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Does e-Government Readiness Drive Maritime Connectivity and Trade Performance? Panel Evidence from Indian Ocean and Gulf Economies

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ABSTRACT

This study examines whether national e-government capability, measured by the United Nations Online Services Index (OSI), is associated with maritime trade connectivity and container port performance. Three internationally recognised datasets are combined: the OSI from the UN e-Government Survey, the UNCTAD Liner Shipping Connectivity Index (LSCI), and the World Bank and S&P Global Container Port Performance Index (CPPI), supplemented with World Development Indicators for economic size. A country-year panel of 1,071 observations spanning 124 economies and nine biennial survey waves from 2008 to 2024 is constructed. Two-way fixed-effects regressions with country and year effects are estimated for the logarithm of exports of goods and services and for the logarithm of LSCI. Country-level cross-sectional models examine long-run associations using time-averaged variables. A port-year panel of 936 observations across 356 ports in 100 economies from 2020 to 2024 is used in port fixed-effects and cross-sectional models for CPPI. The results are consistent across all specifications. In the country panel, OSI shows no statistically significant association with either exports (coefficient: -0.018, 95% CI: -0.215 to 0.179, $p = 0.859$) or LSCI (coefficient: -0.075, $p = 0.445$) once GDP per capita and population are controlled for. In the cross-sectional models, LSCI has a positive and significant relationship with long-run export levels (coefficient: 0.184, $p = 0.036$), while OSI remains insignificant. At port level, OSI is not robustly associated with CPPI in either the fixed-effects panel ($p = 0.067$) or the 2024 cross-section ($p = 0.226$). These patterns hold in the sub-sample of 19 Indian Ocean and Gulf economies. The findings suggest that generic national e-government indices are not reliable proxies for maritime trade performance or shipping connectivity once structural economic determinants are taken into account. Policy assessments of digital readiness in port and trade sectors should draw on sector-specific indicators of maritime and logistics digitalisation.

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1. Introduction

Governments across the world have invested heavily in online public service platforms, electronic customs procedures, and cross-border data-sharing systems over the past two decades, often with the stated goal of reducing trade costs and improving export competitiveness. International composite indices such as the United Nations e-Government Development Index (EGDI) and its component Online Services Index (OSI) have become standard reference points in policy evaluations and academic work on trade facilitation, routinely cited as evidence of a country's digital readiness for commerce. It is worth asking, however, whether these broad national scores actually capture the forms of digitalisation that matter most for maritime connectivity and port operations, which are governed by sector-specific technologies and institutional arrangements that may shift quite independently of how sophisticated a government's general online services happen to be.

At the same time, maritime transport researchers and de-

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velopment finance institutions rely on two other internationally recognised benchmarks: the UNCTAD Liner Shipping Connectivity Index (LSCI), which measures how well integrated a country is into the global container shipping network, and the World Bank and S&P Global Container Port Performance Index (CPPI), which evaluates individual ports on the basis of vessel turnaround times and service reliability. These indicators address different dimensions of maritime performance from different institutional vantage points. The empirical relationship between national e-government maturity and the outcomes they capture has not been tested in a rigorous multi-dataset panel framework, and this gap motivates the present study.

Against this backdrop, the study addresses three interconnected empirical questions: whether changes in national OSI are associated with changes in export performance once shipping connectivity and economic size are controlled for, whether OSI predicts changes in a country's LSCI, which would suggest a pathway through which e-government could support maritime integration, and whether OSI and LSCI are associated with container port performance at the individual port level. To answer them, the study assembles a country-year panel spanning 2008 to 2024 and a port-year panel spanning 2020 to 2024, estimating two-way fixed-effects regressions that control for unobserved country-specific and time-specific heterogeneity.

Beyond the global scope, Indian Ocean and Gulf economies form a strategically significant maritime corridor, encompassing major transhipment hubs such as Jebel Ali and Port Klang, resource-exporting economies whose trade depends overwhelmingly on sea freight, and small island states for which shipping connectivity is an economic necessity. Whether national e-government investment actually translates into measurable improvements in maritime performance in this sub-region has real consequences for how governments and regional bodies should prioritise digital reform spending, and the present study provides the first systematic empirical answer using panel methods.

Section 2 reviews the relevant literature on e-government, maritime connectivity, and port performance. Section 3 describes the data, variable constructions, and econometric models. Section 4 presents results across global country panels, cross-sectional models, regional models, and port-level analyses. Section 5 discusses the implications of the findings, and Section 6 concludes with policy recommendations and directions for future research.

2. Literature Review

2.1. e-Government and Trade Facilitation

Research on e-government has expanded considerably since the early 2000s, examining how digital public services affect governance quality (United Nations, 2022), public sector transparency (Kim et al., 2009), and corruption control (Andersen, 2009). A separate and more applied strand focuses on how e-government reforms, particularly electronic customs, port single windows, and interoperable trade documentation systems, reduce the administrative and time costs of cross-border trade (Moïsé and Le Bris, 2013). Evidence from this trade facilitation literature is broadly positive: electronic customs declarations, advance cargo information sharing, and risk-based inspection targeting are consistently associated with lower dwell times and faster clearance (United Nations Economic and Social Commission for Asia and the Pacific, 2021).

The United Nations E-Government Survey, conducted biennially since 2001, provides the most widely used cross-national index for benchmarking these capabilities. Its Online Services Index assesses the availability and sophistication of government services online across the full range of public domains, from health and education to civil registration and financial services, and is scored on a 0 to 1 scale through a structured survey of government portals (United Nations, 2022). Several studies treat OSI or the broader EGDI as a general indicator of a country's digital readiness for trade, but the index was not designed to measure trade or logistics digitalisation specifically. A country's customs portals, port community systems, and maritime single windows may be highly developed while its overall OSI remains modest, and vice versa. This conceptual mismatch between OSI and maritime digital capability is the central measurement concern that motivates the tests below.

2.2. Maritime Connectivity and the Liner Shipping Connectivity Index

The UNCTAD Liner Shipping Connectivity Index, available annually since 2006, has become the standard measure of a country's integration into global container shipping networks. It aggregates five components: the number and size of container vessels calling at a country's ports, the number of liner services, the number of shipping companies providing those services, and the maximum vessel capacity deployed. Economies situated on major trunk routes, with port infrastructure deep enough to accommodate large vessels, tend to score substantially higher than others (UNCTAD, 2023).

Maritime economics research has established that LSCI is a genuine determinant of trade volumes. Fugazza and Hoffmann (2017) show that higher Liner Shipping Bilateral Connectivity Index (LSBCI) values are associated with greater bilateral exports of containerizable goods after controlling for standard gravity model variables including maritime distance, income, and shared institutions. Wilmsmeier and Hoffmann (2008) demonstrate that improvements in port infrastructure and service frequency reduce effective trade costs and stimulate export diversification. These findings situate the LSCI as both a variable of interest and a potential confound in the present analysis: when testing whether OSI affects exports, LSCI must be controlled for, yet it may also serve as a channel through which any e-government effect on trade would operate. This is a question of over-control that the discussion addresses when interpreting the results.

2.3. Port Performance and the Container Port Performance Index

Published jointly by the World Bank and S&P Global since 2020, the CPPI offers one of the few globally comparable benchmarks of port-level operational efficiency. It draws on automatic identification system (AIS) records to measure the total time vessels spend in port, from arrival at anchorage to departure, benchmarking individual ports against a statistically derived reference value. Positive CPPI scores reflect performance above the reference, while negative scores indicate that a port's vessels spend more time in port than the benchmark, and these are retained as valid observations in the regression sample. The index currently covers several hundred major container ports worldwide (World Bank and S&P Global Market Intelligence, 2023).

A substantial body of research has identified the drivers of port efficiency, including terminal automation, berth occupancy rates, hinterland connectivity, and the management practices of terminal operators (Heilig and Voß, 2017). Digital systems are increasingly recognised as important among these drivers: port community systems that link shipping lines, terminals, customs authorities, and freight forwarders in a shared data environment have been shown to reduce unnecessary vessel waiting and improve scheduling coordination (Carlan et al., 2016). National e-government capability, however, operates at a different level of aggregation from these port-specific investments, and whether a high national OSI score correlates with the presence of effective port-level digital infrastructure remains an open empirical question.

2.4. Conceptual Framework and Hypotheses

Three mechanisms connect national e-government capability to maritime trade outcomes, at least in principle. First, where online service platforms include functioning customs portals, risk-management systems, and electronic documentation, administrative burdens on traders and shipping agents fall and clearance times improve (Moïsé and Le Bris, 2013). Second, digitally capable governments signal institutional quality and transparency, which helps attract foreign direct investment and promotes export performance by reducing administrative bureaucracy and trade-related costs (Soeng and Kao, 2024). Third, countries with higher OSI may be better positioned to implement and maintain the port community systems and logistics technology platforms that directly improve port throughput and performance.

Each mechanism, however, depends on OSI being a reasonably valid proxy for the relevant sector-specific digital capabilities. If customs and port digital systems are developed and funded by autonomous sector authorities, or by international terminal operators with their own proprietary technology standards, then aggregate OSI may move quite independently of the technologies that actually matter for maritime performance. The tests below are therefore tests of the proxy validity of OSI for maritime purposes. They are not tests of whether digitalisation as such affects trade and port performance. With this framing in mind, the following hypotheses are evaluated:

H1: Higher OSI is positively associated with higher exports of goods and services, controlling for LSCI and economic size.

H2: Higher OSI is positively associated with higher LSCI, controlling for economic size.

H3: Higher LSCI is positively associated with higher long-run export levels in cross-country averages.

H4: Ports in countries with higher OSI and LSCI record higher CPPI scores.

H5: The associations in H1 through H4 hold in Indian Ocean and Gulf economies.

3. Data and Methodology

3.1. Data Sources and Sample Construction

The study draws on four primary datasets: the OSI from the biennial releases of the UN e-Government Survey, covering 2008, 2010, 2012, 2014, 2016, 2018, 2020, 2022, and 2024. The LSCI is obtained as annual country-level scores from UNCTAD's statistical database. Annual values are averaged within each two-year survey window to align with the OSI release schedule. Macroeconomic controls, specifically exports of goods and services in current US dollars (indicator NE.EXP.GNFS.CD), GDP per capita in constant 2015 US dollars (NY.GDP.PCAP.KD), and total population (SP.POP.TOTL), are retrieved from the World Bank's World Development Indicators API. Country identifiers are standardised to ISO alpha-3 codes using the `countrycode` package (Arel-Bundock et al., 2018) in R (R Core Team, 2026). The CPPI annex spreadsheet for 2020 to 2024, published jointly by the World Bank and S&P Global, provides port-level performance scores together with LOCODE identifiers, territory names, and World Bank region and income group classifications.

The country-year panel retains all observations for which OSI, LSCI, and export data are simultaneously available, yielding 1,071 observations spanning 124 economies across nine biennial waves from 2008 to 2024. One observation is excluded as a fixed-effect singleton during estimation, leaving a regression sample of 1,070 observations covering 123 countries. OSI changes slowly: the index moves gradually between biennial survey waves, and the within-country variation that fixed-effects estimation relies upon is therefore modest. This inherently limits statistical power and should be kept in mind when reading the OSI estimates throughout the results section. The port-year panel initially contains 1,801 observations for 403 ports across 130 economies from 2020 to 2024. After merging with the national panel, restricting to the biennial survey years for which OSI is observed (2020, 2022, and 2024), and excluding records with missing values, the analysis sample comprises 936 observations for 356 ports in 100 economies.

The regional sub-sample consists of 19 Indian Ocean and Gulf economies: Bahrain, Bangladesh, India, Iran, Iraq, Kenya, Kuwait, Madagascar, Maldives, Mauritius, Mozambique, Oman, Pakistan, Qatar, Saudi Arabia, Seychelles, South Africa, Sri Lanka, Tanzania, and the United Arab Emirates. This grouping encompasses GCC port states, the South Asian maritime littoral, and the East African maritime corridor, producing 163 country-year observations for regional panel estimation. With only 19 countries the regional models have limited degrees of freedom, and the results are therefore treated as a robustness check.

3.2. Variable Definitions

Export performance is measured as ln(exports + 1), where exports are denominated in current US dollars. The logarithmic transformation compresses right skew and allows coefficients to be read as approximate elasticities. When LSCI serves as a dependent variable it enters as ln(LSCI + 1). When it serves as a covariate in the exports model it enters in levels, consistent with its treatment as a linear connectivity measure in the trade facilitation literature. OSI is used in its natural 0 to 1 scale. GDP per capita and population are both log-transformed, and for the cross-sectional models time-averages of all variables are computed at the country level.

3.3. Econometric Specification

The empirical strategy comprises three sets of models, beginning with country-level two-way fixed-effects panels:

$$\ln(\text{exports}_{it}) = \beta_1 \text{OSI}_{it} + \beta_2 \text{LSCI}_{it} + \beta_3 \ln(\text{GDPpc}_{it}) + \beta_4 \ln(\text{Pop}_{it}) + \alpha_i + \gamma_t + \varepsilon_{it} \quad (1)$$

$$\ln(\text{LSCI}_{it} + 1) = \delta_1 \text{OSI}_{it} + \delta_2 \ln(\text{GDPpc}_{it}) + \delta_3 \ln(\text{Pop}_{it}) + \alpha_i + \gamma_t + u_{it} \quad (2)$$

where i indexes countries, t indexes biennial survey years, α_i captures all time-invariant country characteristics, and γ_t absorbs common time shocks such as global trade slowdowns. Standard errors are clustered at the country level.

Country time-averages are used in a second set of cross-sectional models:

$$\overline{\ln(\text{LSCI}_i + 1)} = \theta_1 \overline{\text{OSI}_i} + \theta_2 \overline{\ln(\text{GDPpc}_i)} + \theta_3 \overline{\ln(\text{Pop}_i)} + \nu_i \quad (3)$$

$$\overline{\ln(\text{exports}_i)} = \phi_1 \overline{\text{OSI}_i} + \phi_2 \overline{\ln(\text{LSCI}_i + 1)} + \phi_3 \overline{\ln(\text{GDPpc}_i)} + \phi_4 \overline{\ln(\text{Pop}_i)} + \xi_i \quad (4)$$

estimated by OLS on the cross-section of 124 country means. These models examine persistent country-level differences and are less sensitive to the slow pace of within-country OSI change.

The third set addresses port-level performance through a port fixed-effects panel:

$$\text{CPPI}_{pct} = \kappa_1 \text{OSI}_{ct} + \kappa_2 \text{LSCI}_{ct} + \kappa_3 \ln(\text{GDPpc}_{ct}) + \kappa_4 \ln(\text{Pop}_{ct}) + \mu_p + \tau_t + \eta_{pct} \quad (5)$$

where p indexes ports, c countries, and t years, μ_p absorbs permanent port-level characteristics, and τ_t captures global time shocks. Standard errors are clustered by country. A cross-sectional OLS model for 2024 alone complements the panel:

$$\text{CPPI}_p = \lambda_1 \text{OSI}_c + \lambda_2 \text{LSCI}_c + \lambda_3 \ln(\text{GDPpc}_c) + \lambda_4 \ln(\text{Pop}_c) + \varepsilon_p \quad (6)$$

All models are estimated in R (R Core Team, 2026) using the `fixest` package (Bergé et al., 2026).

4. Results

4.1. Descriptive Statistics

Table 1 summarises the main variables. OSI averages 0.52 across the country-year panel, with a standard deviation of 0.27, reflecting considerable cross-country variation. LSCI displays far more extreme dispersion: the minimum of 3.1 belongs to small or remote economies with minimal liner services, while the maximum of 1,187 belongs to countries that serve as major container transhipment hubs. This concentration of shipping capacity in a handful of economies is an important structural feature of the data and helps explain why population and economic size prove such dominant predictors of connectivity. For port-level CPPI, the mean of 10.6 and a standard deviation of 71.4 together reflect genuine performance differences and the methodology of the index itself, which assigns negative scores to ports where average vessel time in port exceeds the benchmark value. The minimum value of −721 belongs to Durban in 2024, and the sample also includes Savannah and Long Beach in 2022, both widely reported at the time as suffering severe congestion. These are retained in the regression sample as valid below-benchmark records.

4.2. Graphical Overview

Figure 1 plots the raw country-year relationship between OSI and ln(LSCI + 1), separately for the Indian Ocean and Gulf sub-sample and the rest of the panel. A positive bivariate slope is visible in both groups, which might on its own be read as support for a link between e-government and shipping connectivity. As Sections 4.3 and 4.4 show, however, this raw association does not survive the introduction of country fixed effects, and Figure 2 clarifies why: OSI and LSCI both rise steadily over 2008 to 2024 for the whole sample, so the bivariate scatter in Figure 1 is capturing a shared time trend and cross-country scale differences. Figure 2 shows the two series tracking a common upward trajectory in OSI for both groups, while LSCI for the Indian Ocean and Gulf economies remains persistently below the rest-of-world average throughout the period despite comparable or higher OSI levels from 2018 onward, a pattern consistent with the fixed-effects finding that OSI is not the binding constraint on shipping connectivity in this region.

4.3. Country-Level Panel: Exports

Column (1) of Table 2 presents the fixed-effects model for log exports (Equation 1). The OSI coefficient is −0.018, with a clustered standard error of 0.100 and a 95 per cent confidence interval running from −0.215 to 0.179. This interval crosses zero comfortably, and its bounds exclude any economically large effect in either direction. Within-country improvements in OSI are simply not associated with measurable short-run gains in export performance once country fixed effects and year fixed effects are accounted for. H1 is not supported. The LSCI coefficient is similarly negligible ($\hat{\beta} = -0.0009$, $p = 0.167$), a result that almost certainly reflects the slow within-country movement of LSCI over time and its correlation with the structural factors already absorbed by the fixed effects. The coefficient does not indicate a genuine negative relationship.

Table 1: Descriptive statistics: country-year panel and port-year panel

Variable	Mean	SD	Min	Max
Country-year panel (N = 1,071, 124 economies, 2008 to 2024)				
Online Services Index (OSI)	0.52	0.27	0.00	1.00
Liner Shipping Connectivity Index (LSCI)	115.6	141.3	3.1	1,187.1
ln(Exports of goods and services + 1)	23.71	2.58	16.56	28.97
ln(GDP per capita, const. 2015 USD + 1)	8.85	1.32	5.92	11.49
ln(Population + 1)	15.87	2.14	9.21	21.10
Port-year panel (N = 936, 356 ports, 100 economies, 2020 to 2024)				
Container Port Performance Index (CPPI)	10.6	71.4	−721.0	170.0

Sources: UN e-Government Survey, UNCTAD, World Bank WDI, World Bank and S&P Global CPPI Annex 2020 to 2024.
Note: Negative CPPI values, indicating ports where average vessel port-time exceeded the statistical reference benchmark, are retained in the regression sample as valid observations.

What emerges clearly from this model is that within-country export growth is driven by income and scale. The log GDP per capita coefficient of 1.781 (SE = 0.151, $p < 0.001$) implies that a one per cent rise in real income per head is associated with an approximately 1.78 per cent increase in export value, a finding that is entirely consistent with the idea that richer countries produce higher-value exportable goods, maintain broader trading relationships, and absorb the fixed costs of global value chain participation more easily. Log population carries a similarly positive and significant coefficient of 0.779 ($p < 0.001$). The overall adjusted R^2 of 0.992 is dominated by the country fixed effects. The within-country R^2 of 0.452 is the more relevant figure for assessing the dynamic fit of the model.

4.4. Country-Level Panel: LSCI

Column (2) of Table 2 estimates Equation (2), asking whether countries that improve their online service provision subsequently attract additional shipping services or deepen their integration into the global liner network. The OSI coefficient is −0.075 (SE = 0.098, $p = 0.445$), and H2 is accordingly not supported. This is perhaps the least surprising of the null results, since decisions about port calls and service frequency by global liner alliances are driven by cargo demand projections, vessel economics, and network topology considerations that have little to do with how well a national government scores on an online services survey.

GDP per capita is positively associated with LSCI ($\hat{\delta}_2 = 0.373$, $p = 0.0015$), consistent with the idea that growing per capita income generates demand for more diverse and more frequent shipping services. The population coefficient of 0.430 is marginally significant ($p = 0.055$), suggesting a weaker scale effect on connectivity than on exports. The within-country R^2 of only 0.063 is low, but this is not surprising: most meaningful variation in LSCI is cross-sectional, reflecting differences in geography, port infrastructure, and network position that the fixed effects already absorb.

4.5. Country-Level Cross-Section

Cross-sectional models of country time-averages serve a different purpose from the panel regressions: they ask whether countries that have, on average over the full sample period, higher OSI tend to be better connected and more export-intensive. The answer with respect to OSI is no in both specifications (Table 3). In model (3), mean OSI has essentially no association with mean LSCI ($\hat{\theta}_1 = 0.142$, $p = 0.745$), while GDP per capita ($\hat{\theta}_2 = 0.365$, $p < 0.001$) and population ($\hat{\theta}_3 = 0.346$, $p < 0.001$) together explain most of the cross-country variation in connectivity, producing an adjusted R^2 of 0.695. The picture is one of structural advantage: economies that are large, wealthy, and geographically well positioned relative to major trade routes attract regular shipping services regardless of how their governments score on an online services survey.

In model (4) the study's clearest positive finding appears, for LSCI. Countries with higher long-run connectivity levels record substantially higher export values ($\hat{\phi}_2 = 0.184$, SE = 0.087, $p = 0.036$), supporting H3 and aligning with the wider evidence on LSCI as a structural trade facilitator (Fugazza and Hoffmann, 2017; Wilmsmeier and Hoffmann, 2008). OSI continues to show no significant association with exports ($\hat{\phi}_1 = 0.290$, $p = 0.486$) even in this long-run cross-sectional setting where the slow-change problem is less acute. GDP per capita and population account for the overwhelming share of the explanatory power, with the model as a whole explaining 95.3 per cent of variation in mean log exports across the 124 countries.

4.6. Regional Panel: Indian Ocean and Gulf Economies

The regional estimates, presented in Table 4, closely mirror the global panel results and confirm that the null finding for OSI is not an artefact of pooling heterogeneous economies from all income groups and regions. Across the 19 Indian Ocean and Gulf economies, OSI is not significantly associated with either exports ($\hat{\beta} = -0.087$, SE = 0.146, $p = 0.559$) or LSCI ($\hat{\delta} = -0.379$, SE = 0.318, $p = 0.249$), providing no regional support for H1, H2, or H5 with respect to the OSI hypotheses. GDP per capita and population remain the dominant drivers of within-country export variation in the region, with coefficients of 1.126 ($p < 0.001$) and 0.641 ($p = 0.005$) respectively and an adjusted R^2 of 0.993. In the LSCI model, both GDP per capita (0.662,

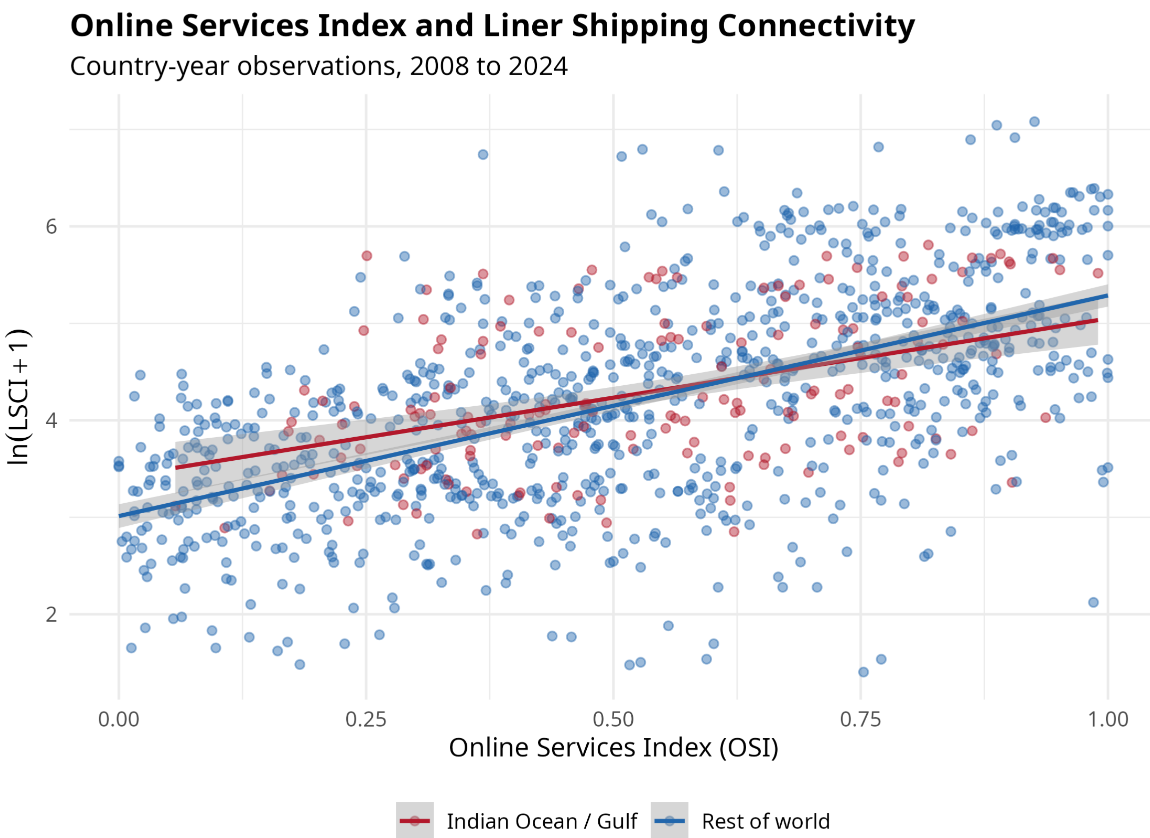

Figure 1: Online Services Index and ln(LSCI + 1), country-year observations, 2008 to 2024. Fitted lines are simple OLS regressions by sub-group and do not include the panel controls or fixed effects used in Table 2.

p = 0.019) and population (0.882, p = 0.038) are positive and significant, again pointing to structural economic scale as the key predictor of shipping connectivity. As noted in the data section, with only 19 countries the regional standard errors are wide, and these results are most informative as a consistency check.

4.7. Port-Level Results

Table 5 presents the CPPI models. In the port fixed-effects panel (Equation 5), the OSI coefficient of −118.1 (SE = 63.8, p = 0.067) falls marginally short of the conventional significance threshold and should not be read as evidence that e-government investment damages port performance. Far more telling is the within-port R^2 of just 0.013: together, OSI, LSCI, GDP per capita, and population explain barely one per cent of the within-port variation in CPPI over the panel window. LSCI is not significant in this specification either (p = 0.767). The most credible interpretation is that short-run fluctuations in port performance over 2020 to 2024 were dominated by the COVID-19 disruption, the subsequent global container congestion of 2021 to 2022, and idiosyncratic terminal-level operational shocks, none of which national - level covariates are equipped to capture. H4 is not supported in the panel dimension.

The 2024 cross-section offers a different and somewhat more informative picture. In model (8), LSCI is the only variable with a robust positive association with CPPI ($\hat{\lambda}_2$ = 0.130, SE = 0.020, $p < 0.001$): ports situated in countries that are better integrated into the global shipping network tend to perform better operationally, which makes sense given that connectivity and port investment are likely to be driven by the same underlying factors of location advantage and cargo demand. OSI remains insignificant (p = 0.226), and population enters with a negative and significant coefficient (p = 0.012), probably reflecting greater congestion and complexity pressures in large-market ports. The adjusted R^2 of 0.137 indicates that country-level characteristics account for a modest but non-trivial share of cross-port performance differences in 2024, with LSCI doing most of the explanatory work. These cross-sectional results partially support H4 for LSCI while confirming the null for OSI.

5. Discussion

Reading across all ten models, the results form a clear and consistent pattern that invites interpretation on several levels. Perhaps the most practically important message is that liner shipping connectivity, not e-government readiness, is what consistently predicts both export performance and port efficiency. In the cross-section of country time-averages, countries with higher LSCI levels export substantially more, even after con-

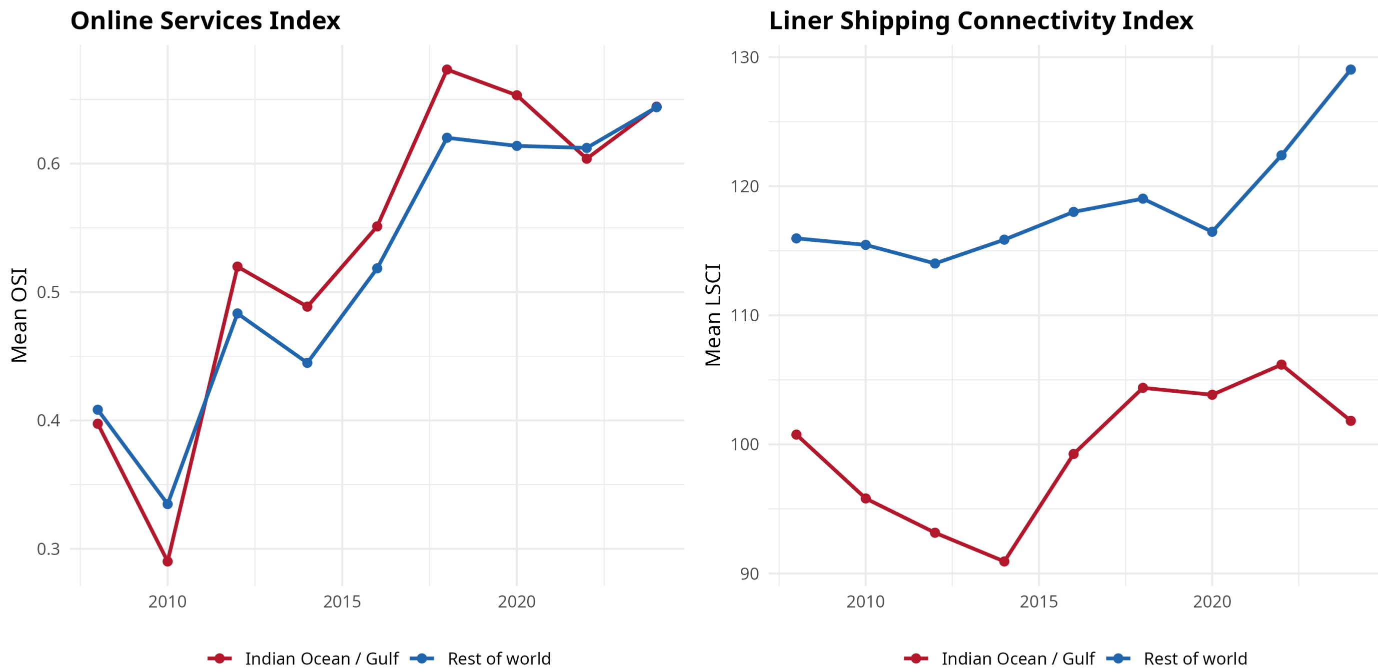

Figure 2: Mean OSI (left) and mean LSCI (right) by survey year, Indian Ocean and Gulf economies versus the rest of the panel, 2008 to 2024.

trolling for income and population, confirming the established view that maritime network integration acts as a structural trade facilitator (Fugazza and Hoffmann, 2017; Wilmsmeier and Hoffmann, 2008). The same pattern appears at port level in 2024: better-connected countries host better-performing ports. For maritime policy makers, this points fairly directly toward investments in physical and network-level maritime infrastructure, including port capacity, service frequency, and transhipment hub development, as the channel most likely to deliver observable gains in trade performance.

The null finding for OSI is consistent and, taken at face value, clear: national e-government maturity, as measured by the Online Services Index, is simply not the kind of variable that moves exports or connectivity on the timescales and through the mechanisms available to this study. Interpreting this result carefully, however, requires acknowledging what it does and does not show. It does not imply that digitalisation is irrelevant to maritime trade performance. There is ample evidence in the literature that port community systems, electronic customs platforms, and AIS-integrated scheduling tools do reduce vessel waiting times and lower trade costs (Carlan et al., 2016; Heilig and Voß, 2017; United Nations Economic and Social Commission for Asia and the Pacific, 2021). The issue is one of measurement: OSI aggregates online service quality across health, education, civil registration, and financial services, not the specific trade and logistics systems that drive port efficiency. A country could achieve very high OSI scores while its customs authority remains largely paper-based, or its ports could deploy world-class terminal management software without this registering in the country's overall online service ranking. Using OSI as a proxy for maritime digitalisation therefore introduces substantial measurement error that is likely to attenuate any real relationship toward zero, and researchers should be cautious about drawing on EGDI components in trade facilitation studies without first establishing that the index captures the relevant domain.

The marginally non-significant port fixed-effects result (OSI coefficient -118.1, $p = 0.067$) deserves a specific word of caution. The within-port R^2 of 0.013 makes clear that this model is not explaining CPPI variation in any meaningful way, and the 2020 to 2024 window is one of the worst possible periods for identifying quiet policy effects in port data, given the scale of COVID-19 disruption and the 2021 to 2022 container congestion crisis. Reading the negative sign as a structural relationship would require a very different and considerably longer panel than is currently available.

GCC economies and other maritime states in the Indian Ocean region have invested substantially in e-government modernisation, often benchmarking themselves against international indices including the EGDI. Nothing in the present results argues against those investments in their own right: transparency, service delivery efficiency, and citizen access to government services are legitimate and valuable objectives. What the evidence does suggest is that aggregate online service scores are not reliable leading indicators of trade or maritime competitiveness, and that targeting maritime digital reforms, specifically the port community systems, electronic customs single windows, and logistics data-sharing platforms that directly support cargo throughput, is likely to be more effective for improving export and port performance than general e-government benchmarking. For regional bodies such as the Indian Ocean Rim Association and for port authorities in the GCC, this distinction

Table 2: Two-way fixed-effects country-year panel regressions

	(1) ln(Exports)	(2) ln(LSCI + 1)
Online Services Index (OSI)	−0.018	−0.075
	(0.100)	(0.098)
	[−0.215, 0.179]	[−0.270, 0.119]
	$p = 0.859$	$p = 0.445$
LSCI (levels)	−0.0009	
	(0.0007)	
	$p = 0.167$	
ln(GDP per capita)	1.781***	0.373**
	(0.151)	(0.115)
	$p < 0.001$	$p = 0.0015$
ln(Population)	0.779***	$0.430^{\cdot}$
	(0.185)	(0.222)
	$p < 0.001$	$p = 0.055$
Country fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
SE clustered by country	Yes	Yes
Observations	1,070	1,070
Countries	123	123
Adjusted R^2	0.992	0.971
Within R^2	0.452	0.063

Cell entries are the estimated regression coefficient, with the clustered standard error directly below in parentheses and the exact p-value below that. $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.10$. 95 per cent confidence intervals in brackets for OSI.

One singleton fixed-effect observation removed from the base sample of 1,071.

Table 3: Country cross-sectional regressions: long-run associations (N = 124 countries)

	(3) Mean ln (LSCI + 1)	(4) Mean ln (Exports)
Mean OSI	0.142	0.290
	(0.437)	(0.416)
	$p = 0.745$	$p = 0.486$
Mean ln(LSCI + 1)		0.184*
		(0.087)
		$p = 0.036$
Mean ln(GDP per capita)	0.365***	1.146***
	(0.073)	(0.076)
	$p < 0.001$	$p < 0.001$
Mean ln(Population)	0.346***	0.841***
	(0.033)	(0.043)
	$p < 0.001$	$p < 0.001$
Constant	−4.594***	−0.723
	(0.853)	(0.905)
Observations	124	124
Adjusted R^2	0.695	0.953

Cell entries are the estimated regression coefficient, with the OLS standard error directly below in parentheses and the exact p-value below that. $^{***}p < 0.001$, $^{*}p < 0.05$.

between aggregate e-government maturity and sector-specific maritime digitalisation is the central policy takeaway from this study.

6. Conclusions

This paper has assembled four internationally recognised datasets, the UN Online Services Index, the UNCTAD Liner Shipping Connectivity Index, World Development Indicators, and the World Bank and S&P Global Container Port Performance Index, into a common panel framework to test whether national e-government capability is associated with maritime trade performance and port efficiency. The analysis spans 124 economies and nine biennial waves from 2008 to 2024 at the country level, and 356 ports in 100 economies from 2020 to 2024 at the port level.

The headline finding is a consistent null for OSI across every specification estimated: no statistically significant association is detected between the Online Services Index and export levels, liner shipping connectivity, or container port performance in global panels, regional panels, or cross-sectional models. By contrast, GDP per capita and population are robustly associated with export performance and, to a lesser extent, with LSCI across all country-level models. LSCI itself is positively and significantly associated with long-run export levels in the cross-section and with port performance in the 2024 cross-section, supporting the existing literature on maritime connectivity as a structural trade facilitator.

For policy makers and development finance institutions, the most direct implication is that aggregate OSI or EGDI rankings should not be treated as proxies for a country's maritime digital readiness: sector-specific assessments of customs, port, and logistics digital infrastructure are necessary and should be developed as standalone benchmarks. For the maritime and trade facilitation research community, future work should invest in constructing indicators of port-specific digitalisation, such as port community system adoption rates, the share of customs declarations processed electronically, and documented deployment of AIS-based scheduling platforms, and test their relationship with LSCI and CPPI using designs similar to those employed here. For Indian Ocean and Gulf economies with maritime ambitions, the evidence points toward network-level shipping connectivity and port operational investment as the higher-return agenda for trade competitiveness policy.

OSI changes slowly between biennial survey waves, and the within-country variation available for fixed-effects identification is modest, which limits statistical power and is a constraint that future research should take seriously. Future designs could exploit sudden changes in OSI associated with specific national digitalisation programmes using difference - in - differences or event-study methods. The CPPI panel covers only five years, a period that happens to coincide with exceptional disruption in global shipping, and a longer time series would allow more stable port-level modelling. Finally, an analysis linking country-level digital policy with firm-level or port-operator-level digital investment data in a multi-level design would provide a more

Table 4: Regional fixed-effects panel: Indian Ocean and Gulf economies (N = 163, 19 countries)

	(5) ln(Exports)	(6) ln(LSCI + 1)
Online Services Index (OSI)	−0.087	−0.379
	(0.146)	(0.318)
	$p = 0.559$	$p = 0.249$
LSCI (levels)	−0.001	
	(0.0007)	
	$p = 0.112$	
ln(GDP per capita)	1.126***	0.662*
	(0.151)	(0.257)
	$p < 0.001$	$p = 0.019$
ln(Population)	0.641**	0.882*
	(0.199)	(0.394)
	$p = 0.005$	$p = 0.038$
Country fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	163	163
Countries	19	19
Adjusted R^2	0.993	0.938
Within R^2	0.361	0.096

Cell entries are the estimated regression coefficient, with the clustered standard error directly below in parentheses and the exact p-value below that. $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.10$.

direct test of the mechanisms discussed here, and would help disentangle the effects of national policy from those of the private sector investments in terminal technology that arguably do most of the work in improving port efficiency.

Declaration of Competing Interest

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

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Author Contributions

Meena Madhavan contributed to conceptualisation, methodology, and writing (original draft, review and editing). Mohammed Ali Sharafuddin is responsible for data curation, formal analysis, methodology, software, and writing (original draft, review and editing).

Declaration of Generative AI Use

During the preparation of this work, the authors used Claude (Anthropic) to assist with data processing scripts and language proofing. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Table 5: Port-level CPPI regressions: fixed-effects panel and 2024 cross-section

	(7) CPPI Panel FE	(8) CPPI 2024 OLS
Online Services Index (OSI)	$-118.1^{\cdot}$	39.1
	(63.8)	(32.3)
	$p = 0.067$	$p = 0.226$
LSCI (levels)	−0.046	0.130***
	(0.155)	(0.020)
	$p = 0.767$	$p < 0.001$
ln(GDP per capita)	33.3	−5.59
	(89.2)	(4.78)
	$p = 0.709$	$p = 0.243$
ln(Population)	−52.5	−8.32*
	(107.1)	(3.29)
	$p = 0.625$	$p = 0.012$
Port fixed effects	Yes	No
Year fixed effects	Yes	No
SE clustered by country	Yes	No
Observations	888	349
Ports / Countries	308 / 95	349 / 95
Adjusted R^2	0.513	0.137
Within R^2	0.013	

Cell entries are the estimated regression coefficient, with the standard error directly below in parentheses and the exact p-value below that. $^{***}p < 0.001$, $^{*}p < 0.05$, $^{\cdot}p < 0.10$. Clustered standard errors in parentheses for column (7), OLS standard errors for column (8).
48 singleton fixed-effect observations removed from the base panel of 936 in column (7).

Data Availability Statement

All datasets used in this study are publicly available. UN e-Government Survey data are available at `https://publicadministration.un.org/egovkb/en-us/Data-Center`. UNCTAD LSCI data are available at `https://unctadstat.unctad.org`. World Development Indicators are accessible via the World Bank API. CPPI data are available at `https://openknowledge.worldbank.org`. All data and the R analysis scripts are archived at `https://github.com/MohammedAliSharafuddin/oman-digital-government-maritime-trade` and permanently archived on Zenodo at `https://doi.org/10.5281/zenodo.21946965`.

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