Article

Green Shipping Effect on Sustainable Economy and Environmental Performance

J. Augusto Felício [1] **, Ricardo Rodrigues** [2] **and Vitor Caldeirinha** [2,*]

1   School of Economics and Management, University of Lisbon, Rua Miguel Lupi, 20, 1249-078 Lisboa, Portugal; jaufeli@iseg.ulisboa.pt
2   Center for Management Studies, School of Economics and Management, University of Lisbon, Rua Miguel Lupi, 20, 1249-078 Lisboa, Portugal; cege@iseg.ulisboa.pt
*   Correspondence: vitorcaldeirinha@gmail.com or vitor.caldeirinha@esce.ips.pt; Tel.: +351-213-970264

Abstract: This paper focuses on green shipping and its' influence on the sustainable economy and environmental performance. Based on the green shipping approach, this empirical study examines a survey sample of 193 responses from Portuguese and Spanish executive managers and uses exploratory factor analysis and structural equation model. The Green shipping approach supports the green theory. The results show the importance of green efficiency, green management, and pollution impact. The confirmation of the sizeable influence of green shipping on the sustainable economy and environmental performance constructs constitutes a major contribution to the literature. Green management and green efficiency contribute to controlling the impact of pollution with practical effects on economic sustainability. Another contribution arises from the fact that tax and financial incentives and environmental sustainability regulations indicate the relevance of the pollution impact and sustainable economy.

Keywords: shipping industry; green theory; green shipping; environmental performance; sustainable economy

1. Introduction

Shipping companies are currently facing new challenges and opportunities in the global economy. The globalization of business activities has highlighted the debate surrounding the environmental questions of resource protection and conservation, as in the case of pollution from maritime transport, leading to an increase in research and deeper knowledge on the problems and potential solutions [1,2]. Green shipping is becoming an important issue for a sustainable economy and environmental performance, with major implications for the shipping industry. However, little is known about the reasons why shipping companies adopt green shipping practices [3–5]. A multiplicity of studies limits research to the financial impact of the adoption of cleaner transportation technologies which does not address the plethora of other factors surrounding this issue [6]. There is also insufficient understanding of the factors that make up green shipping development [7–9].

This research is based on the green shipping approach derived from green theory [7,10–12], and uses exploratory factor analysis and structural equation modeling (SEM). The sample of 193 responses was obtained from a universe of 2360 Portuguese and Spanish executive managers working in the maritime sector, through an electronically distributed questionnaire.

The purpose of this paper is to analyze how green shipping contributes to the sustainable economy and environmental performance. We consider the following objectives: first, to analyze the contribution of green shipping for a sustainable economy; second, to analyze the influence of green shipping in environmental performance; third, to analyze the importance of green efficiency, green management, and pollution impact for green shipping; and fourth, to examine the effect of the tax and financial incentives and environmental

sustainability regulations (or regulations about air pollution and maritime pollution) on the research model.

The main contributions of this research show the strong influence of green shipping on the sustainable economy and environmental performance. Moreover, tax and financial incentives and environmental sustainability regulations highlight the importance of pollution impact and contribute to the enhancement of the sustainable economy of maritime transport. However, the adoption of these incentives and regulations evidences a lesser importance of green management, and green efficiency, which is also reflected in the decreased importance of environmental performance.

The paper is organized as follows. After the introduction, the second section provides a theoretical background and research hypotheses. The following sections present the methods, empirical results, and discussion, followed by conclusions, contributions, and recommendations for future research.

2. Theoretical Background and Hypotheses

Trade has dramatically increased [13], affecting the maritime industry that has been at the center of international attention due to the increasing pressure to reduce emissions from ships in their movements and port operations. Almost 70% of gases and particles emitted by the exhaust of ships occur within 400 km of the coastline [14–17], causing air quality problems, which affects the region's climate and health in coastal areas and harbors with heavy traffic. Significant reductions are necessary to offset the increase in emissions due to the expected growth in seaborne trade [18].

It appears that global industries have been observing changes in the behavior of organizations as a way of responding to pressure from international authorities to adopt environmental management systems in their strategies [19]. The environmental impact of the shipping business derived from routine operations or caused by major accidents has motivated efforts to improve the environmental management systems [20–22]. As a result, the shipping industry began to integrate new technologies and innovations to respond to environmental challenges, not always with the best results [23–26].

Green shipping refers to the set of practices and eco-environmental efficiency adopted in shipping [26–28]. It involves the improvement of procedures and technological innovations for environmental sustainability and trade, while encouraging ecopreneurship. Such environmental impacts include air pollution (SOx, NOx), water pollution (oil spills, ballast water) and waste products [29]. The pollution derived from liquid and solid sediment occurs because of routine shipping operations and has effects on ports and adjacent areas [30]. Reference [31] found that the burning of liquefied natural gas (LNG) results in negligible SOx, NOx and PM emissions. LNG is the cheaper solution in the longer term [32], and LNG constitutes the future for shipping, because it produces almost none of the pollutant. For IMO, the vessels must cut sulfur-oxide emissions in some regions. However, LNG-engines are not common in ships due to the specific safety measures on board, and LNG is not widely available [33]. Nevertheless, the ports of northern Europe are leading the shift to LNG by installing fueling stations to end one of the main pollution sources [34]. Through new regulations designed for this purpose, the European Commission is forcing all major EU ports to provide facilities for LNG supply.

Green management, or environmentally sustainable management, aims to ensure conditions of profitability and greater participation of companies in the market, derived from greater commitment to environmental protection [35,36]. Green management is associated with protecting the environment, recycling, and reusing materials, and reducing gas emissions [37].

Green efficiency or environmental efficiency in this study refers to the efficiency of the operation of the port and maritime transport, considering the economic and environmental benefits and the degree of green development of the ports and transporters, to measure their sustainable development [36,38–40].

Organizational improvements (company policy and transportation documentation) and improvements in technology (equipment and transport design) reduce some of the environmental impacts and contribute positively to green shipping [27]. Transport technology improves products and processes, allowing a cleaner and eco-efficient production [41,42], responding to pressure from customers and the effort to improve the public image of firms in the sector. The adoption of green shipping practices can improve the environmental and productivity performance of the shipping companies [43].

This research is based on the green shipping approach, which encompasses research, development, and innovation in shipping that derives from the green theory focused on the recognition of the legitimacy of the State to 'manage the commons assets', as an alternative or in conjunction with the 'traditional economies management', which requires the acceptance of the political leadership and the civil authority of citizens [11,44,45]. Reference [10] associated green theory with rules for consumers. Sustainability policy and sustainable development are irreducibly political concerns. Hence the importance of institutionalizing the network of relationships between the states and its citizens, which is essential for a green political theory, based on matters of practical judgment, ethics, and knowledge. In this sense, [11] compares the theory of value based on consumer satisfaction with the theory of value based on work and subsequently with the green theory of value based on natural resources to discuss standards or values focused on 'goods' and 'agency' in the sense of 'the law'.

The convention of the International Maritime Organization (IMO) on the prevention of pollution from ships (MARPOL) and the directive on ship-generated waste seeks to regulate this type of pollution [46,47]. Annex VI of the Energy Efficiency Design Index (EEDI) [48] and Energy Efficiency Operational Index (EEOI) is oriented towards eco-innovation [49]. In North America, the Green Marine Environmental Program (GMEP) offers a framework to establish and reduce environmental footprints [50]. Shipping emissions are expected to double by 2050 [51]. The EEDI entered into force recently for all vessels, is an effort to reduce CO^2 emission.

The environmental impact of maritime transport in Europe is at the center of concerns from governmental entities and citizens. In the context of European and global regulation, there is an intention to reduce the impact of toxic gases in air pollution, improving engine emissions, using new fuels—natural gas or hydrogen—and forcing ships to use shore power in ports. Other practices involve reducing sea pollution by depositing waste in ports, enabling ships' material to be recycled through the creation of ecological networks of ship dismantling and the implementation of environmental practices at the construction stage. Reference [46] analyzes the environmental impacts generated by routine operations at ports, verifying that the water pollution is the result of ballast water, diesel waste, ship operations waste, and cargo residues. Reference [27] claims that the pollution and waste created in shipping processes imposes environmental costs and accelerated resource depletion. However, the situation is expected to worsen in the face of trade globalization, which has contributed to sustained growth in international shipping activities. In recent years, increasing attention has been paid to shipping, particularly due to the increasing problem of global air and sea pollution. The world fleet mainly uses diesel engines; therefore, the IMO established the goal of reducing the level of NOx by 30% for vessels operating internationally, leading to engine, fuel, or air system modifications. Based on the literature, we present the following hypothesis:

Hypothesis 1. *Green shipping is explained by green efficiency, pollution impact, and green management.*

A sustainable economy is one that satisfies the needs and aspirations of the present generation without compromising the ability to meet those of future generations [52]. It refers to conditions that ensure good environmental practices with regards to shipping and its economic and social effect on nature. Growing interest has led many companies to examine ways of dealing with environmental issues [53]. In port cities, ships are a major source of urban pollution by greenhouse gas [54]. The costs of environmental protection

for companies have been increasing significantly [55], making the cost–benefit factor of green management a determinant for their competitiveness [56]. We therefore propose the following hypothesis:

Hypothesis 2. *Green shipping influences positively sustainable economy.*

Reference [57] reports a lack of evidence to support the argument that the benefits outweigh the costs in the pursuit of environmental protection initiatives. For example, in the context of the transport of containers, a container terminal is an essential part of the infrastructure of transport [3]. These terminals have evolved from local of loads handling to distribution centers where pollution issues arise at the infrastructure level due to ship emissions [58]. According to [59], companies can improve their performance while simultaneously reducing the negative effects of their activity in the natural environment using environmental management processes. Environmental performance refers to the results obtained in the development of solutions for the ship to ensure quality and environmental efficiency and its defence and protection. The green shipping practices associated with environmental protection improve the productivity of companies [60]. The ensuing hypothesis states that:

Hypothesis 3. *Green shipping influences positively environmental performance.*

Economic and financial incentives have been adopted to encourage less polluting and more environmentally friendly alternatives to be adopted by the maritime industry [54,61,62]. Several studies have assessed the cost-effectiveness of different approaches to reduce emissions from ships [56,63].

It was found that the direct and indirect incentives such as pollution taxes, charges, tradable certificates, and governmental subsidies contributed positively to a trend among ship-owners to invest in environmentally friendly equipment to support the reduction of emissions from ships [54,64]. Market-based instruments, when properly designed and implemented, for example, rates of environmental differentiation and port tonnage tax differential (green tax) and premium green emissions trading has the potential to be more cost-effective [56,65]. Reference [65] considers regulation to play a crucial role for shipping companies to improve their environmental performance to protect the environment.

The Convention on Safe and Environmentally Sound Recycling of Ships (https://www. imo.org/en/OurWork/Environment/Pages/Ship-Recycling.aspx, accessed on 5 March 2021) applies to shipyards, ship owners and ship operators, regulating green shipping, with particular focus on the stages of construction and recycling of ships, which have required certification since late 2012. It is known that ballast water can contaminate ecosystems. The ballast water convention (BWC) is one of the instruments implemented to regulate this type of pollution. European ports have been adopting their own regulations or those imposed by the European Union to encourage green shipping, using reduced waste rates when using the infrastructure and services of the port to recycle the ship waste [66]. Other examples relate to tariff incentives for vessels with green awards or environmental certificates and ships classified in the environmental ship index (World Ports Climate initiative). Portuguese and Spanish ports have been adopting these practices systematically with a resulting positive impact on the ships and resulting waste. We hence propose that:

Hypothesis 4. *Tax and financial incentives affect the model causal relationship.*

Hypothesis 5. *Environmental sustainability regulations affect the model causal relationship.*

3. Methods

3.1. Research Model

The research model relates green shipping, identified by green efficiency, pollution impact, and green management, with environmental performance, and sustainable economy (Figure 1). Tax and financial incentives and environmental sustainability regulations are used as moderator variables.
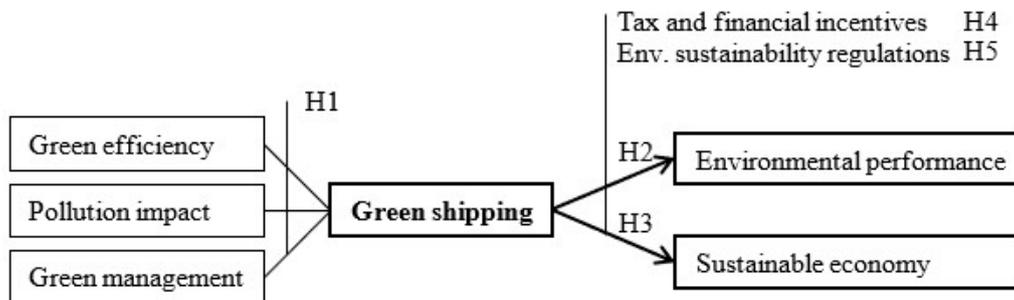

Figure 1. Research model.

3.2. Factors and Variables

The factor green efficiency consists of the following variables: the consumptions efficiency inside the ship (EFFICONSUM), fuel consumption in travel (FUELTRAVEL), traffic congestion at the port (CONGESPORT), and ship efficiency design (DESIGNEFFISHIP).

The factor pollution impact consists of the following variables: air pollution or greenhouse gas emissions (POLLAIR), sea pollution by the ship (POLLSEA), and water pollution with ballast (POLLWATER).

The factor green management consists of the following variables: on board recycling of materials (RECYBOARD), ships equipped with environmental technologies (SHIPTECH), separation of waste on board (WASTBOARD), ship noise in port terminals (NOISEPORT), and ship's waste and oil recycling in the harbour (RECYHARBOR).

The factor environmental performance consists of the variables: environmental protection (ENVIPROTEC), environmental efficiency (ENVIRONEFFI), and environmental quality (ENVIRQUALY).

The factor sustainable economy consists of the variables: scale economies of the ships (SCALECON), productivity gains (PRODUGAINS), fleet growth (FLEETGROW), economic competitiveness (ECONCOMP), and economic growth (ECONGROW).

Moderator variables are tax and financial incentives (TAX) and environmental sustainability regulations (ENVSUSTAIN), identified with regulations on air pollution and maritime pollution, to promote environmentally friendly attitudes and practices among ship-owners. The mean scores obtained with the two variables were used. All variables were measured using a Likert scale from 1 (not important) to 7 (extremely important).

3.3. Data Collection and Measures

Data collection is based on a questionnaire on perceptions regarding the importance attributed to each of the factors of green shipping in the ship call at port. The same was questioned about the importance of each performance variable, due to the adoption of environmental protection measures and good environmental practices by shipowners when calling at ports. Finally, with a view to developing protection and good environmental practices, the importance of fiscal and financial incentives and environmental sustainability regulations with an impact on shipowners' decisions was questioned. The variables were measured using a Likert scale from 1 (not important) to 7 (extremely important).

The questionnaire reflects the view of the executive managers of companies operating in the port on ship-owners behavior. It contains closed questions based on the literature review and aimed to collect data to analyze and investigate the defined hypotheses. The

survey contains three sections of questions. The first section assesses general information. The second section concerns green shipping and the perceptions of pollution in transportation. The third section focuses on sustainability and performance including generic questions on the economic, environmental, and employment situation, and local development and sustainability. The population was constituted by 2360 Portuguese and Spanish executive managers and we obtained 193 valid answers (response rate of 8.2%).

This perspective was adopted to understand the perception that expert working in ports, in particular shipping agents, port operators and towing companies and the port authorities have on green issues shipping and the factors that may influence the future, and the advantages and consequences for the image of maritime transport and ports.

Several steps were taken to ensure the validity and reliability of the survey data. First, all the relevant literature was taken into consideration. Second, the questionnaire was pretested with executive managers of ten companies. These procedures ensure the content validity of the questionnaire and confirm that it is likely to measure the intended factors. Internal consistency was ensured by measuring the correlations among the variables. Reliability (internal consistency) of the scale used was analyzed via Cronbach's alphas ($\alpha > 0.70$). Convergent validity of the original scale was established using exploratory factor analysis (principal axis factoring using varimax rotation) and the reliability of the data was examined through extensive analysis.

3.4. Statistical Instruments

Confirmatory analysis based on structural equation modeling (SEM), with significance for this dimension of the sample, was used to test the hypotheses of the structural model respecting the cause–effect relationships between the observed variables and the latent variables [67]. SPSS AMOS 27 was used to configure and estimate the model and the coefficients related to the weights of the structural model relationships. This model analyses and measures the cause–effect relationship between variables [68] based on the main equations in the SEM matrix.

4. Empirical Results

4.1. Descriptive Analysis

Endogenous variables present averages between 4.39 and 5.04, the exogenous variables averages are between 3.37 and 5.46, and the moderating variables averages are 4.9 and 5.2 (Table 1). Skewness and kurtosis absolute values are lower than 1, except for the case of FUELTRAVEL that has a skewness of 1.6, indicating the normal distribution of variables.

Table 1. Descriptive statistics.

Construct	Variable	Mean	Std. Deviation
Environmental performance (endogenous)	ENVIPROTEC	4.97	1.375
	ENVIRONEFFI	4.94	1.398
	ENVIRQUALY	4.97	1.326
Sustainable economy (endogenous)	SCALECON	4.80	1.329
	PRODUGAINS	5.04	1.266
	FLEETGROW	4.39	1.168
	ECONCOMP	4.67	1.214
	ECONGROW	4.44	1.149
Pollution impact	POLLSEA	4.17	1.417
	POLLWATER	4.06	1.408
	POLLAIR	3.37	1.405
Green efficiency	EFFICONSUM	5.31	1.306
	FUELTRAVEL	5.46	1.220
	CONGESPORT	5.18	1.388
	DESIGNEFFISHIP	4.49	1.307
Green management	RECYBOARD	3.72	1.193
	SHIPTECH	3.79	1.172
	WASTBOARD	4.15	1.181
	NOISEPORT	3.46	1.237
	RECYHARBOR	4.32	1.258
Moderate variables	TAX	4.90	1.407
	ENVSUSTAIN	5.20	1.339

4.2. Exploratory Analysis

First, the normality test of the variables was performed, followed by a factor analysis to determine the main reduced factors. SEM was used to evaluate the measurement model and the structural model. There was a lack of adequate results because some latent variables did not verify the assumptions of internal validity, and we proceeded to explain the endogenous variables based on the factors considered. An exploratory factor analysis followed to redefine the groups of variables. The results obtained were more qualitative and adequate, and we proceeded to a readapted confirmatory analysis.

Internal consistency and validity were determined for the latent variables [69,70] (Table 2). The following results of quality of fit of the SEM model were obtained: χ^2 = 344.431, df = 155, χ^2/df = 2.222, CFI = 0.935, NFI = 0.889, RMSEA = 0.08. The discriminant validity was confirmed [71,72] (r < 0.85), and the square root values of AVE (mean explained variation) of the latent variables were adequate.

**Table 2.** Correlation between latent variables and validity.

Latent Variables		AVE	1	2	3	4	5
Green shipping	2nd Lv	0.749					
Green efficiency	1	0.610	0.781				
Pollution impact	2	0.845	0.485	0.919			
Green management	3	0.669	0.564	0.773	0.818		
Sustainable economy	4	0.702	0.454	0.333	0.444	0.838	
Environmental performance	5	0.914	0.308	0.401	0.486	0.350	0.956
SQRT (AVE) on diagonal							

The content validity or face validity of the latent variables was verified, and the convergent validity higher than 0.5 (*p*-value < 0.01) [73,74]. The explanatory variables loadings are presented (Table 3).

Table 3. Explanatory variables loadings.

Construct	Variable	β	R^2
Environmental performance (endogenous)	ENVIPROTEC	0.99	0.98
	ENVIRONEFFI	0.98	0.96
	ENVIRQUALY	0.79	0.63
Sustainable economy (endogenous)	SCALECON	0.89	0.79
	PRODUGAINS	0.99	0.81
	FLEETGROW	0.71	0.54
	ECONCOMP	0.67	0.45
	ECONGROW	0.58	0.33
Pollution impact	POLLSEA	0.92	0.85
	POLLWATER	0.90	0.82
	POLLAIR	0.78	0.58
Green efficiency	EFFICONSUM	0.86	0.23
	FUELTRAVEL	0.74	0.55
	CONGESPORT	0.70	0.49
	DESIGNEFFISHIP	0.68	0.46
Green management	RECYBOARD	0.68	0.46
	SHIPTECH	0.86	0.74
	WASTBOARD	0.78	0.61
	NOISEPORT	0.58	0.34
	RECYHARBOR	0.76	0.57

The second level latent variable green shipping is reflected in the latent variables of first level green efficiency (β = 0.61; R^2 = 0.38), pollution impact (β = 0.80; R^2 = 0.64) and green management (β = 0.94; R^2 = 0.89). The structural model explaining the cause–effect relationships associates green shipping with the latent variable environmental performance (β = 0.52; R^2 = 0.27) and sustainable economy (β = 0.49; R^2 = 0.24) (Figure 2). The model obtained presented goodness of fit, χ^2 = 356.431, df = 160, χ^2/df = 2.228, CFI = 0.933, NFI = 0.886, RMSEA = 0.08 and unidimensional validity.
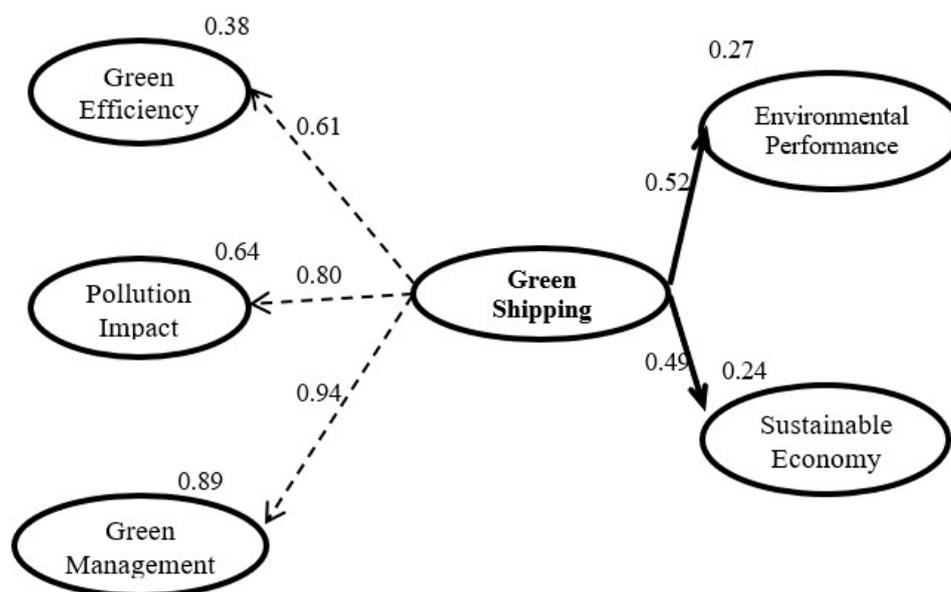
Figure 2. Structural SEM model (base).

In the base model, green management (β = 0.94; R^2 = 0.89) and the pollution impact (β = 0.80; R^2 = 0.64) strongly reflect the second level exogeneous latent variable Green shipping, also supported by ecological efficiency (β = 0.61; R^2 = 0.38). Green shipping

contributes especially to endogenous variables environmental performance (β = 0.52; R^2 = 0.27) and to the sustainable economy (β = 0.49, R^2 = 0.24).

When the moderator variable TAX was applied to the base model, a new model was obtained with a goodness of fit, χ^2 = 234.76, df = 160, χ^2/df = 1.467, CFI = 0.924, NFI = 0.800, RMSEA = 0.085, which confirms expectations concerning the control variable influence on the green shipping model through the type of variables and intensity of relationships (Figure 3).
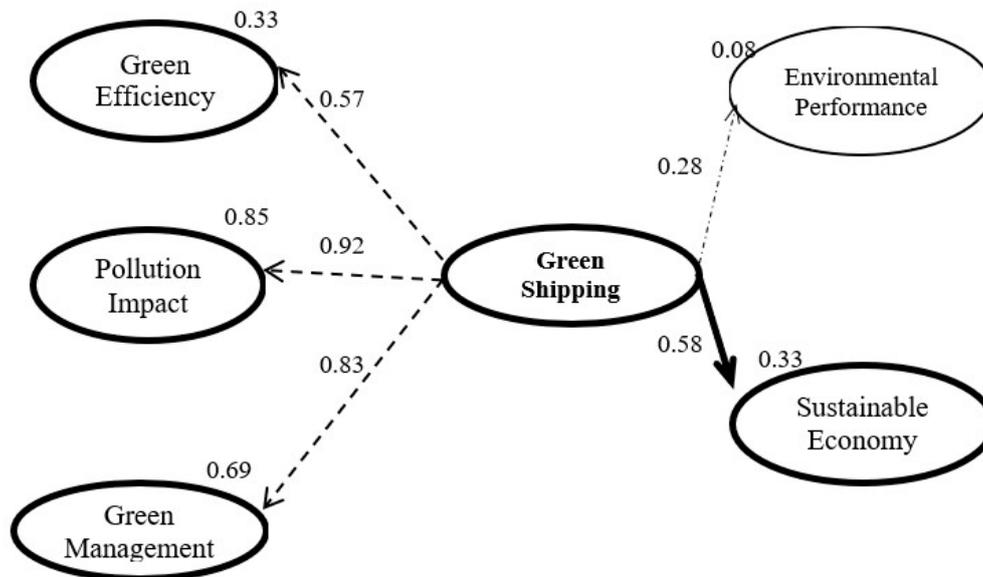

Figure 3. Structural SEM model (TAX).

Tax and financial incentives (TAX) interfere with Green shipping, accentuating the pollution impact (β = 0.92; R^2 = 0.85), while reducing the importance of Green management (β = 0.83; R^2 = 0.69) and green efficiency (β = 0.57; R^2 = 0.33), with effects on the sustainable economy (β = 0.58; R^2 = 0.33).

The moderating variable ENVSUSTAIN (environmental sustainability regulations) was also considered, thereby obtaining another new model with a goodness of fit, χ^2 = 233.337, df = 160, χ^2/df = 1.458, CFI = 0.935, NFI = 0.824, RMSEA = 0.077 (Figure 4). Both in the case of TAX and ENVSUSTAIN, the latent endogenous variable environmental performance has a low R^2 (0.08 and 0.10).

The regulation for environmental sustainability (ENSUSTAIN) affects green shipping relation with the pollution impact (β = 0.91; R^2 = 0.82) and contributes to reduce the importance of green management (β = 0.86; R^2 = 0.74) and green efficiency (β = 0.46; R^2 = 0.21). The effect of green shipping is felt in the sustainable economy (β = 0.66; R^2 = 0.43).

To better understand the importance of the development of green shipping, the direct effects of green efficiency, pollution impact, and green management on environmental performance, and sustainable economy were analyzed and the general model, the model moderated by fiscal and financial incentives (TAX) and the model moderated by the regulation for the sustainable economy (ENSUSTAIN).

The general model (Figure 5) shows important effects of green efficiency on the sustainable economy (β = 0.31; R^2 = 0.19) and the effect of green management on environmental performance (β = 0.39; R^2 = 0.17) e sustainable economy (β = 0.31; R^2 = 0.19).
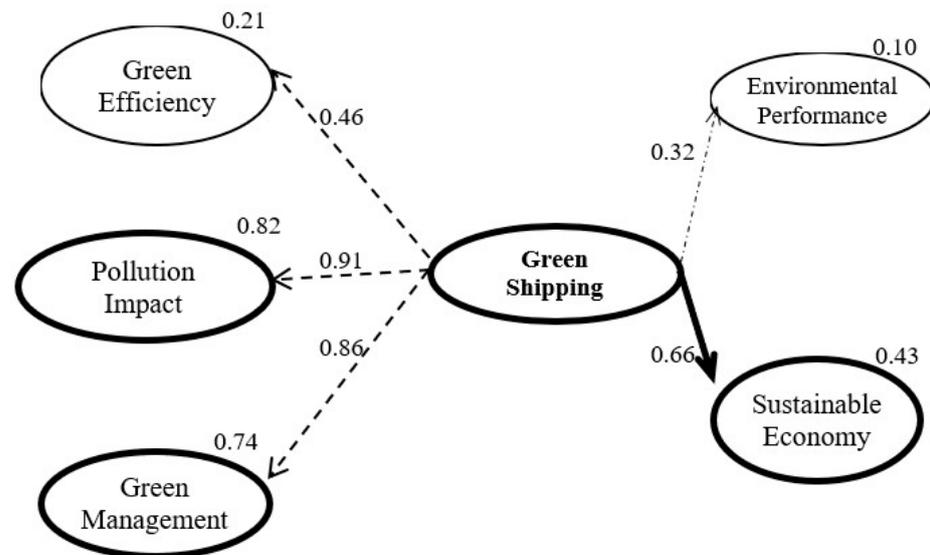
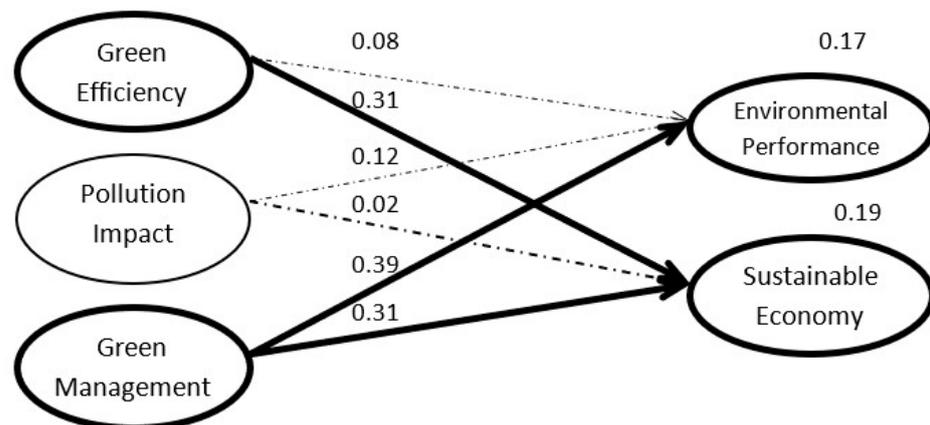**Figure 4.** Structural SEM model (ENVSUSTAIN).

Figure 5. General model with direct relations.

This general model of direct relationships between the variables that support green shipping with environmental performance and the sustainable economy clarifies the important role conferred to ecological management and the partial role of green efficiency. The pollution impact does not contribute to economic sustainability and environmental performance. Green management and the sustainable economy are the most important factors in green shipping. The model that supports green shipping (indirect relations) indicates, however, that the pollution impact is relevant, and that green management and green efficiency contribute to its management and control.

The model moderated by TAX (Figure 6) highlights the effect of green efficiency on environmental performance ($\beta = 0.20$; $R^2 = 0.06$) and on the sustainable economy ($\beta = 0.28$; $R^2 = 0.23$), and the effect of pollution impact on the sustainable economy ($\beta = 0.38$; $R^2 = 0.23$). This model obtained a goodness of fit, $\chi^2 = 304.80$, df = 159, $\chi^2/df = 1.917$, FMIN = 4176, GFI = 0.729, RMSEA = 0.112.

Moderated by the fiscal and financial incentives, the strong effect of green efficiency on the sustainable economy and environmental performance stands out, while, at the same time, the role of the pollution impact and its effect on the sustainable economy is highlighted. In the indirect relations model on which green shipping is based, this same phenomenon played out by the pollution impact on the sustainable economy is verified, which is evident in the direct relations model.
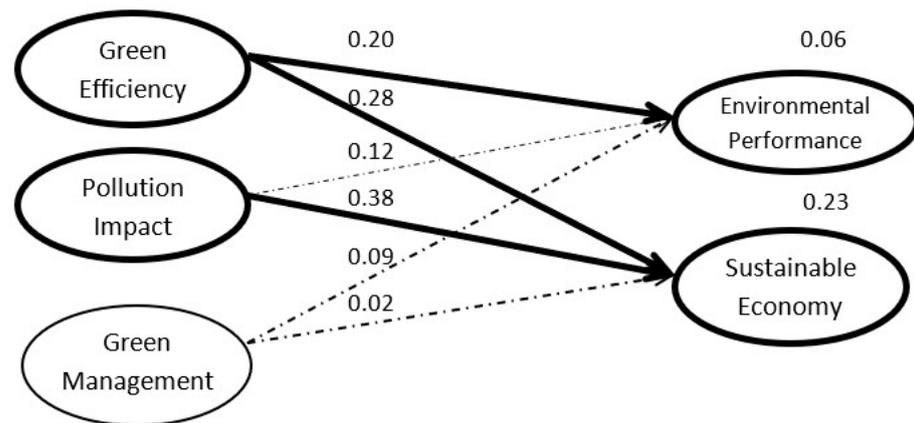
Figure 6. Model with direct relations moderated by TAX.

The model moderated by ENVSUSTAIN (Figure 7) shows important effects of green efficiency on the sustainable economy ($\beta = 0.20$; $R^2 = 0.21$), the effect of green management on environmental performance ($\beta = 0.25$; $R^2 = 0.07$) and sustainable economy ($\beta = 0.28$; $R^2 = 0.21$), and the effect of the pollution impact on the sustainable economy ($\beta = 0.31$, $R^2 = 0.21$). This model obtained a goodness of fit, $\chi^2 = 308.02$, df = 159, $\chi^2/df = 1.937$, FMIN = 3461, GFI = 0.771, RMSEA = 0.103.
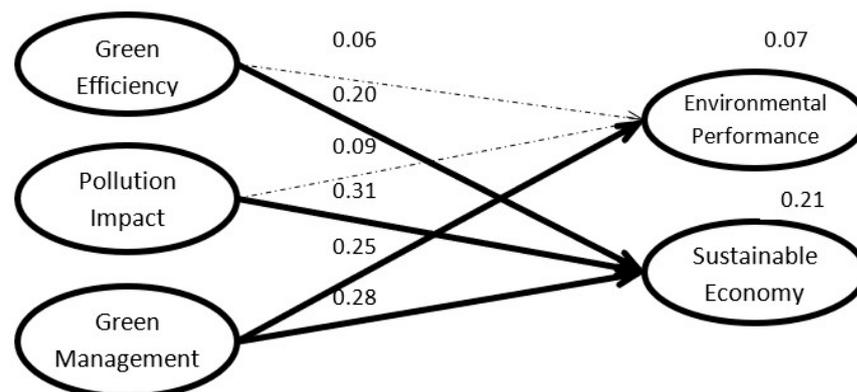

Figure 7. Model with direct relations moderated by ENVSUSTAIN.

With the model moderated by regulations for environmental sustainability, the factors that support green shipping and its strong influence on the sustainable economy stand out. Among the factors that gain greater influence on green management, with emphasis also on the impact of pollution.

5. Discussion

It can be clearly seen that, in the base model, green shipping is reflected on green management ($\beta = 0.94$; $R^2 = 0.89$), pollution impact ($\beta = 0.80$; $R^2 = 0.64$), and green efficiency ($\beta = 0.61$; $R^2 = 0.38$), albeit to different degrees, with a very high preponderance of the green management variable. The results therefore confirm Hypothesis 1. Several authors [29,30,46,58] confirm the impact of pollution on green shipping, arising from solid and liquid sediments from routine operations and air pollution by ships, together with the efficiency of ships in terms of technology used and its consumption that the literature [27,41,42] considers essential to green shipping and green management.

The base model shows that the green shipping influences sustainable economy ($\beta = 0.49$; $R^2 = 0.24$), and environmental performance ($\beta = 0.52$; $R^2 = 0.27$). In the same vein, ref. [50] stresses the current paramount importance of the sustainable economy to preserve the future and safeguard the needs and aspirations of future generations. Ref-

erences [53,55,56] also emphasize the role of environmental issues and the rising cost of environmental protection for sustainable development and competitiveness. According to [54], in the case of port cities, environmental issues are of utmost importance because ships are major sources of pollution, but [57] indicates that there is no evidence that the benefits exceed the costs of environmental protection initiatives. However, [59] admits that it may be possible to improve business performance and reduce the negative effects using environmental management. Key players, such as the IMO, admit that shipping emissions are expected to double by 2050. Hypothesis 2 and Hypothesis 3 are therefore confirmed.

The introduction of tax and financial incentives on the green shipping model promotes changes in the base model. Green shipping reveals a greater preponderance of pollution impact $[(\beta = 0.80; R^2 = 0.64) \rightarrow (\beta = 0.92; R^2 = 0.85)]$ and a lower preponderance of green management $[(\beta = 0.94; R^2 = 0.89) \rightarrow (\beta = 0.83; R^2 = 0.69)]$. In turn, green shipping increases the influence on sustainable economy $[(\beta = 0.49; R^2 = 0.24) \rightarrow (\beta = 0.58; R^2 = 0.33)]$ and decreases its influence on environmental performance $[(\beta = 0.52, R^2 = 0.27) \rightarrow (\beta = 0.28; R^2 = 0.08)]$. In the direct relations model, fiscal and financial incentives moderate the relationship between green efficiency and pollution impact centered mainly on the sustainable economy. In the maritime industry, different authors [54,61,62,64] find a positive influence of the adoption of economic and financial incentives such as pollution taxes, charges, tradable certificates, governmental subsidies, to encourage less polluting and more environmentally friendly alternatives. The European Union encourages the green shipping adoption of rates to ship waste recycling [66]. The results confirm Hypothesis 4.

The demand for greater environmental sustainability through regulatory measures, including the introduction of LNG-engines, affects the green shipping model. Changes in this model in comparison to the base model can be observed, as there is a greater preponderance of pollution impact $[(\beta = 0.80; R^2 = 0.64) \rightarrow (\beta = 0.91; R^2 = 0.82)]$ and a lower preponderance of green management $[(\beta = 0.94; R^2 = 0.89) \rightarrow (\beta = 0.86; R^2 = 0.74)]$ and green efficiency $[(\beta = 0.61; R^2 = 0.38) \rightarrow (\beta = 0.46; R^2 = 0.21)]$ in green shipping. In turn, green shipping increases its' influence on the sustainable economy $[(\beta = 0.49; R^2 = 0.24) \rightarrow (\beta = 0.66; R^2 = 0.43)]$ and decreases in environmental performance $[(\beta = 0.52; R^2 = 0.27) \rightarrow (\beta = 0.32; R^2 = 0.10)]$. In the moderated model of regulation for environmental sustainability, the direct relationship of green shipping factors is established with the sustainable economy. Green management and ecological efficiency absorb the impact of pollution. These results confirm Hypothesis 5. [31] claim that liquid natural gas engines (LNG) do not produce the SOx emissions and makes NOx and PM emissions negligible the. For [32], LNG is the cheaper solution in the longer term. However, LNG-engines are not yet common on ships [33,34].

In short, the introduction of tax and financial incentives to reduce the impact of pollution and the adoption of regulations promoting sound environmental practices to defend the shipping green have strong positive effects in reducing pollution with also a positive impact on sustainable economy. However, their impact reduces the importance of green management and green efficiency with consequences also in terms of reducing environmental performance.

6. Conclusions, Contributions, and Future Research

This study shows that the sustainable economy, notably based on the economy of scale of ships, fleet growth and productivity gains, and the environmental performance based on environmental protection and quality, are influenced by green shipping. The green management associated with the recycling of materials and waste and the type of equipment used by the ships, and the pollution impact on sea and air by ships are preponderant in identifying green shipping, which also contributes to green efficiency derived from fuel consumption, traffic congestion, and ship design.

It is confirmed that tax and financial incentives granted to ship-owners and attention paid to best practices in environmental sustainability regulations impact environmental

performance even further and strongly and positively increase the importance given to pollution. The effect of the weakening of environmental management practices in the case of low tax and financial incentives and lower environmental efficiency is closely associated with this important conclusion because owners fail to meet the effect of good practices for environmental sustainability.

The main contribution to the literature and management practice lies in the influence of tax and financial incentives in the model and the effects of adopting rules for environmental practices, which show a greater recognition of the importance of the impact of pollution on green shipping with positive effects for the sustainable economy. Another important contribution to the adoption of fiscal and financial incentives and better regulatory environmental practices stems from the less importance attributed to green management and green efficiency with lesser effects on environmental performance, when there are no such fiscal and regulatory practices.

Another important contribution is to verify that green management and green efficiency contribute to controlling the impact of pollution with practical effects on economic sustainability.

In future research, a larger number of green shipping factors should be examined along with their effect on sustainable economy, and environmental performance. The evaluation of this model in different contexts, should contribute to a better understanding of the type of relationship between the factors include in the model.

Author Contributions: Conceptualization, J.A.F.; methodology, J.A.F., R.R. and V.C. validation, R.R.; formal analysis, V.C.; investigation, J.A.F.; writing—original draft preparation, J.A.F. and V.C.; writing—review and editing, R.R.; visualization, J.A.F.; project administration, J.A.F.; software and data curation, V.C.; All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement: Not Applicable.

Informed Consent Statement: Not Applicable.

Data Availability Statement: Not Applicable.

References

1. Ostrom, E. The Challenge of Common-Pool Resources. *Environ. Sci. Policy Sustain. Dev.* **2008**, *50*, 8–20. [CrossRef]
2. Kaiser, W.; Meyer, J.-H. *International Organizations and Environmental Protection: Conservation and Globalization in the Twentieth Century*; Berghahn Books: New York, NY, USA, 2016.
3. Lun, Y.H.V.; Pang, K.W.; Panayides, P.M. Organizational growth and firm performance in the international container shipping industry. *Int. J. Shipp. Transp. Logist.* **2010**, *2*, 206–223. [CrossRef]
4. Lam, J.S.L. Designing a sustainable maritime supply chain: A hybrid QFD–ANP approach. *Transp. Res. Part E Logist. Transp. Rev.* **2015**, *78*, 70–81. [CrossRef]
5. Poulsen, R.T.; Ponte, S.; Lister, J. Buyer-driven greening? Cargo-owners and environmental upgrading in maritime shipping. *Geoforum* **2016**, *68*, 57–68. [CrossRef]
6. Viana, M.; Amato, F.; Alastuey, A.; Querol, X.; Moreno, T.; Dos Santos, S.G.; Herce, M.D.; Fernández-Patier, R. Chemical Tracers of Particulate Emissions from Commercial Shipping. *Environ. Sci. Technol.* **2009**, *43*, 7472–7477. [CrossRef] [PubMed]
7. Lun, Y.H.V.; Lai, K.-H.; Wong, C.W.; Cheng, T.C. *Green Shipping Management*; Springer International Publishing: Geneva, Switzerland, 2016.
8. Poulsen, R.T.; Johnson, H. The logic of business vs. the logic of energy management practice: Understanding the choices and effects of energy consumption monitoring systems in shipping companies. *J. Clean. Prod.* **2016**, *112*, 3785–3797. [CrossRef]
9. Ellram, L.; Murfield, M. Environmental Sustainability in Freight Transportation: A Systematic Literature Review and Agenda for Future Research. *Transp. J.* **2017**, *5*, 263–298. [CrossRef]
10. Boyd, D.R.; Suzuki, D.T. *Suzuki's Green Guide*; Allen & Unwin: Melbourne, Australia, 2008.
11. Goodin, R. *Green Political Theory*; Routledge: London, UK, 1992.
12. Jun, L.; Yuguo, Z. Green theory research and practice on indoor air pollution by overall process controlling. *Inf. Comput. Appl.* **2011**, *243*, 651–656.
13. Dittrich, M.; Bringezu, S. The physical dimension of international trade, part 1: Direct global flows between 1962 and 2005. *Ecol. Econ.* **2010**, *69*, 1838–1847. [CrossRef]

14. Corbett, J.J.; Fischbeck, P.S.; Pandis, S.N. Global nitrogen and sulphur inventories for oceangoing ships. *J. Geophys. Res.* **1999**, *104*, 3457–3470. [CrossRef]

15. Endresen, Ø.; Sørgård, E.; Sundet, J.K.; Dalsøren, S.B.; Isaksen, I.S.A.; Berglen, T.F.; Gravir, G. Emission from international sea transportation and environmental impact. *J. Geophys. Res.* **2003**, *108*, 456. [CrossRef]

16. Eyring, V.; Köhler, H.W.; Van Aardenne, J.; Lauer, A. Emissions from international shipping: 1. The last 50 years. *J. Geophys. Res. Atmos.* **2005**, *110*, D17305. [CrossRef]

17. Fan, Q.; Zhang, Y.; Ma, W.; Ma, H.; Feng, J.; Yu, Q.; Yang, X.; Ng, S.K.W.; Fu, Q.; Chen, L. Spatial and Seasonal Dynamics of Ship Emissions over the Yangtze River Delta and East China Sea and Their Potential Environmental Influence. *Environ. Sci. Technol.* **2016**, *50*, 1322–1329. [CrossRef] [PubMed]

18. Eyring, V.; Kohler, H.W.; Lauer, A.; Lemper, B. Emissions from international shipping: 2. Impact of future technologies on scenarios until 2050. *J. Geophys. Res. Atmos.* **2005**, *110*, D17306. [CrossRef]

19. Chen, Z. Green technology and environmental standards. In Proceedings of the CIRP International Symposium—Advanced Design and Manufacture in the Global Manufacturing Era, Hong Kong, China, 21–22 August 1997; pp. 425–434.

20. Hyvättinen, H.; Hildén, M. Environmental policies and marine engines—Effects on the development and adoption of innovations. *Mar. Policy* **2004**, *28*, 491–502. [CrossRef]

21. Loureiro, M.L.; Ribas, A.; López, E.; Ojea, E. Estimated costs and admissible claims linked to the Prestige oil spill. *Ecol. Econ.* **2006**, *59*, 48–63. [CrossRef]

22. Toffoli, A.; Lefèvre, J.; Bitner-Gregersen, E.; Monbaliu, J. Towards the identification of warning criteria: Analysis of a ship accident database. *Appl. Ocean Res.* **2005**, *27*, 281–291. [CrossRef]

23. Tsamboulas, D.; Mikroudis, G. EFECT—Evaluation framework of environmental impacts and costs of transport initiatives. *Transp. Res. Part D Transp. Environ.* **2000**, *5*, 283–303. [CrossRef]

24. Vieira, J.; Moura, F.; Viegas, J.M. Transport policy and environmental impacts: The importance of multi-instrumentality in policy integration. *Transp. Policy* **2007**, *14*, 421–432. [CrossRef]

25. Lee, T.; Nam, H. A Study on Green Shipping in Major Countries: In the View of Shipyards, Shipping Companies, Ports, and Policies. *Asian J. Shipp. Logist.* **2017**, *33*, 253–262. [CrossRef]

26. Lai, K.-H.; Luna, V.Y.; Wong, C.W.; Cheng, T.C. Green shipping practices in the shipping industry: Conceptualization, adoption, and implications. *Resour. Conserv. Recycl.* **2011**, *55*, 631–638. [CrossRef]

27. Shi, W.; Xiao, Y.; Chen, Z.; McLaughlin, H.; Li, K.X. Evolution of green shipping research: Themes and methods. *Marit. Policy Manag.* **2018**, 1–14. [CrossRef]

28. Hjelle, H.M. Short sea shipping's green label at risk. *Transp. Rev.* **2010**, *30*, 617–640. [CrossRef]

29. Darbra, R.; Pittam, N.; Royston, K.; Darbra, J.; Journee, H. Survey on environmental monitoring requirements of European ports. *J. Environ. Manag.* **2009**, *90*, 1396–1403. [CrossRef]

30. Helfre, J.-F.; Boot, P.C. Emission Reduction in the Shipping Industry: Regulations, Exposure and Solutions, Sustainalytics. 2013. Available online: www.sustainalytics.com (accessed on 8 April 2020).

31. Kassar, M. LNG as a Marine Fuel in Malta: Case Study: Regulatory Analysis and Potential Scenarios for LNG Bunkering Infrastructure. Available online: https://commons.wmu.se/all_dissertations/573 (accessed on 5 March 2021).

32. Bijlsma Projects, B.V. LNG project Layman report, (Lemmer), LIFE03 ENV/NL/000474. 2005. Available online: https://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=LIFE03_ENV_NL_000474_LAYMAN.pdf (accessed on 8 April 2021).

33. Northern European Ports Spearhead Move to Gas as Ship Fuel. Available online: https://www.reuters.com/article/energy-gas-transport-idUSL6N0BS6ZM20130305 (accessed on 8 April 2021).

34. Van Hock, R.I.; Erasmus, I. From reversed logistics to green supply chains. *Logist. Solut.* **2000**, *2*, 28–33. [CrossRef]

35. Wang, L.; Zhou, Z.; Yang, Y.; Wu, J. Green efficiency evaluation and improvement of Chinese ports: A cross-efficiency model. *Transp. Res. Part D Transp. Environ.* **2020**, *88*. [CrossRef]

36. Starik, M.; Marcus, A. New research directions in the field of management of organizations in the natural environment. *Acad. Manag. J.* **2000**, *43*, 539–546.

37. Kang, C.-C.; Khan, H.A.; Feng, C.-M.; Wu, C.-C. Efficiency evaluation of bus transit firms with and without consideration of environmental air-pollution emissions. *Transp. Res. Part D Transp. Environ.* **2017**, *50*, 505–519. [CrossRef]

38. Song, M.; Zheng, W.; Wang, Z. Environmental efficiency and energy consumption of highway transportation systems in China. *Int. J. Prod. Econ.* **2015**, *181*, 441–449. [CrossRef]

39. Tovar, B.; Wall, A. Environmental efficiency for a cross-section of Spanish port authorities. *Transp. Res. Part D Transp. Environ.* **2019**, *75*, 170–178. [CrossRef]

40. Hellström, T. Dimensions of environmentally sustainable innovation: The structure of eco-innovation concepts. *Sustain. Dev.* **2007**, *15*, 148–159. [CrossRef]

41. Machiba, T. Eco-innovation for enabling resource efficiency and green growth: Development of an analytical framework and preliminary analysis of industry and policy practices. *Int. Econ. Econ. Policy* **2010**, *7*, 357–370. [CrossRef]

42. Chang, Y.-T.; Danao, D. Green Shipping Practices of Shipping Firms. *Sustainability* **2017**, *9*, 829. [CrossRef]

43. Barry, J. Green Political Theory: Nature, Virtue and Progress. Ph.D. Thesis, University of Glasgow, Glasgow, UK, 1996.

44. Habermas, J. Citizenship and national identity: Some reflections on the future of Europe. *Praxis Int.* **1992**, *12*, 1–19.

45. Ng, A.K.Y.; Song, S. The environmental impacts of pollutants generated by routine shipping operations on ports. *Ocean Coast. Manag.* **2010**, *53*, 301–311. [CrossRef]

46. Walker, T.R.; Adebambo, O.; Del, M. Environmental Effects of Marine Transportation. In *Word Seas: An Environmental Evaluation*, 2nd ed.; Elsevier: Amsterdam, The Netherlands, 2018; Chapter 27.

47. Cariou, P.; Parola, F.; Notteboom, T. Towards low carbon global supply chains: A multi-trade analysis of CO2 emission reductions in container shipping. *Int. J. Prod. Econ.* **2019**, *208*, 17–28. [CrossRef]

48. Ashford, N.A.; Hall, R.P. The Importance of Regulation-Induced Innovation for Sustainable Development. *Sustainability* **2011**, *3*, 270–292. [CrossRef]

49. Walker, T.R. Green Marine: An environmental program to establish sustainability in marine transportation. *Mar. Pollut. Bull.* **2016**, *105*, 199–207. [CrossRef]

50. UNEP. The Emissions Gap Report 2012. Available online: https://digitallibrary.un.org/record/3894834/files/EGR2012.pdf (accessed on 8 April 2021).

51. O'Brien, C. Global manufacturing and the sustainable economy. *Int. J. Prod. Res.* **2002**, *40*, 3867–3877. [CrossRef]

52. Bevilacqua, M.; Ciarapica, F.E.; Giacchetta, G. Development of sustainable product life cycle in manufacturing firms: A case study. *Int. J. Prod. Res.* **2007**, *45*, 4073–4098. [CrossRef]

53. Cofala, J.; Amann, M.; Hayes, C.; Wagner, F.; Klimont, Z.; Posch, M.; Schopp, W.; Tarrason, N.; Jonson, J.E.; Whall, C.; et al. *Analysis of Policy Measures to Reduce Ship Emissions in the Context of the Revision of National Emission Ceilings Directive*; International Institute for Applied Systems Analysis (IIASA): Laxenburg, Austria, 2007.

54. Christmann, P. Effects of "best practices" of environmental management on cost advantage: The role of complementary assets. *Acad. Manag. J.* **2000**, *43*, 663–680. [CrossRef]

55. Farrell, A.; Redman, D.H.; Corbett, J.J.; Winebrake, J.J. Comparing air pollution from ferry and landside commuting. *Transp. Res. D Energy Environ.* **2003**, *8*, 343–360. [CrossRef]

56. Montabon, F.; Sroufe, R.; Narasimhan, R. An examination of corporate reporting, environmental management practices and firm performance. *J. Oper. Manag.* **2007**, *25*, 998–1014. [CrossRef]

57. Winebrake, J.J.; Corbett, J.J.; Green, E.H.; Lauer, A.; Eyring, V. Mitigating the Health Impacts of Pollution from Oceangoing Shipping: An Assessment of Low-Sulfur Fuel Mandates. *Environ. Sci. Technol.* **2009**, *43*, 4776–4782. [CrossRef] [PubMed]

58. Shrivastava, P. Environmental technologies and competitive advantage. *Strat. Manag. J.* **1995**, *6*, 183–200. [CrossRef]

59. Lun, Y.H.V.; Lai, K.-H.; Wong, C.W.Y.; Cheng, T.C.E. Green shipping practices and firm performance. *Marit. Policy Manag.* **2014**, *41*, 134–148. [CrossRef]

60. Seik, F.T. Urban environmental policy—The use of regulatory and economic instruments in Singapore. *Habitat Int.* **1996**, *20*, 5–22. [CrossRef]

61. Stavins, R.N. Experience with market-based environmental policy instruments. In *Handbook of Environmental Economics*; Mäler, K.-G., Vincent, J., Eds.; Elsevier Science: Amsterdam, The Netherlands, 2002.

62. Kågeson, P. *Economic Instruments for Reducing Emissions from Sea Transport*; Swedish NGO Secretariat on Acid Rain: Goteborg, Sweden; The European Federation for Transport and Environment (T&E) and The European Environmental Bureau (EEB): Brussels, Belgium, 1999.

63. Volk, B.; Hader, G.A.; Zachcial, M. *Incentive-Based Instruments for Environmentally Acceptable Sea Transportation*; Institute of Shipping Economics and Logistics: Bremen, Germany, 2000.

64. Harrington, W.; Morgenstern, R.D. Economic incentives versus command and control. *Resources* **2004**, *152*, 13–17.

65. Mathiesen, T.-C. The human element in environmental protection. *Mar. Pollut. Bull.* **1994**, *29*, 375–377. [CrossRef]

66. Nagarseth, P. Ship recycling. In *Shipping, Marine & Ports Exposition*; Deloitte: London, UK, 2012.

67. Hoyle, R.H. The structural equation modelling approach: Basic concepts and fundamental issues. In *Structural Equation Modelling: Concepts, Issues, and Applications*; Hoyle, R.H., Ed.; Sage Publications Inc.: Thousand Oaks, CA, USA, 1995; pp. 1–15.

68. Jöreskog, K.; Sörbom, D. *LISREL 8: Structural Equation Modelling with the SIMPLIS Command Language*; Scientific Software International Inc.: Chicago, IL, USA, 1993.

69. Hair, J.F., Jr.; Anderson, R.E.; Tatham, R.L.; Black, W.C. *Multivariate Data Analysis*, 5th ed.; Prentice-Hall: Hoboken, NJ, USA, 1998.

70. Tabachnick, B.G.; Fidell, L.S. *Using Multivariate Statistics*; Allyn and Bacon: Boston, MA, USA, 2001.

71. Fornell, C.; Larcker, D.F. Evaluating structural equation models with unobservable variables and measurement error. *J. Mark. Res.* **1981**, *18*, 39–50. [CrossRef]

72. Kline, R.B. *Principles and Practice of Structural Equation Modelling*, 2nd ed.; The Guilford Press: New York, NY, USA, 2005.

73. Anderson, J.C.; Gerbing, D.W.; Hunter, J.E. On the assessment of unidimensional measurement: Internal and external consistency, and overall consistency criteria. *J. Mark. Res.* **1987**, *24*, 432–437. [CrossRef]

74. Garver, M.S.; Mentzer, J.T. Logistics research methods: Employing structural equation modelling to test for construct validity. *J. Bus. Logist.* **1999**, *20*, 33–57.