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Econometric Evidence of Catalytic Effect of Seaport Activity in OECD Countries: Getting It Right

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ABSTRACT

Within the transportation sector, ships and seaports constitute a significant portion. During the last decade, there has been a rise in the containerization era. This paper quantifies the relationship between seaport activity and GDP per capita while addressing Cross-sectional Dependence and slope heterogeneity issues in 28 OECD countries from 2000 to 2019. Suitable proxies for economic development and seaport activity are subjected to panel data analysis. Cross-Sectionally Augmented Autoregressive Distributed Lag is used, and Common Correlated Effects Mean Group and Augmented Mean Group are employed for the Robustness check. Seaport activity has a positive long-term relationship with income per capita. Country-specific effects are also used to highlight the relative strength of the relationship across sample countries. Panel Granger causality shows the feedback effect between seaport activity and GDP per capita. Causality is also investigated using the Dumitrescu-Hurlin causality test, which is suitable for heterogeneous panels in the presence of cross-sectional dependence. Recommendations include the lessons for carefully appraised investments and standardization of operations in the seaport industry in OECD countries.

1. Introduction

With increased economic globalization, the world economy, industry, and trade structure have changed. Such resulted in more production, operating activities/services, and resource allocation and reallocation. Seaports have become an integral part of international logistics. Ports' functioning has become prominent in global trading networks.

A seaport, a spatial system of nodes and links over the movement of passengers and cargo, plays a critical role in economic growth as it involves many economic activities. These activities include the incoming volumes of trading cargoes and outgoing container cargoes to or from waterways and shores. Earnings through these activities on ports lead to the economic growth of the regions having ports. Ports' activities, directly and indirectly, affect economic activities. They indirectly help boost the local economies by generating jobs and income for the laborers working on ports and those involved in providing services for port activities. They directly help increase the economic welfare of the port-containing regions through value-addition activities.

The traces of revolution in mass transit can be felt in the 1st (1800), second (1850), and fourth (1950) Kondratiev waves

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(Papenhausen, 2008; Korotayev and Sergey, 2010). More specifically, during the mid-1950s, containerization was initiated by the Road Haulage company of the USA to increase the productivity of traditionally costly cargo handling operations. Moreover, a costly administrative process that slowed down road traffic and experiments would be initiated. Similarly, in 1956 a sea bridge was formed to move cargo in bulk in containers from one state to another, and the experiment remained successful (Levinson, 2006). According to Levinson (2006) and Cho and Yang (2011), four stages of container throughput growth, namely, introduction, adoption, growth, and maturity, led to the containerization era (Fig. 1).

Musso et al. (2006) picture the evolution of seaports from traditional labor-intensive merchant ports to manufacturing sites with increasingly large and expensive equipment. Finally, the specialization of ships and terminals led to the "Maturity" phase of the containerization era. The increase in growth can be justified by the technological up-gradation in the shipping industry and, most importantly, due to the introduction of containerization in the seaborne trade. The maritime industry plays a critical role in the global economy, with a substantial amount of trade transported through ships via seaports. According to multiple sources (Peters, 2020; Haralambides, 2019; Schnurr & Walker, 2019; and George, 2013), around 80-90% of global trade is moved through seaports, highlighting the importance of the maritime industry in international trade. Out of various forms of seaborne trade, this study uses container port traffic as a proxy. Though there are other sizeable components of seaborne cargo (e.g., dry bulk shipping), yet container port traffic substantially fulfills the panel data requirement of time and cross-section dimensions.

This indicates the significant role that containerization has played in shaping the industry, leading to more efficient and streamlined transportation of goods across borders. Container ports act as a platform for containerized activities and are critical to economic growth. The fundamental objective of container ports is to maximize the annual port throughput subject to minimum profit constraints. Earnings through these activities on ports lead to the economic growth of the regions having ports. Therefore, the study used Container port traffic as a proxy variable of seaport activity. The evidence of the significance of seaports in economic growth and development can be judged by the increased spending on infrastructure and superstructure related to seaports by developed countries (Musso et al., 2006).[1]

Moreover, due to their positive economic effects, seaports are crucial in domestic and international trade. They contribute to many supply chains and distribution channels and thus play an essential role in economic growth. Seaports are logistics centres that increase the functioning of the global market together with their port region (Shan et al., 2014). By considering the recent containerization era and the expected positive role of the seaport industry in economic development, this paper empirically quantifies the contribution of seaports to economic performance in OECD countries.

The rest of the paper is organized as follows: the second section covers the literature review. The third section describes the methods used in this study. The fourth is assigned for an empirical analysis where econometric techniques are described. The fifth section belongs to the conclusion, and the last section is preserved to references.

2. Literature Review

According to the author's best knowledge, the empirical work on seaports' contribution to economic growth is limited. Initial studies include the justification of the seaport's economic benefits, including increased consumer and producer surpluses, technical efficiency, and economies of scale. The relevant work is done for some countries with different economic aspects of seaport activities. For instance, Lee et al. (2008) found that Asian hub port cities have evolved with time and the increasing demand for sea transportation for trade. Hub port cities were developed to cater to increased global competition demand. Accordingly, the 'Asian Consolidation Model' is the title used for the Asian context. Gonzalez and Trujillo (2009) conducted a systematic analysis through economic efficiency and productivity analysis. They highlighted knowledge gaps in the efficiency measurement of port activities due to the unavailability of port data. Jung (2011) investigated the economic performances of major port cities in Korea. According to his analysis, many port cities failed to get out of the poor economic state's presence of ports, so readily available services cannot guarantee economic success. Economic leadership and harmonization of ports could lead to regional economic development.

Bottasso et al. (2013) investigated the effect of 116 seaports' activity of OECD on local employment using the system GMM approach for data from 2000-2006. They found a significant positive relationship but not using local employment; instead, using service and manufacturing employment. Deng et al. (2013) analyzed the effect of port supply, port demand, and value-added activities on the regional economies connected to ports. They employed the structural equation method for finding the results. Results showed that value-added services significantly affect the regional economies, compared to the port's supply and demand.

Mehmood et al. (2015) examined the nexus between air transport and the macroeconomic performance of Asian economies from 1970 to 2014. By employing sophisticated panel data techniques, results concluded that air transport significantly impacts the economic growth of sample countries. The panel granger causality test shows the feedback effect from macroeconomic performance and air transport. Park and Seo (2016) investigated the economic impact of the seaport in Korea by using an augmented Solow model based on panel data covering regions of Korea over the period from 2000 to 2013. The study revealed the positive impact of container port activities on regional economic growth, and indirect investment in port increase economic growth. Lastly, public investments in seaport activity contribute positively to economic growth by contributing to value-added and developing other economic activities.

Yudhistira and Sofiyandi (2018) studied the relationship between access to existing port infrastructure and regional economic

[1] Infrastructure includes yards, specific transport infrastructure, reclamation work carried out prior to the realization of superstructures. Whereas superstructure includes transportation systems, cranes, ware-houses, office buildings, etc., and other instrumental assets used to produce saleable services.

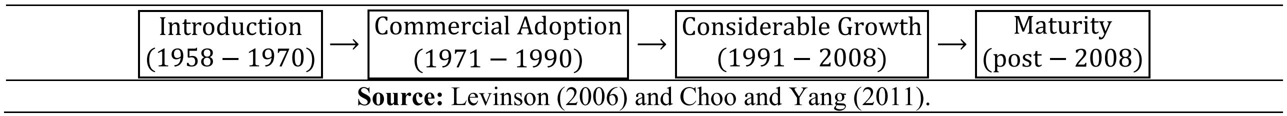

Fig. 1. Evolution of Containerization Era
Source: Levinson (2006) and Choo and Yang (2011).

development at Indonesia's district level. Findings concluded that proximity to the main ports positively impacts economic indicators such as GDP per capita, labor productivity, poverty rate, and poverty gap. In regions with a distance of over 150 Km to the nearest seaport, the manufacturing sector contributed 5.7% to 7.1% of the Gross Domestic Regional Product. In contrast, regions located 29-67 km from the nearest seaport have a relatively low poverty rate (10.3-12.2% on average).

Park et al. (2019) examined the role of transport Infrastructure on the economic growth of OECD and non-OECD countries. Transport infrastructure includes roads, highways, railways, seaports, and airports. This study adopted a hybrid production approach that combines economic growth with the demand and supply of transportation. Results of panel two-stage least square concluded that maritime transport contributed more to economic growth than air, land, and transport. Efimova et al. (2020) explored how ports cargo turnover affects fundamental economic indicators such as gross regional product, employment level as well as job creation by comparing two north-western Russian regions (St. Petersburg and Leningrad Province) and two western European regions (Antwerp Province and Groot-Rijnmond) for the period 2000-2015. The study revealed that ports under consideration differ in their impact on socioeconomic development.

Mudronja et al. (2020) analyzed the impact of seaports on the growth of 107 European Union Port regions from 2005 to 2015. Results of generalized moments of methods concluded that seaports significantly impact the economic growth of European Union port regions. Nguyen et al. (2021) examined the impact of logistics and infrastructure on economic growth in the case of Vietnam over the period 2007-2019. Explanatory variables include logistic activities such as logistic infrastructure, service quality, up-to-date delivery information, competitive price, and convenient customs. The study uncovered that logistic infrastructure, on-time shipment, up-to-date delivery, and competitive prices positively boost Vietnam's economy. Krmac and Kaleibar's (2022) systematic review was conducted to screen and analyze the port performance and efficiency by incorporating data envelopment analysis (DEA). The study showed that DEA is a good assessment tool for predicting future port performance. The results also indicated that ports are crucial to countries' trade and economic growth. Moreover, seaport efficiency and port throughput significantly positively impact economic development in Africa. Therefore, improvement in seaport activities is crucial to attaining a more significant impact of a seaport on economic growth (Ayesu et al., 2022).

3. Contribution

This paper fills the literature gap of cross-country evidence on seaport-led growth. Existing literature deals with country studies or provincial panel data, for instance, and Park & Seo (2016). In panel settings, the studies overlook the cross-sectional dependence (CSD) and slope heterogeneity, for instance, Mudronja et al. (2020), Park et al. (2019), and Ayesu, Sakyi, & Darku (2022). While dealing with macro panels, as in the current study, it is necessary to take care of significant concerns associated with panel data, including cross-sectional dependence (OECD, 2004). If this issue is overlooked, it can render the estimates biased and unreliable. The standard factor model used in the current study takes care of these issues across panel members. Real-life implications of cross-sectional dependence (e.g., the oil price shock, global financial crisis, and local spillover) remain untapped in seaport research. This research addresses this issue using sophisticated econometric tools such as Augmented Mean Group and Common Correlated Effects Mean Group estimation.

4. Testable Hypothesis

The current study is conducted to test the following hypothesis:

H_A: A long-run causal relationship exists between seaport activity and GDP per capita while considering cross-sectional dependence.

Seaports' macroeconomic effects are bifurcated into catalytic, Keynesian, and Neoclassical effects. The catalytic effects of seaports include attracting businesses, creating jobs, and generating income within the seaport area. Furthermore, a rise in income leads to effects whereby income is multiplied (in a Keynesian sense), and investment is accelerated (in a Neoclassical sense). Oil-exploring developed countries give the importance of catalytic effects is duly considered by developed countries engaged in oil exploration as it relates to their development capabilities. The schematic diagram is furnished in (Fig. 2).

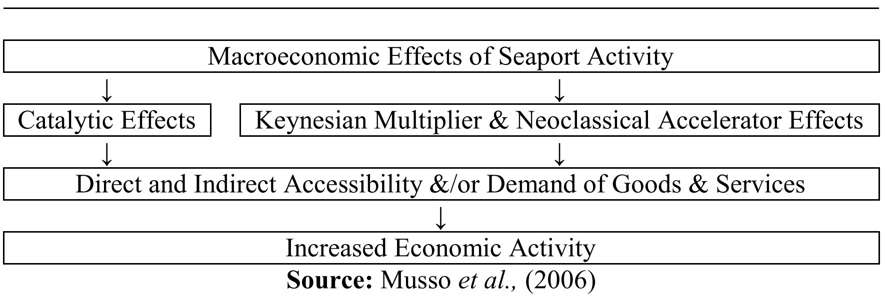

Fig. 2. Macroeconomic Effects of Seaport Activity
Source: Musso. *et al.* (2006).

The following data and methodology are used to test the validity of this hypothesis.

5. Data and Methods

For the empirical evidence about the involvement of seaport activity in economic growth, a balanced panel dataset of 20 years from 2000 to 2019 is used for a group of OECD countries. Depending upon the availability of data, 28 OECD countries were selected. Data constitute a macro panel, i.e., large T (time) and large N (cross sections), Eberhardt and Teal (2010). For large T and large N assumption of slope homogeneity is often inappropriate (Pesaran and Smith, 1995; Im, Pesaran & Shin, 2003; Pesaran et al., 1999; Phillips & Moon, 2000). Therefore, a heterogeneous slope model should be used. For the slope heterogeneous dynamic panel data model, consistent estimators are provided by CS-ARDL, AMG, and CCEMG techniques for a panel, which employ the panel extension of the single equation autoregressive distributed lag (ARDL) model. After converting the CS-ARDL model into error correction, AMG and CCEMG estimators are obtained to check the robustness of the results. Data sources include World Development Indicator (WDI), and the extent of its availability determines the dimensions of the balanced panel dataset.

We have a macro-panel that spans over 20 years. So, CS-ARDL, CCEMG, and AMG are suitable estimation techniques as they are appropriate for macro panels instead of other dynamic panel estimators such as Arellano-Bond. Arellano-Bond is a micro-panel data suitable when the time dimension is between 3 to 10 periods (Roodman, 2009). Further, Arellano-Bond does address autocorrelation, heteroscedasticity, and endogeneity. However, it doesn't incorporate the Cross-sectional dependence, which is quite common in heterogeneous panels. CS-ARDL, CCEMG, and AMG also consider the slope heterogeneity among the cross-sections. These points make CS-ARDL, CCEMG, and AMG superior to Arellano-Bond.

The GDP per capita (YPC) is treated as the dependent variable. In contrast, this study treats seaport activity as the primary independent variable, with capital formation and trade volume as control variables. The Container port traffic is used as a proxy variable of seaport activity because it covers the central dimension of seaport activity. In the maritime industry, 90% of global freight moves through seaports, from which 80% is moved through containers. Such indicates the importance of containerization in global shipping transportation. Container ports act as a platform for containerized activities and play a critical role in economic growth (Musso et al., 2006). Capital formulation and trade are suitable to control variables because seaport activity is usually capital-intensive and facilitates trade with other countries. As Musso et al. (2006) noted, the gradual transformation of seaports into manufacturing sites and a capital-intensive industry characterizes the containerization era's current "maturity" phase. International trade also provides a platform for national and regional economic development, especially in European Union (Winkelmans, 2004; Martine et al., 2004). Moreover, greater trade openness benefits economic growth (Zahonogo, 2016). In short, evidence shows that capital formation and trade openness play a vital role in the economic growth of OECD countries (Ogbeifun & Shobande, 2022).

Gross fixed capital formation is formally called gross domestic fixed investment. It includes plant, machinery, land improvements, equipment purchase, and construction of schools, offices, roads, railways, commercial and industrial buildings, and hospital and private residential dwellings (World Bank national accounts data and OECD National Accounts data files). Data are in the form of constant 2015 US$.

5.1. Estimable Production Function

The functional form of the model to estimate the relationship between GDP per capita and seaport activity in OECD countries is given as follows:

$$\boldsymbol{YPC}_{i,t} = \boldsymbol{f}\left(\boldsymbol{CPT}_{i,t},\ \boldsymbol{CAP}_{i,t}, \boldsymbol{TRD}_{i,t}\right)$$

Where:

$\boldsymbol{YPC}_{i,t}$ = GDP per capita (constant 2005 US$).
$\boldsymbol{CPT}_{i,t}$ = Container port traffic (TEU: 20-foot equivalent units).
$\boldsymbol{CAP}_{i,t}$ = Gross fixed capital formation (constant 2005 US$).
$\boldsymbol{TRD}_{i,t}$ = Trade (% of GDP).

All other variables except for $TRD_{i,t}$, are in natural logarithmic form. *i* and *t* stand for cross-sections and periods, respectively. The list of selected OECD countries includes Australia, Austria, Belgium, Canada, Chile, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Rep., Netherlands, New Zealand, Norway, Poland, Portugal, Slovenia, Spain,

Table 1
Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
YPC	5.04×10^{11}	1.11×10^{12}	0	5.20×10^{12}
TRD	96.46466	83.67108	0.015	447.24
CAP	2.06×10^{11}	4.53×10^{11}	0	3.30×10^{12}
CPT	1.02×10^{7}	2.16×10^{7}	5962.88	1.40×10^{8}

Source: Authors' calculations

Sweden, Switzerland, United Kingdom, and the United States. The descriptive statistics of the panel dataset are as follows:

Table 1, the descriptive statistics of the data show the mean, standard deviation, and minimum and maximum values. The results show that the mean value and Standard Deviation (SD) value of GDP per capita (YPC) are 5.04 $\times 10^{11}$ and 1.11 $\times 10^{12}$, respectively, indicating more significant variation in observations from the mean. Similarly, the mean value of CAP is 2.06 $\times$ $10^{11}$and SD value is 4.53 $\times 10^{11}$, showing a more significant variation in observation from the mean. Most SD values are higher, indicating that observation varies from the mean within a broad range. The results also suggest a slight variation in the TRD in the sample countries.

5.2. Slope homogeneity Test

Swamy (1970) developed the framework to find if the slope coefficients of the cointegration equation are homogeneous. Pesaran and Yamagata (2008) improved Swamy's slope homogeneity test and formed two **'delta'** test statistics; $\widetilde{\Delta}$ and $\widetilde{\Delta}_{adj}$.

$$\widetilde{\Delta} = \sqrt{N}\left(\frac{N^{-1}\overline{S} - k}{\sqrt{2k}}\right) \sim X_k^2$$

$$\widetilde{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{-1}\overline{S} - k}{v(T,k)}\right) \sim N(0,1)$$

N denotes the number of cross-section units; S denotes the Swamy test statistic; k denotes independent variables. If p value of the test is more significant than 5%, the null hypothesis is accepted at a 5% significance level, and the cointegrating coefficients are considered homogenous. $\widetilde{\Delta}$ and $\widetilde{\Delta}_{adj}$, are suitable for large and small samples, respectively, where $\widetilde{\Delta}_{adj}$, is the 'mean-variance bias adjusted' version of $\widetilde{\Delta}$.

Standard delta test $(\widetilde{\Delta})$ requires error not to be autocorrelated. By relaxing the assumptions of homoskedasticity and serial independence of Pesaran and Yamagata (2008), Blomquist and Westerlund (2013) developed a Heteroskedasticity and Autocorrelation Consistent (HAC) robust version of slope homogeneity test; Δ_{HAC} and $(\Delta_{HAC})_{adj}$:

$$\Delta_{HAC} = \sqrt{N}\left(\frac{N^{-1}S_{HAC} - k}{\sqrt{2k}}\right) \sim X_k^2$$

$$(\Delta_{HAC})_{adj} = \sqrt{N}\left(\frac{N^{-1}S_{HAC} - k}{v(T,k)}\right) \sim N(0,1)$$

The results of both of these tests are furnished in Table 2.

The null hypothesis of slope homogeneity can be rejected in all cases because the probability values are smaller than 0.05. The slope coefficients are not homogeneous. Heterogeneity exists across sample countries which recommends employing heterogeneous panel techniques.

5.3. Cross-Sectional Dependence

5.3.1. Cross-Sectional Dependence in Residual

In Table 3, two cross-sectional tests are reported. Chudik and Pesaran (2015) and Bailey et al. (2016), along with Bailey et al.

Table 2
Slope Homogeneity Tests

	Statistic	value
Pesaran and Yamagata (2008)		
$\widetilde{\Delta}$	$\sqrt{N}\left(\frac{N^{-1}\overline{S} - k}{\sqrt{2k}}\right) \sim X_k^2$	5.257[a]
$\widetilde{\Delta}_{adj}$	$\sqrt{N}\left(\frac{N^{-1}\overline{S} - k}{v(T,k)}\right) \sim N(0,1)$	6.556[a]
Blomquist and Westerlund (2013)		
Δ_{HAC}	$\sqrt{N}\left(\frac{N^{-1}S_{HAC} - k_2}{\sqrt{2k_2}}\right)$	12.393[a]
$(\Delta_{HAC})_{adj}$	$\sqrt{N}\left(\frac{N^{-1}\overline{S}_{HAC} - k_2}{v(T,k)}\right) \sim N(0,1)$	15.456[a]

[a] represents statistical significance at 1%.

$\widetilde{\Delta}$ and $\widetilde{\Delta}_{adj}$, represent the 'simple' and 'mean-variance bias adjusted' slope homogeneity tests, respectively.

Δ_{HAC} and $(\Delta_{HAC})_{adj}$, represent the 'Heteroskedasticity and Autocorrelation Consistent' versions of 'simple' and 'mean-variance bias adjusted' slope homogeneity tests, respectively.

(2019) versions of Pesaran (2004) CD tests are estimated to scrutinize the presence of cross-sectional dependence in residuals of the estimable model. Both tests are statistically significant at 1%, supporting the assumption of cross-sectional dependence in the residuals of the estimable model.

5.3.2. Cross-Sectional Dependence in Variables

Based on Chudik, and Pesaran (2015); Bailey et al. (2016), and Bailey et al. (2019), Table 4 delves deeper by estimating cross-sectional dependence statistics for relevant variables. $(\boldsymbol{YPC}_{i,t}, \boldsymbol{CPT}_{i,t}, \boldsymbol{CAP}_{i,t}, \boldsymbol{TRD}_{i,t})$. All of the variables show statistically significant at 1% showing cross-sectional dependence in the variables of the estimable model.

Table 3 and Table 4 show the cross-sectional dependence in the residual and the model variables. So, those estimation tools that incorporate cross-sectional dependence in the estimation process will be chosen.

5.4. Stationarity Tests

Cross-sectional dependence has a strong presence in residuals and variables, as tested in Table 3 and Table 4. It calls for checking stationarity using the second generation of unit root tests since the first generation of unit root tests (Im et al., 2003; Levin et al., 2002; Maddala and Wu, 1999) do not account for cross-sectional dependence in testing for stationarity.

Considering the evident cross-sectional dependence, we use second-generation unit root tests proposed by Pesaran to shed light on the findings. Mathematically:

$$\Delta y_{i,t} = a_i + b_i y_{i,t-1} + c_i \overline{y}_{t-1} + d_i \Delta \overline{y}_t + \varepsilon_{i,t}$$

Where a_i is a deterministic term, $\overline{y}_t$, is the cross-sectional mean at time $\boldsymbol{t}$ and $\boldsymbol{\rho}$ is the lag order. $\boldsymbol{t}_i(\boldsymbol{N}, \boldsymbol{T})$ denotes the corresponding $\boldsymbol{t}$-ratio of $\boldsymbol{\alpha}_i$ and is known as cross-sectional ADF {CADF, attributed to Pesaran (2003)}. The average of the $\boldsymbol{t}$-ratios gives the cross-sectional IPS {CIPS, attributed to Pesaran (2007)}. This test is estimated with a constant term at a level and first difference. The mutual consensus of both CADF and CIPS tests reveals that all variables are stationary at the first difference, i.e., $\boldsymbol{I}(1)$ (Table 5).

6. Empirical Analysis

6.1. Long Run and Short Run Analysis

The mutual consensus of both CADF and CIPS tests reveals that all variables are stationary at the first difference, i.e., $\boldsymbol{I}(1)$. After checking the stationarity of the variables, we apply the Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL, henceforth) model. Attributed to Chudik and Pesaran (2015), CS-ARDL is used to study the long-run and short-run relationship among ***YPC***, ***CPT***, ***CAP***, and ***TRD***. The equation is given as follows:

$$D_{i,t} = \sum_{I=0}^{p_D} \vartheta_{I,i} D_{i,t-I} + \sum_{I=0}^{p_X} \delta_{I,i} X_{i,t-I} + \epsilon_{i,t}$$

To solve the issue of cross-sectional dependency and slope heterogeneity, the extended version of the last equation is given as:

$$D_{i,t} = \sum_{I=0}^{p_D} \vartheta_{I,i} W_{i,t-I} + \sum_{I=0}^{p_X} \delta_{I,i} X_{i,t-I} + \sum_{I=0}^{p_Z} \sigma_i^{'} I \overline{Z}_{t-I} + \epsilon_{i,t}$$

In the last equation, $\overline{Z}_{t-I} = (\overline{D}_{i,t\bar{I}}, \overline{X}_{i,t\bar{I}})$, provides the averages; similarly, lags are shown through p_D, p_X, p_Z: D_{it} is the dependent variable (here *GRD*), followed by $X_{i,t}$, for all the independent variables (here ***YPC***, ***CPT***, ***CAP***, and ***TRD***. $\overline{Z}$, is a dummy for a period. The long-run coefficients are generally represented as:

$$\widehat{\theta}_{CS-ARDL,i} = \frac{\sum_{I=0}^{p_X} \widehat{\delta}_{I,i}}{1 - \sum_{I=0}^{p_D} \widehat{\vartheta}_{I,i}}$$

Whereas the following equation shows the mean group coefficients:

Table 3
Tests for Cross-Sectional Dependence in Residuals

Test	Statistic	Value
CD_{NT}^{2015}	$\sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \frac{1}{\sqrt{T}} \sum_{t=1}^{T} \xi_{it} \xi_j$	22.963[a]
CD_{BKP}	$\sqrt{\frac{TN(N-1)}{2}} \widehat{\rho}_N$	41.139[a]

[a] represents statistical significance at 1%.
Source. Authors' estimates.

Table 4
Tests for Cross-Sectional Dependence in Variables

Test	Statistic	Value for: $YPC_{i,t}$	$CPT_{i,t}$	$CAP_{i,t}$	$TRD_{i,t}$
CD_{NT}^{2015}	$\sqrt{\frac{2}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\frac{1}{\sqrt{T}}\sum_{t=1}^{T}\xi_{it}\xi_{j}$	22.963[a]	35.577[a]	27.774[a]	28.240[a]
CD_{BKP}	$\sqrt{\frac{TN(N-1)}{2}}\widehat{\overline{\rho}}_N$	23.373[a]	40.232[a]	28.329[a]	28.664[a]

[a] represents statistical significance at 1%.
Source. Authors' estimates.

Table 5
Second Generation Unit Root Tests for Individual Variables

Cross-Sectional ADF (CADF) Test							
$YPC_{i,t}$	$\Delta YPC_{i,t}$	$CPT_{i,t}$	$\Delta CPT_{i,t}$	$CAP_{i,t}$	$\Delta CAP_{i,t}$	$TRD_{i,t}$	$\Delta TRD_{i,t}$
-1.286	-2.453[a]	-2.060[c]	-3.345[a]	-1.639	-2.177[b]	-1.940	-3.019[a]
Cross-Sectional IPS (CIPS) Test							
$YPC_{i,t}$	$\Delta YPC_{i,t}$	$CPT_{i,t}$	$\Delta CPT_{i,t}$	$CAP_{i,t}$	$\Delta CAP_{i,t}$	$TRD_{i,t}$	$\Delta TRD_{i,t}$
-1.589	-3.785[a]	-2.863	-5.627[a]	-1.959	-3.698[a]	-0.092	-2.980[a]

Note: By definition: $\boldsymbol{CIPS} = \frac{\sum_{i=1}^{N} t_i(N,T)}{N} = \frac{\sum_{i=1}^{N} CADF_i}{N}$
[a], [b] and [c] represent statistical significance at 1%, 5%, and 10%.

$$\widehat{\overline{\theta}}_{MG} = \frac{1}{N}\sum_{i=1}^{N}\widehat{\theta}_i$$

Similarly, the short-run coefficients are expressed with the following four equations:

$$\Delta D_{i,t} = \vartheta_i\left[D_{i,t-1} - \theta_i X_{i,t}\right] - \sum_{I=1}^{p_{D-1}}\vartheta_{I,i},\Delta_I W_{i,t-I} + \sum_{I=0}^{p_X}\delta_{I,i}\Delta_I X_{i,t} + \sum_{I=0}^{p_Z}\sigma_i' I\overline{Z}_t + \varepsilon_{i,t}$$

$$\widehat{\alpha}_i = -\left(1 - \sum_{I=1}^{p_D}\widehat{\vartheta}_{I,i}\right)$$

$$\widehat{\theta}_i = \frac{\sum_{I=0}^{p_X}\widehat{\delta}_{I,i}}{\widehat{\alpha}_i}$$

$$\widehat{\overline{\theta}}_{MG} = \sum_{i=1}^{N}\widehat{\theta}_i$$

In CS-ARDL, the *ECM* should be statistically significant, as it shows the speed of adjustment towards equilibrium.

Table 6 shows the results of CS-ARDL estimation. The results reveal that Container Port Traffic, Gross fixed capital formation, and trade (% of GDP) have a statistically significant relationship with GDP per capita. The positive values in the short and long-run (CS-ARDL) of coefficients of CPT, CAP, and TRD show that an increase in these variables helps GDP per capita in sample countries to grow. i.e., $\frac{\partial YPC_{i,t}}{\partial CPT_{i,t}} > 0, \frac{\partial YPC_{i,t}}{\partial CAP_{i,t}} > 0$ and $\frac{\partial YPC_{i,t}}{\partial TRD_{i,t}} > 0$. The *p*-values show the relevant statistical significance of variables. The coefficient of CPT shows

Table 6
CS-ARDL Estimations

	Dependent Variable: $YPC_{i,t}$ Long Run			Short Run	
Variable	**Slope coefficient**	**Standard Errors**	**Variable**	**Slope coefficient**	**Standard Errors**
$CPT_{i,t}$	0.1201[a]	0.0349	$\Delta CPT_{i,t}$	0.2557[a]	0.0914
$CAP_{i,t}$	0.3021[b]	0.1597	$\Delta CAP_{i,t}$	0.7587[b]	0.0623
$TRD_{i,t}$	0.0794[c]	0.0392	$\Delta TRD_{i,t}$	0.1409[c]	0.0318
-	-	-	$ECT(-1)$	-0.8799[b]	0.349

[a], [b] and [c] show statistical significance at 1%, 5%, and 10%, respectively.
Source: Authors' estimations

that a 1% increase in CPT will increase YPC by 0.12% in the long run while a 0.25% increase in the short run at a 1% significance level. The seaport activities are caused for catalytic effects that attract business, create jobs, and generate revenue and income within the seaport area. The catalytic effects are essential for OECD countries due to their developmental ability. Furthermore, the direct and indirect accessibility and demand for goods and services increase due to catalytic effects within seaport areas that ultimately push economic activities and development (Musso et al., 2006).

This finding of the positive effect of Container Port Traffic on GDP per capita can be supported by the results of Park et al. (2019); Efimova et al. (2020); Mudronja, Jugović & Škalamera-Alilović (2020), Nguyen, et al., (2021) and consistent with the findings of Park & Seo, (2016), and Ayesu, Sakyi, & Darku (2022). Hence, despite accounting for CSD, the findings of this study align with those of previous research, verifying that seaport activity has a positive impact on economic growth. Additionally, this study differs from previous studies by estimating country-wise slopes for the seaport-led growth hypothesis, providing a more nuanced understanding of the relationship between seaports and economic development. The results for $\boldsymbol{ECM}(-1)$ show that around 87.9% of disequilibrium is corrected yearly.

6.2. Robustness Check

This study used the Common Correlated Effects Mean Group (CCEMG) by Pesaran (2006) and the Augmented Mean Group (AMG) by Eberhardt and Teal (2010) for a robustness check. These estimators provide reliable results with unobserved common factors, non-stationarity, cross-sectional dependence, and heterogeneous slopes. Pesaran and Smith (1995) provided a Mean Group (MG) estimator of dynamic panels for a large number of time observations and a large number of groups. In this method, separate equations are estimated for each group, and the coefficient distribution of these equations is examined across groups.

However, in the case of dynamic analysis, the presence of CD requires the implementation of improved versions of the MG approach. Therefore, it is logical to deploy estimation techniques that cater to cross-sectional dependence. Pesaran (2006) forwarded the Common Correlated Effects Mean Group (CCEMG) model with an estimator $\beta_j(=\beta+\omega_j)$ which implies a common parameter β across the countries while $\omega_j \sim IID(0, V_\omega)$. CCEMG tends to eliminate CD asymptotically. Moreover, it allows heterogeneous slope coefficients across group members that are captured simply by taking the average of each country's coefficient.

Attributed to Eberhardt and Teal (2010), the Augmented Mean Group (AMG) is a surrogate to CCEMG, which also captures the unobserved common effect in the model. Moreover, the AMG estimator also measures the group-specific estimator and takes a simple average across the panel. The highlight of AMG is that it follows the first difference OLS for pooled data and is augmented with year dummies.

In functional form, the estimable model can be rewritten as follows:

$$\boldsymbol{YPC}_{it} = \boldsymbol{\alpha}_i + \boldsymbol{c}_i\boldsymbol{t} + \boldsymbol{d}_i\widehat{\boldsymbol{\mu}}_t^{\boldsymbol{va\bullet}} + \boldsymbol{\beta}_{i,1}(\boldsymbol{CPT}_{i,t}) + \boldsymbol{\beta}_{i,2}(\boldsymbol{CAP}_{i,t}) + \boldsymbol{\beta}_{i,3}(\boldsymbol{TRD}_{i,t}) + \boldsymbol{\varepsilon}_{i,t}$$

where, i stands for cross-sectional dimension $i = 1,\ldots,$n and time period t $= 1,\ldots,$t and α_i represents country-specific effects and d_it denotes heterogeneous country-specific deterministic trends. α_i, is related to the coefficient of respective independent variables $\beta_{i1} = \frac{\alpha_{i1}}{1-\alpha_{i1}}$, $\beta_{i2} = \frac{\alpha_{i2}}{1-\alpha_{i2}}$ and $\beta_{i3} = \frac{\alpha_{i3}}{1-\alpha_{i3}}$, that are considered heterogeneous across the countries. It is also assumed that the short-run dynamics and their adjustment towards the long run take place via error term$u_{i,t}(=\Gamma_i' f_t + \varepsilon_{i,t})$. f_t Characterizes the vector of unobserved common shocks. f_t, can be either stationary or nonstationary, which does not influence the validity of the estimation (Kapetanios, Pesaran, & Yamagata, 2011). AMG estimation finds an explicit estimate for f_t which renders $\widehat{\mu}_t^{va\bullet}$ (Common dynamic process) economic

Table 7
Dynamic Analysis – Cointegration Results with Cross-Sectional Dependence

	Common Correlated Effects Mean Group		Augment Mean Group†	
	WoT	*WT*	*WoT*	*WT*
$\boldsymbol{CPT}_{i,t}$	0.0354[b] (0.017)	0.0392[c] (0.020)	0.1378[a] (0.031)	0.0405[b] (0.016)
$\boldsymbol{CAP}_{i,t}$	0.0091[a] (0.002)	0.0066[a] (0.002)	0.0052[a] (0.002)	0.0084[a] (0.002)
$\boldsymbol{TRD}_{i,t}$	-0.0671 (0.070)	-0.0026 (0.058)	0.1055[a] (0.031)	0.0791[a] (0.028)
$(\boldsymbol{CDP})\ \widehat{\boldsymbol{\mu}}_t^{\boldsymbol{va\bullet}}$	–	–	0.0154 (0.048)	0.1519[a] (0.055)
Country Trend	–	0.0065[a] (0.002)	–	0.0063[a] (0.002)
Constant	7.6852[a] (0.522)	7.5488[a] (0.584)	7.6470[a] (0.414)	9.0065[a] (0.194)
NST	–	8	–	14
RMSE	0.0196	0.0149	0.0336	0.0220
Observations	560	560	560	560
Groups	28	28	28	28
CD	1.93[c]	0.89	1.58	4.62[a]

Notes: ***WoT*** and ***WT*** stand for estimation without and with country-specific trends. CDP is a common dynamic process. $\widehat{\boldsymbol{\mu}}_t^{\boldsymbol{va\bullet}}$ is the common dynamic process. In parenthesis, standard errors are given, whereas [a] [b], and [c] shows statistical significance at 1%, 5%, and 10%, respectively. ***NST*** stands for Number of Significant Trends. ***RMSE*** stands for root mean squared error and uses residuals from group-specific regression.

meaningfulness. Total factor productivity (TFP) is one of the plausible interpretations of $\widehat{\mu}_t^{va\bullet}$. It's coefficient d_i, represents the implicit factor loading on common TFP. In addition, the cross-sectional specific errors $\varepsilon_{i,t}$, are permissible to be serially correlated over time and weakly dependent across the countries (Cavalcanti et al., 2011). However, the regressors and unobserved common factors have to be identically distributed.

All MG estimators can capture the individual effect of an omitted variable that evolves linearly by including group-specific time trends (Bond and Eberhardt, 2013; Gundlach & Paldam, 2016). Furthermore, panel data has the advantage of controlling for the effects of unobserved or missing variables (Branas-Garza, Bucheli & Garcia-Munoz, 2011; Sisay, 2015) (Table 7).

A statistically significant positive relationship is found in both estimations. Container Port Traffic remains statistically significant, though its level varies among the CCEMG and AMG over the estimators of Without Trend and With Trend. Control variables, including fixed capital formation and trade volume, show positive signs with statistical significance. Hence, the results found using CS-ARDL are robust when subject to contemporary estimation techniques; CCEMG and AMG.

As already, the presence of cross-sectional dependence is evidenced by the tests. Such implies an effect of some unobserved common factors, common to all units and affecting each, although possibly in different ways. For instance, like-mindedness in sharing the values of existing countries, i.e., democratic principles, market-based economy, good governance, human rights, and the rule of law, are prerequisites of OECD membership (OECD, 2004). Augmented Mean Group (AMG) provides the facility of estimating Common Dynamic Process (CDP) $\widehat{\boldsymbol{\mu}}_t^{\boldsymbol{va\bullet}}$. The dynamic process is estimated using two assumptions. i.e., Without Trend and With Trend. Estimates are statistically significant (0.0154 and 0.1519, respectively). These show the effect of cross-sectional dependence on gross domestic product per capita.

6.3. Expected, Unexpected, and Inconclusive Country-Specific Effects

This section gives the country-wise slopes for the seaport-led growth hypothesis. 75% of the sample OECD countries have expected country-specific effects, i.e., positive and statistically significant relationships. Only two countries (Greece and Iceland) showed paradoxical results, i.e., a negative and statistically significant relationship. Such could be attributed to the absence of the private sector in the seaport industry, which reduces the overall efficiency (Pallis and Syriopoulos, 2007; Psaraftis, 2007; Vaggelas, 2007). The remaining five countries, including Italy, have no statistically significant relationship. Barros (2006) highlighted the obstructive role of the public sector in removing inefficiencies and implementing competitive strategies concerning Italian seaports. However, other factors like customer demand adaptability are crucial to port competitiveness and contribute to GDP (Tongzon & Heng, 2005). Such factors can be considered the reason for insignificant relationships in the said countries. From a policy perspective, the investment in the seaport activity sector in these countries can be a role model for other countries in the panel in terms of their policies (Table 8).

6.4. What Causes What?

6.4.1. Panel Granger Causality Test

The work of Granger (1969) laid the foundation of a causality test that uses bivariate regressions in a panel data context:

Table 8
Country-Specific Effects

Country	β_i	S.E	Country	β_i	S.E
Expected Country Specific effects					
Australia	0.2465[a]	0.015	**Japan**	0.1198[c]	0.064
Austria	0.0612[b]	0.026	**Korea, Rep.**	0.3517[a]	0.086
Belgium	0.0371[b]	0.017	**Netherlands**	0.1757[a]	0.043
Canada	0.1786[a]	0.035	**New Zealand**	0.1291[a]	0.012
Chile	0.2709[a]	0.029	**Norway**	0.0538[a]	0.014
Denmark	0.0269[b]	0.013	**Slovenia**	0.1390[a]	0.029
Estonia	0.2868[a]	0.074	**Spain**	0.0947[a]	0.019
Finland	0.1695[c]	0.093	**Sweden**	0.2602[a]	0.029
France	0.0504[a]	0.008	**United Kingdom**	0.3806[a]	0.090
Ireland	0.4248[a]	0.045	**United States**	0.2794[a]	0.035
Israel	0.2736[a]	0.064	–	–	–
Unexpected Country Specific effects					
Greece	-0.0434[a]	0.015	Iceland	-0.5251[b]	0.208
Inconclusive Expected Country Specific effects					
Germany	0.0208	0.049	Switzerland	0.0197	0.041
Portugal	0.0032	0.005	–	–	–
Inconclusive Unexpected Country Specific effects					
Italy	-0.0157	0.056	Poland	-0.2002	0.124

Country specific slopes $(\boldsymbol{\beta}_i)$
[a], [b] and [c] show statistical significance at 1%, 5%, and 10%, respectively. ***S.E*** stands for standard error.
Source: Authors' estimates.

$$y_{i,t} = \alpha_{0,i} + \alpha_{1,i}\, y_{i,t-1} + \ldots + \alpha_{p,i}\, y_{i,t-p} + \beta_{1,i}\, x_{i,t-1} + \ldots + \beta_{p,i}\, x_{i,t-p} + \epsilon_{i,t}$$

$$x_{j,t} = \alpha_{0,j} + \alpha_{1,j}\, x_{j,t-1} + \ldots + \alpha_{p,j}\, y_{j,t-p} + \beta_{1,j}\, y_{j,t-1} + \ldots + \beta_{p,j}\, y_{j,t-p} + \varepsilon_{j,t}$$

Depending on the assumptions about the homogeneity of the coefficients across cross-sections, there are two forms of panel causality tests. The first and conventional type treats the panel data as one sizeable stacked data set and performs the causality test in the standard way that assumes all coefficients are the same across all cross-sections.

$$\alpha_{0,i} = \alpha_{0,j},\ \alpha_{1,i} = \alpha_{1,j}, \ldots, \alpha_{p,i} = \alpha_{p,i},\ \forall_{i,j}$$

$$\beta_{1,i} = \beta_{1,j}, \ldots, \beta_{p,i} = \beta_{p,i},\ \forall_{i,j}$$

Results of panel Granger causality are shown in Table 9.

Bi-causality between seaport activity and GDP per capita is evident from the results mentioned in Table 9. The mechanism of causality from seaport activity to GDP per capita is already explained by (Musso et al., 2006; Song and Mi, 2016). However, causality from GDP per capita to seaport activity needs some explanation. Increased national income increased direct and derived demand for goods and services, implying an increased volume of trade in terms of goods and services, which puts pressure on the seaport industry to expand its infrastructure and superstructure. Such improves the seaport industry and hence its activity.

6.4.2. *Rationale for Dumitrescu-Hurlin Causality*

However, one of the main issues specific to panel data models is the specification of the heterogeneity between cross-sections. Dumitrescu-Hurlin (2012) developed an assumption of allowing all coefficients to be different across cross-sections to consider the heterogeneity across cross-sections. In this causality context, the heterogeneity can be between the heterogeneity of the regression model and in terms of a causal relationship from x to y. Indeed, the model considered may differ from one individual to another, whereas there is a causal relationship from x to y for all individuals. The simplest form of regression model heterogeneity is slope parameter's heterogeneity. More precisely, in a p-order linear vectorial autoregressive model, four kinds of causal relationships are defined. Under the Homogeneous Non-Causality (HNC) hypothesis, no individual causality from x to y occurs.

On the contrary, there is a causality relationship for each individual in the sample in the Homogeneous Causality (HC) and Heterogeneous Causality (HEC) cases. To be more precise, in the Homogeneous Causality (HC) case, the same regression model is valid (identical parameters' estimators) for all individuals, whereas this is not the case for the HEC hypothesis. Finally, under the Heterogeneous Non-Causality (HENC) hypothesis, the causality relationship is heterogeneous since the variable x causes y only for a subgroup of $N - N_1$ units.

Authors based their version of the causality test on Granger (1969) and extended it to the non-causality test for heterogeneous panel data models with fixed coefficients.

Considering linear model:

$$y_{i,t} = \alpha_i + \sum_{k=1}^{K} \gamma_i^{(k)} y_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{i,t} i \ = \ 1, 2, \ldots, N :\ t \ = \ 1, 2, \ldots, T$$

where x and y are two static variables observed for N individuals in T periods. $\beta_i = \left(\beta_i^{(1)}, \ldots, \beta_i^{(K)}\right)'$ and the individual effects α_i, are assumed to be fixed in the time dimension. It is assumed that there are lag orders of K *identical* for all cross-section units of the panel. Moreover, autoregressive parameters $\gamma_i^{(k)}$ and the regression coefficients $\beta_i^{(k)}$, are allowed to vary across groups. Under the null hypothesis, it is assumed that there is no causality relationship for any of the panel units. This assumption is called the Homogeneous Non-Causality (HNC) hypothesis, which is defined as:

$$\mathrm{H}_0 : \beta_i = 0\ \forall i = 1, \ldots, N$$

The alternative is specified as the Heterogeneous Non-Causality (HENC) hypothesis. Under this hypothesis, two subgroups of cross-section units are allowed. There is a causality relationship from x to y for the first one, but it is not necessarily based on the same regression model. There is no causality relationship for the second subgroup from x to y. A heterogeneous panel data model with fixed coefficients (in time) in this group is considered. This alternative hypothesis is as follows:

$$\mathrm{H}_1 : \beta_i = 0\ \forall i = 1, \ldots, N_1$$

$$\beta_i \neq 0\ \forall i = N_1 + 1, \ldots, N$$

It is assumed that β_i May varies across groups, and there are $N_1 < N$ individual processes with no causality from x to y. N_1, is unknown, but it provides the condition $0 \leq N_1/N < 1$.

The average statistic $W_{N,T}^{HNC}$, which is related to the null Homogeneous non-causality (HNC) hypothesis are proposed:

$$W_{N,T}^{HNC} = \frac{1}{N} \sum_{i=1}^{N} W_{i,T}$$

Where $W_{i,T}$ indicates the individual Wald statistics for the i$^{\text{th}}$ cross-section unit corresponding to the individual test $\mathrm{H}_0 : \beta_i = 0$.

Let $Z_i = [e : Y_i : X_i]$ be the (T, 2K+1) matrix, where e indicates a (T, 1) unit vector and $Y_i = [y_i^{(1)} : y_i^{(2)} : \ldots : y_i^{(K)}]$, $X_i = [x_i^{(1)} : x_i^{(2)} : \ldots : x_i^{(K)}]$. $\theta_i = (\alpha_i \gamma_i' \beta_i')$, is the vector of parameters of the model. Also, let $R = [0 : I_K]$ be a (K, 2K+1) matrix.

For each $i = 1, \ldots, N$, the Wald statistic $W_{i,T}$ corresponding to the individual test $H_0 : \beta_i = 0$ is defined as:

$$W_{i,T} = \widehat{\theta}_i' R' \left[\widehat{\sigma}_i^2 R \left(Z_i' Z_i\right)^{-1} R'\right]^{-1} R \widehat{\theta}_i$$

Under the null hypothesis of non-causality, each Wald statistic converges to a chi-squared distribution with K degrees of freedom for $T \to \infty$.

$$W_{i,T} \to \chi^2(K), \ \forall i = 1, \ldots, N$$

The standardized test statistic $W_{N,T}^{HNC}$, for $T, \ N \to \infty$ is as follows:

$$Z_{N,T}^{HNC} = \sqrt{\frac{N}{2K}} \left(W_{N,T}^{HNC} - K\right) \to N(0,1)$$

Also, the standardized test statistic $\widetilde{Z}_N^{HNC}$, for fixed T samples are as follows:

$$\widetilde{Z}_N^{HNC} = \sqrt{\frac{N}{2K} \times \frac{(T-2K-5)}{(T-K-3)} \times \left[\frac{(T-2K-5)}{(T-K-3)} W_{N,T}^{HNC} - K\right]} \to N(0,1)$$

Where $W_{N,T}^{HNC} = \left(\frac{1}{N}\right) \sum_{i=1}^{N} W_{i,T}$

In addition to heterogeneity among cross-sections, if cross-sectional dependence exists in the panel, Dumitrescu-Hurlin causality is suitable. Results of CD tests in Table 2, Table 3, and Table 4 show the presence of cross-sectional dependence. At the same time, stationarity is a fundamental requirement of the Dumitrescu-Hurlin causality test. The second-generation unit root test, Pesaran's CADF (2003) and CIPS (2007) statistic, fulfils the objective of checking for stationarity in the presence of cross-sectional dependence. Therefore, the Dumitrescu-Hurlin causality test should be applied. Its results are as follows:

Table 10 shows the statistical significance of first $\widetilde{Z}_N^{HNC}$ The test statistic shows that the null hypothesis cannot be rejected that C does not homogeneously cause Y, whereas it gets rejected in reverse causality. It implies that the causality from seaport activity to GDP per capita is not homogeneous. However, homogenous causality is present in the reverse case. This specialized form of causality provides insights into the causal relationship without contradicting the prior result of the bi-causal Granger causality in Table 9. Homogenous causality from GDP per capita to seaport activity can be attributed to the uniform growth effects of economic growth on all industries, including that of seaports. However, non-homogenous causality from seaport activity to v can be attributed to seaport heterogeneity across sample countries regarding the port's organizational models (Vaggelas, 2007). Ledger and Roe (1996) and Vaggelas (2007) highlight the heterogeneity in terms of technical standards and philosophies of port operations.

7. Conclusion

This paper conducted a rigorous econometric analysis of the seaport-led growth hypothesis for a sample of OCED countries. Empirical results have supported the hypothesis. Special attention was given to econometric concerns of cross-sectional dependence, heterogeneity among countries in the panel, country-specific slopes, and robustness of slope parameters. The support for the seaport-led growth hypothesis withstood the robustness checks, and the relationship gained substantial validity.

A positive relationship can also be explained in light of the seaport industry's backward and forward linkages with other sectors. These linkages enhance the productive effects on the economy. The seaport industry is capital-intensive and can generate ample employment and income opportunities. Vaggelas (2007) listed 19 direct and indirect beneficial effects of seaport activity, including direct taxes, trade facilitation, urban planning, local and regional development, value addition, lower transport costs, and free trade zones. Whereas indirect beneficial effects also contribute to the economy. These include national security, indirect taxes, land value increase, and a sense of safety for citizens. A feedback effect is also found, which shows that increased national income favours seaport activity. In economic jargon, catalytic and multiplier-accelerator effects hold under the seaport-led growth hypothesis.

Greece, Portugal, Italy, etc., recommend country-specific studies on the seaport-led growth hypothesis. Reforms are also suggested for such countries (Pallis and Syriopoulos, 2007; Psaraftis, 2007). Investments for these reforms should be appropriately appraised (Musso, Ferrari, and Benacchio, 2006). This paper also empirically reflects the heterogeneity of seaports in terms of organizational models and operations. This study recommends homogenizing standards across seaports in OECD countries to agglomerate the network externalities fully.

Due to limitations in available data, the authors could not include other types of cargo, such as dry bulk, wet bulk, and gas bulk, in addition to container port traffic, as a proxy for seaport activity. As a result, future research can focus on investigating these specific variables of interest. Moreover, future research on the relationship between seaport activity and economic development could be conducted with a focus on Greece, specifically. The current study uncovered some paradoxical findings, such as a negative relationship between seaport activity and GDP per capita, which warrants further investigation. Given the importance of seaports in Greece's economy, it is crucial to understand the underlying reasons for this unexpected relationship. By investigating, future studies could provide a more nuanced understanding of the relationship between seaport activity and economic development in Greece. This, in

Table 9
Panel Granger Causality Test Results

Causality	F-Statistic	Remarks
$CPT_{i,t} \rightarrow YPC_{i,t}$	3.8268[b]	Bi-causal Relationship between seaport activity and GDP per capita (**Feedback View**)
$YPC_{i,t} \rightarrow CPT_{i,t}$	4.8423[a]	

Source: Authors' estimates

Table 10
Dumitrescu-Hurlin Causality Test Results

Causality	$W_{N,T}^{HNC}$	$\tilde{Z}_{N}^{HNC}$	p-value	Remarks
$CPT_{i,t} \rightarrow YPC_{i,t}$	3.5595	1.2528	0.210	Non-homogenous causal relationship from ***CPT*** to ***YPC***
$YPC_{i,t} \rightarrow CPT_{i,t}$	4.1954	2.1449	0.032	Homogenous causal relationship from ***YPC*** to ***CPT***

Source: Authors' estimates

turn, could inform policymakers and stakeholders in the maritime industry, enabling them to make informed decisions regarding the future development of seaports and their role in the country's economy.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Descriptive Statistics Per Country

Country	Variable	Mean	Standard Deviation	Minimum	Maximum
Australia	**CPT**	6262700	1481780	3542802	8569337
	YPC	51505.14	4075.979	44334.42	57183.37935
	CAP	2.87715×10^{11}	6.65E+10	1.68256×10^{11}	3.66148×10^{11}
	TRD	41.92545	2.018912	37.12073	45.79790421
Austria	**CPT**	305805	35894.73	285900	379740.7072
	YPC	46549.1	2567.579	42001.21	50536.66415
	CAP	9.58E+10	8.6E+09	8.39E+10	1.14256×10^{11}
	TRD	98.00526	7.887183	85.3605	108.1108202
Belgium	**CPT**	9628698	2528458	5057579	13570790
	YPC	43771.29	2316.178	39588.6	47541.09604
	CAP	1.1323×10^{11}	1.7E+10	8.64E+10	1.42337×10^{11}
	TRD	151.2978	11.01042	132.7156	166.2370873
Canada	**CPT**	4770799	1179628	2890388	7004090
	YPC	46821.65	4107.993	39338.84	51583.10488
	CAP	3.71749×10^{11}	6.01E+10	2.61951×10^{11}	4.43755×10^{11}
	TRD	67.42578	6.052177	58.62247	83.04164705
Chile	**CPT**	2936854	1235745	1080545	4662910
	YPC	12676.52	1994.737	9419.983	15111.69542
	CAP	4.67E+10	1.59E+10	2.31E+10	65765507110
	TRD	65.71846	7.103379	55.65567	80.78977343
Denmark	**CPT**	763512.9	154492.5	457386	1213919
	YPC	59478.78	2803.845	55850.63	65867.00172
	CAP	6.87E+10	8.92E+09	5.82E+10	85755872293
	TRD	96.15577	9.282342	80.88171	109.2924316

(*continued on next page*)

(*continued*)

Estonia	**CPT**	204332.6	36734.3	130939	260293
	YPC	15757.45	2980.968	10062.44	20851.17736
	CAP	5.95E+09	1.58E+09	3.04E+09	8538007334
	TRD	141.2159	15.3844	116.1078	169.4917665
Finland	**CPT**	1364898	211913.4	928318	1632000
	YPC	45892.36	2669.903	40403.2	49440.85519
	CAP	5.75E+10	5.45E+09	4.99E+10	67733653897
	TRD	75.56208	5.002724	68.0558	86.18433583
France	**CPT**	4686822	953615.3	2923190	5963100
	YPC	40994.86	1607.358	38309.44	44320.05773
	CAP	6.10766×10^{11}	5.34E+10	5.35845×10^{11}	7.15785×10^{11}
	TRD	57.46994	4.329258	50.46245	64.52272903
Germany	**CPT**	15622913	4118231	7695688	19866700
	YPC	42274.56	3355.438	37934.45	47469.47708
	CAP	7.07115×10^{11}	5.66E+10	6.07277×10^{11}	8.11529×10^{11}
	TRD	77.49483	10.15542	60.93489	88.59638721
Greece	**CPT**	2625585	1541852	672522	6098800
	YPC	25330	2682.765	22251.26	30054.88934
	CAP	5.04E+10	2.08E+10	2.55E+10	86165505256
	TRD	58.61513	7.779834	47.74385	74.38446689
Iceland	**CPT**	263538.8	55455.06	193000	352300
	YPC	44858.48	4417.448	37465.45	51592.65461
	CAP	3.27E+09	1.03E+09	1.9E+09	5473024376
	TRD	85.02233	11.75961	68.28669	104.2675029
Ireland	**CPT**	889096	136834.9	721395	1175155
	YPC	55219.58	10710.76	44101.11	79823.01422
	CAP	6.6E+10	3.59E+10	3.83E+10	1.73237×10^{11}
	TRD	183.1734	28.77564	146.5523	239.2150917
Israel	**CPT**	2178995	517968.2	1378259	2946000
	YPC	30532.11	2921.535	26360.09	35276.19347
	CAP	4.8E+10	1.21E+10	3.32E+10	70483129317
	TRD	68.4502	8.43662	56.39104	81.85208576
Italy	**CPT**	9183559	1049769	6918588	10610893
	YPC	36038.98	1385.371	33666.69	38272.2041
	CAP	4.2666×10^{11}	4.99E+10	3.48721×10^{11}	5.05567×10^{11}
	TRD	53.16053	4.39892	45.41876	60.34838059
Japan	**CPT**	18297502	2920923	13100000	22610460
	YPC	45200.46	2226.104	42169.73	49187.83309
	CAP	1.38761×10^{11}	9.35E+10	1.17936×10^{11}	1.51174×10^{11}
	TRD	29.18675	5.960141	19.79813	37.5457698
Korea, Rep.	**CPT**	19206563	6378461	9030174	28955300
	YPC	22357.75	4129.923	15414.29	28675.03441
	CAP	3.66012×10^{11}	6.93E+10	2.60418×10^{11}	4.91417×10^{11}
	TRD	79.45984	14.31309	58.35304	105.5663136
Netherlands	**CPT**	10791322	2643442	6227321	14986800
	YPC	50613.23	2689.293	46435.21	55450.50042
	CAP	1.79855×10^{11}	1.97E+10	1.57843×10^{11}	2.17415×10^{11}
	TRD	135.9075	16.29364	111.92	158.8232102
New Zealand	**CPT**	2328399	759907.8	1067438	3444356
	YPC	34334.6	2557.723	29354.51	38505.10221
	CAP	3.29E+10	6.4E+09	2.19E+10	44961227790
	TRD	58.57666	4.359569	52.21016	68.51692688
Norway	**CPT**	618639.7	189149	318924	836102
	YPC	88279.99	3139.712	81653.34	92556.32164
	CAP	1.10253×10^{11}	1.99E+10	7.62E+10	1.38382×10^{11}
	TRD	70.14679	2.525918	66.55282	74.8893594
Poland	**CPT**	1479224	889936.3	261419	3046440
	YPC	12343.26	2744.221	8545.452	17409.02743
	CAP	9.99E+10	2.79E+10	5.71E+10	1.44804×10^{11}
	TRD	83.12187	15.27632	58.15676	107.4202649
Portugal	**CPT**	1687456	956350.9	86003	3191600
	YPC	22298.39	894.3577	21256.76	24618.11652
	CAP	4.79E+10	8.17E+09	3.4E+10	59827122679
	TRD	72.34743	8.619489	61.13895	86.78232742
Slovenia	**CPT**	645516.1	234105.4	305648	980200
	YPC	23087.88	2420.453	18523.17	27421.02871
	CAP	1.12E+10	2.22E+09	8.68E+09	16817646376
	TRD	131.4935	19.61451	102.3246	161.1022713
Spain	**CPT**	12013610	3653844	5789693	17372960
	YPC	30723.81	1395.18	28408.81	33352.32896
	CAP	3.27953×10^{11}	4.82E+10	2.52319×10^{11}	4.23501×10^{11}

(*continued on next page*)

(*continued*)

	TRD	59.01437	5.452406	46.99487	67.57285294
Sweden	**CPT**	1297352	265433.2	805610	1630900
	YPC	52390.43	4120.55	44941.67	58050.01925
	CAP	1.17237×10^{11}	2.11E+10	8.95E+10	1.53E+11
	TRD	83.89847	4.483205	75.24559	92.56415043
Switzerland	**CPT**	99651.69	7649.859	78285	105000
	YPC	73697.64	3929.694	67385.3	79402.50921
	CAP	1.35367×10^{11}	9.81E+09	1.17202×10^{11}	1.5592×10^{11}
	TRD	110.5291	12.18389	89.5299	131.7965515
United Kingdom	**CPT**	8484792	1215382	6434734	10313000
	YPC	40246.47	2200.142	35672.91	43710.45145
	CAP	4.34259×10^{11}	4.54E+10	3.55689×10^{11}	5.00217×10^{11}
	TRD	56.61139	4.645599	49.9157	64.28777356
United States	**CPT**	41715989	8223827	27307576	55518880
	YPC	49483.28	3180.862	44726.97	55753.14437
	CAP	3.19405×10^{12}	4.1885×10^{11}	2.54394×10^{12}	4.00161×10^{12}
	TRD	26.82597	2.675155	22.15427	30.78929406

Source: Authors' calculations

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