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Emission reduction policies and their impacts to port efficiencies : an empirical study based on Qingdao port

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Emission reduction policies and their impacts to port efficiencies

An Empirical Study Based on Qingdao Port

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Statement of authorship

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No other person's work has been used without due acknowledgement in the main text of the dissertation.

Sign

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Abstract

All ports in the world are making efforts to save energy and reduce emissions in recent decades. Chinese Ministry of Transport issued an emission-offset plan, which targets to mitigate CO2 emissions in ports by 8%, and energy consumption by 10% till 2015 compared to 2005 emission levels. More and more ports put forward regional policies under “Suggestions on speeding up the construction of ecological civilization” of The State Council, but whether it will impact the target of becoming leader of world port, remained to be discussed. One key performance of great port is port efficiency which includes port capacity, this dissertation aims to find the relationship between emission reduction policy and port efficiency.

This paper first did a comparison research now and past on emission reduction policies among IMO, EU, US and China, finding common and differentiate. When it comes to efficiency analysis, empirical study introduced in this dissertation, took Qingdao port as an example, using DEA model to estimate port efficiency from 2008 to 2016, besides, developed SBM-DEA model for considering environmental efficiency, compared scores with undesirable output (CO2 emission). The results showed, efficiency scores would less when considering CO2 emission. To what extent the emission policy would influence port efficiency? There’s no doubt that emission reduction results in heavy costs and damages economic efficiency, in order to maintain ports’ revenue and stimulate enterprises’ motivation on environmental protection, policy needs to work in with economic instrument, such as incentives. This research also gave policy advice for port entity improving pollutant, market-based methods and command & control approaches should interwork and help with each other.

It would be great if the conclusion and suggestion of this paper could be helpful for port entity decision-making, reducing energy consumption, developing clean port atmosphere and maintain the port competitive power at the meantime.

Keywords: policy, emission reduction, port efficiency, DEA, incentives

Contents

1. Introduction

1.1Background

Environment problems attract more and more people's attention, in almost every industry. Though one quarter of the global CO2 e missions emits approximately by the transportation sector (International Energy Agency (IEA), 2015), it still has so much potential in emission reduction area. Since air quality became first order in Top 10 environmental priorities of European ports (ECOSLC publications, 2017), Europe as pioneer, has put forward several regulations and methods to reduce pollutant, such as Emission Control Area (ECA), global emission cap, usage of renewable energy, Energy Efficiency Design Index (EEDI) and Ship Energy Efficiency Management Plan (SEEMP), etc.

It seems existing regulations relate ships emission mostly, that because ship makes significant contributions to air pollution, including greenhouse gases (GHGs), sulfur oxides (SOx), nitrogen oxides (NOx) and particulate matter (PM). MARPOL, the most important pollutant regulation of IMO, supplementary terms Annex VI sets a maximum limitation of 0.1% sulphur for all ship operations in ECAs. From technical point of view, shore power and electrification equipment recommended to ports subject, other alternative measures like port state control and bunker tax could also improve air quality in ports.

However, in China emission reduction policies still in its beginning stage. Government issued profiles, such as "Marine environmental protection law", "Environmental protection law", "Prevention of marine pollution of the marine environment management regulations", "Damage compensation levy management measures of ship oil pollution ", "Air pollution prevention law" "Water pollution prevention law" etc. In addition, China has so many inland and coastal ports which keep different function and features, it requires various policy instruments to regulate their operation and emission. Therefore, different regions own different emission standards. In this competing world, port performance or in other words, production efficiency represents a country's economic strength, so how to measure port efficiency is the aim of decision-maker.

In current studies and practice, majority ports efficiency estimation incorporates ports' scale efficiency, technology efficiency and overall efficiency. Theses all calculate objective value through inputs and outputs then make comparison to each other to figure out which part drags overall efficiency. But what will happen if we consider economic efficiency and environment efficiency into overall efficiency? DEA-CCR model has been first used by Roll and Hayuth (1993), analyzing the efficiencies of 20 virtual ports. After them, DEA-BBC model was developed by more scholars, fixed assets, labor costs, and other expenditures are the major three inputs through evaluation, as well as two outputs on cargo throughput and port revenue (Joon-Ho Na et al., 2017). Meanwhile, port enterprise must think highly of profit and ROR which closely about economic efficiency.

Above studies usually been researched separately, relationship between regulatory frameworks of emission at port and efficiency is so far, missing in literature. This dissertation aims at filling in this gap by finding emission reduction policies do impact port efficiency.

1.1 Research problems

There are so many researches on emission estimation, using "top-down approach" or "bottom-up" method, but in this dissertation the author assumes emission reduction policies certainly cut port emission otherwise there's no need to implement environment policy. Therefore, discussing causal relationship between emission reduction policy and port efficiency is the consistent thread of this paper. Measures to realize reduction policies is going to consider as well, installing LNG propulsion, scrubbers or using low-sulphur fuel (Stevens et al., 2015), but the author more emphasis on cost-effective way which in relation to economic efficiency.

There are so many policies worldwide to stimulate motivation of port enterprises on emission reduction, Union Emission Trading Scheme (ETS), cap-and-trade approach, subsidies and preferential taxation policies, emission quota allocations, emission credit system, ECA and METS. But it couldn't deny that these are guiding policies nearly, each country applies these should combine with their national conditions. Moreover, Chinese shipping industry can be really complex, environment-related law and policies are overlapped sometimes, provinces' local policies supposed to be connected with macroscopic instruction. Previous research regard emission policies isolated, the author is going to compare European policies with American and Chines, discuss Chinese overall policy with local policy as well in this dissertation.

Considering Chinese national condition, a case study of Qingdao port is quoted in chapter four to study port emission policy in detail and how it affects Dalian port efficiency. Cost-effective scenario and environmental efficiency are arranged to discuss in this research.

1.2 Literature review

European Union has pushed forward IMO on shipping emission reduction process for a long time, many scholars discussed EU's emission reduction policies since European countries are pioneer of shipping environment protection.

For vessels exceed 5000 GT calling at any EU port, shipowners and operators are supposed to monitor, report and verify CO2 emissions annually. Besides, ships on voyages call at or go through EU ports also require to provide information on energy efficiency parameters. (Tichavska et al., 2017). Niedertscheider M., Haas W. & Görg C. (2018) investigated Austrian climate change mitigation (CCM) policies since 1990 with a particular focus on Climate policy integration (CPI). To speed up environmental procedure, IMO corrected MARPOL Annex VI in 2011 mentioned 0.1% reduction of Sulphur content will be attained by 2015 in the SECA in the North Sea, and that, globally, reduced to 0.5% by 2020.

SOx produced by ships caused acid rains and unexpected health harms to human beings and animals, the good thing is emission reduction method on SOx is more specific and practicable, in order to deal with the establishment of an SECA in the North Sea, Marine diesel oil (MDO) are supposed to apply on vessels when operating inside the SECA and HFO when operating outside it. (Hassel E. V. et al., 2013). Yang, Bonsall & Yan (2012) has concluded that the most cost-effective method of mitigating SOx and PM emissions is to use the bi-fuel option. Numbers of ports in the United States designated a Reduced Speed Zone (RSZ) with the aim to reduce the emissions from ships, install hydrogen fuel cells and upgrade propellers, the Port of Los Angeles/Long Beach, New York/New Jersey, and San Diego all join in this plan.

Asia countries are now take emission issues seriously, established China-ASEAN Environment, China-ASEAN Environmental Cooperation Center, China Environment Publishing Group Co., Ltd. In their publication 2018, Chapter 4 “Policy Measures for Regional Green Development”, looking back the environmental policies and economic & social benefits in China and ASEAN. They hold the positive view that the industrial structure is now on optimizing procedure, so that the resources are more effectively allocated to eco-friendly business. Preferential taxes and subsidies settled for improving energy efficiency and pollution control products also lead trades and consumers to pollution prevention.

Above the existing policies, more researchers prefer to figure out which approach is the optimized. Mo Zhu, Kevin X. Li & Jasmine Siu Lee Lam (2017) discussed the economic and social benefits of eight alternative reduction approaches for PM emission reduction in China, average reduction of PM emissions of LNG, Diesel Particular Filter and Distillate fuel oil +CDPF up to 90%. There is no lack of advice on the use of economic means, Jun Yuan & Szu Hui Ng (2017) used marginal cost-effectiveness to rank the emission reduction methods, provide a further ranking system by estimating the preference feasibility between each pair of measures. Yang, X., Teng, F. & Wang, G., (2013) also analyze environmental co-benefit into climate policies, Garyfalia Nikolakaki (2012) discussed the various policy options for addressing greenhouse gas emissions from international maritime shipping, with an emphasis on the use of economic instruments. For example, the maritime administrative authorities in Swedish and Norway offers reduced fairway dues to those ships that qualified in accordance with the applicable certification and registration regime ships calling annually at their ports. Hamburg Port Authority joined a scheme offering cheaper tonnage dues through discounts of up to 10 % to vessels. Not only in Europe, but also apply in other area. Singapore port has launched a green port programme to encourage vessels calling at Singapore to reduce the emission of pollutants by giving a 15% concession in port dues. But Wang Haifeng, Liu Dahai & Dai Guilin (2009) puts up with “marginal law” with exact quantity method, calculating the cost of reducing SO2 in the SECAs would vary from $665 per ton to about $16228 per ton, that CO2 reduction cost for containerships is between $ 40 per ton to $ 220 per ton. Conclude that the shipping industry will be the last industry to reduce CO2. Before that, they are net buyers from the carbon market. Economic methods leading industries choose a better way for themselves to cut emissions.

As for port efficiency aspect, data envelopment analysis (DEA) model is widely used, Zhou Baogang, Hu Ling ＆ Li Xin (2016）choose Liao Ning economic area as an object to estimate port efficiency, finding scale efficiency lower than pure technical efficiency obviously in 2009~2013, which demonstrates scale element is the main reason decreasing overall efficiency in port. Through port operation, machinery closely relates to efficiency, so Xue-shu Liu & Bin Yang (2013) established a model of port cargo handling machinery based on production efficiency and energy consumption, taking 43 forklifts of A port as an example to calculate forklifts’ efficiency ratio and utilization ratio. But in emission reduction studies, we pay more attention on environment performance. Based on DEA model, Jiasen Sun et al. (2017) choose indicators employee number, operational costs, and fixed assets as DMU, the regression results indicated that port fixed assets like quantity of berth and geographical position can significantly determine the environmental performance of Chinese ports, it also shows that the average efficiency of all port enterprises is lower if considering environmental factors. We have to mention ecoefficiency indicators as well, AHP method is applied in Taih-cherng Lirn et al. (2012), contributing hierarchy structure of green indicators in ocean ports measuring a port's green performance. Miluše Tichavska, & Beatriz Tovar (2015) also estimates ecoefficiency indicators from externality costs of vessel emissions in Las Palmas Port. Rational economic analysis is considered by some authors since port enterprises are businessman, when adjusted for a major environmental cost, how the productivity of seaports is concerned by Anthony T.H. China & Joyce M.W. Low (2010). The findings in this study suggest that technically efficient is more likely to achieve environmental efficiency in shipping. Liu X. S. & Bin Yang (2012) took forklifts as an instance of general cargo handling machinery issue, demonstrating the effective control of expense and improvement in port handling equipment for production efficiency of the entire port. In recent research Joon-Ho Na et al. (2017) illustrated that low value comes to the pure technical environmental efficiency (PTEE) of container ports, and high CO2 efficiency results to a relatively high PTEE, which means the most vital method for increasing environmental efficiency of ports is reducing CO2 emission.

However, it could be hard to collect all target information, how to deal with when there is missing data appear in a port assessment problem? Shaher Z. Zahran, et al. (2017) proposes Imprecise DEA (IDEA) to assess the efficiency of ports. By using the proposed non-radial DDF-VRS models, Jiasen Sun et al. (2017) analyze whether or not the Chinese port involved in their study had sufficiently good performance in resource utilization by applying the classical DEA-CCR model. They also drew matrix of 17 Chinese port enterprises in environmental efficiency results, concluded that Medium and Large scale of port enterprises need to take measures reducing emissions, while small scale of port should consider more about fully utilize existing resources.

1.2 The structure of dissertation

This dissertation consists of three main chapter, theoretical study on port emission reduction policy and efficiency estimation methodology, after analysis theoretically, an empirical study introduced in chapter 4, took a north port in China, Qingdao, as an instance, using DEA model estimate port efficiency scores, then gave policy suggestion. Conclusion was summarized in the last passage.

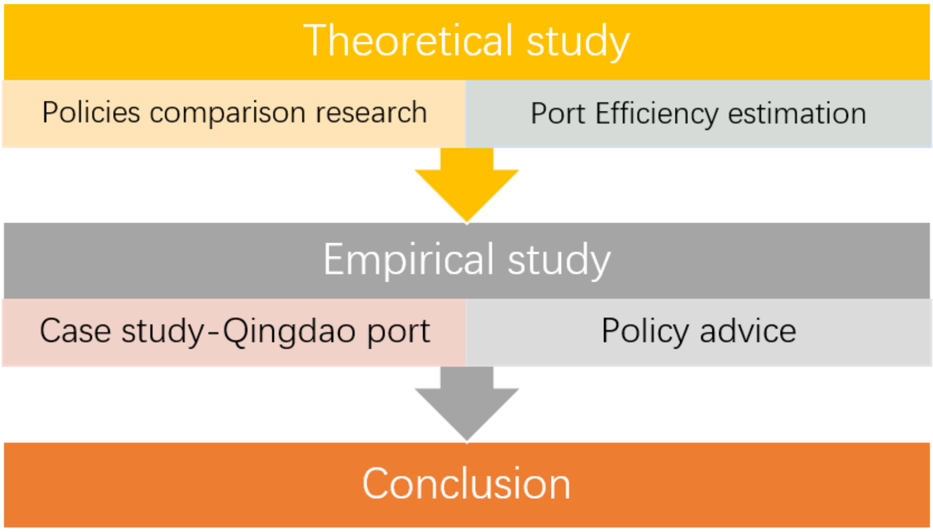

Fig. 1. Dissertation structure

2. World-wide emission reduction policies

2.1 EU & IMO

2.1.1 General Guidance

With growing trade volumes, shipping has become a major source of carbon, NOx, SOx and PM2.5. In recent decades, there is growing endeavor in mitigating emissions from the maritime sector.

However, unlike other industries, shipping is excluded from “EU climate and energy package”, though EU is calling for global approach in emission reduction, there still lack of exact general policy that play a guiding role. But there provided several separated regulations on emission reduction, since 2010 the Directive has asked ships berthing at EU ports to use 0.1% sulphur fuel. This restriction brought tangible benefits in short time. The research found that ports in Mediterranean changed to a significant decrease in the sulphur dioxide concentrations of up to 66%, thanks to the introduction of EU directive. Besides, EU’s 2011 White Paper on transport suggests that the EU's CO_2 emissions from maritime transport should be cut by at least 40% from 2005 levels by 2050 (EU White Paper 2011). More specific strategy came out in 2013, the EU Commission decided to progressively integrate maritime emissions into the EU's policy to reduce its domestic greenhouse gas emissions, which consists of 3 consecutive steps: (1) For large vessels, Monitoring, reporting and verification (MRV) of CO_2 emissions is possible. (2) Set CO2 emission reduction targets. (3) Market-based measures, in the short to long term (EU website). According to EU's MRV Shipping Regulation adopted in April 2015, all large ships (over 5000 GT) calling EU ports must report their fuel consumption, emission data and other parameters, which will effective from 1 January 2018 (Wayne Lei Dai et al., 2017).

Even so, they still have a strong preference for a global approach led by the International Maritime Organization (IMO), regard this will be the most effectiveness. In 2016, it reached an agreement on a global data collection system in MEPC 70 meeting, which symbolled an important step to tackle CO_2 emissions, data verification procedures and draft guidelines are still yet to be developed. It seems the first step for EU and IMO to control emission is Information Collection, which is crucial to master whole direction and adjust strategy. Since European countries reached consensus in some respects, they believe uniform plan could maximize the effectiveness of measures taken and create economies of scale. Related measure to work in with these targets are Emission Trading System (ETS), Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP). Although some progresses have been made on setting international standards for ship's energy efficiency, implement more emission abatement policies globally still faces loads of challenges, the hit regulations such as ECAs and regional speed limits will be discussed later.

Community action still has much room for improvement, both in making operation in a interactive and consistent way and integrating the variety aspects of protection of the ocean.

2.1.2 Experiment of European countries

Some European ports operate under high efficiency (either commercial or environmental). The 6 port authorities in Baltic sea have developed the Environmental Ship Index (ESI) to give scores to ships ranging from 0 to 100 with 100 points. Vessels with a score above a certain threshold can be granted a discount on port dues when calling at ports (Han & Notteboom, 2017).

The fact that emission amount is directly proportional to fuel consumption. Since vessels' emission takes part in 70% of port total emission, it's necessary for vessels to exhaust every means to reduce emission. Currently there are three technical means a ship can fulfill the proposed emission limits: (1) using lower sulphur content fuels, like MGO and MDO (2) installing a scrubber on vessel (3) traditional fuel support vessel convert to LNG (EMSA 2010; Bengtson et al. 2011; Stenhede 2012). But it's definitely a burden on shipowners, changing HFO to LSFO increases bunker costs and hard to ensure bunker quality. We can make a simple calculation here, suppose a 20,000 TEU vessel using 250t bunker/day, the price of LSFO is $200 higher than HFO, if voyage day is 300 days, bunker cost= 200x250x300=15 million. How about second choice, installing scrubber, which seems can put things right at once. Although scrubber only cost 5 million to 10million per vessel, Hapag Lloyd and Mearsk clearly declare that they don't approve installing scrubber because it same as Micro refinery on the vessel. The third method which causes a heat debate worldwide, according to rough statistics, about extra 20% vessel price for each LNG ship. Despite huge initial investment, the space of 500 TEU sacrificed to accept bunker box.

Above discussion reminds us only shipowners hardly afford total expense, whereas the introduction of SOx regulation brings ports new responsibilities to develop rules about infrastructure and maintenance. Ports reliable more on enabling cleaner operations via the establishment and maintenance of reception facilities (for scrubber wastewaters and sludge), LNG infrastructure (storages, bunkering terminals) and shore-side electricity facilities. The scrubber installation is monitored by PSC authorities, therefore, defining function of ports in related to monitoring the implementation of sulphur fuel reduction is a core, even though the regulatory environment is ambiguous in respect to implementation of this function (Gritsenko, D. & Peuralahti, J.Y, 2013). The port of Gothenburg offers connections to the on-shore power (OPS) grid at six RoRo. As a result, OPS correspond today to a 10% reduction in CO2 emissions from the Ferry/RoRo category (Styhrea et al. 2017).

Besides, port authorities prefer using Market access, a port area includes fairway channels which takes part in top three CO2 emissions in port. Sweden launched Registration system for fairway, which maritime administrative authorities offered reduced fairway dues to those ships that qualified in accordance with the applicable certification and registration regime, this scheme target to reduce SO2 and NOx ship emissions by 75%, the results showed after first 18 months of application, nearly one third of ships calling annually at Swedish ports were registered in the program for continuous low-sulfur operation (Garyfalia Nikolakaki, 2013). To encourage slow steaming for ships in port areas, more and more ports give incentives to shipowners who reach the criterion of low speed. As for other activities cause emissions in ports, an extensive adoption of reduced speed in fairway channels has been proved potentially accomplish large reductions. (Winnes, H. et al., 2015.) In Hamburg Port, discounts of 10 % tonnage dues offering to vessels. To be honest, subsidies and preferential taxation schemes are all under the control of general regulation, cap-and-trade program. It creates a total number of emissions allowances which is “Cap” established by different regulators, each allowance is allocated to the emitters. Within the cap, every emitter is free to trade (either buy or sell) allowances with other entities, make sure the total emission indicator won’t excess.

In order to improve efficiency, some European ports are looking for stablishing collaborative networks. The Ports of Stockholm, Turku and Helsinki have cooperated in environmental issues since 2009 to improve the environment in the Baltic Sea. The ports collaborate in facilitating the use of LNG vessels bunkering in both ports, by investigating the possibilities of supply electricity from the shore side to more vessels operating with frequent liner schedules (The Ports of Stockholm 2011). All three ports also share same shipping lines to save resources and maximize efficiency. In January

2013 a new vessel 'Grace', which uses LNG started sailing on the Turku-Stockholm route (Viking Line 2013a,b). After that, nine Baltic ports (Aarhus, Helsingborg, Helsinki, Malmö, Copenhagen, Tallinn, Turku, Stockholm, and Riga) together with ship owners, LNG companies, national port organizations and European Seaports Organization work hand in hand to enable LNG bunkering for vessels in Baltic ports (TEN-T EA, Trans-European Transport Network Executive Agency 2012).

Port infrastructure has to be built under emission reduction policies, but larger ports might have more assets to pay for new infrastructures and better possibilities to manage co-financed schemes, smaller ports often lack of resources and feel that their competitiveness is threatened, they are losing traffic. How to enhance transparency on ports' financing and clarifying the objective of public funding to diffesrent port activities, is an important problem in green port procedure with a view to avoid any distortion of competition. (COM (2011) 144 final of 28 March 2011)

2.2 United State

2.2.1 General States policies

United States Environmental Protection Agency (EPA) is a leading part of US environment protection in all aspects, which propose emission standards in marine industry. In early 2011, EPA pulled the Enforcement of MARPOL Annex VI as implemented by the Act to Prevent Pollution from Ships in US. It also did a lot effort in improving marine diesel engines, the proposed Tier 1 standards are equivalent to the internationally negotiated NOx standards and would be enforceable under US law for new engine build after 2004, emission limits under the Clean Air Act for marine diesel engines at or above 30 liters per cylinder. In later Tier 2 standards is more stringent which would apply to new engines built after 2007, it would also take HC and CO emissions into consideration. This act limits what fuel engines use (residual fuel, typically a high-sulfur fuel, etc.) to control emission from original. A second tier of NOx limits, is expected to reduce national inventories of NOx emissions from engines by about 11% by 2030 (Regulatory Announcement Emission Standards for New Marine Diesel Engines2002, EPA Web)

As a professional field regulator, Maritime Administration (MARAD) manages Maritime Environmental and Technical Assistance (META) Program, test, evaluate and demonstrate the viability and applicability of alternative technologies are important component of MARAD's META Program (MARAD, 2018). But MARAD's work on environmental protection is more weighted on finding cooperation with other parties to research feasible method reducing emission by technical way. MARAD has sponsored several objects included biofuel initiative which began in 2010 and marine applications of fuel cells, the use of LNG for vessels. Theses effort indicated direction for shipowners and port authorities on emission reduction. MAEAD also launched a few guidance, Scrubber Guide which worked with the Ship Operator's Cooperative Program to update the Exhaust Gas Cleaning Systems Guide (EGCS), which was developed to assist operators with determination of which scrubber is available, practical, and cost effective to meet ECA requirements. Besides, Energy Efficiency White Paper, discussed how the various technologies work, potential fuel savings and a battery risk assessment study for hybrid tugs.

The nation has also asked for neighbouring countries to build green ecology. Together with Canada and France, North American Emission Control Area. U.S. Caribbean Sea ECA for both fuel-sulfur limits and NO_x emission standards. Influence on Mexico on establishment of a Mexican Emission Control Area (ECA), shared work between the United States and Mexico began in 2009. Not like technology method guidance, ECA has a specific requirement: Vessels must follow not exceed 0.10 weight percent Fuel-sulfur concentrations or use an approved equivalent method. Moreover, engines above 130 kW installed on vessels built (or modified) since 2000 must be certified to meet appropriate emission standards corresponding to the vessels' build date (or modification date)[1].

[1] As of January 1, 2016, engines installed on new and modified vessels are subject to the Annex VI Tier III NO_x standards while those engines are operating in the ECA.

2.2.2 Inter-port cooperation & differentiation

As for much shared bay and close ports, US choose to construct inter-port cooperation to face environmental problems together. The most effective and famous program is Clean Air Action Plan (CAAP) which hosted by the Ports of Los Angeles and Port of Long Beach since 2005. This program includes a network of four air monitoring stations that use for measuring a comprehensive set of air pollutants. The second five years planning published in 2010, in this publication, the emission target for 2014 include cutting Port-related DPM emissions by 72%, NOx emissions by 22%, and SOx emissions by 93% below 2005 levels (CAAP, 2017). Not only the total goal amount is unconcealed, but also estimated amount through measuring procedure is published for supervise by public. Incentive for enterprises is the other approach to reduce emission, by using clean technique and operation system, fix air problems from trucks, vessels, trains and machineries.

Other ports unified emission plans as well, GMAP includes all ports in California implement exhaust gas emission, NPCAS unified North American three ports in Puget Sound to achieve emission target, next step is launching national emission reduction strategy, which means setting a minimum emission reduction goal and a long-term target to push emission reduction process (Lu, Y. & Hu, H., 2008). Whereas in California, the Global Warming Act (2006) was enacted, which requires a reduction of CO2 emissions from all sectors including ships in port and thus represents a more conventional “command & control” measure to its climate change mitigation approach. As for port authority of NY & NJ, has extensive environmental programs, ranging from proposed strategies to mitigate emissions from voyage applied for Environmental Management System (EMS) to reduce impact from facilities' operations. NY & NJ took actions include of “Old truck replacement”, “Development of shore power capability” at Brooklyn Cruise Terminal, “Switcher locomotives reformation with GenSet systems”, and “Cargo handling equipment modernization” (NY & NJ website). Incentives method also been used in NY & NJ, for example, $1,750,000 has been awarded for its Truck Replacement Program. This project will replace model in year 2006 and older short-haul trucks serving Port Authority facilities, with cleaner 2012 and newer models. This investment will reduce about 246 tons of nitrogen oxides and about 16 tons of fine particles.

Reduced Speed Zone is the good choice for US too, a few ports in the United States put forward requirement of upgrade propellers, and install hydrogen fuel cells with the aim to reduce the emissions from ships (Na, J., H., et al., 2017). Since highway is pretty advanced in US, trucks' emission become serious issue in US port, every port has Clean Truck Program, searching for facilitates that can replace old trucks with low-emission vehicles.

2.3 China

2.3.1National level policies

It obvious China regards energy-saving and emission reduction issues seriously since "12th Five-Year plan" in 2011, the “Green Performance Evaluation Indices " is expected to become the most important part of the plan, which is considered in local official performance. To address this issue, China sets up several carbon and energy targets based on 2010 emission levels, which make up a main content of “Green and Low-carbon Development” mode. As for transportation industry, Chinese Ministry of Transport issued an “Emission-offset Plan” that aims to reduce energy consumption by 8% and CO2 emissions by 10% in 2015 based on 2005 emission levels in ports (Zhang et al., 2015). The five-year plan involves several branches projects including “Green port evaluating standard system” and “Guidance of the transformation and upgrading of advancing harbor.” (Na J.H. et al., 2017)

In order to reduce the levels of ship-generated gas emission, especially the sulfur content, the government has decided to construct three Emission Control Zones (ECZs), Pearl River Delta, the Yangtze River Delta, and Bohai Bay (Mo Zhu et al., 2017). With corresponding supporting measures, Carbon emission trading policy, provincial carbon trading department is supposed to formulate Quota management to key enterprises in their province area, under the limitation of gross emission amount issued by the State Council.

2.3.2 Response from shipping industry

Transport department took a quick reaction to “12th Five-Year Plan”, issuing “Land and water transportation, energy conservation and emission reduction 12th Five-Year plan" in 2011. This profile is the guide of every part of transport, whose key notes are technology improvement and enterprises monitoring. On the technology level, encourage wide use of shore power, RTG program and replacement of renewable power. On the monitoring level, confirm high-emission enterprises list according to the amount of consumption, making incentives and punishment measures. Besides, build “Ship energy efficiency database”, formulating the report and verification system of ship energy efficiency data, establish a comprehensive, unified and classified ship energy efficiency design index and operating index database, data support supervising.

There are other regulations setting a standard on port operation and pollution prevention, such as “Regulations on prevention and control of marine environment pollution in ships and their related activities”. It regulates vessels’ operation in port, refers to the activities of ship handling, refutation, clearing, cleaning, oil supply, repairing, salvaging, disassembling, packing, filling, cleaning, and other underwater ship construction operations (Ministry of transportation, 2016). In “Implementation plan for pollution prevention and control of ships and ports” special plan, put forward the idea of Structural adjustment of ships, from 2016, forbidding single hull chemical ships and tankers above 600 tons to enter into specific waters. By the end of 2017, classified ships and their facilities with environmental standards, and before the end of 2020, complete the transform of the equipment of the ship which doesn’t meet the requirements of the standards, obsolete the overdue (JSCD Government, 2015). The promotion and application of new energy and clean energy vehicles also show up in "ecological civilization opinion", including the promotion of the standardization of the ship type, the elimination of old ships, etc.

Except for above command & control policies, governments must play a significant role in promoting the application of preferential taxation and subsidies policies toward shipping company. Such kind of policies can enhance a shipping company's financial affordability and thus improve the attractiveness of emission reduction technologies. “Temporal Measures for the management of carbon emissions trading” is the exact market-based policies to initiate relevant enterprises, the pilot emission trading schemes in China have recognized a low liquidity for participants wishing to trade emission permits (Zhu et al., 2017).

Economic mechanisms mostly consist of fees, levies, rebates, and subsidies, these all set by policymakers to increase the costs of undesired actions and, at the same time, to reward desired actions. The choice of the preferred policy instruments is nominated by diverse issues that pertain from the geographical specification, technological constraints, private interests, and political considerations.

2.4 Policy comparison

In pace with IMO MARPOL supplementary articles of SEEMP implement in 2013, the participation to the World Ports Climate Initiative and Environmental Ship Index (ESI) is now compulsory for all the Green Award certified ships, and the use of the IMO guidelines on energy efficiency measures is particularly encouraged (Garyfalia Nikolakaki, 2013). Main countries respond to this line by several methods, there exist quite similar policies among western and eastern countries, regulations guide both shipowner side and port side to reduce emission. General speaking, governments always settle a target to limit enterprises total amount of emission, China has “Five-Year plan” and US has “Clean Air Action Plan” etc. Cap-and-trade approach used worldwide to regulate total emission, which means authorities distribute quota to key accounts who is contributed a lot to emissions and they can trade with each other depending on their demand. Meanwhile, Emission Control Area is quoted to ports in order to reduce Sox emissions. The other exact policies are summarized below.

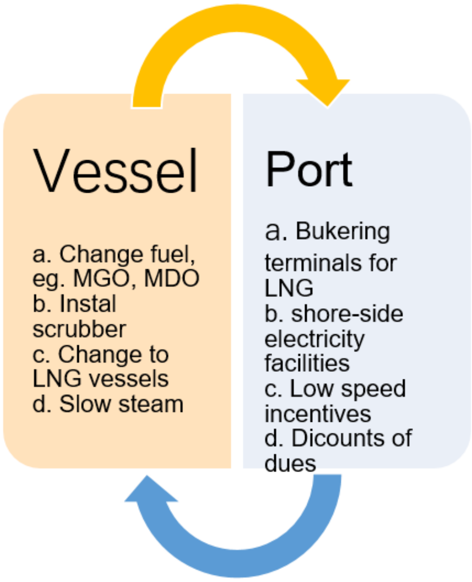

Fig. 2. Main emission policies from ship and port sides

Port authorities and ship operators could do something hand-in-hand to reduce emissions. Technologies such as exhaust gas cleaning systems for vessels, shore power at ports, and the use of fuel cells all show promising emission reduction benefits (Jong-Kyun Woo et al., 2017). Ports not only provide hardware to support vessels' operating but also give incentives due to high costs of vessels.

However, according to different characteristic, it is obvious that there exists quite a discrepancy between the IMO and some other governments about what is the best way introducing emission regulation (Styhrea. L. et al., 2017). United States focus more on technology improvement, where local government prefers cooperation with tech-research organizations to find out advanced methods on emission reduction which could definitely guide enterprises to choose more green strategies. The $2-billion Clean Air Action Plan within five years was created by the cooperation of South Coast Air Quality Management District, California Air Resources Board and U.S. EPA, jointly participation advocates the use of shore electricity at the ports extensively. Moreover, a commitment to use pollution-based impact charges so that polluters pay their part to improve air quality makes great motivation (San Pedro Bay Ports Clean Air Action Plan (CAAP), 2017).

Different from China, European countries and United States are seeking collaborative networks cross nearby countries. The Pacific Ports Clean Air Collaborative (PPCAC) group is a collaborative pollution control mechanism among ports, which is a voluntary group of international participants from ports, private industries and environmental agencies throughout central and North America, Pacific Rim countries as well (Taih-cherng Lirn et al., 2012). Meanwhile, in North European ports, ships are assumed to use MDO when operating inside the SECA which is good for establishing an SECA in whole North Sea (Edwin van Hassel, 2016). On the contrary, China lack of cooperation with neighbouring countries, we have internal joint work, such as Bohai-rim waters ECA regulation, but we are weak in relationship with nearby regions like Korea.

Fig. 3. Geographical locations of the newly proposed ECAs in China

Resource: D. Sheng et al., Transportation Research Part E pp101 (2017)

But in Changjiang Economic Zone, governments think highly of cooperation among variety transport method, multi-transport and in passing transport collaboration which could improve efficiency, reducing wasted consumption (Special action on prevention and control of ship pollution in the Changjiang Economic Zone, 2017). Therefore, general policies are much similar among EU, US and China, but each continent emphasis difference strategies which in my point of view should be referenced by each other in different pace.

3. Port performance evaluation

3.1 Port efficiency

Efficiency is a relative concept that requires a clear definition of a benchmark, it's convenient for operators to manage their performance based on their target. As for port efficiency, port managers may value different goals, some are operating efficiency, some are economic efficiency and some are berth utilization, etc. Indeed, port efficiency that we generally mentioned to is analyzing the ability of a port, up to the maximum output under a given amount of inputs or through the use of the minimum amount of inputs under a given amount of outputs. Port efficiency researches relationships between inputs and outputs, in other words, a port's physical facilities and quantities or movements in ports (Ancor S.A. et al., 2016).

The crucial thing for managers is what factors should they concern, such as technical and environment efficiency, different factors they considered will definitely effect on the efficiency score of a given port. There are loads of studies on container port efficiency, not only can such analysis provide a management tool, but it also forms related inputs for constituting regional and national port layout and operations (Regan and Golob, 2000; Cullinane et al., 2006). It can be said gains from efficiency, represent a condition to a situation closer to optimal.

Studying container port performance regards more important than before due to rapid changes in transportation technology and the competitiveness of the market share (Yang et al., 2011; Cullinane et al., 2002; Wilson et al, 2002; Park and De, 2004). The most important determinants of terminal efficiency described as the following factors: 1) Operation practices: Delays in commencing and during stevedoring, delays during work could cause inefficiency. The reason for these delays may be equipment breakdown, ship problems, weather, etc. 2) Crane efficiency. Crane hours/working hour reflects effectiveness of crane operation. Moreover, the number of cranes used to loading/unloading determine whole terminal's working hour, which refers to crane productivity effectiveness measured in terms of number of lifts/crane hour (Jose L. Tongzon, 1995). 3) Vessel size called at ports is also an important determinant of terminal efficiency. When cranes work for a large vessel with a large cargo exchange requires better container selectivity in the vessel hold and more efficiency operating.

Quite a bit research indicated that the average efficiency of ports become lower when environmental elements are considered. Large amounts of capital have been invested in infrastructure to stimulate throughput and profits. However, lack of restriction of pollution in ports will lead to a lower environmental performance (Jiasen Sun et al., 2017). Consequently, identify influential factors as well as environmental variables is essential for port conditions and surroundings that affect port operations and management (Chen H.K. et al., 2018).

3.2 Measurement of the port efficiency

3.2.1 Methodologies of efficiency analysis——DEA model

To that purpose mentioned in previous chapter, it is necessary to estimate a production or cost frontier in ports. Stochastic Frontier Analysis (SFA) with parametric and Data Envelopment Analysis (DEA) with nonparametric are two different approaches contributed to an efficient frontier, the latter one is widely used in many researches.

DEA is a nonparametric method been widely used to evaluate the relative efficiency of decision-making units (DMUs) with multi-inputs and multi-outputs (Charnes, Cooper, and Rhodes 1978). If the DMU i=1, DMU i is technically efficient DMU, if its efficiency less than 1, it represents technically inefficient (Cui Qiang, 2017). DEA calculations are nonparametric tools of evaluating the efficiency of a firm with various inputs and outputs (Poitras et al, 1996). When it comes to inputs and outputs, considering performance of port enterprise, fixed assets (length of quay, scope of terminal, amount of cranes) are usually selected, and operational costs, labor number as input indicators. Port annual throughput, company’s profits as output indicators.

However, it's a huge challenge to find every information in detailed, so we choose the representative elements, for example, capital/operational costs on behalf of finance, length of quay and area of terminal represent geographic resource, number of cranes is fixed cost and number of labor of each port enterprise.

The DEA has two basic models. The first model is known as CCR (Charnes, Cooper & Rhodes, 1978) model that had an input orientation and presumed constant returns-to-scale. Another one is BCC (Banker, Cooper, 1984) with an assumption of variable return-to-scale (Wang & Cullinane, 2006). Both can be solved by Banxia Frontier Analysis or Maxdea software. When using DEA model, it's important to realize the objective and policy of company, Bauer (1990) and Wang et al. (2005) explained that the frontier model is consistent with the economic theory of the firms' optimizing behavior, deviations from the frontier can be explained as an evaluation of the efficiency through which firms attain their objectives, and the information they provide in terms of the relative efficiency of firms is of great value to decision makers.

But when consider environmental efficiency into port management, several studies have confirmed the importance of incorporating environmental aspects in port management, (air emissions, waste generation, energy and water consumption and noise, etc.), to guarantee better economic performance, affirming that improved environmental performance can reduce costs and enhance stakeholder engagement (Taliani E.C. et al., 2017) Here recommended improved model upon the traditional DEA models, the inseparable input–output SBM model is able to calculate environmental efficiency more accurately (Joon-Ho Na, 2017). Explicitly adding the undesirable outputs to both the objective function and separate constraint function (Chang Y.T., 2013). For this dissertation, we'd like to add CO2 emissions as an undesirable output.

3.2.2 Suitable methodology of this research

This dissertation plan to figure out the relationship between port emission policies and port efficiency, so the author is going to study in two stages. First estimating port efficiency by DEA model, choose Qingdao port as an example, each year is DMU for research. As for inputs & outputs, five inputs usually considered in step one which are length of the berths (in meters), number of berth, number of cranes and storage area (in m2), number of labor. Elsayeh & Mohi-Eldin (2015) highlighted these inputs factors are part of the services provided from the ports in three main stages production process: vessels reach ports (length of berth), cargo handling operations (gantry cranes) and reservation in yard (storage area).

But the reality is that, the complex of ports hard to be reflected by simple number, equipment in port are extremely complicated which lack of standards, if we include the handling equipment, it would become a trouble in classifying too much different types of handling equipment involved in the port level (Young-Tae Chang, 2013). Besides, labor may include others who do not contribute to port operation. Therefore, we only choose length of quay and number of berth which is totally fixed. For outputs, use cargo throughput (million tons) and container throughput (million TEU).

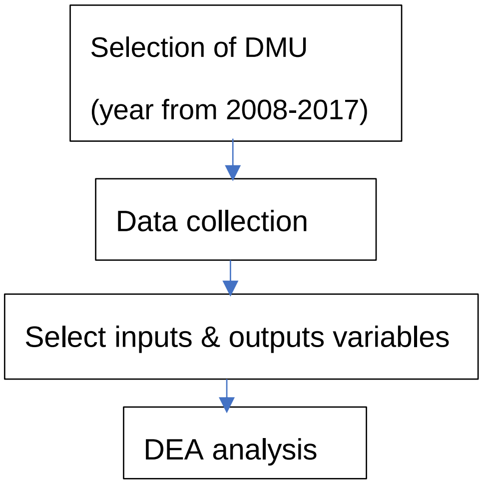

Fig. 4. Flow Chart of port efficiency

After estimating of port efficiency and checking the emission policies variation, correlation analysis finally put forward to inspect whether it exists causal relationship between two aspects.

4. Case study—— Qingdao port

4.1A brief review of Qingdao port

4.1.1 Function and natural view of Qingdao Port

On the west coast of the pacific, Qingdao port is the center of the coastline in North China, consists of four port areas, namely Dagang Port Area, Huangdao Oil Port Area, Qianwan Port Area, and Dongjiakou Port Area. Except for Dagang Port aimed to become world-class cruise port, Qianwan Port Area is mainly for container and dry bulk with 12 square kilometers, the depth of Qingdao port generally very deep, 20 meters, it can accommodate world's large containerships ever. Huangdao port with an area of 0.5 square kilometers engaged in operation of crude oil, liquid chemicals and LPG. Dongjiakou Port covers huge 150 square kilometers, planned quay length up to year of 2017 is 35.7 kilometers and altogether 112 berths. So far large iron ore terminal and LNG vessel specified terminal. The four areas, with reasonable layouts and specific functions, are jointly contributing to the comprehensive strength of Port of Qingdao (Qingdao Port International CO., LTD website).

4.1.2 Green port procedure of Qingdao Port

Qingdao port won the award of “National Green Port” last year, however, Qingdao have endeavored in energy-saving and emission-reduction from early period.

Back to 2008, Qingdao port done 80 projects on “Replacing oil with electricity”, which saved 4.2% energy consumption. At the meantime, put forward the responsibility system of energy saving and emission reduction, making reward and punishment. Even in 2009, government developed “Assessment methods and Implementation Rules for energy saving and emission reduction targets of port and shipping systems” to better implement emission reduction (Port Yearbook of 2009, 2010). This core port in north of China is the first one setting a goal of developing low-carbon port. On March 1, 2010, Qingdao Port Group issued “Guidance on developing Low-Carbon Economy and constructing Green Port”, setting a goal of cutting down 10 thousand tons energy consumption by the year 2020 that equals to 40% decline compared to that of 2005. Since the “Tenth five-year plan”, the port's annual throughput has increased by nearly 200% but consumption has declined by 39.7% per TEU (Li J. et al., 2011). 130 yards and 106 container cranes have been modified to electricity in 2010, which saved expends of 76.68 million and reduced 45901 tons of CO_2 emission (Xue Z.W., 2011)

In order to response national policy, Shandong province tackle “Implementation of the document No. 2014 [32] to promote the healthy development of the marine industry”

(2016), setting the target that 90% of the operating vessels and official ships used shore power in main ports, 50% of the container, cruise and roll professional wharf had the ability to supply shore electricity to ships by 2020. For the large coal and ore storage in terminal yard, dusts could be a great resource of pollute, ports in Shandong province build closed warehouse for wind and dust suppression, and endeavor to realize 100% this kind of facilities in the main ports by 2020. In 2016, Qingdao Qianwan port, QQCTU103 container quay realized 100% shore power utilization, eliminated pollution from vessels berthing (Ding Yi, 2016). Policy guidance helped a lot in Qingdao green port building procedure, "Green port development plan in 13th Five-Year" and "Green port construction guide" published in 2016, made influence on technology of LED lighting, heating transformation and energy saving, green area expanded 135 thousand as well (2017 Port Year Book).

After Qianwan port accomplished shore power in 2016, 400 thousand iron ore of Dongjiadu port implement shore power project in 2017. Qingdao port dedicated in wide use of shore power, tug & tow also using it. Subsidy of using shore power in Qingdao port become more and more popular these years, Qianwan port earned 11.43 million RMB in container port shore power subject (Qingdao Daily, 2017). In the near future, Qingdao port will control pollution from ship ballast water, washing water and residual oil, extend use of renewable resources as well.

4.2 Data Sampling

This paper uses the Length of quay and number of berth as the input variable. The data comes from the Year Book of Chinese Port, taking cargo throughput and container throughput as the input index. The research defines each year (2009—2017) of Qingdao port as a DMU,DMU_i, i = 2009, 2010,…, 2017. The CCR model based on constant return-to-scale and BCC model with variable return-to-scale are adopted in this dissertation, considering the rules of using DEA model, the number of studied DMUs should be at least twice the sum of input & output variables, so we use 9 years data, 4 input and output variables.

Usually, efficiency can be calculated with Total Outputs divided by Total Inputs, but the units should be the same which is hard for different types of port elements involvement. However, the DEA method, as an objective evaluation method, does not need to take into account the influence of the different units of each index on the results of the calculation. The original data can be directly involved in the calculation, and the operation process is simplified (Xiong H.B, 2013). For undesirable outputs, we get the CO2 emissions through converting the energy consumption of the ports (Cui Q., 2017).

Table1. 2008-2016 Collected data of input & output variables of Qingdao Port

Year	Length of quay (m)	number of berth	cargo throughput (million tons)	Container throughput (M-TEU)
2008	16639	69	300.29	10.02
2009	19769	79	315.46	10.26
2010	21903	98	350.12	12.01
2011	20518	81	372.30	13.02
2012	20944	102	414.66	14.50
2013	24588	104	457.83	15.52
2014	25998	110	468.02	16.62
2015	28335	121	484.53	17.44
2016	28589	121	500.36	18.05

Sources: Year book of Chinese port 2009-2017

4.3 Efficiency estimation of Qingdao port

The estimated efficiency over 2008 to 2016 of Qingdao Port area depicted in Table 2, MaxDEA software is considered as primary tool to research port efficiency. The results of efficiency of Qingdao port is reported with Scores following, generally, the efficiency is pretty high, all above 0.8. However, we can still recognize slightly fluctuation correspondingly, except for extremely high volume of trade increasing port operation in 2008, it's obvious that scores go up since 2011.

By using DEA software, the result of optimized inputs and outputs are got easily, the author calculated possible improvement space of each variable. Here exists an unusual phenomenon, improvement ratio is negative in inputs while all output variables are positive. This means the facilities of Qingdao port are over-abundant, which results in a kind of waste, while productivity still has room to improve. Actually, the low utilization rate of berths is usual in China, thus leading to a waste of berth resources and low activity performance. For example, the efficiency of ports in 2009 derived from using the DEA-CCR model amounts to 0.8752. This demonstrates that, in theory, the sample ports can increase the level of their outputs (throughput) to 1.14 (=1/0.8752) times as much as their current level while using the same inputs.

Table2. Efficiency evaluation results of Qingdao Port

Year	Score	Input 1- Length of quay (m)		Input 2- number of berth		Output 1- Cargo Throughput		Outp2-Container Throughput	
		Improvement ratio	Projection	Improve ratio	Projection	Improve ratio	Projection	Improve ratio	Projection
2008	0.9754	0	16639	0	69	2.52%	307.85		10.02
2009	0.8752	-11.70%	17456.17	-0.946	72	14.25%	360.42	21.44%	12.46
2010	0.8374	-15.10%	18596.10	-15.1%	83	19.42%	418.10	20.50%	14.47
2011	1.0	0	20518	0	81	0	372.30	0	13.02
2012	1.0	0	20944	0	102	0	414.66	0	14.5
2013	0.9984	0	24588	0	104	0.16%	458.58	0	15.52
2014	0.9765	-0.14%	25626	-4.54%	105	0	468.02		16.62
2015	0.9349	-0.68%	27291.96	-3.68%	117	8.81%	527.23	2.70%	17.91
2016	0.9621	0	28589	0	121	5.88%	529.80	0	18.05

This appears differently when considering environmental issues, by using SBM-DEA model. to scale. The basic DEA models assume a criterion for efficiency is that producing more outputs relative to less inputs, and the total input & output proportions remain sustainable (Anthony T.H. & Joyce M.W., 2010), but externalities like environmental are not embodied in markets, this is considered as undesirable output which would also influence port strategy and target. A slack-based measure model (SBM) works out differentiate outputs which CO2 emission is chosen as the undesirable output in computation of efficiency scores.

Table 3. Efficiency scores containing CO2

Year	Scores exclude CO2	Scores include undesirable output- CO2
2008	0.9754	0.8382(14.06)
2009	0.8752	0.7579(13.40)
2010	0.8374	0.7268(13.20)
2011	1.0	0.9264(7.36)
2012	1.0	0.9184(8.16)
2013	0.9984	0.9074(9.11)
2014	0.9765	0.8953(8.31)
2015	0.9349	0.8659(7.38)
2016	0.9621	0.8967(6.79)

Notice: The figure in brackets is rate of increase & decrease.

As shown in Table 2, the environmental efficiency value containing CO2 is lower than the efficiency value that exclude CO2, because the carbon emissions from undesired output have a negative impact on the efficiency of container ports. The highest decreasing rate is 14.6% in 2008, but when we sight the number vertically, the trend of decline rate is going down, which means CO2 emission is reducing, especially in 2011, environmental efficiency improved a lot to 0.9264.

4.4 Relationship investigation between policies and the efficiency of Qingdao port

It's obvious that from year 2008 to 2016 throughput of Qingdao port keep going steadily, but referring to global ocean environmental protection trend, how to ensure productivity of port and decrease pollution at the meantime remains though problem. Fortunately, Qingdao port put environment protection into agenda very early and up to peak in 2011. The container operation part developed "Import loaded containers organization mode" in 2011, which decreased transfer rate by 40%. "Replacing oil with electricity" project was expanded and the new mode of cold box electricity-saving was carried out, which was rated as the lowest container terminal for each container in China." Moreover, "The application of automatic computation system for crane operation in Qingdao port" has been selected as the third batch of energy saving and emission reduction exemplary projects of the Ministry of transportation (2016 port year book).

Environment improvement definitely need finance report, from 2009, Qingdao port invest about 40 million RMB building "The wall of preventing wind and dust from dry bulk", and the investment of millions of RMB in seeding large trees at surrounding area. Also invested about 35 million RMB purchasing 71 new LNG trailers and buses to promote the application of "Replacing oil with gas". In addition, three new LNG filling station has been built in port area correspondingly, total capacity of storage is 110 water cube, and the total capacity of daily gas filling is 27 thousand. Thanks to new energy application and equipment, the port afforested area reached about one million square meters, and the rate of domestic sewage treatment in the port area reached 100%, it came to effect in 2011, been admitted by World Environment Centre and China enterprise Consortium awarding "The best enterprise of energy saving and environmental protection" jointly (Xinhua News Agency, 2010). Achieving more than 500 tons of carbon dioxide emission reduction in 2013, annual fuel cost savings of about 2.2 million RMB.

We can also see from research that CO2 efficiency improve a lot in 2016, which is the beginning of "13th Five-Year plan". In this year, Qingdao port dedicated in establishing fully automated wharf. 6th July Qingdao port empower Zhenghua Heavy Group built fully automated equipment and control system, which could save labor input by 70%, increase operating ratio about 30% (2016 Port Year Book). 2016 is also a rich year of Port technology Improvement for Qingdao port, who's awarded "The air filter centralized cleaning device", "Three in one turn-over container machine", "Berth pre-warning and monitoring system", etc. (2016 Sustainable Development Report of Qingdao Port)

In order to find out the corresponding relationship, the author defined the number of policies each year as independent variable x, efficiency scores as dependent variable y. After using simple regression method, the outcome shows R^2=0.7 which means exists common changes between policies and efficiency, and the fitting effect higher than general standard, as for uncomplete policies data, 0.7 is an acceptable result which could demonstrate two variables have thoroughly relationship. From the Regression parameter table following, we can conclude the quotation is: y=0.72+0.095x.

Table 4. Regression parameter

	Coefficients	Standard error
Intercept	0.721415	0.056263
X Variable 1	0.095405	0.036833

It is clearer when viewing the normal probability plot, scatters in the graph present in line, showing policies could do influence on port efficiency, the more policies carried out to regulate port environment, the more port production will bump, including consideration of CO2 emission reduction efficiency. However, the content of each policy and how much it strengthen the pollutant influence to emission reduction without doubt, this paper only quantifies the number of existing policies issued by authorities, which made the amount of policies a variable when considering efficiency scores.

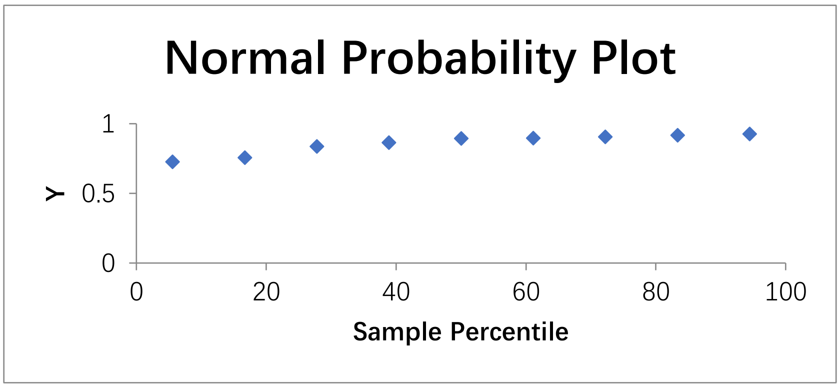

Fig. 5. Normal Probability Plot of variable x and y

4.5 Policy advice

4.5.1 Market-based method

Economists always have their criterion, which can be summarized as ‘marginal law’, in such circumstances, cutting a unit emission should at least equal to a unit of benefit of these emissions. For each ship company and port enterprise, businessman, only pursuing profit. Since bunker costs usually take part of 50%-60% of the total operating cost of a shipping company (Notteboom, 2006; Golias et al., 2010), switching from regular HFO to expensive MGO brings a significant burden to OPEX, which could harm both shipping companies and shippers.

Therefore, finding market-based approaches could definitely stimulate related companies to improve environmental situation. If the Marginal Benefit is larger than the Marginal Damage, further emissions should be reduced to take advantage of the MB (Hackett, 2006). They favor economic means because industries can choose the best way voluntarily for themselves to mitigate emissions. Under such circumstances, the invisible hand (market system) plays a crucial role (Wang H.F., 2009). However, the number of ports deploying financial incentives is still fairly low, and where they are applied, only a handful of ships are benefiting from the schemes-often less than 5% of the ships calling at port. Any incentives shipowners may have to order more efficient ships with lower emissions can only to a very small extent be result of savings from port-based incentives (Spurrier A., 2018). To ensure this was the barrier, the role of ports themselves needed to have a wider range of incentives to reward operators of green vessels.

Fees, rebates, and subsidies are all economic mechanisms given by policymakers to increase the costs of undesired actions, or otherwise, to reward desired actions. The choice of the preferred policy instruments is dominated by a variety of issues, from the geographical features, technological constraints, to private interests, and political considerations. By these ways, original costs going-up will be balanced through redistribution of revenues, port enterprises rewarded shipping companies who behave excellent in emission reduction, then authorities give prize to port entities who consume or emit less. And how to define duties and amount of prize offered need complete system, "Emission rate". Regulating the emission threshold according to different types of vessel and capacity, the classification should consider main engine's power. It is important that correct and consistent monetary incentives are given to users, operators and investors. Some research concluded high intensities of emissions were located in the docks, anchorage areas and channels. Emissions from voyage ships generally concentrated along the shipping routes, over 20% ship emissions could be reached in July due to their close location to the docks (Chen D.S. et al., 2017). This high percentage of contribution from ships pushes highly demanded of emission control measures on ship side, fuel switch and shore power need to be developed, it was also demonstrated that the most cost-effective way of mitigating SOx emissions is to use bi-fuel option (Lindstad, Sandaas & Strømman 2015), however, the price of using MDO is nearly double than FO, here comes the port incentives to encourage shipping companies using less pollute fuel and remain traffic at the meantime. Close to half of the port can still facilitate the process by using environmentally differentiated port dues and by offering alternative fuel supply in port (Winnes H. et al., 2015), but a unilateral emission regulation harms the ports and shipping companies which are in low cargo volume, and benefits some others not subject to such regulation (Dian Sheng et al., 2017). Although, the emission regulations on shipping company's operations would come into effects, the competition of regional ports and shipping companies also need to be considered.

It has many advantages if reducing turnaround time: reduces unit vessel emission, mitigates emissions from the auxiliary engines when berthing, booms the transport operation, and cuts down vessels' speed at sea (Sheng D. et al., 2017). It also increases the berth capacity for the port and then improves total efficiency of ports. Here are several means to enhance turnaround time, such as increasing productivity, reducing waiting time for stevedores, and more efficient clearance procedures or other ways to relief congestions, (Johnson & Styhre, 2015).

4.5.2 Command & Control measures

ETA is definitely a regulation that enforced, it regional planning of the Yangtze River Delta, Bohai Delta and the Pearl River Delta issued by the State Council is without doubt, however, the area in red circle below shows the Bohai-rim, it obvious Qingdao port isn't included in it,

Fig. 6 Map of Bohai-rim

Sources: Qingdao Newspaper, 2015.

The regulation of Chinese ECA clarified, from 1st Jan., 2017, using 0.5 low sulfur crude oil during the berthing of the ship in several core ports, then it covers all ports in the ECA in January 1, 2018. By 1st Jan., 2019, ECA expanded to 12 nautical mile, and before 31st Dec., 2019, sulfur oil will be reduced to 0.1 or keep expanding ECA (China ports & Harbour Association, 2016). This criterion can be adapted to Qingdao port as well, since Qingdao port is near Bohai-rim and responding the country's policy.

Tax could be sets of coordinated measure with ECA, the government will prefer a highly public concerned port to maximize overall social welfare (Cui H. et al., 2017). However, we can find in 2014 and 2018 Qingdao port International Co. Ltd Prospectus, more and more stakes which belonged to the state (Qingdao port was wholly state-owned company in 2011), now transferring to publics. The optimal emission tax will consider more about affordability of shipping company but is always lower than the marginal environmental damage (MED). Transport charges and taxes must be restructured to wider application, direct to the "polluter pays" and "user pays" principles, while the overall burden for the sector should reflect the total costs of transport including infrastructure and external costs.

From ports side, provide possible and useful technical infrastructure and strategic location like Automated Mooring Systems (AMS) that can cut down operative time when approaching the berthing area (Miluše Tichavska et al., 2017). AMS with vacuum technology enable vessel pulled towards the quay steadily, allow engines to be shut off approximately half an hour earlier in addition, this tech should be widely used in port. Governments must perform with a significant part in promoting the application of emission reduction technologies. This can be recovered from preferential taxation policies. Zhu Mo et al., proposed "Reserve price" in 2017, which should be considered with trading emission permits, in this way, the market regulator can act to buy and store a seller's emission permits at the reserve price when there are no potential buyers, and then sell those permits when new buyers come into the market. In this way, the trade volume and the liquidity of emission permits are likely to be increased. Joint strategy is better to be considered, ports can work together to make a general rule of tax and dues which could benefit multiparty, "Environmental Port Index" collects best practices and identifies KPIs, it aims at "creating a joint strategy for differentiated port dues and reducing ship-borne air pollution at sea, in ports and in cities" (Clean Air 2014).

5. Conclusion

This article examines environmental policy impacts on port efficiency, the analysis shows that emission reduction policies do positive correlation to port efficiency. This study has analyzed emission reduction policies in different regions globally, then introduced the environmental efficiencies methods and took Qingdao port as example to estimate it efficiency score during 2008–2016, using an output-oriented DEA model. To explore the relationship between emission policies and efficiency, we have investigated by simple regression method. On the basis of the results, conclusions can be obtained as following:

(1) Port emission reduction policies concentrated on these three points worldwide:

a. Macro policy plays an instructive role in emission reduction, for instance, Ministry of Transport 's of China published “13th-Five-Year Plan”, declaring that by 2020, ship SO2, NO2 and PM emissions should be reduced by 65%, 20% and 30% respectively, relative to 2015.

b. Emission Control Areas introduced to almost every country in the shipping world.

Table 5 Standard of ECA

Maximum sulphur in fuel	IMO			EU			China		
	2012	2015	2020	2012	2015	2020	2012	2017	2020
Non SECAs	3.5%	3.5%	0.5%	3.5%	3.5%	0.5%	/	/	0.5%
SECAs	1.0%	1.0%	0.1%	1.0%	0.1%	0.1%	/	0.5%	0.1%
Passenger Ships	/	/	/	1.5%	1.5%	0.1%			
At berth				0.1%	0.1%	0.1%			

c. Regional ports policies: charges for pollutant vessels and subsidy for energy-saving shipping companies, promoting shore power. In order to encourage shipowners’ invest more often in installing LNG propulsion, scrubbers or using low-sulphur fuel for improved economic or energetic performance (Stevens et al., 2015), port authorities give incentives to shipping companies who fulfil certain ecological requirements. For example: The *Port of Turku* in Finland grants a reduction in the port fee if the sulphur content of the fuel used is less than 0.5% or if the nitrogen content is below 10g/kWh (Clean air Europe organization, 2014). At the meantime, port itself draw cleaner power from shore side, China has been encouraging shore power for decades, like the feed of electricity to a ship from wharf. This allows ships to shut down dirty engines by replaced by cleaner electricity. Government is subsidizing implementation and targets to equip 493 berths with shore power by 2020 (Su Song, 2017).

(2) Data Envelopment Analysis (DEA) is usually used in estimate port efficiency, in this paper, we conclude port efficiency keep increasing steadily from 2008 to 2016, in particular, input inefficiency more significantly affects the port efficiency of Qingdao port compared with output inefficiency. In this condition, port fixed resources are not been used at a satisfying efficient level in Chinese port. When take environmental efficiency into total port efficiency, the score is less than before, reducing CO2 emission is the most effective way to improve environmental efficiency of a port (Joon-Ho Na et al., 2017). How to reduce emissions while maintaining reasonable economic growth is one of the major problems facing China (Han et al., 2017). From result of port efficiency calculated upon Qingdao

port, improving input resource wasted condition is possible, shortening working lead-time on berth, implementing efficient management on yard, and developing working efficiency of equipment can obviously lessen the input inefficiency. Port pollutant mostly derived from fuel burnt from vessels, so if forms of energy efficiency develop, it will reduce air pollution. Further, if electric energy is managed in an intelligent way, it is possible to restore parts of the energy and decrease heavy charges.

(3) Emission reduction policies do influence a lot with port efficiency, especially take environmental element into account. Policy is used for improving environmental awareness and consciousness of port enterprise, analysis of linear regression shows the positive correlation between two elements, when the tight policy issued, port efficiency would improve more than the year policy didn't issue. Consequently, establishment of the port environmental protection and regulatory system is deemed to do. On the other hand, changes in port productivity may be derived from changes in technology part. Since higher ship utilizations improves the environmental efficiency scores for all O–D pairs (Anthony T.H. Chin & Joyce M.W. Low, 2010), this study suggests that shipping is more likely to achieve environmental efficiency.

Environmental improvement wouldn't realize if parties only focus on themselves without cooperation, costs going up and effects being lower. In order to finance such changes, shipowners (via duties and fees) can be involved, ports can invest their own resources or find investors among the third parties (nation states, EU funds, private investors), only if all parties involved in this world issue, emission reduction will make better.

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