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The impact of Covid-19 on the performance of seaports: A Tunisian case study

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ABSTRACT

The COVID-19 outbreak had a serious effect on the global economy, particularly, on the volume of port trade. This article was intended to investigate the impacts of the economic landscape, severity of the outbreak, and governmental control measures on the import and export goods of eight seaports in Tunisia. To achieve this, panel regression models were employed, utilizing a time series dataset spanning from the first quarter of 2020 to the third quarter of 2022. Based on the attained results, the preventive measures and stringent governmental control index and the cumulative number of confirmed cases have negative impact on the imported and exported goods, though the exported goods have been rather severely affected by the pandemic.

At the economic level, the industrial added value has been discovered to be significantly and positively correlated with the imported and exported cargos respective throughputs, while GDP turned out to be significantly and negatively correlated with imported and exported goods. Such findings could be of great help to the shipping companies, port operators as well as the governmental authorities to shift strategies and opt for appropriate measures likely to help in coping with any potential effects of similar crises.

1 Introduction

In a bid to prevent the emergence of Covid-19 and curb its spread, governments around the world tried to adopt various types of preventive measures, such as work stoppage and travel restrictions (Lau et al., 2020; Perillo et al., 2021) , which noticeably hindered economic activities. Hence, the world came to witness a second global crisis, following the 2009 financial crisis (Notteboom and Pallis, 2020). Throughout the pandemic predominance period, Tunisia has been struggling and grappling with the ensuing economic repercussions that have significantly damaged the country's already weak and fragile economy. Consequently, the economy has been expected to contract by further 3.9 percent to 6 percent, and state resources to decrease by more than $1.753 billion, relative to the year 2019 (Abouzzohour and Ben Mimoune, 2020).

Actually, the most recently prevalent COVID-19/ SARS-CoV-2 pandemic state has almost impeded most of the world countries' entire economies, mainly throughout the beginnings of the year 2020, predominantly impacting their domestic economic activities. COVID-19 has affected most of the developing as well as developing countries' activity sectors, most particularly the maritime industry that accounts for 90% of world trade by volume, including such necessity shipments as aliment/ and food supplies, medical supplies, medicines, and raw material. Indeed, the Corona virus spread has negatively affected the entirety of maritime supply chains, including seaports, the entire maritime industry's corner stone. In effect, following the COVID-19 imposed inter-country restrictions, such as border closures, shutdowns and semi-lockdowns, several seaports have ceased the importation and exportation transactions of goods, thereby, production levels dropped

considerably, remarkably interrupting and disrupting international trade flows (Narasimha et al., 2022). There has also been a drop in global demand and supply by almost 60%, coupled with some 41% drop in global exports following the spread of this epidemic (Baldwin and Weder di Mauro, 2020). In this respect, Tunisia witnessed a decrease by 8% in bulk solids' traffic, and by 3% in general cargo, by the end of June 2020 compared to the same period of the year 2019. Simultaneously, goods transported in wheeled units also marked a drop by 13%, going down from 1.054 million tons in June 2019 to 917 thousand tons in June 2020 (OMMP). Consequently, the Tunisian manufacturing industries and exports were heavily hurt, severely affecting the global supply chain.

Noteworthy, however, despite the noticeable number of studies dealing with the impact of COVID-19 on global seaports' traffic, a significant gap is perceived in the relevant literature as to the relevant impacts on export and import traffic (Olapoju, 2022; Zhou et al., 2022; Cariou and Notteboom, 2023). Besides, no study has so far been discovered to focus on the extent to which the COVID-19 pandemic affected seaport activities in Tunisia. Hence, the present analysis contribution in the literature lies in exploring in what ways COVID-19 disproportionately affected the Tunisian trade's imports as well as exports' volumes. It follows, therefrom, that two major questions appeared to emanate, namely: to what extent could the decline in Tunisian trade be attributed to the outbreak of COVID-19? How did COVID-19, government measures, and economic factors participate in international trade decline? To address these questions, we considered constructing a panel regression model, based on eight Tunisian seaports relevant quarterly time series data, observed from the first quarter of 2020 to the third quarter of 2022, including the port operation indicators, economic indicator, epidemic severity indicator and government control indicator.

The present work englobes six sections. The upcoming section (Section 2) involves a literature review dealing with the Covid 19 pandemic's impact on seaport activities. As to the implemented technique, it is described in section 3. Section 4 includes detailed depiction of the sample ports, subject of our modeling application, along with the variables used to carry out the analysis. As to Section 5, it is devoted to discussing the reached results, while Section 6 bears the major drawn conclusions.

2 Literature review

Only recently has the world experienced a relieving upheaval following the COVID-19 outbreak, officially announced on March 11, 2020 by the World Health Organization (WHO), following release of the quarantine restriction measures, such as work and production stoppages and border crossings, resulting in heavy losses in trade, logistics and transport (Xu et al., 2021 a). Noteworthy in this respect, however, is that most researchers tended to focus on studying the impact of COVID-19 on human health and the environment, overlooking the coronavirus associated effects on the shipping and seaport sector.

Michail and Melas (2020) applied a GARCH regression to grasp the maritime industry's response to the COVID-19 pandemic, to reach the finding that the pandemic proved to display negative impacts not only on dry bulk, but also on crude oil shipping vessels. In this regard, Yazir et al. (2020) provided a comprehensive literature review depicting the effects of COVID-19 on the shipping industry, including the four major sectors of dry bulk, tanker, container as well as ship-cruiser traffic. They concluded that maritime operators incurred noticeable operational losses due mainly to the lack of health and safety states. They added that the results obtained should help in raising awareness of COVID-19, and improving port performance by reducing operational risks. With regard to Xu et al. (2021 a), they used a linear panel regression model to analyze the effect of COVID-19 pandemic on the import and export goods of fourteen major Chinese ports, to conclude that these throughputs have been noticeably struck by the epidemic's severity, strict governmental preventive index and control of economic indicators.

In turn, Millefiori et al. (2021) used maritime traffic data collected via a global network of Automatic Identification System (AIS) receivers, analyzed the effects of the COVID-19 pandemic and containment measures on the shipping industry. They ended up quantifying a variation of traffic between −5.62 and −13.77% for container ships, between +2.28 and −3.32% for dry bulk, between −0.22 and −9.27% for wet bulk, and between −19.57 and −42.77% for passenger traffic. With respect to Xu et al. (2021 b), who applied a dynamic panel-data model to examine the COVID-19 epidemic's impact on the European Union, North American, and Southeast Asian shipping trade from a micro-economic perspective, they demonstrated that the container throughputs at the Shanghai, Hong Kong, Singapore and Los Angeles seaports displayed the largest year-on-year drops of the rates of 19.6%, 7.1%, 10.6% and 30.9%, respectively, from 2019 to 2020. Still, the governmental preventive and control measures proved to have a positive impact on import trade, yet, a negative impact on export trade. As for Oyenuga (2021), who analyzed the COVID-19 pandemic impact on the maritime transport sector, regarding both of the global as well as African contexts, he concluded that the pandemic's short-term impacts were manifested in a drop in the maritime shipping trade volume. He also analyzed the pandemic's long-term impacts on five critical trends globally facing the MTS,

particularly, persistence of trade tensions, geopolitical developments, structural disruptions, regulatory pressures, and environmental incidents. Regarding the African context, the analysis highlighted that with a mere 4% share of global container port traffic, as well as 7% and 5% shares of international maritime exports and imports (measured in tons), respectively, Africa's participation in the global MTS significance remained rather insignificant. He also noted that the pandemic lead to decreasing trade transaction levels between the United States and China, resulting in a global economic slump. With respect to Wang et al. (2022), who applied Automatic Identification System (AIS) data to estimate the impacts of COVID-19 on ship visits' trends, a special scale was advanced to analyze the pandemic's effect on port traffic. Their findings revealed that the average anchoring and berthing spans tended to increase by, respectively, 62% and 11% for cargo ships, and by 112% and 63% for oil tankers following the pandemic's outbreak, as compared with the pre-COVID-19 period. As for Alamoush et al. (2022), they used a multi-source exploratory review to assess the COVID-19 pandemic's impact on the shipping and supply chains of the Jordanian Port of Al Aqaba, to conclude that in container ships calls proved to decline by 53% during the second quarter of 2020. They also added that ports had to maintain stronger resilience policies during the pandemic, through implementation of effective risk management schemes and maintaining cooperation strategies with other ports, both regionally and globally. Similarly, on using an exponential smoothing modeling framework, Zhao et al. (2022) considered analyzing the Covid-19 pandemic's effects on the shipping market, coastal bulk freight and container throughputs, through examining a selection of four major world seaports of Shanghai, Hong Kong, Singapore and Los Angeles, observed over the period ranging between 2019 and 2020. They noted that dry bulk traffic largely decreased during the second month of the pandemic, due mainly to the imposed lockdowns. Concerning Narasimha et al. (2022), however, they studied the impacts of COVID-19 on the Indian shipping and entire supply chain. Regarding the quantitative performance of Indian major seaports, their results indicated the persistence of a negative growth in cargo and vessel traffic, as compared to the pre-COVID-19 span. They outlined that maritime organizations and stakeholders tended to grapple with providing vaccines and cures to the infected populations.

Similarly, on exploring the COVID-19 impacts on the Shanghai port container activities, Zhou et al. (2022) outlined potential economic losses for the port, and advanced suggestions for recovery. They concluded that due to the pandemic, the port experienced noticeable losses in terms of traffic and profit, due mainly to reduce handling services, as well as the installations and mooring high security costs. As for Tai et al. (2022), they evaluated the pandemic's impact on Shanghai port under different scenarios via a System Dynamics model, to conclude that the epidemic appeared to display a rather significant impact on passenger transport, with a milder effect on cargo transport. Concerning Shi and Weng (2021), they examined the COVID-19 epidemic's impacts on merchant ship activities. On comparing AIS data since February 2019 and since February 2020, they discovered that the merchant ship counts were reduced throughout the epidemic span. For Camarero et al. (2022), who investigated the pandemic's impacts on European ports, they concluded that unlike the Baltic ports, the figures revealed that the Mediterranean ports appeared to face the most significant drop in traffic of all types, resulting in higher loss risks for their service providers.

However, Sakawa and Watanabel (2023) undertook to examine the Japanese shipping sector and the related stocks' reaction to the COVID-19 pandemic prevalence, through considering such facts as the number of infected people on a boat and border closures. This depicted literature review reflects well that the two COVID-19 related events turn out to negatively affect the shipping companies' stock returns. With respect to Gu et al. (2023), they examined the pandemic related factors and port operations binding relationship through a panel regression analysis, using data relevant to three major Asian ports of Shenzhen, Hong Kong, and Singapore. They concluded that the ports' new locally confirmed cases tended to negatively impact cargo throughput, while the outside ports' newly confirmed cases turned out to positively impact cargo throughput worldwide.

It is worth highlighting, however, that despite the importance of the Covid-19 and associated impacts on maritime transport relevant literature, no studies were discovered to deal with the context of Tunisia as a major study case.

In this context, the present study was conducted to investigate the key factors contributing to affecting the Tunisian maritime transport sector throughout the pandemic period.

3 Methodology

At this level, we considered implementing the panel-linear-regression model, given the diverse advantages it exhibits. Indeed, compared to cross-sectional modeling, the panel data technique displays higher levels of freedom and sample-variability. Moreover, the control variables are incorporated into the model so that the effect of other indicators could be excluded. Thus, following Xu et al. (2020), we reckoned to estimate four modeling frameworks, namely, the Mixed Effects (MEM), Random Effects (REM), Fixed Effects (FEM), and the Two-Level Fixed Effects Model, to explore the covariates' effects on the import and export freight flows within the context of the COVID-19 pandemic.

It is worth recalling that the mixed-effect model (MEM) incorporates both fixed effects and random factors, which represent two important sets of components, useful for analyzing port data. On the one hand, fixed effects should enable to identify and quantify each port's constant and specific characteristics, thereby, enabling to understand the stable relationships binding variables. On the other hand, the random factors would help in capturing any non-systematic variations and, therefrom, allowing for capturing any individual variabilities and unpredictable fluctuations over time, i.e., each port's associated constant (fixed) effects as well as random variations could be effectively assessed over time.

As part of our analysis, also, the MEM serves to account for the external effects impacting seaport operations, including global economic conditions, trade policies and seasonal tendencies. Through such a holistic approach, we intend to achieve a thoroughly global assessment of port traffic process, by depicting each port specific effects distinguishing it from the entire maritime industry common features (Xu et al., 2020).

Accordingly, the MEM relevant mathematical formula turns out to be:

$$y_{i,t} = \beta_0 + \beta_1 CUM_{i,t} + \beta_2 STR_{i,t} + \beta_3 GDP_{i,t} + \beta_4 VA_{i,t} + \\ + \alpha_1 OU_{i,t} + \alpha_i + \mu_i + \varepsilon_{i,t} \quad (1)$$

where:

- β_0 is the intercept coefficient;
- $y_{i,t}$ designates the goods' import and export volumes of port i during the quarterly time t;
- t is the temporal index;
- *CUM* denotes the number of cases confirmed of port-city's i during the quarterly time t;
- *STR* designates the Stringency index of port-city's i during the quarterly time span t;
- *GDP* denotes the regional Gross Domestic Product of port-city's i during the quarterly time t;
- *VA* denotes the industrial added value of port-city's i during the quarterly time span t;
- *OU* denotes the import and export commodities of the seaport recorded during the identical quarterly range of the year 2019;
- β stands for the independent variable associated regression coefficients, $CUM_{i,t}$, $STR_{i,t}$, $GDP_{i,t}$, $VA_{i,t}$ and $OU_{i,t}$ are the explanatory variables of port (i) at time (t);
- α_i is the port-specific fixed effect (i), representing the port's unique constant aspects that do not vary over time;
- μ_i is the port's specific error term (i), assumed to be random and correlated with the explanatory variables, and
- $\varepsilon_{i,t}$ is the error term.

Accordingly, the random effects' model (REM) proves to stand as an error-component or generalized-least-square (GLS) based statistical approach, enabling to estimate panel data by accounting for interference factors across different time spans and seaports. More particularly, it has been discovered to be remarkably effective in depicting the seaport characteristics associated random variations, such as GDP, added value, Stringency index and number of confirmed cases, as introduced in our model. Thus, by jointly incorporating the ports' marking differences and distinct error terms, we have been able to simultaneously account for inter-port variations along with each port specific features (Zulfikar, 2018). Actually, the random effects model (REM) also maintains that such seaport characterizing factors might randomly vary over time. Therefore, such relevant unpredicted events as global economic volatilities or health crises might randomly interfere to impact each single port's commercial performance, therefrom, affecting the port's traffic activities over time.

The relevant random effects' depicting mathematical formula turns out to be:

$$y_{i,t} = \beta_0 + \beta_1 CUM_{i,t} + \beta_2 STR_{i,t} + \beta_3 GDP_{i,t} + \beta_4 VA_{i,t} + \\ + \alpha_1 OU_{i,t} + \mu_i + \varepsilon_{i,t} \quad (2).$$

Regarding the fixed effects model (FEM), however, each seaport is assumed to bear uniquely constant characteristics (economic, geographic, health related etc.) throughout the period under review. For instance, some ports might display a rather developed industrial activity (higher industrial added value), a stronger regional economic location (higher regional GDP), or a rather strategic geographic location, which makes them more or less vulnerable to an epidemic propagation and stringent governmental policies, likely to render them hard or easily accessible to international trade. In this sense, fixed effects would stand as constants, associated to each single port, to be incorporated in the regression equation to help capture the seaports' characterizing systematic differences.

The fixed effects model related mathematical formula is written under the form:

$$y_{i,t} = \beta_0 + \beta_1 CUM_{i,t} + \beta_2 STR_{i,t} + \beta_3 GDP_{i,t} + \beta_4 VA_{i,t} + \\ + \alpha_1 OU_{i,t} + \alpha_i + \varepsilon_{i,t} \quad (3).$$

Hence, even though such variables as industrial added value, regional GDP, epidemic severity level and government control measures might vary over time with respect to each single port, the FEM would enable to depict and isolate the constant and specific effects characterizing each port, to estimate the extent of their effect on port traffic over time. As to the two-level fixed effects model, it intervenes to extend the concept of fixed effects by considering both of the individual seaport and time span related variations. Thus, it enables to depict

how each port's specific characteristics turn out to affect its traffic transactions, while accounting for the global temporal variations affecting the entirety of the ports.

The two-level fixed effects model associated mathematical formula is written as:

$$y_{i,t} = \beta_0 + \beta_1 CUM_{i,t} + \beta_2 STR_{i,t} + \beta_3 GDP_{i,t} + \beta_4 VA_{i,t} + \\ + \alpha_1 OU_{i,t} + \alpha_i + \gamma_t + \varepsilon_{i,t} \quad (4)$$

where:

– γ_t denotes the fixed effect associated to time t, depicting the global temporal variations affecting the entirety of ports.

It is worth recalling, at this level, that for any heteroscedasticity and serial correlation due unstable regression to be avoided, the significance level estimating cluster-robust standard error was considered in the four applied approaches' analysis procedures (Petersen, 2009).

4 Research data

As reported by the National Institute of Statistics (INS), nearly 98% of Tunisia's value of imports, exports, and trade transactions in 2018 was achieved via maritime transport. This extensive maritime activity is enhanced through a network of eight major ports, extending over a coastline of approximately 1,300 km. These key seaports, which involve the Ports of Bizerte, La-Goulette, Rades, Sousse, Sfax, Gabes, Zarzis, and Skhira, are instrumental in handling wide ranges of vessels, including car ferries, conventional ships, roll-on/roll-off (Ro-Ro) ships, container ships, bulk carriers for solids and liquids, as well as tankers for both petroleum and liquefied gases. More particularly, the port of Bizerte, with a draught of seventeen meters, is distinct for its capacity to accommodate vessels of various types, thereby, playing a major role in maintaining container traffic. The Tunisian maritime transport and port sector involves thirty-five regular maritime lines and more than 550 companies. It plays a pivotal role in securing over 6,000 direct jobs and sustaining over 3,000 businesses engaged in maritime, transit, and port-related activities. Recognized for its critical contribution in boosting economic growth, export operations, logistic efficiency, and overall competitiveness, the maritime sector significantly propels the trade development activities, enhanced by the availability of strategic maritime routes.

For the sake of assessing the impact of COVID-19 on seaport performance, a set of eight Tunisian seaports relating panel data, relevant to the time period ranging from the first quarter of 2020 to the third quarter of 2022, was collected. The dependent variables relate to each separate seaport associated import (IMPO) and export (EXPO) cargo traffic volumes. Both variables have been collected from the Merchant Marine and Ports Office (OMMP) authority official website, and are expressed in tons. Due to data availability constraints, only four independent variables were selected, and classified into three categories, namely, port city economy, pandemic transmission as well as government prevention and control measures. A depiction of the applied statistical data is provided on Table 1.

The first Stringency index factor (STR), denoted a figure ranging from 0 to 100. The higher the index was, the higher the stringency level turned out to be. This index was initially provided by the University of Oxford, and computed on the basis of nine factors, particularly, the closures of public transport, schools and workplaces, cancellation of public events, restriction of gatherings, internal and international travel and home confinement. It is worth recalling, in this respect, that the maximum value recorded for this index was of the rate of 92, recorded during the first quarter of 2020 on attempting to combat the pandemic spread and its repercussions. In fact, this variable was actually used by Xu et al. (2020 a). As to the second factor, it designated the confirmed cases' characteristics, involving the number of cases confirmed (CUM) over a semester to help in measuring the virus severity in the port city. Actually, the relevant data were collected from the official website of the Tunisian Health Ministry. It is worth noting that this variable was originally applied mainly

Table 1 Descriptive statistics.

Variable	Description	Obs.	Min.	Max.	Mean	STD.
IMPO	Import cargo throughput	88	149333	2706012	781612.3	501200
EXPO	Export cargo throughput	88	22116	5014912	1918246	1484411
GDP	GDP	88	6.03e+08	4.20e+09	1.99e+09	1.15e+09
VA	Industrial added value	88	1.58+05	8.80+05	4.89+05	2.40+05
CUM	Cumulative confirmed cases	88	0	4584	510.1028	944.4231
SRI	Stringency index	88	12.4	92	54.211	19.1667
IOU	Import cargo throughput in 2019	88	29535	4 671757	1135121	1339001,2
EOU	Export cargo throughput in 2019	88	85513	2954 673	885148	642214,023

Table 2 The applied variables associated correlation coefficients.

	IMPO	EXPO	GDP	VA	CUM	STR
IMPO	1.0000					
EXPO	0.4527	1.0000				
GDP	-0.0515	-0.3224	1.0000			
VA	0.0721	0.0701	0.5560	1.0000		
CUM	-0.0023	-0.0657	0.3148	0.2881	1.0000	
STR	-0.2973	-0.4321	0.1457	0.0196	-0.0915	1.0000

by Yazir et al. (2020) as well as Oyenuga (2021). Regarding the third factor, industrial added value (VA), expressed in Tunisian Dinars (TND), it stood for an economic indicator involving the industrial enterprises provided new wealth, achieved over the production process of a particular time span, which could be expressed in monetary form. This variable was also used by Xu et al. (2020 a). As for the ultimate factor, regional GDP, also expressed in Dinars (TND), it should serve to depict the port-city's total economic activity. As to the two remaining factors, they were provided by the INS (Institute for National Statistics).

A summary of the inter-variable correlation coefficients is displayed on Table 2. Accordingly, it is worth noting that, apart from the linear correlation linear between the volume of goods imported and exported recorded during the identical quarterly span of 2019, there were no issues of multi-collinearity among the remaining explanatory factors was perceived. In the analytical section, we seek to explore the regional GDP, industrial added value, outbreak severity, and governmental control measures respective effects on seaports throughput via panel regression models.

5 Results and discussion

For the purpose of assessing the key factors affecting the import and export goods over the COVID-19 pandemic span, regarding the eight major Tunisian seaports, three models turned out to be worth implementing, specifically, the FEM, the REM, the MEM, along with the two-way fixed effects model. Actually, the analyses major attained conclusions are depicted on Tables 3 and 4, with their respective P-values. Based on the results displayed in the tables, the entirety of the explanatory variables appeared to bear a p-value that is inferior to 0.05, which made them statistically significant.

Both of the imports and exports cargos associated regression results are depicted on Tables 3 and 4, below. On comparing these results, one could well note that the entirety of MEM, FEM and two-way fixed effects models attained regression coefficients turn out to be rather significant. Indeed, the mixed-effects model (MEM) scored R2 was too close to the unit value, which testifies the MEM's supremacy in maintaining a thorough data explanatory power, thanks to the high covariance levels it was able to depict via the dependent variable. Moreover, the F-test of Chow statistics was also administered to pinpoint which among the mixed-effects and fixed-effects models proved to be better fit for implementation. Actually, the computations reached results turned out to reject the null hypothesis H0 (ui- u = 0) with respect to the fixed effects model, which favors its implementation over the mixed-effects framework. Noteworthy, also, is that the mixed effects model scored R2 was discovered to exceed that achieved via the two-way fixed effects model, further highlighting the fixed effects model's supremacy and optimal choice.

As Tables 3 and 4 indicate, the imported freight throughput is discovered to be positively correlated with industrial value added. With the revival and advancement of primary industry, the industries' requirement for raw resources started to increase over time. Such a relationship could be explained by increased traffic witnessed in some ports, mainly that of Bizerte, whose import traffic proved to increase from 4.1 million tons over the fourth quarter of 2019 throughout the fourth span period, to 4.6 million tons during the same period (span four) of the year 2020. The same applies to the port of Sfax, wherein, the import traffic registered an increase from 2.9 million tons in 2019 during the fourth span period of 2019, to 3.2 million tons during the fourth quarter of the year 2020. Noteworthy, also, is the specialization noticeable in goods' imports, predominantly categorized into raw materials, mainly chemicals and pharmaceuticals (2.345 million tons in 2020 versus 1.956 million tons in 2019), agricultural products (2.653 million tons in 2020 versus 1.836 tons in 2019) as well as office and telecommunication equipment (1.09 million tons in 2020 versus 823 tons in 2019). Such goods represented the major products imported in 2020. In regard to export freight traffic, industrial added value proved to demonstrate a rather positive impact. Such a relationship could be explained by the increase in export traffic registered in some ports, such as that of the La Goulette seaport, whose traffic went up from 550967 tons during the last quarter of 2019 to 609578 tons during the ultimate quarter of the year 2020. Actually, the exportation of large

amounts of raw materials, such as Petroleum and mining products (1.3 million tons in 2022, versus 1.021 million tons in 2019), as well as steel (73 tons in 2022, versus 655.231 in 2019), contributed significantly in enhancing the industrial value added. These findings indeed coincide with those published by Xu et al. (2020 a).

It is also important to note that GDP was discovered to be negatively correlated with both of the goods import and export factors (see Tables 3 and 4). Such a relationship could be justified by noticeable GDP drop, increased unemployment and poverty rates, particularly induced by the workplaces' total or partial closures or shut downs, widening of public and current account deficits, etc. Indeed, the estimated number of unemployed was estimated to reach 725100 during the fourth quarter of 2020, relative to roughly 676600 unemployed in third quarter of 2019, marking an increase by 17.4%, in relation to 16.2% increase registered during the fourth quarter of 2019. Actually, the Covid-19 pandemic resultant crisis seriously affected the supply and demand chain, causing the Tunisian trade sector's noticeable disruption. Officially considered to occur in March 2020, the first quarter of 2020 recorded a GDP drop by 1.7% and 2% in relevance to 2019 initial and ultimate quarters, respectively (National Statistics Institute (INS), 2020). In parallel, this GDP drop was accom-

Table 3 Regression results of the Tunisian ports recorded import freight throughputs.

	1	**2**	**3**	**4**
GDP	(-0.0002) 0.014**	(-0.0000) 0.214	(-0.0009) 0.000***	(-0.9878) 0.000***
VA	(0.0085) 0.041**	(0.0010) 0.000***	(0.9845) 0.000***	(0.0822) 0.000***
CUM	(-82.600) 0.015**	(-16.6522) 0.029**	(-639.008) 0.033**	-(301.521) 0.017**
STR	(-75.1) 0.011**	(-54.664) 0.022**	(-178.892) 0.012**	(-712.488) 0.035**
OU	(-0.0012) 0.000***	(-0.9886) 0.034**	(-0.4766) 0.000***	(-1.1892) 0.002***
T2 (2020)	N/A	N/A	N/A	(-0.0038) 0.521
T3 (2020)	N/A	N/A	N/A	(0.0147) 0.034**
T4 (2020)	N/A	N/A	N/A	(1.009) 0.000***
T1 (2021)	N/A	N/A	N/A	(0.0032) 0.000***
T2 (2021)	N/A	N/A	N/A	(0.0170) 0.019**
T3 (2021)	N/A	N/A	N/A	(0.2491) 0.000***
T4 (2021)	N/A	N/A	N/A	(0.0846) 0.002***
T1 (2022)	N/A	N/A	N/A	(0.1166) 0.000***
T2 (2022)	N/A	N/A	N/A	(0.1088) 0.000***
T3 (2022)	N/A	N/A	N/A	(0.1468) 0.000***
CST	(912.170) 0.033**	(1023.047) 0.026**	(1003.01) 0.036**	(1403.14) 0.024**
N	88	88	88	88
R-squared	0.953	0.611	0.733	0.701

N.B.: Significance levels at 1% (***), 5% (**) and 10% (*), respectively.

Table 4 Regression results of the Tunisian ports recorded export freight throughputs.

	1	2	3	4
GDP	(-0.0003) 0.003***	(-0 .0019) 0.401	(-0.0021) 0.000***	(-0.9954) 0.009***
VA	(0.0012) 0.009***	(0.0011) 0.000***	(1.0721) 0.000***	(0.0901) 0.001***
CUM	(-77.714) 0.007***	(-14.0211) 0.000***	(-521.852) 0.001***	-(109.118) 0.000***
STR	(-27.125) 0.000***	(-39.5127) 0.000***	(-151.947) 0.000***	-(578.5546) 0.002***
OU	(-0.1459) 0.000***	(-0.0011) 0.004***	(-0.0087) 0.000***	(-0.569) 0.000***
T2 (2020)	N/A	N/A	N/A	(-0.0122) 0.456
T3 (2020)	N/A	N/A	N/A	(0.0022) 0.000***
T4 (2020)	N/A	N/A	N/A	(0.1122) 0.000***
T1 (2021)	N/A	N/A	N/A	(0.0074) 0.011**
T2 (2021)	N/A	N/A	N/A	(0.5641) 0.000***
T3 (2021)	N/A	N/A	N/A	(0.7532) 0.007***
T4 (2021)	N/A	N/A	N/A	(0.1982) 0.009***
T1 (2022)	N/A	N/A	N/A	(0.2559) 0.000***
T2 (2022)	N/A	N/A	N/A	(0.2236) 0.000***
T3 (2022)	N/A	N/A	N/A	(0.2691) 0.000***
CST	(899.0078) 0.001***	(1891.22) 0.042**	(1659.42) 0.016**	(2841.69) 0.017**
N	88	88	88	88
R-squared	0.922	0.618	0.721	0.612

N.B.: Significance levels at 1% (***), 5% (**) and 10% (*), respectively.

panied with a decrease in shipment transactions. As the Gross Domestic Product (GDP) continued to decrease, there was a tendency for seaport activities to decline. This relationship underscored the fact that GDP could serve as an economic indicator of trade volume, wherein, a shrinking economy was associated with reduced imports and exports, severely affecting the seaports' overall performance. As GDP is simultaneously linked to both imports and exports, a negative correlation would denote that a weaker economy, as reflected in lower GDP, might well result in reduced demand for imported goods and a decline in exports' volume, thereby, affecting the seaports' activities by handling less volumes of goods that enter and leave the country.

Compared to other variables, both of the variables 'prevention' and 'strict governmental control index' (STR), along with the CUM turned out to display the highest effects on the imported and exported goods' cargos. The high coefficients could well testify that Both STR and CUM were dynamic variables likely to undergo noticeable fluctuations over time. Indeed, the high associated coefficients might reflect their dynamic nature, wherein, sudden changes in governmental policies or pandemic severity could display immediately substan-

tial effects on the resultant variables. The negative correlation binding CUM and the movement of imported and exported goods' cargo appeared to indicate that a noticeable increase in the cumulative number of confirmed COVID-19 cases (CUM), reflecting that the higher the severity of the pandemic was, the more adversely intensified the impact on the transportation of imported and exported goods would be, i.e., the more the severity of the health crisis tended to increase, the more directly impacted the seaports' capacity to handle goods efficiently turned out to be. In effect, the potential imposition of stricter measures in response to the aggravating situation not only affected public health, but also reverberates through the economic domain, affecting seaport activity. Similarly, the STR relating negative impacts illuminated the broader ramifications of stringent governmental control measures. Hence, the imposed stringent lockdowns and trade restrictions, though critical for managing public health, transcended its immediate objectives to meet the intricacies of international trade. Indeed, the impediment of goods' movement via seaports did not stand as simply an operational challenge, but also as a highlight of the delicate equation faced by governments in meeting public health imperatives and maintaining economic vitality. Such an intermingling implied well that higher STRs are actually is connected with reduced port operational efficiency in handling imports and exports, thereby, creating hindrances in the supply chain, affecting timely handling of merchandise, therefrom, resulting in higher costs for the international trade engaged businesses. Noteworthy, however, is that the exported goods associated throughput turned out to be rather severely affected by the pandemic, as judged by the exported goods recorded regressions, displaying higher figures than those registered for the imported goods' estimated regression results. Clearly, infection prevention and control were but a set of measures, practices, and procedures designed to prevent people from catching infectious diseases, and restrict the pandemic spread once infected. Indeed, both of the variables' negative effect on goods' traffic highlighted well the severity of the Pandemic, of the Tunisian prevention and strict governmental control measures' considerable effects on seaport production, as justified by the cessation of the supply-chain activities, along with the closure of several production units and ports, seriously affecting the exportation and importation of goods, predominantly reserved to medical and sanitary equipment transactions (masks, protective clothing, medicines, medical equipment etc.) throughout the entire pandemic prevalence span. In effect, In this regard, the Skhira port imports dwindled down from 333269 tons during the 2019 first quarter to 192684 tons during the 2022first quarter, along with a drop in exports, which dwindled down from 679239 Tons to 549885 tons over the same quarters, respectively. As to the Rades seaport, the imports' volume dwindled down from 2.292 million tons during the second quarter of 2019, to 1.109 million tons during the first quarter of 2022, while the exports' volumes dropped from 913137 Tons to 440045 Tons over the same quarters, respectively. More importantly, also, is that the control variable appeared to display a very significantly negative impact on the port's import and export goods during the same quarter of the year 2019. In sum, the negative effects of the strict government control index and the cumulative number of confirmed cases on imported and exported cargoes reflected well the hard challenges and disruptions emanating from the strengthening of regulatory measures and pandemic severity. Actually, these findings appear to corroborate those achieved by Narasimha et al. (2021) and Zhao et al. (2022). Accordingly, for any potential health crises' effects on the Tunisian maritime trade to be effectively accounted for, a number of effective safeguarding actions and policies, likely to attenuate such incurred hazards and losses, seem worth highlighting. Actually, intervening parties and actors are recommended to put forward flexibly relaxed, rather than strict, governmental control (STR) measures, based on the COVID-19 pandemic experience provided teachings and directives. Hence, the real question lies in setting up convenient policies that simultaneously account for the necessity to maintain public health safety, while preserving seaport activity continuity. In this respect, strategic planning intervenes by devising effective preemptive schedules and contingency plans, likely to cope with any unexpected crises. To this end, strategic investment plans in resilient port infrastructure, involving technological and logistics innovative schedules, would certainly help in handling such serious and fortuitous events and handle any ensuing disruptions. Such a strategy involves a scientific running of all port berths to promote operational effectiveness, thus, reducing shipping waiting time and congestion while enhancing traffic flexibility. It is also necessary to boost international cooperation in this respect, through standardizing regulatory systems, customs clearance and handling methods, fit for coping with Tunisian maritime sector's specificities, thereby, coordinating response to imminent crises, likely to threaten international trade. Hence, by synchronizing with such procedures, Tunisian policymakers could contribute in enhancing the seaport sector's healthy state, and maintaining its strength face to any turbulences, therefrom, safeguarding the nation's economic stability and resilience at crisis times.

Another worth raising point is that the control variable (OU), designating the ports' import and export goods, recorded during the same quarterly span of the year 2019, appeared to display significant negative impacts on the dependent variable with respect to both models. Such a finding highlights well that, starting from the first quarter of 2020 to the third quarter of 2022, the ports' import and export goods continued to

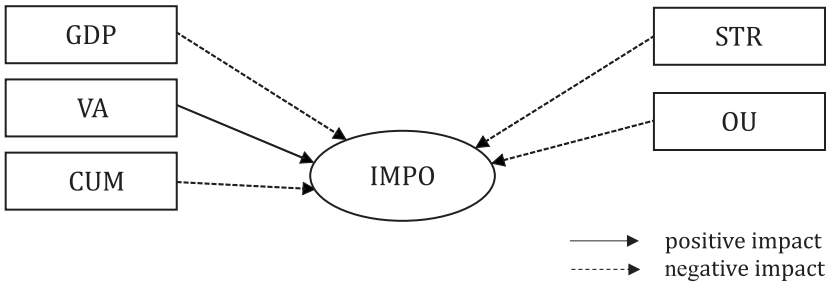

Figure 1 Regression results of the Tunisian ports recorded import freight throughputs.

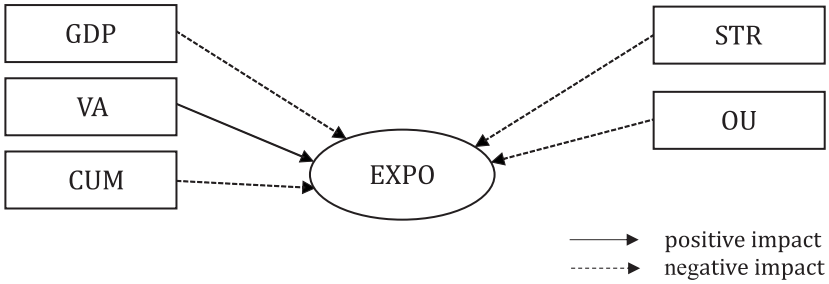

Figure 2 Regression results of the Tunisian ports recorded export freight throughputs.

dwindle down, as compared to the year 2019. It is also worth stating that the dummy variables' coefficients, recorded during the second quarters of 2020, proved to be negatively correlated with import and export goods, but turned out to be positively and statistically correlated starting from the third quarter of the year 2020, owing mainly to the fact that ever since June, 27, 2020 Tunisia reopened its maritime borders, and that, thanks to the stiff governmental control and the remarkable healthcare workers efforts, the crisis began to attenuate and subside gradually, marking the shipping sector's start to resume regular operations.

6 Conclusion

The effect of the COVID-19 pandemic on seaport activity has made subject of various studies dealing with different contexts. Nevertheless, studies treating such an impact on the Tunisian ports are very scarce, or rather inexistent. Hence, the present study was conducted to investigate to what extent the COVID-19 pandemic disproportionately affected the Tunisian trade sectors' transaction volumes. The aim has been to provide a contribution, though modest, relevant to recognizing the pandemic ensuing economic changes.

To this end, eight Tunisian seaports' panel data, relating to the period ranging from the first quarter of 2020 to the third quarter of 2022, were collected. The data involved epidemic indicators and city-level economic data, to evaluate the impact of various indicators on the Tunisian ports' activities, within the context of the global COVID-19 pandemic imposed circumstances. Actually, on implementing the panel-regression modeling frameworks, more specifically, port cargo throughput, to depict the ports' cargo import and export activities, while maintaining port cargo throughput as a control variable, regarding the same quarter span of the year 2019, and on investigating a number of relevant theories and conducting a thorough empirical analysis, a number of effectively useful conclusions have been reached.

Firstly, the preventive measures and stringent governmental control index, coupled with the cumulative number of confirmed cases appeared to display a significantly negative effect on the throughputs linked to imported and exported merchandise, though the exported goods relating throughput has been rather severely affected by the spread pandemic.

At the economic level, the industrial added value has been discovered to be significantly and positively correlated with the imported and exported cargos respective throughputs, while GDP has turned out to be significantly and negatively correlated with imported and exported goods.

Secondly, from a time-factor perspective, it is worth retaining that the first quarters of the year 2020 have been marked as serious pandemic predominance spans, after which, the pandemic tended to subsequently ease by June 2020, date when the shipping industry started to gradually resume normal activities anew. In effect,

the model attained results proved to be actually fit for dealing with the lived experience. Hence, as a potential crisis safeguarding strategy, policymakers, along with maritime and seaport authorities are required to refine the STR measures, drawing a 'lesson' from the already survived pandemic. Lax policies, equating health concerns and ongoing maritime operations need be equally maintained. Such a strategy also involves boosting investment in seaport logistics and infrastructure, including hi-tech tools state of the art technologies to ensure the sector's continuity and avoid disruptions during turbulent periods. Finally, with global efforts and international cooperation, 'crises' ensuing shocks could be minimized, and the Tunisian seaports' economic role could continue to support the country's sustainable growth and stability.

As a future research vein, we might consider going further with the analysis to elaborate on its several potentially overlapping perspectives. In effect, due to the unavailability of relevant data, our study was predominantly focused on investigating port cargo activity as measured by throughput. Other factors, however, such as handling efficiency, seem worth investigating, as well. Moreover, global trade exchange between Tunisia and other countries seems worth examining, for a rather comprehensive analysis of the pandemic's impacts on the world seaports, including the Tunisian ports, to be achieved. Additionally, the factors affecting the seaports' operations are not restricted to the cities wherein the ports are sited. A potential research line could therefore examine how adjacent ports and their respective hinterlands might jointly interact. Finally, our study was exclusively centered on discussing the impacts of a selection of factors on the overall throughput of Tunisian ports, within the context of the Covid-19 pandemic, and we could then proceed with treating the subject of their respective impacts on wider ranges of cargo traffic.

Table 5. Technical terms relevant descriptions.

Technical Terms	Description
IMPO	Import cargo throughput
EXPO	Export cargo throughput
GDP	GDP
VA	Industrial added value
CUM	Cumulative confirmed cases
SRI	Stringency index
IOU	Import cargo throughput in 2019
EOU	Export cargo throughput in 2019
FEM	Fixed Effects model
REM	Random Effects model
MEM	Mixed effects model

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