

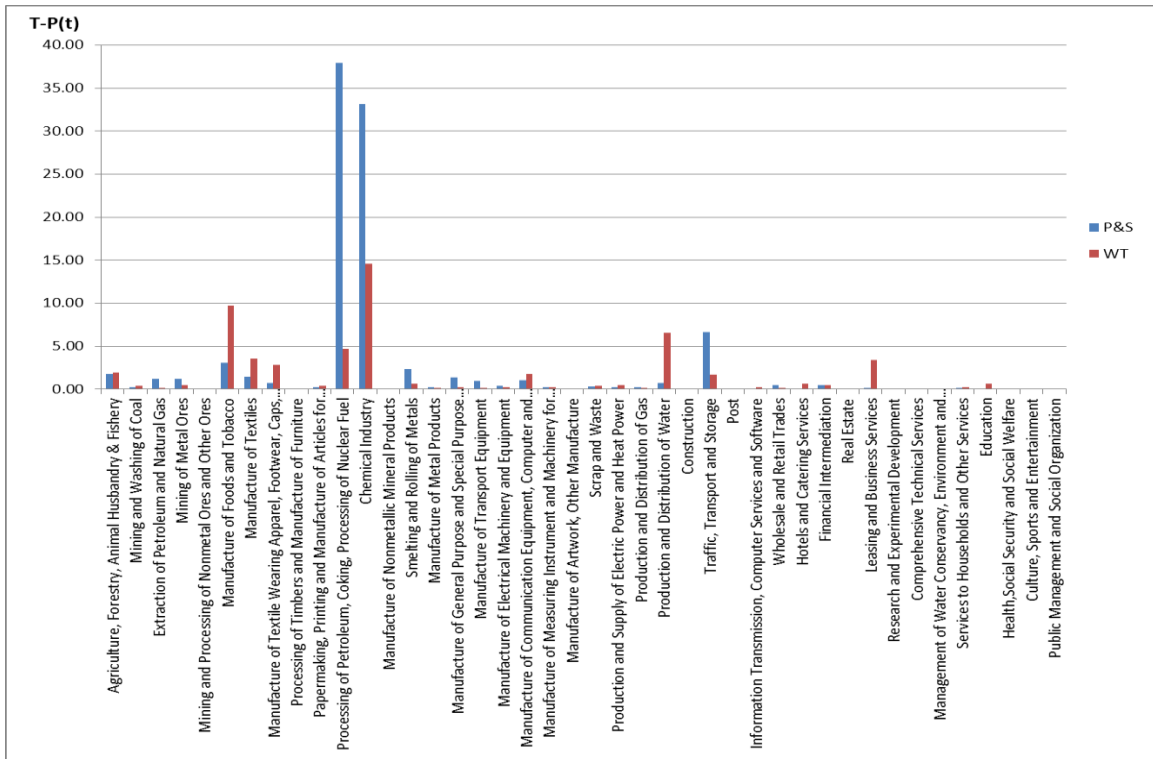


Figure 5.11 TP discharge induced by two marine functional uses in 2007