INTERNATIONAL REGULATIONS AND SUSTAINABLE DEVELOPMENT IN TOURISTIC EUROPEAN PORT'S EFFICIENCY AFTER THE PANDEMIC

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Abstract

The port's adoption of environmental criteria and the incorporation of sustainable activities involves numerous challenging issues, such as limiting emissions caused by current and upcoming port operations. One of the three dimensions of sustainability that have been specified by Souza and Alves (2018) is environmental sustainability. On the other hand, the public authorities and the wider community have put strong pressure on ports to fulfil their social responsibility (De Grosbois, 2016). The current study aims to promote the linkage of the largest European port's efficiency with environmental regulations and the International Convention for the Prevention of Pollution from Ships (MARPOL). Previous studies have examined the effect of basic individual environmental factors on the port's effectiveness. The innovation of the study focuses on the relation of MARPOL regulations to the port's efficiency as well as several environmental guidelines and sustainable development goals after the pandemic. It is the first study that incorporates efficiency variables with climatology programs, safe and healthy environmental variables, global reporting initiatives, and MARPOL Annexes. The basis of the data is the top twenty ports obtained from Eurostat and processed using multiple regression analysis.

Keywords: MARPOL, Sustainability Development, Environment, Pollution Control Adoption and Costs, Climate, Tourism, Development

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1. INTRODUCTION

The pollution that is being caused in the seas is coming not only from land-based sources (restaurants, touristic businesses, hotels, etc.) but also from the ports themselves through their various infrastructures and marine traffic (Cheon, 2017). Throughout the years there has been a great insert of hazardous substances in the ecosystem via maritime activities. Europe is mainly wet by the Mediterranean, the Atlantic, and the Baltic Sea. All of them are important touristic passages (Roh et al., 2016), especially the Mediterranean Sea which is considered to provide the most frequent route for global maritime transport (Eurostat, 2011). The sustainability of touristic ports has become rather crucial not only for the protection of coastal waters but also for the hygiene these ports provide to tourists (Di Vaio & Varriale, 2018). The current study aims to investigate on the one hand the correlation between revenues and sustainability variables and on the other hand net profits with environmental regulations. Using multiple regression analysis innovative results are being developed for the years 2020 and 2021. It is the first study in literature so far that incorporates international regulations such as MARPOL (International Convention for the Prevention of Pollution from Ships) in its dataset alongside environmental variables such as global performance indicators (GRI), sustainable development goals (SDGs), etc. The results of the two consecutive years are consistent with each other, providing evidence that environmental and sustainability variables, give the same sign when they are related to profits and revenues.

The structure of the paper is as follows. Section 2 refers to the literature review of sustainability importance, whereas Section 3 refers to the research methodology of the paper. Section 4 describes the data used in the analysis and presents the sustainability variables of the current research in detail. Following, Section 5 provides the analysis of the results for 2020 and 2021. Lastly, Section 6 concludes the main findings of the paper.

2. LITERATURE REVIEW

All port stakeholders, policymakers, port users, tourists, and local communities must invest resources to achieve sustainability but at the same time, they must achieve effectiveness. In other words, not only they must use appropriately their basic resources to maintain environmental standards, but they must also produce profit out of the maritime and touristic operations at the same time. Port sustainability is a crucial matter that is highlighted by the World's Association for Waterborne Transport Infrastructure (PIANC, 2014) and by Cheon et al. (2017) who link sustainability with the fulfillment of social needs that a port may cover. Port's sustainability will be attained if environmental and social consciousness is addressed. These goals are interrelated and interconnected. If for example, a port has developed actions to minimize CO2 emissions, it simultaneously looks after environmental and social sustainability. Proactive practices and green policies followed by ports add value to the ports' sustainable routes (Davarzani et al., 2016). In the current paper sustainability will be represented by environmental variables such as *Climate and Energy*, *Environmental Performance Indicators*, *Climate Programs*, the usage of *Next Generation Fuels*, the existence of *Safety and Healthy Environment* procedures followed by the port's personnel, *Bio* clustered technologies adopted by ports, *Measures* activities that assist port's everyday activities. Alongside these variables, *Digitalization and Mobility Offered for Employees* will highlight the social consciousness of ports as this variable shows how accessible and easy it is for the employees to track certain information for their daily activities through technological systems. Last but least, the *Global Reporting Initiative (GRI)* and the opportunity for ports to accept ships that are certified by *MARPOL* are extra variables that measure the environmental consciousness of certified ports that are aligned with European guidelines. As such these variables are more robust to our dataset.

3. RESEARCH METHODOLOGY

The data were processed using the SPSS Statistics (version 27) program from Windows. To obtain the basic data for the study, a descriptive statistics analysis was performed, in order to summarize and describe the main features of the dataset, such as its central tendency, variability, and distribution. These methods provide an overview of the data and help identify patterns and relationships.

Then, Fisher's exact test, a non-parametric method, was used to determine if there are non-random associations between two categorical variables. It is an exact test (returns exact p-value) and can be applied to smaller sample sizes. The null hypothesis[1] is that the relative proportions of one ordinal variable are independent of the second variable.

Finally, a multiple regression (extension of simple linear regression) is applied. Multiple regression includes a family of techniques that can be used to explore the relationship between one continuous dependent variable and a number of independent variables or predictors. Multiple regression can be used to answer questions such as:

- how well a set of variables can predict a particular outcome;
- which variable in a set of variables is the best predictor of an outcome;
- whether a particular predictor variable is still able to predict an outcome when the effects of another variable are controlled for.

4. DATASET AND SUSTAINABILITY VARIABLES

4.1. Data sources

The data in this study are based on the dataset used in the research of Koskeridi and Balla (2023). That is all data were retrieved from the port's official websites, Sustainability Report, Port Environmental Reports, Port Environmental Reviews, and Master Plans. As far as the financial variables these were retrieved from the ports' financial statements on their official websites. The dataset ranges from 2020 to 2021 capturing the trigger event of the pandemic. Table A.1 (in Appendix) shows the Eurostat selective list of the twenty largest container handling ports in the last decade. Having selected data from the 80% of the Eurostat port's list we combined those with sustainability and efficiency variables explained in the following section. Table 1 shows the names of the ports as well as the year that sustainability and efficiency variables were retrieved from the aforementioned resources. The variables data were in the year 2020 or 2021 depending on the environmental report's year, since the necessity to publicize these reports is not mandatory on an annual basis. In other words, it was not possible to select all ports' data from years 2020 and 2021 enlarging the dataset, since there are no reports in every following year. Therefore, Table 1 shows the ports that were ultimately retained in the analysis, along with their country of origin and the date the report was issued. The first column "*Rank in 2018*" shows the exact place in ranking regarding the amount of handling containers from Eurostat.

[1] https://www.statisticshowto.com/probability-and-statistics/null-hypothesis/

Table 1. Ports in dataset

*Ranking in 2018**	*Date of Issue*	*Port*	*Country*
1	2020	Rotterdam	Netherlands
2	2021	Antwerp	Belgium
3	2020	Hamburg	Germany
4	2021	Bremen-Bremerhaven	
6	2020	Piraeus	Greece
13	2020	Genoa	Italy
19	2020	La Spezia	
9	2021	Felixstowe	United Kingdom
14	2021	Southampton	
17	2021	London	
18	2020	Mersin	Turkey
15	2020	Sines	Portugal
16	2021	Gdansk	Poland
5	2021	Valencia	Spain
7	2020	Algeciras	
10	2020	Barcelona	

Note: (*) Data source — Eurostat (2018).

4.2. Sustainability variables

The variables used in the data analysis are shown below in Table 2. All variables (except "*Measures*", "*Next Generation Fuels*", "*Database Programs*" and "*Climate Programs*") contain sub-variables (see Table A.2 in the Appendix). Koskeridi and Balla (2023) as well as Laxe et al. (2017) proved that these variables in aggregate provide fruitful insights into the environmental management each port follows.

Table 2. Environmental and sustainability variables

No.	*Variables*
1.	*Safe and Healthy Environment*
2.	*Climate and Energy*
3.	*Digitalization and Mobility Offered for Employees*
4.	*Measures*
5.	*Next Generation Fuels*
6.	*Bio*
7.	*Environmental Performance Indicator*
8.	*Database Programs*
9.	*Climate Programs*
10.	*Sustainable Development Goals (SDGs)*
11.	*Global Reporting Initiative (GRI)*
12.	*MARPOL*

4.2.1. Safety and healthy environment

This variable (*Safe and Healthy Environment*) exposes the quality of flood risk management, the number of organized truck stops, discounts for clean shipping that some ports may offer to ships, and the existence of electronic sensors. Ports of Rotterdam, Antwerp, and Bremen-Bremerhaven are bigger and as such are expected to demonstrate better safety regulations contributing 14% to the overall index. For example, the existence of "Bird Valley" in Rotterdam's port, where many different species of coastal birds and singing birds can be found living in the valley, or the creation of a "spawning zone" at the port of Antwerp which is used for the reproduction of fish that makes smooth quay walls rougher to create a refuge where small aquatic animals could live are major examples. Also, in the port of Bremen-Bremerhaven, there is the *Lune-Plate* (an official EU bird habitat), and the nearby river of Billerbeck which is suitable as a habitat for plants and animals is another important example as well. On the contrary, there are other ports that contribute at minimum levels like Le Havre port or Algeciras port (Koskeridi & Balla, 2023). The subcategories are presented in the Appendix (see Table A.2).

4.2.2. Climate and energy

This variable outlines the energy usage (solar, wind, electric) of each European port. Steam/shore power, is a technique that reduces emissions, improving air quality at the same time while reducing noise pollution. The usage of LED lights and the port's carbon footprint are also included in this criterion. Finally, through ISO[2] and PERS[3] certifications each port's energy management is measured as an environmental review tool. Ports of Rotterdam, Southampton, and London are the ones with the highest percentage in this criterion. The subcategories are presented in the Appendix (see Table A.2).

4.2.3. Digitalization and mobility offered for employees

This powerful tool provides information about possible mistakes and omissions prevention in the information system. Some examples are the estimation of the project's duration or the assessment of the infrastructure damage. Furthermore, it encompasses data about the organization of the traffic with the use of autonomous vehicles, drones, etc., or data about eco-transport for the employees (e.g., the Bike Bus of the Port of Antwerp-Bruges or the Waterbus). The first place is taken by the port of Antwerp followed by the port of Hamburg. The subcategories are presented in the Appendix (see Table A.2).

4.2.4. Measures

This variable in turn captures whether there are any extra activities related to green policies (UNCTAD 2019, 2020). Energy neutral buildings (triple glazing, heat, cold storage, and underfloor heating), new types of asphalt, 24-hour air quality monitoring stations, and chargers for e-bikes are some of the information that are revealed. None of the ports fulfil this criterion.

4.2.5. Next generation fuels

Green hydrogen, blue hydrogen, gas to liquids (GTL), or biokerosene are different types of diesel fuels that are considered to pollute the environment at a minimum level. These types of fuels are called *fuels of next generation*. Several ports have moved to next generation fuels such as the port of Rotterdam, Antwerp, Hamburg, and Southampton.

[2] ISO certification is a seal of approval from a third-party body that a company runs to one of the international standards developed and published by the International Organization for Standardization (ISO). The ISO are an independent, non-governmental international organization who brings together experts to share knowledge and develop international standards that support innovation and provide solutions to global challenges. ISO Quality Services LTD (see https://www.isoqsltd.com/faq/).

[3] The Port Environmental Review System (PERS) does not only incorporate the main general requirements of recognized environmental management standards (e.g. ISO 14001), but also takes into account the specifics of ports. PERS builds upon the policy recommendations of the European Sea Ports Organization (ESPO) and sets clear goals for ports to work towards. The PERS certification is valid for 2 years (see https://www.ecoports.com/pers).

4.2.6. Bio

Some ports have adopted advanced technologies that assist them in reusing and exchanging their raw materials (bio-based cluster) such as plastic waste, reuse of water, etc. In addition to that, there are other ports that have new technologies that entail vessels that collect waste and plastic (separating them as well) and they have adopted a land waste management system (Recycling Hub). On the other hand, there are ports like that of Rotterdam that have created 250-hectare depots for contaminated dredged material, or that of Antwerp and Bremen-Bremerhaven that have adopted related technologies (*Clean Port*). Once again, the port of Antwerp comes first in this criterion incorporating circular chemistry (*Economic* subvariable) as a quite large port adopting other environmental protection measures as well. The subcategories are presented in the Appendix (see Table A.2).

4.2.7. Environmental performance indicators

This variable (sub-variables) contains information about the safety of the port environment, accident prevention, the amount of air emissions, the energy transition, the odour nuisance, noise pollution, and the overall level of cleanness as have been discussed by Walker et al. (2019). The ports of Rotterdam and Antwerp take the first places. The subcategories are presented in the Appendix (see Table A.2).

4.2.8. Database programs

Amongst the ports from the list, only the port of La Spezia does not have any relative program (like the Digital Twin program[4]) whereas all other ports have developed their own programs. These programs assist them in their daily operations.

4.2.9. Climate programs

The Operation Clean Sweep (OCS) project at the port of Antwerp or "Port-Klima" ("Port-Climate"), implemented by the Bremen University of Applied Sciences for the port of Bremen-Bremerhaven, are environmental project in which operational procedures are being developed to adapt to climate change. Once again, all ports have taken action through these kinds of programs apart from the port of La Spezia.

4.2.10. Sustainable Development Goals (SDGs)

The Sustainable Development Goals (or Global Goals) were adopted by all United Nations Member States in 2015 to end poverty, reduce inequality, and build more peaceful, prosperous societies by 2030. It contains seventeen goals, presented as subcategories in the Appendix (see Table A.2). As far as ports are concerned, they should operate in an environmentally friendly manner as well as in an effective manner increasing economic prosperity. Ports of Antwerp and Valencia succeeded to fulfil most of the SDGs' goals.

4.2.11. Global Reporting Initiative (GRI)

The port of Bremen Bremerhaven and the port of Piraeus rank first in terms of achieving the current criterion — compliance with the GRI Standards. The subcategories are presented in the Appendix (see Table A.2).

[4] Visualizes port's activities, improving security procedures, sharing data.

4.2.12. MARPOL

The International Convention for the Prevention of Pollution from Ships (MARPOL) is a very significant variable as it links pollution to the marine environment of ships. In the Appendix (see Table A.4) all the annexes of the MARPOL are presented analytically. Again, in this criterion, the port of Bremen Bremerhaven and the port of Piraeus take the first places.

5. RESULTS

5.1. Results for 2020

Table 3 shows the descriptive statistics of nine ports in 2020. The variables that are being examined revealing the effectiveness of the ports are *Revenues* and *Net profit*.

Table 3. Descriptive statistics of nine European ports in 2020

		Revenues	*Net profit*
N Valid		9	0
Missing		0	0
Mean		107,264,183.2	41,643,292.99
Median		10,152,362.0	160,784.0
Std. Deviation		232,312,651.1	116,574,795.5
Variance		5.397E+16	1.359E+16
Range		713,659,169.0	359,436,184.0
Minimum		129,983,100.0	-7,718,184.0
Maximum		714,959,000.0	351,718,000.0
Percentiles	25	6,453,466.5	-1,366,462.93
	50	10,152,362.0	160,784.0
	70	102,719,261.4	16,583,555.38

The mean of the annual revenues is equal to 107,264,183.2 EUR with a standard deviation of 232,312,651.1 EUR. Half of the ports have revenues of less than 10,152,362.0 EUR, whereas 25% of the ports produce less than 6,453,466.5 EUR, and 75% of the ports produce less than 102,719,261.4 EUR. The difference between the *Max* and *Min* value (Range) is equal to 713,659,169.0 EUR. Respectively, the mean of the variable *Net profit* is equal to 41,673,292.99 EUR with a standard deviation of 116,574,795.5 EUR. Half of the ports have a net profit of less than 160,784.0 EUR, 25% of the ports produce less than -1,366,462.93 EUR, and 75% of the ports produce less than 16,583,555.38 EUR. The difference between the *Max* and *Min* value (Range) is equal to 359,436,184.0 EUR.

Following the analysis, qualitative characteristics are examined. Each variable is equal to value 1 if the port fulfils the feature and equal to 0 if it does not. The method of cross-tabulation allows us to summarize the data in categorical variables examining the presence of any association amongst the variables. For that purpose, we use the statistical package SPSS which contains fifteen different inferential statistics for comparing categorical variables. In our case, we use Fisher's exact test to investigate the significance of the differences between observed frequencies for two dichotomous distributions. The results show that all variables are independent and uncorrelated, except *Climate and Energy* with *Next Generation Fuels* (Fisher's p-value = $0.048 < 0.05$) which have a strong positive correlation, as $\varphi = 0.8$ with p-value = 0.016. Phi Coefficient (φ) is a correlation coefficient that is used when the two variables are qualitative and dichotomous, $\varphi \in [-1, 1]$. Moving on to the next step in the analysis we apply a multiple regression model. Considering "*Revenues*" to be the dependent variable the following variables are set as independent ones to our model.

Table 3. Independent variables set in the model

No.	*Variables*
1.	*Safe and Healthy Environment*
2.	*Climate and Energy*
3.	*Digitalization and Mobility Offered for Employees*
4.	*Next Generation Fuels*
5.	*Bio*
6.	*Environmental Performance Indicator*
7.	*Database Programs*
8.	*Climate Programs*
9.	*Sustainable Development Goals (SDGs)*
10.	*Global Reporting Initiative (GRI)*
11.	*MARPOL*

As the variable *Measure* takes value 1 for all ports, it is excluded from the analysis. Moreover, for the dependent variable, *LnRevenues* is used so that the assumption that the residuals follow the normal distribution will be satisfied.

In the current study, Stepwise linear regression is applied, removing variables that are not significant by regressing multiple variables from the dataset. Stepwise regression does multiple regression several times, each time removing the weakest correlated variable. In the end, the model produces the remaining variables that explain the distribution best. The only requirements are that the data is normally distributed (normally distributed residuals) and that there is no correlation between the independent variables (collinearity).

Table 4. Stepwise linear regression results for 2020 data analysis

Model		*Unstandardized B*	*Coefficients Std. Error*	*Standardized coefficients, Beta*	*t*	*Sig.*	*Zero-order*	*Correlations partial*	*Part*	*Collinearity statistics*	
										Tolerance	*VIF*
1	(Constant)	16.3180	0.517		31.577	< 0.001					
	Safe and Healthy Environment	4.069	1.550	0.704	2.625	0.034	0.704	0.704	0.704	1.000	1.000

Note: Dependent variable — LnRevenues.

The estimates of the constant and the regression coefficient are equal to 16.318 and 4.069, respectively. So, the equation resulting is:

$$\widehat{LnRevenues} = 16.318 + 4.069 * Safe\ and\ Healthy\ Environment \quad (1)$$

A variable *Safe and Healthy environment* contributes positively to the port's revenues.

The model analysis for the above equation presents the positive contribution of the *Safe and Healthy Environment* variable for 2020 revenues. This variable is related to the protection that port activities have set as far as safety and health regulations are concerned. European ports apply safety controls and the use of innovative procedures to create safer and more accessible port areas for port staff as well as port passengers. For example, they demonstrate the quality of flood risk management, increase the number of organized truck stops, and clean shipping discounts that some ports may offer to ships.

Moving on to research the relation of *Net Profits* to environmental variables, the backward method is used. This is a stepwise regression approach that begins with a full (saturated) model and at each step gradually eliminates variables from the regression model to find a reduced model that best explains the data. Also it is known as Backward Elimination regression.

$$\widehat{LnNetProfits} = 12.10 - 4.464 * Climat\ and\ Energy - 3.905 * Bio + 16.059 * Environmental - 0.183 * Climate\ Programs + 0.687 * SDG + 8.475 * MARPOL \quad (2)$$

Following the above equation, *Climate and Energy* and *Bio* have a negative influence on the *Net Profits* whereas the *Environmental Performance Indicators*, the *Climate Programs*, the *SDGs,* and the *MARPO*L have a positive one.

The negative relationship of *Climate and Energy* is due to the goals that ports have set to facilitate their energy transition, that is the preparation and the actions they take to achieve them. For example, several ports have set a target to eliminate CO2 emissions by 2050 and to reduce them by 50% by 2030. In addition, there are many ports that are installing alternative energy sources, such as shore power. Ports of Rotterdam and Antwerp have developed mechanisms to distribute electric power from land to ships and vice versa. The variable *Bio* has a reasonable negative relationship with net profits since ports spend a lot of money to achieve this criterion. The expenses given for projects to protect the environment and the surrounding biodiversity from the environmental impacts of their activities impact directly profits. These projects mainly focus on water, air, soil, sediments, and natural habitats. Investments are made in projects that deal with air and water pollution as well as the collection, reuse, and recycling of industrial waste as well as projects related to the protection of habitats and biodiversity in ports. For example, Rotterdam has created a 250-hectare warehouse to store their polluted dredged materials. Moreover, the ports of Antwerp and Bremen-Bremerhaven respectively are implementing projects on circular chemistry and the "Seabin Marine Garbage Collector" project which is designed to catch garbage from the water in the harbour. The *Climate Programs* factor exhibits a negative relationship with the above model for the same reason as the *Bio* variable. The *Climate Programs* factor is associated with projects that focus on the resilience and sustainability of port infrastructure and services, with the aim of improving them. The projects in this category relate to new modern facilities, making the most of existing port capacity in combination with the management of oversized ships and the resistance and adaptation of their infrastructure to climate change. Some of these projects are Antwerp's port "Operation Clean Sweep" and Bremen-Bremerhaven port "Port-Klima".

As opposed to the previous variables that present a negative relationship with this model, the *Sustainable Development Goals* and *MARPOL* variables give a positive sign. This is a logical explanation since for these variables the ports had acted earlier and as a result, they have a positive impact on the ports' profits. Moreover, already some of the criteria had been completed before the COVID-19 era. Finally, in this model there is a positive relationship with the variable *Environmental Performance Indicators*, supporting the opinion that European ports have developed an ecological consciousness.

5.2. Results for 2021

The next step is the analysis of *Revenues* and *Net profit* of seven ports in the year 2021. Table 5 shows the descriptive statistics of these ports in 2021.

As we can see from Table 5 the mean of the annual *Revenues* is equal to 187,435,059.6 EUR with a standard deviation of 216,416,088.7 EUR. Fifty (50) percent of the ports have revenues less than 85,323,389.0 EUR, 25% of the ports less than 22,273,500.0 EUR, and 75% of the ports less than 395,562,030.4 EUR. The difference between the *Max* and *Min* value (Range) is equal to 574,985,916.0 EUR. Respectively, the mean of the *Net Profit* is equal to 27,306,466.52 EUR with a standard deviation of 44,580,868.78 EUR. Fifty (50) percent of the ports have *Net Profit* of less than 10,254,754.0 EUR, 25% of the ports less than 948,220.0 EUR, and 75% of the ports less than 30,859,539.0 EUR. The difference between the *Max* and *Min* value (Range) is equal to 125,639,397.0 EUR.

Table 5. Descriptive statistics of seven European ports in 2021

		Revenues	*Net profit*
N Valid		7	7
Missing		0	0
Mean		187,435,059.6	27,306,466.52
Median		85,323,389.0	10,254,754.0
Std. Deviation		216,416,088.7	44,580,868.78
Variance		4.684E+16	1.987E+15
Range		574,985,916.0	125,639,397.0
Minimum		4,646,186.0	61,264.0
Maximum		579,632,102.0	125,700,661.0
Percentiles	25	22,273,500.0	948,220.0
	50	85,323,389.0	10,254,754.0
	70	395,562,030.4	30,859,539.0

Using again Fisher's Exact test we conclude that all variables are independent. Applying a multiple regression model. Here, *Revenues* is the dependent variable, and the independent variables are *Safe and Healthy Environment*, *Digitalization and Mobility Offered for Employees*, *Bio*, *Environmental Performance Indicator*, *SDGs*, *GRI*, and *MARPOL*.

Using the stepwise method, we have the following results for *Revenues*.

The estimates of the constant and the regression coefficient are equal to 487,597,066.2 and -420,226,809.0, respectively.

Table 6. Stepwise linear regression results for 2021 data analysis

Model		*Unstandardized B*	*Coefficients Std. Error*	*Standardized coefficients, Beta*	*t*	*Sig.*	*Collinearity statistics*	
							Tolerance	*VIF*
1	(Constant)	487,597,066.2	53,612,774.69		9.9095	< 0.001		
	MARPOL	-420,226,809.0	63,435,490.49	-0.947	-6.624	0.001	1.000	1.000

Note: Dependent variable — Revenues.

The equation resulting is:

$$\widehat{Revenues} = 487597066.2 - 420226809 * MARPOL \quad (3)$$

The model of 2021 of ports' revenues shows the negative relationship that revenues have with the *MARPOL*. Even though the results of 2020 showed a different relation with revenues and logically it was expected that the same should be found in 2021 as well, a surprising result came out in 2021. The International Maritime amendments of the International Maritime Organization (IMO) that entered into force required the introduction of corresponding amendments to the basic Annex I, V, and IV of MARPOL. This resulted in extra expenses in 2021 decreasing European ports' revenues since they had to adjust to this transition.

As far as the relations of the rest variables to net profit the results are shown below.

$$\widehat{NetProfits} = 142324492 - 130789985 * Safe\ and\ Healthy\ Environment - 16623832 * Digitalization\ and\ Mobility\ Offered + 117502497.3 * Environmental + 5150588 * SDG + 126809031.3 * GRI - 116615541 * MARPOL \quad (4)$$

While the 2020 revenue model showed a positive contribution of the variable *Safe and Healthy Environment*, in 2021 the same variable is presented with a negative sign in the net profit model. This negative relationship is explained by the fact that investment outflows regarding the upgrading of safety and health measures are increased to incorporate COVID-19 requirements.

The variable *Digitalization and Mobility Offered* also shows a negative relationship in this model. This variable relates to projects that implement innovative digital technologies in port management and operations. Furthermore, it includes innovative digital applications, port management systems, and data collection. In general, this indicator relates to smart port initiatives, how technologically advanced a port is, and how much it provides a green approach to transporting its employees in and out of the port. Therefore, the project requirements for this criterion together with the requirements and influence of COVID-19 during this period provide the negative sign in this model.

The last variable in the model that shows a negative relationship with net profit is *MARPOL*, which is due to the announcement of the amendments to the MARPOL main Annexes that took place in 2019. Since then, there has been exhaustive investment to prevent pollution of ships and to ensure that ports follow the Annexes on time.

Positive relationships are shown by the *Environmental Performance Indicators* as the analysis of both models that are positive reveals that ports have developed ecological consciousness as mentioned above. Furthermore, the *SDGs* variable makes a positive contribution to the model since ports during and after the COVID-19 era continue to fulfil and bring positive results to the ports. Finally, in the model, the next variable with statistical significance is *Net Profit* adding a positive sign to the study. This variable is the *GRI*, which is a stricter environmental variable that increases the credibility and transparency of ports. The ports of Sines, Bremen-Bremerhaven, Piraeus, and Mersin fulfil this variable to a high percentage.

6. CONCLUSION

The European guidelines (such as MARPOL and GRI) are a solution of one way for European ports (Notteboom et al., 2020). Apart from this, all ports have developed their own systems to confront contemporary laws and regulations that are environmentally related. When this is not possible, other activities are being developed (activities and procedures that are developed by the ports themselves) exposing the necessity for environmental consciousness. The ports examined in this study reveal the touristic interest that is related to the port's sustainable activities. The ports included in the research are the ones that rank first according to handling containers. The results confirm that these ports carry the burden of trade and commerce for the area where they belong. Such areas are major on the European map, either because they are located at the crossroad of big countries (as far as their geographical extent is concerned) or are considered a passage for the next harbour (Wang et al., 2021). In the first case, the port is considered as a terminal destination, and in the second case, the port serves transit needs for further destinations. The results of this specific study confirm the Eurostat ranking list of 2018.

The innovative findings of the current study contribute to the existing literature in the following ways. First, the results prove that the environmental and sustainability issues are interrelated and not separable. That is, environmental and sustainability variables, provide the same sign when they are related to profits and revenues. This finding reveals that the port's management understands and appreciates similarly the importance of sustainability. However, in other industries, the management may translate in different ways the environmental issue. In the marine sector, ports manage their in similar ways their sources in order to succeed in revenue goals and through this achieve net profit goals without ignoring that ports still have room for full implementation of sustainability into their maritime operations (Sislian et al., 2016). Second, this is the first time that MARPOL Annexes are examined with other environmental and sustainability variables giving fruitful insights for further investigation. Another important finding is that although the data are being measured every other year, the results provided seem to be robust, the fact that shows that the results do not conflict with each other. This in line proves that the environmental notes and sustainable records that are published from the ports are adequate and appropriate to inform all ports' stakeholders effectively. Ports are prepared and are alert to MARPOL guidelines amendments.

As far as further research is concerned extension of current research may include other variables, so it can be applied principal component regression (PCR). It is a technique that combines principal component analysis (PCA) with multiple linear regression (MLR). It can be used when there are a large number of predictors in order to reduce dimensionality while retaining predictive power.

Furthermore, the research could be enhanced by including in the dataset more years so as to reinforce the results. An interesting extent of our research could also be the examination of third countries ports (Asia-America-Australia) whereas the intercorrelation of the variables amongst all countries.

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APPENDIX

Table A.1. Top 20 ports handling containers (*thousand TEUs*)

Rank 2018	***Port***	*	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***		***2018***		***Change 2018/2017, (%)***	
			Total	*Total*	*Total*	*Total*	*Total*	*Total*	*Total*	*Total*	*Total*	*Total*	*of which empty*	*Total*	*of which empty*	*Total*	*of which empty*
1	Rotterdam (NL)	=	10 631	9 579	11 017	11 340	11 418	11 021	11 634	11 577	11 675	12 892	2 485	13 598	2 635	5.5	6.0
2	Antwerp (BE)	=	8 379	7 014	8 144	8 317	8 174	8 256	8 812	9 370	9 891	10 032	1 495	10 830	1 560	7.9	4.4
3	Hamburg (DE)	=	9 767	7 031	7 906	9 035	8 891	9 302	9 775	8 848	8 929	8 860	1 191	8 741	1 104	-1.3	-7.3
4	Bremerhaven(DE)	=	5 451	4 552	4 858	5 911	6 111	5 822	5 731	5 467	5 510	5 458	858	5 442	729	-0.3	-15.0
5	Valencia (ES)	=	3 606	3 654	4 211	4 332	4 471	4 328	4 407	4 609	4 693	4 814	1 050	5 169	1 211	7.4	15.3
6	Piraeus (EL)	+2	437	667	850	1 681	2 815	3 199	3 493	3 360	3 736	4 120	805	4 886	1 070	18.6	32.9
7	Algeciras (ES)	-1	3 291	2 947	2 773	3 593	4 113	3 988	4 555	4 516	4 762	4 381	646	4 773	770	9.0	19.2
8	Gioia Tauro (IT)	+1	3 165	2 725	3 897	3 307	3 725	3 652	3 708	3 030	3 796	3 391	311	4 005	347	18.1	11.5
9	Felixstowe (UK)	-2	3 131	3 021	3 415	3 249	3 368	3 434	4 072	4 043	4 016	4 160	1 172	3 781	985	-9.1	-16.0
10	Barcelona (ES)	+1	2 567	1 846	1 928	2 006	1 745	1 717	2 056	1 950	2 225	2 998	756	3 422	767	14.2	1.4
11	Ambarli (TR)	-1	nd	nd	2 464	2 625	3 024	3 318	3 445	3 062	2 781	3 123	718	3 170	685	1.5	-4.6
12	Le Havre (FR) ([1])	=	2 512	2 257	2 369	2 222	1 997	2 186	2 433	2 560	2 480	2 799	460	2 866	467	2.4	1.6
13	Genova (IT)	=	1 462	1 311	1 020	1 277	1 578	1 546	2 014	2 079	2 356	2 332	13	2 554	29	9.5	115.5
14	Southampton (UK)	=	1 617	1 385	1 567	1 591	1 489	1 489	1 894	1 956	2 040	2 008	541	1 970	562	-1.9	3.9
15	Sines (PT)	=	220	253	382	447	553	931	1 228	1 332	1 513	1 669	131	1 750	151	4.9	15.2
16	Gdańsk (PL)	+2	183	233	510	685	933	1 189	1 232	1 041	1 559	1 473	255	1 736	315	17.8	23.4
17	London (UK)	+2	983	646	733	737	687	944	1 059	1 185	1 492	1 375	459	1 680	417	22.2	-9.3
18	Mersin (TR)	-1	nd	nd	1 016	1 127	1 251	1 367	1 484	1 428	1 406	1 554	338	1 662	379	7.0	12.3
19	La Spezia (IT)	-3	1 186	840	1 181	1 205	1 181	1 207	1 262	1 579	1 605	1 612	93	1 653	191	2.5	105.6
20	Izmit (TR)	+1	nd	nd	416	508	630	808	899	989	1 143	1 316	236	1 598	290	21.4	22.6
Total top 20 ports ([2])			64 363	54 306	63 093	67 267	69 569	70 181	75 483	74 247	77 710	80 413	13 988	85 285	14 665	6.1	4.8

Note: TEU: Twenty-foot Equivalent Unit (unit of volume equivalent to a 20-foot ISO container). (*) column indicates the number of positions lost or gained compared to 2017. ([1]) 2012–2013: partially estimated by Eurostat. ([2]) Total figure for the ports being part of the top 20 ports of the countries reporting data during the reference year concerned. Turkish ports are not included in 2008–2009.
Source: Eurostat (https://ec.europa.eu/eurostat).

Table A.2. Variables and sub-variables examined in the research

Variables	***Sub-variables***
Safe and Healthy Environment	Flood risk management
	Truck stop
	Discount for clean shipping
	Nature in the port
	Electronic sensors
Climate and Energy	Solar power
	Wind power
	Heat alliance
	Shore power
	Carbon capture and storage
	Led lights
	Decrease carbon footprint
	Upgraded Terminals
	Energy management/Environmental review tools
	Electrical power
Digitalization and Mobility Offered for Employees	Mobility offered by the port (for employees)
	Mobile port/Digitalisation/Autonomous digitization
Bio	Bio-based cluster
	Recycling Hub
	Clean Port (based on dredging)
	Economic
Environmental Performance Indicators	Safe environment (accidents)
	Air emissions
	Climate change and energy transition
	Odour nuisance
	Noise pollution
	Cleanliness
Sustainable Development Goals (SDGs)	No. 1 — No poverty
	No. 2 — Zero hunger
	No. 3 — Good health and well-being
	No. 4 — Quality education
	No. 5 — Gender equality
	No. 6 — Clean water and sanitation
	No. 7 — Affordable and clean energy
	No. 8 — Decent work and economic growth
	No. 9 — Industry, innovation and infrastructure
	No. 10 — Reduced inequality
	No. 11 — Sustainable cities and communities
	No. 12 —- Responsible consumption and production
	No. 13 — Climate action
	No. 14 — Life below water
	No. 15 — Life on land
	No. 16 — Peace, justice and strong institutions
	No. 17 — Partnership for the goals

Table A.3. GRI Standards: A modular system of interconnected standards

GRI (Global Reporting Initiative)	
102 — General Disclosures	402 — Labor/Management Relations 2016
103 — Management Approach	403 — Occupational Health and Safety
201 — Economic Performance	404 — Training and Education
202 — Market Presence 2016	405 — Diversity and Equal Opportunity
205 — Anti-corruption	406 — Non-Discrimination
203 — Indirect Economic Impacts	407 — Freedom of Association and Collective Bargaining
204 — Procurement Practices	408 — Child Labor
206 — Anti-competitive Behaviour 2016	409 — Forced or Compulsory Labor 2016
207 — Taxes 2019	410 — Security Practices 2016
301 — Materials	411 — Rights of Indigenous Peoples 2016
302 — Energy	412 — Human Rights Assessment
303 — Water and Effluents	413 — Local Communities 2016
304 — Biodiversity	414 — Supplier Social Assessment 2016
305 — Emissions	415 — Public Policy 2016
306 — Waste	416 — Customer Health and Safety 2016
307 — Environmental Compliance	417 — Marketing and Labeling 2016
308 — Supplier Environmental Assessment	418 — Customer Privacy 2016
401 — Employment	419 — Socioeconomic Compliance

Table A.4. Annexes of International Convention for the Prevention of Pollution from Ships (MARPOL)

Annex I — Prevention of Pollution by Oil
Annex II — Carriage of chemicals by ship
Annex III — Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form
Annex IV — Regulations for the Prevention of Pollution by Sewage from Ships
Annex V — Prevention of Pollution by Garbage from Ships
Annex VI — Prevention of Air Pollution from Ships