RIS Discussion Paper Series

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Discussion Paper # 300

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December 2024

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Assessing Performance and Productivity of Major Ports of India

Prabir De* and Arpit Barman**

Abstract: Ports are the lifeline of Indian economy. More than 80 per cent of India's merchandise trade (by volume) is transported via ocean routes. Not only does it handle trade, but ports are also planned to serve the country's strategic needs. However, low productivity and inefficiency of ports in India have been identified as major constraints affecting India's trade. Why is productivity of port so important? A productive and efficient port has often been a prerequisite for successful growth strategies, particularly those driven by exports. By sharp contrast, a poorly functioning or inefficient port can hinder growth. This discussion paper analyses the TFP growth (TFPG) of the Indian ports. One of the conclusions is that major ports in India have witnessed significant productivity strides post-inauguration of the Sagarmala project.

Keywords: Indian ports, Port performance, Total Factor Productivity, TFPG, Efficiency

1. Introduction

Ports are the lifeline of Indian economy and have been playing a critical role in India's international trade. More than 80 per cent of India's merchandise trade by volume is transported via ocean routes. Not only does it handle trade, ports are also planned to serve the country's strategic needs. At the time independence, India was left with five major ports. Today, India has 13 major with over 200 notified non-major ports, which are the key nodes in global supply chains and crucial to the growth of the economy.[1]

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Authors are grateful to Professors K L Krishna, Biswanath Goldar and Dibyendu Maiti for their useful comments. Authors are equally grateful to Professor Sachin Chaturvedi, Director General, RIS for his valuable guidance and support. Authors are thankful to MoPSW's TRW for sharing the statistical archive. Authors sincerely acknowledge the comments of an anonymous referee. Views expressed are personal. Usual disclaimers apply.

The last decade and half were the watershed period of the Indian economy, where ports were identified as key growth enabler. While the Indian economic size has grown to US$ 3 trillion in 2022 from US$ 1.5 trillion in 2010, total port cargo in India in the same period has increased from 885 million tonnes in 2010-11 to 1410 million tonnes in 2022-23. Notwithstanding the rise of Indian economy, ports remain a slow-starter. The accentuation of structural constraints has been one of the factors contributing to as low as 4 per cent growth in cargo during 2010 to 2022. One of the common constraints identified in De (2006, 2009), Monteiro (2010), Gaur *et al*. (2011), Mandal *et al*. (2016), Sinha and Bagodi (2019), Mitra *et al*. (2021), Nanyam and Jha (2023) is low productivity and inefficiency of Indian ports. In other words, efficient and productive port has been identified as a key contributor to overall port competitiveness and international trade costs.[2]

A question arises as to why is productivity of any port important. A productive and efficient port has often been a prerequisite for successful growth strategies, particularly those driven by exports. By sharp contrast, a poorly functioning or inefficient port can hinder growth. India's growth slowdown in the past was identified as an outcome of the sharp decline of the Total Factor Productivity (TFP).[3] Several studies have shown that benefits of early port reforms were partly wiped out by the inefficiency of ports in India.[4] For example, quality of port infrastructure and operational efficiency of ports are critical to export manufactured products from India.[5]

Therefore, to add further impetus to the maritime sector and scale up the development, India has subsequently introduced the National Maritime Development Programme (NMDP)[6], Sagarmala, Maritime India Vision (MIV) 2030 and Maritime Amrit Kaal Vision (MAKV) 2047. Needless to add, boosting performance and productivity of India's maritime sector has remained one of the prime objectives of these initiatives.[7] For example, enhancing efficiency through technology and innovation is one of the stated objectives of the MAKV 2047.[8] This grand plan underscores the need for technology advancement, innovation and transformation with the aim to bring in efficiency in operation, cost optimisation and ease of doing business. Therefore, there is an in-built need to study the trends in productivity of the Indian ports, which would help us not only to understand inter-port productivity relations but also to better implement the strategic plans such as the MAKV 2047.

There is also a need to analyse the trends of productivity growth across the major ports of India over the years. A plausible measurement of the productivity of the ports of India evolved in this study may be found useful to measure productivity of ports in other countries. Globally, the empirical evidences suggest that a country's or a region's economic growth in the long run is supported by sustained growth in Total Factor Productivity (TFP).[9] Labour and capital significantly improves TFP. However, there are other factors that affect productivity such as innovation and technological efficiency. On the other hand, performance has a significant impact on TFP. Building upon De (2006, 2009), this paper aims to assess the TFP growth (TFPG) of the major ports of India. This study has three research objectives: first, to assess the performance of major ports of India; second, to analyse the trends in productivity of major ports of India over time; and three, to look at factors like performance responsible for variation in the TFPG across ports.

Rest of the paper is organised as follows. Section 2 presents data and methodology. Thereafter, Section 3 presents an overview of Indian major ports, followed by trends in port performance in Section 4. Empirical results are briefed in Section 5, which leads to policy implications and conclusion in Section 6.

2. Data and Methodology

Productivity is a measurement of the overall efficiency of production. It describes the complex interlinked relationship between the output and inputs used in the production process. Productivity is often considered as a residual once we account for the growth in output due to the growth in inputs of labour and capital. The TFP compares total outputs relative to the total inputs used in the production of an output. Since both outputs and inputs are usually expressed in terms of volume of indices, the indicator measures the TFPG. TFP cannot be explained using the growth in other observable inputs, since firm level inputs are measurable and not the residuals. In analysing the residual growth, the underlying dynamics in the economy that may influence the output growth are ignored by the traditional estimation methods of TFP such as the Solow residual. In this study, we are interested in understanding TFP in the sense of 'unexplained residual' from the contributions of labour (L) and capital (K). Besides, the TFP being accounted as residual from L and K, we further like to investigate TFP impact due to other factors such as performance of port via creating a port performance index, supporting infrastructure provided by States via creating State Infrastructure Index and law and order situation of States, which is further discussed in later sections.

Production, which can be simply defined as a process by which inputs are combined, transformed, and turned into outputs, is a fundamental concept in economic theory. Productivity and efficiency are the two most important but different concepts in measuring performance. The productivity of a producer can be loosely defined as the ratio of output(s) to input(s). This definition is easily and very obviously capable of explaining any situation where there is a single output and single input. As production has multiple outputs and inputs, it is more common to refer to TFP, a productivity measure involving all factors of production (Coelli *et al*., 1998).

Efficiency can be defined as relative productivity over time or space, or both. For instance, it can be divided into intra- and inter-firm efficiency measures. The former involves measuring the use of the firm's own production potential by computing the productivity level over time relative to a firm-specific Production Frontier, which refers to the set of maximum outputs given the different level of inputs. In contrast, the latter measures the performance of a particular firm relative to its best counterpart(s) available in the industry (Lansink *et al*., 2001). Efficiency can be defined as technical efficiency and includes output- and input-oriented technical efficiencies, i.e. the producer can either improve output given the same input (output-oriented) or reduce the input given the same output (input-oriented,) by improving technology. The production frontier reflects the current state of technology in the industry.

The TFP Model

The TFP is a measure of technological change in industry. There are two related approaches to the measurement of TFP: the production function approach and the growth accounting approach using some fixed shares. In our study, we use the first approach explicitly in terms of a Cobb-Douglas production function. The econometric approach to estimation of TFP demands that we must specify the form of the function. In a single commodity two factor world, it looks like:

$$Y_t = A_t L_t^{\alpha} K_t^{\beta} \quad (1)$$

where Y_t, L_t and K_t are output (in our case port traffic), labour input and capital input used in the production process at time *t*, respectively. A_t is the technology parameter which conceals within it all the myths about the invisible that governs the shift in production function. Here, α is the output elasticity of labour, β is that of capital, and when the sum of these two elasticities (α+β) is one, it is termed as a case of Constant Returns to Scale (CRS). In other words, returns to scale are equal to (α+β), implying that the Cobb-Douglas production function is homogeneous of degree (α+β). The form of A_t can be defined in many ways, but we consider the simplest one i.e. equation (2).

$$A_t = A_0 e^{\lambda t} \quad (2)$$

The equation (2) implies that technology progresses at a constant exponential rate of λ, which is positive. Putting this value into (1), we get:

$$Y_t = A_0 e^{\lambda t} L_t^{\alpha} K_t^{\beta} \quad (3)$$

Taking logarithm on both sides, which happens to be applicability of a beautiful mathematical tool of Cobb-Douglas model, gives us the final estimable equation:

$$LnY_t = LnA_0 + \lambda t + \alpha\, LnL_t + \beta LnK_t + \varepsilon_t \quad (4)$$

To derive the TFP estimates in our particular case, we incorporate time coefficients into the equation (4), and we get:

$$LnY_t = LnA_0 + \lambda\, t + \alpha LnL_t + \beta LnK_t + D_1 t_1 + \varepsilon_t \quad (5)$$

$$LnY_t = LnA_0 + \lambda\, t + \alpha LnL_t + \beta LnK_t + D_1 t_1 + D_2 t_2 + \varepsilon_t \qquad (6)$$

where the time dummy in equation (5) is for the whole period (2000 to 2022), and the additional time dummy in equation (6) is for the period 2015 to 2022. Purpose of putting an additional dummy in equation (6) is basically to test the impact of the Sagarmala project initiated in India in 2014.

What is important is that equation (4) helps us to estimate the technology parameter (λ), the labour elasticity (α) and the capital elasticity (β), if we have the time series data on Y, K and L. The determination of λ helps to understand the contribution of technological change to the growth of output in the Indian port sector. However, the meaning of λ must be clearly understood before extending it too far as is very common in the existing literature. Here, λ is disembodied, exogenous and Hicks-neutral technological progress. 'Disembodied' technological change means that it is not embodied into the factor inputs (labour and/or capital) but it takes place like 'manna from heaven' in the forms of better methods, organization and management of production that improve efficiency of input use. 'Exogenous' here means that it is independent of the variables utilized in the growth model. Therefore, we are left only with 'time' as the only factor. Quite contrary to this, the entire endogenous growth literature has been based on various internal (in a sense man-made) factors of production which govern, or which have strong influence on productivity, efficiency and technological change. On the whole, this λ fails to take into account the entire range of external factors on which the port has no direct control such as social, economic and political infrastructure facilities like education, transport, R&D, energy, openness, governance, etc.

After estimating the TFP ($EstTFP_{it}$), we then aim to analyse the likely determinants of the TFP. In other words, how the TFP is affected by port's internal as well as external factors with the following equation:

$$EstTFP_{it} = \alpha_0 + \beta TFP_{i(t-1)} + \gamma(X_{it}) + \varepsilon_t \qquad (7)$$

where $TFP_{i(t-1)}$ are the lag values of $EstTFP_{it}$ and X_{it} is the function of the following variables:

$$X_{it} = f(PPI_{it}, II_{it}, LO_{it}) \qquad (8)$$

where II is the state-level Infrastructure Index and *LO* is the Law and Order situation of respective States in which the ports are located. We want to understand the significant determinants from internal and external sides that can influence a port's TFP. Here, *PPI* (Port Performance Index)[10] is purely a port's internal indicator, whereas the *II* and *LO* are some external indicators of the port. Note that for the analysis of TFP with internal and external factors, we have utilised three models; model 1 comprises of internal and external factors without the lag value of TFP, time and port dummies; model 2 comprises of all the factors except the lag value of TFP and model 3 is inclusive of all the factors. Lag of TFP also helps us to check the issue of endogeneity.

Measuring of Port Performance

Another component of this study is to assess the port performance. We attempt to measure the performance of Indian major ports by developing a composite index, called Port Performance Index (PPI) as mentioned in the preceding para. It comprises of indicators of operational performance (TRT, PBWT), asset performance (OSBD, BTR, BOR) and financial performance (PTOS, RRT).[11] The definitions of the performance indicators are briefed in Appendix 2. The basic limitation of the conventional method of constructing a composite index from a number of indicators is that often subjective and fixed weights are given to individual indicators, which actually vary over time and space. To overcome this limitation, we employ the well-known multivariate technique of 'factor analysis' (or what is known as 'Principal Component Analysis' (PCA)) from which the weights of the respective factors follow (Fruchter, 1967).

In the PCA approach, the first principal component is a linear combination of the weighted variables which explains the maximum of variance across space. Hence, here, the sole objective of the weighting mechanism is to explain the maximum variance for all the individual indicators across the ports at a particular point of time. The rationale for using PCA is that it helps one to reach an aggregative representation from various individual port performance indicators. Its broader objective is quite pari pasu with homogenising the overall requirements for the individual indicators across the ports.

We have at our disposal values of eight port performance variables for six different years between 2000 and 2022, across 13 major ports. PPI is a linear combination of the unit free values of the individual indicators such that:

$$PPI_{ij} = \Sigma W_{kj} X_{kij} \qquad (9)$$

where PPI_{ij} = port performance index of the i^{th} port in j^{th} time, W_{kj} = weight of k^{th} indicator in j^{th} time, and X_{kij} = unit free value of the k^{th} indicator for the i^{th} port in j^{th} time. Each individual indicator was made unit free by dividing each individual observation with mean values of each indicator.

Data

In view of the aforesaid discussion, we have chosen the period from 2000 to 2022 for our analysis. A period of 23 years is supposed to be reasonable enough for our purpose to check the extent of the impact of new technology on the productivity of the factors of production in Indian port sector. However, technological issues like import of technical know-how and/or techniques are basically embodied in our analysis and not directly dealt with.

It may be admitted here that the measurement of the stock of capital always poses some conceptual problems. For our purpose, we have followed the Perpetual Inventory Accumulation (PIA) method. Most researchers who have dealt with capital stock in Indian industries (and also elsewhere) have preferred to use the Gross Fixed Capital Stock (GFCS), perpetuated from the base year and converted into real terms with the help of capital formation deflators. In fact, there are conflicting views about the measurement of capital in general, particularly that in Indian industry. One basic and pioneering work on capital stock in Indian industries is by Hashim and Dadi (1973). Some of the other important works using this method are Roychoudhury (1977) and Ahluwalia (1991).

The major source of our data relating to traffic, capital and labour of Indian ports are various issues of Basic Port Statistics of India, published by the Ministry of Ports, Shipping and Waterways (MoPSW). While tabulating port-wise capital, we have considered year-wise capital employed (expenditure). Year-wise capital data were converted into real terms with the help of capital formation deflator. Similarly, port performance indicator data are obtained from the various issues of Basic Ports Statistics of India.Unlike the TFPG analysis based on the KLEMS database[12], our estimation is based on MoPSW's own database, mostly drawn from the *Basic Ports Statistics of India.*

Finally, the data for external factors have been taken from multiple sources. The state-wise LO variable is represented by crime variable, which is the percentage share of murder (under Section 302 of IPC) with the total murder at all India. The data is collected from *National Crime Records Bureau of India*. Infrastructure Index comprises of four variables: (a) Per Capita Availability of Power (in kilowatt hours) collected from Central Electricity Authority of India; (b) ratio of state-wise length of national highway (km) to state area (in km^2), collected from the Ministry of Road Transports and Highway; (c) ratio of state-wise railway route (km) to state area (in km^2), collected from Ministry of Railways; and (d) state-wise telephones per 100 population, collected from the Telecom Regulatory Authority of India.

3. Overview of Indian Ports

India has six major ports in the west coast (Kandla or Deendayal, Mumbai, Jawaharlal Nehru, Mormugao, New Mangalore or Mangaluru, Kochi or Cochin) and six major ports in east coast (Tuticorin or V.O.Chidambaranar, Chennai, Kamarajar or Ennore, Visakhapatnam or Vizag, Paradip, Kolkata or SMP (Kolkata Dock System) and Haldia or SMP (Haldia Dock Complex)) along its 11,098 km long coastline and with vast network of navigable waterways. Four of the major ports, that is, Kolkata, Mumbai, Chennai, and Mormugao are more than 100 years old. Cochin and Vizag ports are more than 50 years old. The ports of Deendayal, V.O. Chidambaranar, New Mangalore, and Paradip came into existence after independence. Jawaharlal Nehru port became operational only after 1989. Ennore (Kamarjar) port is the first corporate port of India under the public sector, established in 1999.

Indian major ports have witnessed a moderate rise in its cargo throughput during the period 2010-11 and 2021-22 (Table 1). With an annual CAGR of 4 per cent, total cargo of all major ports increased from 570.09 million tonnes in 2010-11 to 720.05 million tonnes in 2021-22, and the growth in cargo has been increasing steadily since the 2000s. Out of the total cargo handled by major ports, it is the overseas cargo (export and import cargo) accounted for 76.2 per cent (548.73 million tonnes), which recorded an increase of 4.5 per cent in 2021-22 compared to 2020-21.[13] Port-wise analysis of the traffic growth indicates that Kamarajar recorded the highest growth of 49.6 per cent in 2021-22, followed by Jawaharlal Nehru (17.3 per cent) and Mumbai (12.3 per cent) in 2021-22, compared to 2020-21.[14] Among the major ports, Deendayal handled the highest cargo (127.10 MT) in 2021-22, followed by Paradip (116.13 MT) and Jawaharlal Nehru (76 MT) (Table 1). Deendayal port (located in Gujarat) has consistently occupied the top rank among the major ports of India since 2010-11, thus showing a remarkable strength in the Indian port sector. Another interesting development is ports located in bigger urban clusters like Kolkata, Chennai, or Mumbai have witnessed negative or very marginal growth in traffic over time, thereby indicating cargo diffusion in the geographic space.

Containerisation started in India in 1973 in a limited way with the creation of interim container handling facilities at Mumbai and Cochin ports. Since then, container traffic has steadily increased over the years in tune with the increasing use of containers in international trade (Government of India, 2022). Presented in Table 1, Jawaharlal Nehru port continues to function as a major container port in India, followed by Chennai (30.93 million tonnes) and V.O Chidambaranar (15.91 million tonnes). The share of Jawaharlal Nehru port in total container traffic in

Table 1: Profile of Major Ports of India

Major Ports	Cargo Handled			Container Traffic			Port Capacity		Turnaround Time	
	2010-11	2021-22	CAGR	2010-11	2021-22	CAGR	2010-11	2021-22	2010-11	2021-22
	MT	MT	(%)	MT	MT	(%)	MT	MT	Hours	Hours
Kolkata	35 (6.1)	15.30 (2.1)	-7.9	6.22 (5.4)	8.44 (5)	3.1	67.05	92.77	149.04	82.8
Haldia	12.54 (2.2)	42.88 (5.9)	13.1	2.84 (2.5)	3.35 (2)	1.7			106.8	51.19
Paradip	56.04 (9.8)	116.13 (16.1)	7.6	0.07 (0.06)	0.18 (0.1)	10.3	76.5	289.75	185.52	53.16
Visakhapatnam	68.04 (11.9)	69.30 (9.6)	0.2	2.57 (2.5)	8.58 (5.10	12.8	64.93	134.18	140.16	73.83
Kamarajar	11.01 (1.9)	38.74 (5.3)	13.4		9.27 (5.5)		31	91	66.72	46.38
Chennai	61.46 (10.8)	48.56 (6.7)	-2.3	29.42 (25.8)	30.93 (18.5)	0.5	79.72	135	104.64	53.19
V.O.Chidambaranar	25.73 (4.5)	34.12 (4.7)	2.9	8.17 (7.2)	15.91 (9.5)	6.9	27.04	111.46	96	48.54
Cochin	17.87 (3.1)	34.55 (4.8)	6.8	4.42 (3.9)	10.28 (6.1)	8.8	40.98	78.6	52.8	45.87

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New Mangalore	31.55 (5.5)	39.30 (5.4)	2.2	0.57 (0.4)	2.31 (1.4)	15.1	45.57	108.96	64.8	47.99
Mormugao	50.06 (8.7)	18.46 (2.5)	-9.5	0.22 (0.2)	0.18 (0.1)	-1.8	41.9	63.4	250.32	63.94
J.L.Nehru	64.32 (11.2)	76.00 (10.5)	1.7	56.43 (49.4)	69.09 (41.3)	2.0	64	141.37	63.36	28.04
Mumbai	54.59 (9.6)	59.89 (8.3)	0.9	0.65 (0.6)	0.24 (0.1)	-9.6	44.53	84	119.04	57.99
Deendayal	81.88 (14.7)	127.10 (17.6)	4.5	2.59 (2.3)	8.62 (5.1)	12.8	86.91	267.1	141.6	59.99
All Ports	**570.09**	**720.05**	**2.4**	**114.16**	**167.38**	**3.9**	**670.13**	**1597.59**	**126.96**	**53.34**

Source: Authors' compilation from various editions of *Basic Ports Statistics of India*, MoPSW.

Notes: Port capacity of Kolkata and Haldia are combined, MT- Million Tonnes. Figures in brackets are share of individual ports (%) in all major ports.

2021-22 stood at 50.6 per cent (in TEUs) and 41.3 per cent (in tonnage), making it the premier container port in India.

Port capacity of the major ports have increased significantly from 670.13 million tonnes in 2010-11 to 1597.59 million tonnes in 2021-22, but mostly concentrated in Paradip (289.2 million tonnes), Deendayal (267.1 million tonnes) and Jawaharlal Nehru (141.4 million tonnes). Port capacity utilisation has drastically declined from 85 per cent in 2000-01 to 45 per cent in 2021-22. India has also been witnessing under-utilisation of port capacity.

Table 1 presents one of the key performance indicators of the major ports of India and provides comparison for the years 2010-11 and 2021-22. The average Turnaround Time (TRT), the time spent by a ship while entering, unloading, loading, and exiting the port, has significantly improved in the last two decades, reducing to half from around four days (101.7 hours) to roughly two days (53.34 hours). Jawaharlal Nehru has the lowest TRT time of roughly one day (28.04 hours), followed by Kamarajar and New Mangalore having close to two days. Ports like Paradip, Mormugao, Deendayal, Kolkata and Mumbai have managed to improve the TRT between 2000-01 and 2021-22.

It can be inferred that over the last two decades, there has been a steady increase in handling of cargo traffic at Indian ports and some of the other performance indicators as well such as TRT. India's export growth has also shown vigour and vitality over the past few years. However, compared to countries like the USA and China, Indian ports are often small, inefficient and lack the draft to accept larger sized vessels. Only two Indian ports (Jawaharlal Nehru Port and Mundra) make into the top 50 list of major container ports, according to the World Shipping Council (Table 2). India lags behind in other few port KPIs such as port capacity stock and Average Turn Around Time, compared to the USA and China. The average size of a container vessel calling at Indian ports is around 5,000 TEUs while for China it is around 12,000 TEUs.[15]

Table 2: Indian Ports in Comparative Perspective

Key Indicators	India	China	USA
Port capacity stock (per cent of GDP)	1	3	10
Number of shipyards*	7	70	45
Number of Ports in Global top 50	2	18	4
Container Traffic (million TEUs)	11	185	44
Average Annual Growth in container Traffic (million TEUs)**	0.5	10	0.4
Average Turnaround Time (Days)	4.5	1	1.2

Source: Authors' calculation from Sagarmala, National Perspective Plan and World Shipping Council.

Notes: *Considers more than 120m long ships; **For the period 2008-2012.

To conclude, there has been a steady increase in handling of cargo at Indian ports over the last two decades. However, to sustain the momentum of exports and improve competitiveness, the country would need adequate and efficient ports and maritime services. This also raises the question as to how effectively India's major ports, which handle 76 per cent of overseas cargo, can efficiently handle the trade. The TFP analyses will, therefore, help us to understand the productivity of each of these major ports.

4. Trends in Port Performance

Over the years, cargo handling capacity of major ports has steadily increased to cater to the growing volume of internal and external trade. The capacity of the ports, which was 172.59 million tonnes at the end of 1993-94, increased to a level of 1560.61 million tonnes at the end of 2020-21, and further increased to 1597.59 million tonnes at the end of 2021-22. The average overall Pre-Berthing Detention Time (PBWT) for all major ports declined from 51.84 hours in 1990-91 to 24.96 hours and further to 18.82 hours in 2021-22. Average TRT for all major ports improved from 194.40 hours in 1990-91 to 101.76 hours in 2000-01.

Thereafter, the average TRT has increased steadily to 126.96 hours in 2010-11 and further reduced to 53.34 hours in 2021-22. In the last 25 years, Average Output per Ship Berth-day (OSBD) has seen a tremendous improvement. OSBD has increased more than six times from 3,372 tonnes in 1990-91 to 19171 tonnes in 2020-21 and further increase to 21002 tonnes in 2021-22 for the major ports.

Table 3: Principal Components (Eigen Vectors): Port Performance Indicators

Variable	2000-01	2005-06	2010-11	2015-16	2020-21	2021-22
PBWT	-0.134	0.439	0.438	0.433	0.041	0.009
TRT	-0.484	0.479	0.504	0.323	-0.069	-0.398
PITTWB			0.208	-0.062	-0.484	-0.465
OSBD	0.446	-0.382	-0.386	0.322	0.346	0.441
BOR	0.155	0.434	0.466	0.323	0.308	0.072
BTR	0.402	-0.221	0.192	0.404	0.509	0.472
PTOS	0.338	-0.139	-0.191	0.368	0.176	0.119
RRT	0.500	-0.419	-0.267	0.446	0.505	0.435
Eigen Value	2.485	3.076	2.967	4.442	2.956	3.530
Exp. Variance	0.355	0.439	0.371	0.555	0.370	0.441

Source: Authors' computation.

Notes: 1. Eigen value: The factor loading of the eight port performance indicators for three different years is derived by the formula eigen vector = (factor loading)/√(eigen value). Eigen value is the first value of the 'variance explained' column in the unrotated factor loading (pattern).

2. Exp. Variance: Explained variance as per cent of total.

Table 3 provides Eigen Vectors of the individual performance indicators to derive Port Performance Index (PPI) based on the PCA (as discussed in Data and Methodology). The absolute values of OSBD and RRT have been consistently the most influential variables while deriving the port performance scores. In 2021-22, OSBD, RRT and BTR are the most influential factors for determining the PPI. However, in 2010-11,

Table 4: PPI Scores (S) and Rank (R)

Major Ports	2021-22		2020-21		2015-16*		2010-11		2005-06		2000-01	
	S	***R***	***S***	***R***	***S***	***R***	***S***	***R***	***S***	***R***	***S***	***R***
KDS	-0.81	13	-0.48	13	1.39	12	0.42	13	0.49	5	-0.38	11
HDC	0.18	11	1.02	10	2.24	8	1.95	7	1.18	1	2.59	1
PPA	1.77	2	2.59	1	3.37	3	2.74	3	0.07	9	1.89	3
VPA	0.31	9	1.33	8	2.53	5	2.10	5	0.12	8	1.61	5
KPL	1.79	1	1.96	3	5.69	1	2.52	4	-1.62	13	**	**
ChPA	0.23	10	0.78	11	1.16	13	1.30	10	0.25	7	0.46	10
VOCA	0.84	5	1.46	6	2.44	6	1.59	9	0.06	10	1.36	7
CoPA	0.72	7	1.20	9	1.55	11	0.55	12	0.29	6	0.83	9
NMPA	0.73	6	1.36	7	1.87	10	1.63	8	-0.28	11	1.89	4
MoPA	0.51	8	1.51	5	2.34	7	3.02	2	0.88	3	1.54	6
JNPA	1.61	3	2.12	2	3.76	2	3.31	1	-0.59	12	2.06	2
MbPA	0.01	12	0.64	12	2.15	9	1.16	11	0.70	4	-0.50	12
DPA	0.99	4	1.83	4	2.73	4	2.05	6	0.95	2	1.32	8
CV	**1.09**		**0.58**		**0.47**		**0.47**		**3.84**		**0.78**	

Source: Authors' computation based on Government of India (2024).

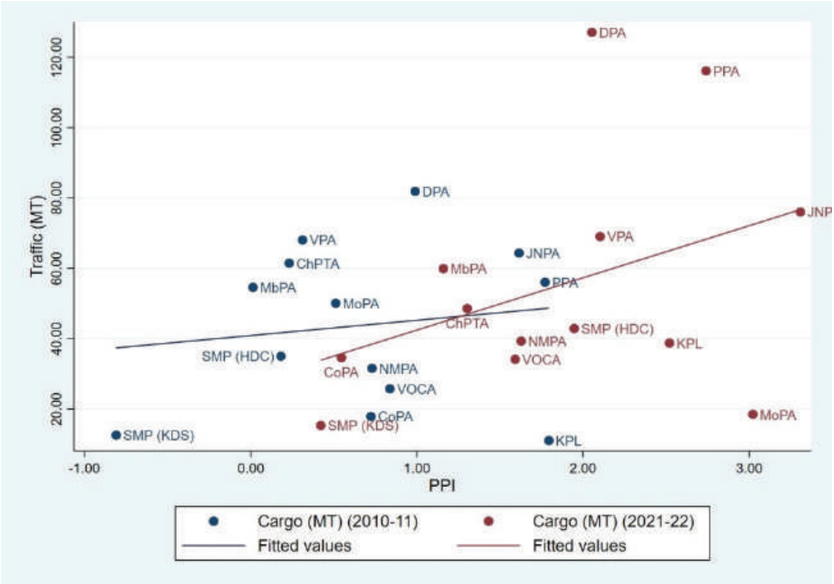
Notes: CV is Coefficient of Variation, *Starting year of Sagarmala project **Port was not established.

PBWT, TRT and BOR and in 2000-01, OSBD, BTR, RRT and PTOS came out as the most influential indicators determining the PPI.

Table 4 provides PPI scores and individual ranking for each selective year. One can infer that port of Jawaharlal Nehru (JNPA), Paradip (PPA) and Kamarjar (KPL) have shown significant improvement in port performance relative to other major ports since 2000-01 and thus they are the top three performers in 2021-22. It is important to note that the share of total cargo handled by these three ports has increased from 22.9 per cent in 2010-11 to 31.9 per cent in 2021-22. Also, the ports of SMP Kolkata Dock System (SMP KDS) and Mumbai (MbPA) are having poor performance since 2000-01. Their shares' in total cargo handled by major ports have declined since 2010-11 from 6.1 per cent to 2.1 per cent and 9.6 per cent to 8.3 per cent in 2021-22, respectively (Table 1). The relative performance of the port of SMP Haldia Dock Complex (SMP HDC) has also declined since 2000-01. Ranks of individual ports in terms of port performance, given in Table 4, make it clear that Kolkata, Haldia, Vizag and Chennai ports of the east coast and Mumbai port in the west coast have been gradually retreating in terms of the PPI.

It is noted that those ports which are performing better are attached with economically prosperous hinterland and vice versa. It is argued that since overall performance of states like Gujarat, Tamil Nadu, and Maharashtra are much better than that of West Bengal, Karnataka and Kerala, performance of ports of the first group of states is ahead of those in the second group. Figure 1 illustrates this more clearly. Port traffic and port performance are positively correlated, thereby showing that better port performance has been associated with the higher port traffic. The positive shift of the fitted curve in 2021-22, suggests higher strength of performance index explain the increase in the port traffic compare to 2010-11. Therefore, it may not be out of merit to find some sort of a scale economy to exert its positive impact on the performance index.

Figure 1: Port Traffic and PPI: 2000-01 and 2021-22



***Source*s**: Authors' computation.

The Coefficient of Variation (CV) score has declined from 2005-06 to 2015-16, thereby implying that there was a tendency towards equalisation of inter-port performance till pre-Sagarmala. In Post-Sagarmala, however, one can infer that CV has increased from 0.47 in 2015-16 to 1.09 in 2021-22, thereby suggesting divergence in port performance among the major ports of India.

From the forgoing analysis, it may not be out of merit to find the trends in productivity, which we have dealt in the next section. This may be helpful in formulating the sequential priority of maritime policy MAKV 2047 in particular and its overall direction.

5. Estimation and Results

In this section we present the results of the estimation of Cobb-Douglas production functions for three time periods: pre-Sagarmala (2000-01 to 2013-14), post-Sagarmala (2014-15 to 2021-22) and the whole period

(2000-01 to 2021-22), respectively. To estimate the Cobb-Douglas production function, we use Fixed Effect (FE), Random Effect (RE) and Pooled OLS. To check which model (FEM or REM) is preferred, we first run the Hausman tests.[16] From the Hausman tests, we infer that when observations are taken for the whole period and pre-Sagarmala, we conclude that there are systematic differences in coefficients of FEM and REM ($p<0.05$). Thus, the FEM for estimation gives us efficient and consistent estimates. However, in case of post-Sagarmala, we infer from Huasman tests that there are no systematic differences in coefficients of FEM and REM ($p>0.05$). So, the REM for estimation gives us efficient and consistent estimates. Lastly, applying the Breusch Pangan Lagrange Multiplier test we conclude that there is presence of unobserved effect in all time periods across all the production functions, thus the statistical result from pooled OLS gives the same result from the RE estimation. Pair-wise correlation matrix indicates that Y (cargo handled), L (labour) and K (capital) are not correlated. However, Y/L is positively correlated with K/L for all three periods.[17] The TFPG estimates are robust since estimated coefficients of Ln(K/L) are positive, statistically significant coefficient and less than unity (Table 5).

Table 5 presents the estimates of production function parameters for Cobb-Douglas production function. The term statistically significant is used to indicate that the coefficient is significantly different from zero and is of the sign indicated at 5 per cent level of significance of a two-tailed test. We infer that Pooled OLS estimation provides the best results for the whole period and pre-Sagarmala timeline. The labour coefficients are positive and statistically significant when applying Pooled OLS estimation in all the three production functions. Although, in case of post-Sagarmala timeline, Cobb-Douglas production function estimation using the Pooled OLS provides positive coefficient estimates for labour, rest of the estimation by FE and RE. When estimating the log of capital some important observations need to be noted. First, the coefficients of *LnK* are statistically insignificant pre-Sagarmala and whole period. Second, in case of post-Sagarmala, the coefficient of *LnK* estimated using Pooled OLS in Cobb-Douglas, is statistically significant and positive.

Table 5: Estimates of Cobb Douglas Production Function Parameters

Dependent Variable: Ln(Y)				Dependent Variable: Ln(Y/L)			
	RE	FE	OLS		OLS	RE	FE
2000-01 to 2021-22							
LnL	-0.228	-0.338	0.182***	Ln(K/L)	0.418***	0.212***	0.149***
	(0.210)	(0.203)	(0.019)		(0.048)	(0.055)	(0.041)
LnK	0.009	0.008	0.008				
	(0.007)	(0.007)	(0.008)				
Constant	18.942***	19.811***	15.221***	Constant	3.176***	6.835***	7.734***
	(1.831)	(1.665)	(0.201)		(0.602)	(0.705)	(0.538)
N	188	188	188	N	188	188	188
R-squared		0.184	0.292	R-squared	0.55		0.063
2000-01 to 2013-14							
LnL	-0.037	-0.322	0.221***	Ln(K/L)	0.445***	0.109	0.0485
	(0.231)	(0.441)	(0.02)		(0.065)	(0.073)	(0.051)
LnK	0.002	0.003	0.004				
	(0.003)	(0.003)	(0.008)				
Constant	17.459***	19.746***	14.816***	Constant	2.619***	7.791***	8.653***

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	(1.931)	(3.516)	(0.207)		(0.817)	(0.825)	(0.659)
N	116	116	116	N	116	116	116
R-squared		0.073	0.399	R-squared	0.534		0.014
2014-15 to 2021-22							
LnL	-0.156**	-0.189**	0.064	Ln(K/L)	0.388***	0.0760*	0.0533
	(0.077)	(0.077)	(0.045)		(0.0692)	(0.0396)	(0.0367)
LnK	0.027	0.027	0.11**				
	(0.019)	(0.019)	(0.050)				
Constant	18.181***	18.419***	14.707***	Constant	4.719***	9.245***	9.660***
	(0.779)	(0.681)	(1.128)		(0.954)	(0.633)	(0.499)
N	72	72	72	N	72	72	72
R-squared		0.181	0.09	R-squared	0.355		0.03

Source: Authors' own calculation.

Notes: Models follow cross-section time-series panel for 13 major ports. Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1

To what follows is that labour input had positive impact on the port traffic in the whole period as well as the pre-Sagarmala phase, whereas the capital input led to impact port traffic in post-Sagarmala.

Thereafter, we predict the TFP and TFPG using Pooled OLS estimation based on the Cobb-Douglas production function. Note that in Cobb-Douglas production function, the sum of the estimates of coefficients of LnL and LnK measure the degree of homogeneity of the production function and accordingly the returns to scale. Here we infer that for all the three periods the Decreasing Returns to Scale is observed (Homogeneity < 1).

Table 6: Predicted Average TFP and TFPG

Major Ports	2000-01 to 2013-14		2014-15 to 2021-22		2000-01 to 2021-22	
	TFP	TFPG (%)	TFP	TFPG (%)	TFP	TFPG (%)
ChPA	1.26	-1.01	0.84	-2.08	1.21	-0.45
CoPA	0.47	-2.44	0.75	-2.56	0.53	0.96
DPA	1.77	-1.84	2.16	29.63	1.94	0.30
JNPA	1.57	2.08	1.55	-1.41	1.56	2.04
KPL	0.89	0.36	0.80	0.20	0.94	3.73
MbPA	0.96	-3.22	1.09	7.27	1.02	-0.21
MoPA	1.05	2.17	0.55	3.04	0.82	6.01
NMPA	1.02	-2.12	1.05	3.49	1.03	-0.76
PPA	1.16	5.84	2.44	7.61	1.66	6.76
SMP (HDC)	1.04	1.80	0.79	-0.97	0.96	3.04
SMP (KDS)	0.34	1.57	0.35	-4.00	0.34	1.09
VOCA	0.63	3.24	0.93	6.02	0.72	2.81
VPA	1.54	-4.71	1.38	3.69	1.51	-1.95
CV	**0.4**		**0.54**		**0.42**	

Source: Authors' own calculation.

Table 6 provides the estimated values of TFP and TFPG using Cobb-Douglas production function based on the pooled time series cross-section data. From the Table 6, one can conclude that on an average the TFP growth has accelerated in post-Sagarmala period (2014-15 to 2021-22) compared to pre-Sagarmala period (2000-01 to 2013-14).[18] In case of pre-Sagarmala period, Port of Deendayal (DPA) (1.77), Jawarhalal Nehru Port (JNPA) (1.57) and Vizag Port (VPA) (1.54) had the highest average TFP among all major ports. In post-Sagarmala period, Paradip (PPA) (2.44), Deendayal (DPA) (2.16) and Jawaharlal Nehru (JNPA) (1.55) had the highest average TFP. Overall (period 2000-01 to 2021-22), DPA (1.94), PPA (1.66) and JNPA (1.56) have been the top three productive ports.

The TFPG rates have shown significant rise in post-inauguration of Sagarmala project. In case of pre-Sagarmala period, seven ports had positive average TFPG with highest growth experienced in Paradip port (PPA) (5.84 per cent) and V.O. Chidambaram Port (VOCA) (3.24 per cent). In post-Sagarmala period, eight ports had positive average TFPG with highest growth experiences by DPA (staggering 29.4 per cent), followed by PPA (7.61 per cent). When considering the whole period, nine ports had positive average TFPG with DPA (1.96) had the highest productivity levels, followed by PPA (1.66). One can infer from the TFP trends the Paradip Port has shown consistent rise in productivity from 2000 to 2022.

It can be said that although some Indian major ports such as Paradip, Jawaharlal Nehru, Deendayal have shown improvement in productivity levels post implementation of Sagarmala project, other ports such SMP Haldia and SMP Kolkata have not shown any improvement in productivity levels in post-Sagarmala period. Therefore, there seems to be an increase in divergence among major ports in terms of productivity level (as measured by CV) post-Sagarmala (Table 6). Nonetheless, the acceleration of TFPG after the implementation of Sagarmala project suggests that investments in infrastructure development have yielded positive results.

Table 7: Determinants of TFP

Variable	Model 1	Model 2	Model 3
$LnTFP_{t-1}$			0.603***
			(0.005)
LnPPI	0.162**	0.139**	0.063
	(0.046)	(0.045)	(0.112)
LnII	-0.070	0.151	0.014
	(0.583)	(0.463)	(0.924)
LnLO	-0.209***	0.053	-0.015
	(0.000)	(0.861)	(0.927)
Constant	0.752***	-0.256	0.025
	(0.008)	(0.785)	(0.964)
Year Dummy	No	Yes	Yes
Port Dummy	No	Yes	Yes
R-square	0.300	0.902	0.937
No. of observations	50	50	50
Method	OLS	OLS	OLS

Source: Authors' own calculation.

Note: Dependent variable: Log (TFP_t), p-values (in bracket) ***p<0.01, **p<0.05, *p<0.1

At the end, we determine the factors that affect the TFP – port's internal and external factors. As discussed extensively we know that internal factors (represented the Port Performance Index) affect the TFP. To assess the effects of some external factors, we have taken Infrastructure Index (II), Law and Order (LO) (denoted by crime rate) and lagged values of the TFP. The Infrastructure Index has been computed using the PCA.[19] As discussed in Section 2, the predicted value of TFP is analysed using three types of models. Cross-section pooled data are taken for four time periods: 2010-11, 2015-16, 2020-21 and 2021-22. The regression results are presented in Table 7. Following observations are worth noting.

First, we use robust standard errors to check the heteroskedasticity. In model 1, coefficient of PPI and LO were significantly different from zero. Thus, we can infer that, *ceterius paribus,* 1 per cent improvement in PPI may lead to increase the TFP by 0.16 per cent. Similarly, *ceterius paribus,* 1 per cent reduction in crime rate (represented by LO) may lead to increase the TFP by 0.21 per cent. The caveat is low R-square value in model 1 indicates that the OLS does not have a good fit. In case of Model 2, the estimated coefficient of II is positive but statistically insignificant. In fact, the coefficient of the LO is statistically insignificant and the sign is positive. Nonetheless, PPI has come out positive and statistically significant in model 1 and model 2. However, the model 3 resolves the signs of the coefficient of each variable. In this model, the past values of TFP have significant and positive impact on current TFP.

6. Conclusions and Policy Implications

Based on the Cobb-Douglas production function, this study shows that Indian major ports have shown an increase in TFPG in post-Sagarmala period compared to pre-Sagarmala period. Deendayal, Jawaharlal Nehru and Paradip are the top productive ports in the country. These are the ports which came out to be top performing ports consistently since 2010-11. Therefore, Indian ports have witnessed significant strides in TFPG in post-Sagarmala period.

It can be further inferred that although some Indian major ports such as Paradip, Jawaharlal Nehru, Deendayal have shown improvement in productivity levels post implementation of Sagarmala project, other ports such as Haldia and Kolkata have not witnessed any improvement in productivity levels. Therefore, there seems to be an increase in divergence among major ports in terms of productivity level in post-Sagarmala period.

This study also presents the major determinants of the TFP particularly those which are linked to port's internal and external economies. Port performance, law and order situation, where the port is located, may lead to increase in the TFP. This study also suggests that past values of TFP have significant and positive impact on current TFP in the major ports of India.

The findings of this study may be revalidated with the help of other forms of production function such as Leontief, Solow, etc.

Ports are the lifeline of Indian economy. Since India's Independence, ports have been playing a key role in India's trade and economic integration. Outcomes of this study indicate that boosting of productivity of ports must be taken up as a priority objective of the Government of India. Besides, Government may attempt to undo the divergences of productivity through augmenting higher capital and technology to those ports which are falling behind. Port authorities should continue prioritizing investments in port infrastructure, including berths, cargo handling equipment, and connectivity to hinterland, to sustain this momentum.

While some ports like Deendayal (DPA), Paradip (PPA), and Jawaharlal Nehru (JNPA) have shown consistent improvement in productivity, other ports need targeted interventions to improve their performance. Policies should focus on addressing the specific bottlenecks faced by these ports, such as infrastructure limitations, inefficient processes, or skill gaps.

Boosting of productivity of ports must be taken up as a priority objective by not only Centre but State governments as well. In particular, the Centre must allocate higher capital and technology to those ports which are lagging.

Policies should be undertaken to encourage the adoption of advanced technologies like automation and artificial intelligence (AI), to further enhance productivity in ports. Also, AI and automation will further improve the port analytics by providing real time data of some of the key port indicators, which will allow for live tracking of key performance indicators, thus improving policy-making decisions. A separate port-wise plan for technology upgradation shall be monitored closely. Port authorities should prioritise skill development and training programs for port workers to ensure they have the necessary competencies to operate modern equipment and handle increasingly complex cargo.

Today's ships must comply with the environmental regulations. Ship building, therefore, requires more strategic push. India may consider inviting investments and technology from Korea and Japan.

By 2030, India's annual port capacity is likely to exceed 3,000 million tonnes. In order to achieve this target, involvement of private sector is important, besides government's active guidance and engagement. Landlord port model only pays when the port and port services are managed by the private operators. Greater Centre-State coordination in the maritime sector will pave the way for a comprehensive and inclusive development. Strengthening the Maritime State Development Council (MSDC) and launching the Maritime Development Fund (MDF) are some low-hanging fruits that can be implemented in the short run.

Endnotes

1 Refer, for example, Sahai (1986), which discussed the role that was played by ports after Independence in India.

2 Improved efficiency of ports has a positive impact on country's export performance. Goldar and Paul (2018) argued that improved port efficiency enhances competitiveness of India's manufactured exports enabling Indian manufacturing firms to export more.

3 Refer, for example, Ahluwalia (1991), Virmani (2004) Goldar (2022), Goldar et al. (2023), RBI (2021), etc.

4 Refer, for example, De (2009). Also refer, Virmani and Hashim (2011) who argued that the fall in productivity in the post-reform era was the result of technological obsolescence and the gradual adoption of new technology, and the slow effect of learning by doing.

5 Refer, for example, Goldar, B and M Paul (2018)

6 Refer, https://pib.gov.in/newsite/PrintRelease.aspx?relid=133484

7 Refer, Appendix 1 which presents the broad contour of India's major port development initiatives.

8 Refer, for example, https://shipmin.gov.in/

9 Refer, for example, Solow (1956); Griliches and Jorgenson (1967); Kendrick and vaccara (1980); Klenow and Rodriguez-Clare (1997); Hall and Jones (1999); van Ark et al. (2000); Dieppe (2021); etc.

10 PPI has been calculated using eight performance indicators which are port's internal factors, computed based on the PCA.

[11] Refer, De (2009) for a detailed discussion on the PPI.

[12] The industry-level TFP growth estimates are based on the gross output function framework, and these estimates were drawn from the India KLEMS database.

[13] Refer, https://shipmin.gov.in/sites/default/files/MoPSW%20achievemnts%20and%20initiatives%20of%20FY%202023-24_0.pdf

[14] ibid

[15] MoPSW, https://shipmin.gov.in/

[16] Diagnostic tests results are available on request from authors. For all time periods and both the production functions, the models suffer from heteroskedasticity and first order autocorrelation as per the results of modified Wald Tests and Wooldridge tests, respectively. Therefore, we use robust cluster variance (Robust Standard Error) for estimating the p-values of various models to check for significance of independent variables.

[17] Refer, Appendix 5 for pair-wise correlation

[18] Also refer Appendix 6 for the trend of the TFP and TFPG across major ports

[19] Due to space constraints, we avoid presenting the weights and state-wise Infrastructure Index scores and rank, which are available on request.

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Appendix 1

Table 1: India's Maritime Development Programme

Initiative	**Primary objectives**
National Maritime Development Programme (NMDP) (2005-2012)	• To modernize port infrastructure through adding new cargo handling facilities, construction/upgradation of berths, deepening of channels, rail/road connectivity projects, equipment upgradation/modernization schemes and other related schemes for creation of backup facilities. • To benchmark the performance of ports to international standards.
Sagarmala (2015 – 2023)	• To reduce logistics cost for both domestic and export-import cargo with minimal infrastructure investment. • To implement projects for port modernization, port connectivity, port-led industrialization, coastal community development, and coastal shipping and IWT.
India Maritime Vision 2030 (Introduced in 2021)	• MIV 2030 emphasizes on boosting performance and productivity of India's maritime sector. • To strengthen India's position in the global maritime sector, MIV 2030 identifies over 150 initiatives across various maritime sub-sectors like ports, shipping and waterways. These initiatives particularly focus on operational efficiency improvement, port-driven industrialization and creating safe and sustainable world class ports to address the growing trade volume needs, as well as reducing logistics cost through better evacuation and cost effective processes.

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Maritime Amrit Kaal Vision 2047 (Introduced in 2023)	• The Amrit Kaal Vision 2047 builds on the Maritime India Vision 2030 and aims to develop world-class ports and promote inland water transport, coastal shipping, and a sustainable maritime sector. • It encompasses aspirations in logistics, infrastructure, and shipping, supporting India's 'Blue Economy' for enhancing ports, shipping, and waterways by 2047.

Source: Authors' own based on several secondary sources

Appendix 2

Definition of Performance Indicators

- Ship Turn-Round Time (TRT) is the duration of the vessel's stay in port and is calculated from the time of arrival to the time of departure.
- Pre-Berthing Waiting Time (PBWT) is the time a ship has to wait before getting entry into a berth.
- Percentage of Idle Time at Berth to Time at Working Berth (PITTWB) is the ratio of total idle time to total working time while a ship is in the port.
- Output per Ship Berth Day (OSBD) means total tonnage handled, or distributed over the total number of ship berth days.
- Berth Throughput Rate (BTR) means total cargo handled by a berth in a port.
- Berth Occupancy Rate (BOR) is the time that a berth is occupied by ships.
- Operating Surplus per tonnes of Cargo Handled (PTOS) derives from total operating surplus divided by total tonnage of cargo handled by the port.
- Rate of Return on Turnover (RRT) derives from operating surplus divided by operating income of a port.

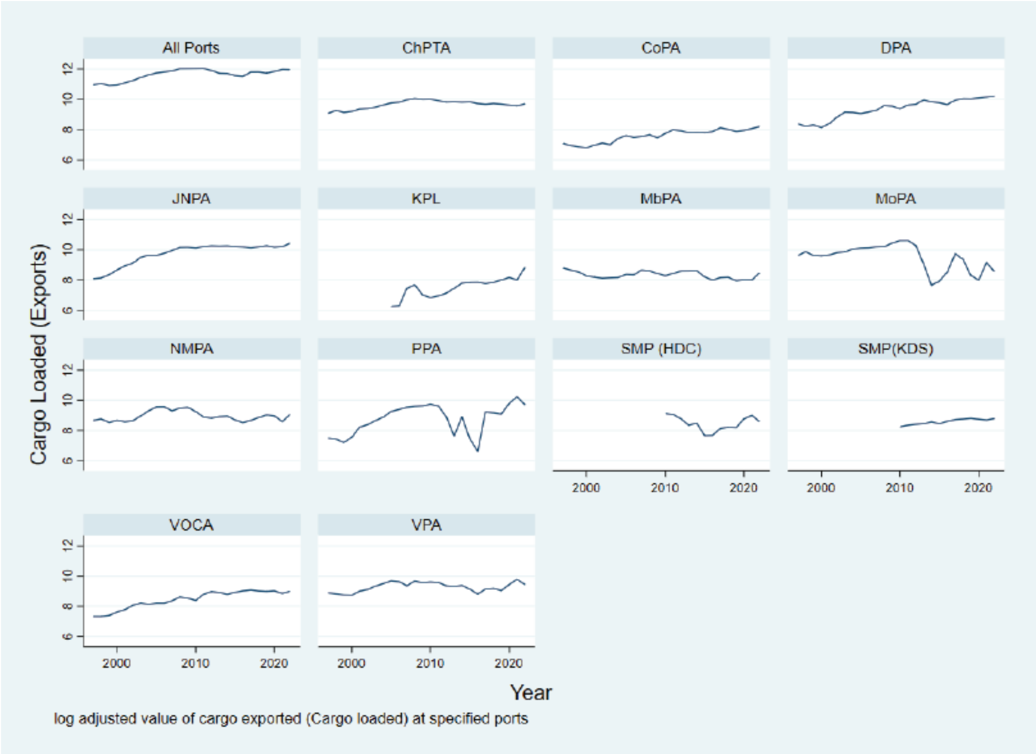
***Source*s**: Based on De (2009) and MoPSW (2024)

Appendix 3

Major Ports of India and Their Location

Source:https://www.mapsofindia.com/answers/india/what-are-the-major-ports-in-india/

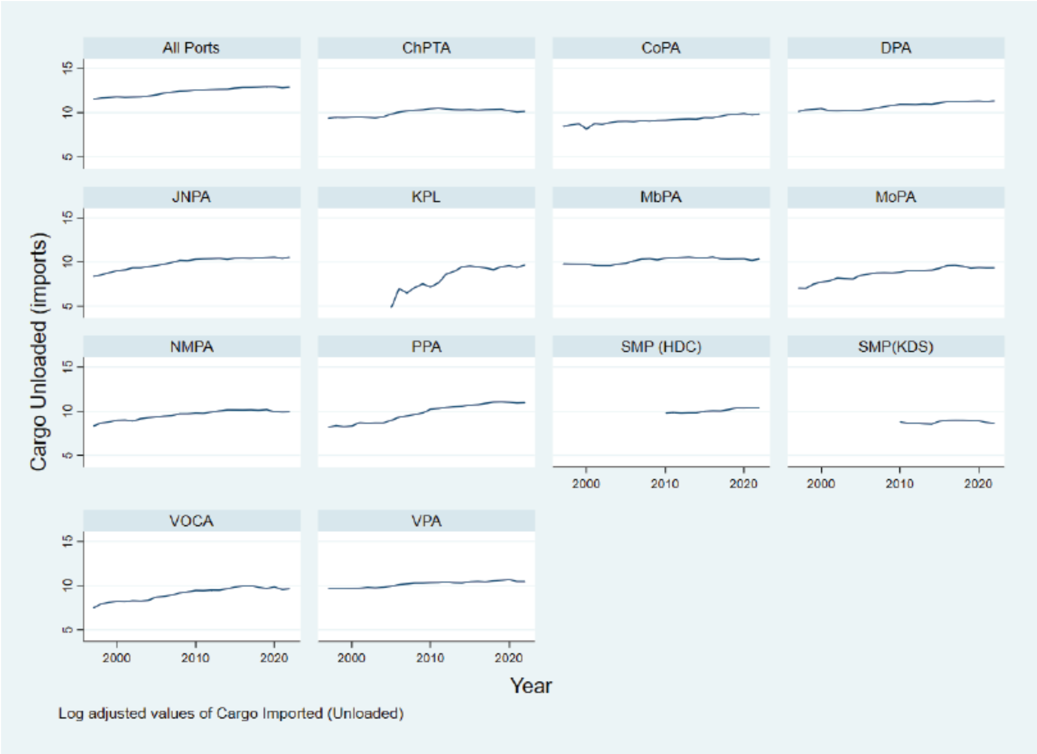
Overseas Cargo Loaded and Unloaded by Major Ports from 1997 to 2023



Source: Author's compilation from Basic Port Statistics of India.

Notes: 1. Cargo Loaded trend port wise (overseas) over the period of 1997-2023.

2. Data segregated data for Kolkata ports (SMP (HDC) and SMP (KDS)) available 2010 onwards.



Source: Author's compilation from Basic Port Statistics of India.

Notes: 1. Cargo unloaded trend port wise (overseas) over the period of 1997-2023.

2. Data segregated data for Kolkata ports (SMP (HDC) and SMP (KDS)) available 2010 onwards.

Appendix 5

Pair-wise Correlation Matrix

2000-2022 (whole Period)

Variables	(1)	(2)	(3)
(1) Y	1.000		
(2) L	0.008	1.000	
(3) K	0.044	-0.001	1.000

Variables	(1)	(2)
(1) y/l	1.000	
(2) k/l	0.363	1.000

2000-14 (pre-Sagarmala)

Variables	(1)	(2)	(3)
(1) Y	1.000		
(2) L	0.141	1.000	
(3) K	0.004	0.042	1.000

Variables	(1)	(2)
(1) y/l	1.000	
(2) k/l	0.437	1.000

2015-22 (post-Sagarmala)

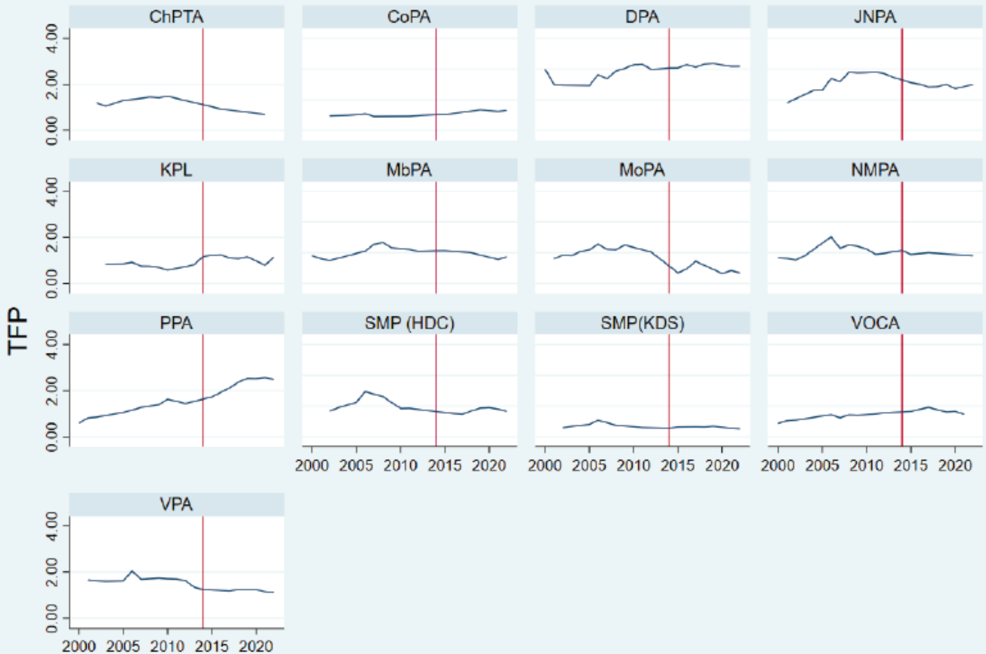
Variables	(1)	(2)	(3)
(1) Y	1.000		
(2) L	0.121	1.000	
(3) K	0.075	-0.136	1.000

Variables	(1)	(2)
(1) y/l	1.000	
(2) k/l	0.590	1.000

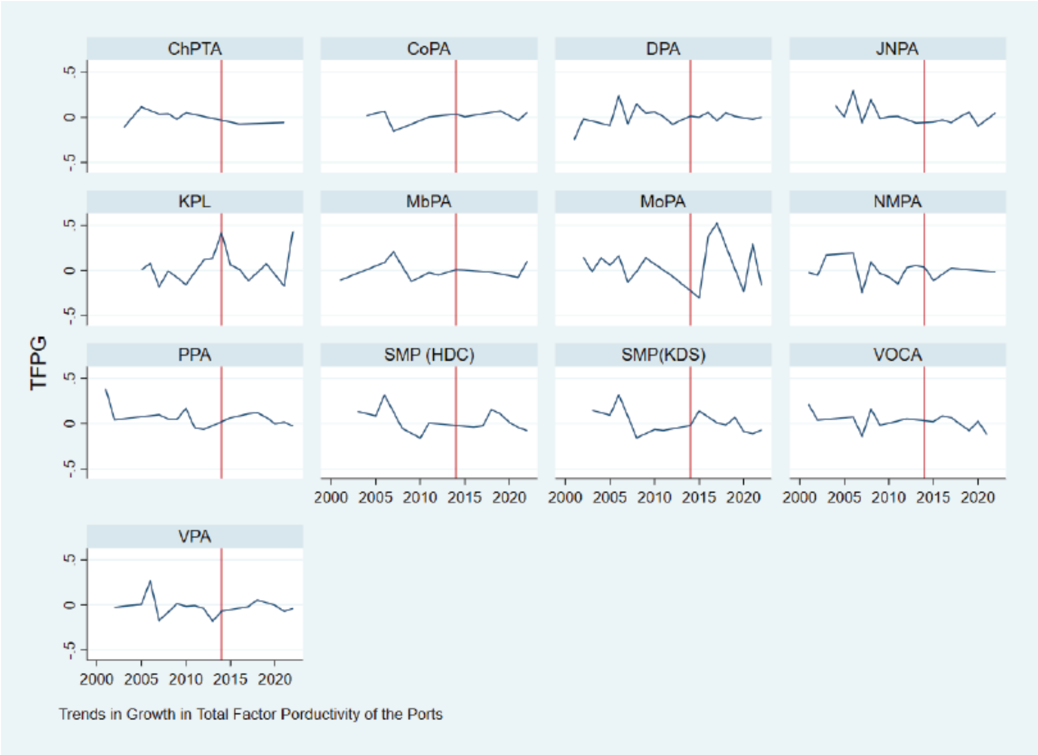
Source: Authors' own calculation.

Appendix 6

Trends in TFP and TFPG for the Period 2000-2022



Trends In Total Factor Productivity of Ports for the whole period (2000-22)



Source: Authors' own calculation.

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