Causality between performance and traffic: an investigation with Indian ports

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This paper attempts to find out the causal relationship between port performance and port traffic by using Indian data. The use of cointegration analysis has come out with the result that performance precedes traffic in most of the ports of India. Hence, government policy towards performance augmenting facilities should be given priority so that higher efficiency induces higher traffic.

1. Introduction

In India, awareness towards the impact of port efficiency on infrastructure in general and foreign trade in particular has increased in recent years, partly as a result of numerous reports regarding the fragile state of the nation's port infrastructure. The importance of an efficient port for the growth of the port sector stems from the chain linkage between production, performance of individual ports and overseas transportation leading to exports ever since the liberal economic regime initiated in 1991 [1].

The effects of poor port performance on a country's trade have become too obvious [2]. Inefficient ports, whether through lack of integrated transport network, outdated work practices or obsolete facilities, can stall a country's growth, even in a borderless world. The unreliability and poor quality of other complementary infrastructural services often add to the costs of production of exportables and adversely affect a country's international competitiveness [3–5]. Rising inefficiencies in ports have forced the governments all over the world to deregulate the port system [6–8]. Many governments have began to deregulate economic activities and decentralize decision-making, with the objective of increasing financial viability and productive efficiency of the public sector. Towards this direction, governments across the world are presently reformulating the way they control, regulate, and manage ports, with the general principle of reducing direct intervention and, where feasible, the use of the private sector for typical port operations is being introduced.

The present paper addresses these issues in the context of India. There are some studies which have tried to understand the relation between a country's openness, port performance and port traffic [9, 10], but none has touched upon the empirical causality between port performance and port throughput. Several reasons explain

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the choice of the Indian port sector. First, the port sector in several erstwhile developing countries has been undergoing transformation from a subsistence infrastructure resource into a more capital intensive, commercially oriented facility during the last two decades. On the other hand, India has lately thought about taking some steps leading to deregulation of her port sector. Indian ports are currently characterized by the existence of obsolete and poorly maintained equipment, hierarchical and bureaucratic management structures, weak coordination between the port trusts and users of the ports, lack of synchronization of working times, excessive labour, and, in general, an institutional framework that is considerably in variance with the government's overall economic objectives [11–14]. Secondly, considering the country's entry into the second stage of reform, the analysis will help to assess potential benefits of moving to a deregularized port sector under a liberal trading regime when more than 75% of the country's foreign trade pass through seaports. For instance, if performance stimulates traffic, then the benefits of performance augmenting factors might be responsible not only for redistribution of existing traffic but also for attracting new manufacturers/suppliers. There are ample examples to show that even if a country produces technologically advanced quality goods (pure theory of trade), non-price factors like transport costs and facilities often work as decisive deterrence to trade. So, causal inspection of trends of a country's overseas trade suggests the need for an investigation into the linkages between port performance and port traffic.

Rigorous theoretical arguments could be advanced in support of a possible 'causality' between performance and traffic. The nature of this causality is essentially an empirical question. There are three basic reasons why the study of causality for understanding the economic functioning of ports will be highly instructive for future policy in an era of worldwide *laissez faire*.

The first relates to the very nature of the subject as an inseparable part of social decision making. Here, one deals with extremely imperfect knowledge and information which give birth to conclusions that cannot be established with precision. In sharp contrast, in physical sciences, there are many 'laws' which can be called with precision 'universal'. Hence, the application, even partly, of a gross technique of identifying some relationship between the concerned variables as 'prior' or 'after' would certainly make one millionth of a step forward in understanding the relevant thrust of policy [15].

Secondly, in understanding the nature of the relationship among the relevant variables, one must have to bring 'time' into the framework. Unlike other fields of knowledge, the economists are mainly concerned with the 'present' time, and historians with the whole of recorded history—the 'past'. Interestingly, the very 'present' is really fleeting: one does not have time to think about it until it becomes 'past'—a past that is measurable either in terms of seconds, minutes, hours, years or centuries. This means that even economic logic is (should, because one major purpose of such study is to enlighten the future policy makers) highly linked with the past and also with the future. However, it is with the past that one has to begin. This series of past information through the present that help make generalizations for predicting the future, guide the policy makers in undertaking relevant planning. In the true sense of the term, 'time' in such a framework is one of long run. However, in reality, one does have to sometimes contend with information in the past which cannot go beyond a couple of decades. That may impose some amount of limitation in the efficacy of the estimated parameters; nonetheless it would certainly be an additional advantage over working in a cross-section framework.

Thirdly, unlike other subjects of social science, economics is especially concerned with the making of decisions (and, hence, guiding future course of actions through relevant policies) and also with the consequences that follow from these decisions. There are profound implications involved in this process of policy-making and subsequent economic development. This is more desirable than a 'counter-factual' logic of defending an *ad hoc* policy [16].

Investigating this causality may be highly paying in terms of future policy. For example, if under certain conditions, there is enough evidence towards the fact that performance precedes traffic, then performance-augmenting factors should get priority in the chain of policy making such that higher traffic will be a resultant of better policy induced investment. At a later stage, this will improve the trading status of the nation. If, on the other hand, it is seen that traffic appears to cause performance, then reducing trade restrictions and transaction costs may encourage adoption of performance augmenting technology which in its turn will have a positive impact upon traffic and, hence, on foreign trade.

Four mutually exclusive causual relationships can be contemplated. These are: unidirectional causality from performance to traffic or traffic to performance, no causality in either direction and causality in both directions. Each of these cases has different implications for port policy.

The main purpose of this study is to analyse the causality between performance and traffic of Indian ports over the period from 1985–1999. The organization of the paper is as follows. Section 2 deals with the data. Individual performance indicators of Indian ports, along with the construction of a port performance index (PPI) are discussed in section 2. Section 3 tests the causality between port performance and port traffic. Finally, policy implications and concluding remarks are briefed in section 4.

2. Data and methodology

In general, port facility can be taken as public infrastructure input from the supply side. The authors have attempted to measure the performance of Indian ports by developing a composite index with the help of principal component analysis. This is called the port performance index (PPI), which comprises of indicators of operational performance (ship turnaround time (TRT), pre-berthing waiting time (PBWT), and percentage of idle time at berth to time at working berth (PITTWB)), asset performance (output per ship berth day (OSBD), berth throughput rate (BTR), and berth occupancy rate (BOR)) and financial performance (operating surplus per tone of cargo handled (PTOS) and rate of return on turnover (RRT)) for 12 major (Central) ports over a period of 15 years starting from 1985–1999 [17]. The details of PPI and its construction are explained in section 2.2. The functional values of the port performance indicators appear to give a fairly representative and reasonable picture of port efficiency.

To determine the causal relationship which best describes the empirical reality in the Indian port sector, an attempt is made to apply some econometric tests. Unit root tests, cointegration tests, and Granger causality tests are conducted in a sequential manner to judge the nature and strength of this causality in section 3.

The choice of the initial year (1985–1986) is influenced by the fact that, since the mid-1980s, India embarked for the first time upon a path of trade liberalization with special emphasis on the telecommunication and electronics sectors. In 1991–1992, India undertook economic reform as explicit state policy which began with the announcement of the new Industrial Policy in July 1991. A break in 1991–1992 helps evaluate the nature of the relationship among the variables in the post-liberalization period [18]. Due to lack of adequate information on performance indicators, minor (State) ports have not been considered in this study.

The main data for this study have been collected from various issues of (i) Basic Ports Statistics of India, and (ii) Transport Statistics of India—all published by the Ministry of Shipping, Government of India. This data set is supplemented by several issues of 'Major Ports of India: A Profile', published by the Indian Ports Association, New Delhi.

2.1. *Measures of port performance*

As the objective of this study is to examine the causality between port performance and port traffic, it considers only those indicators which are directly linked with port performance. To understand the impact of such indicators, it is necessary to identify the factor(s) which lead to influence most on the overall performance of a particular port. Hence, an attempt is made to measure the performance of Indian major ports by developing a composite index, called port performance index (PPI) comprising indicators of operational performance (TRT, PBWT, PITTWB), asset performance (OSBD, BTR, BOR) and financial performance (PTOS, RRT). Eight individual variables were taken, as described in section 2, of the major ports over the period from 1985–1999. The definitions of the performance indicators are spelt out 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, the well-known multivariate technique of 'factor analysis' (or what is known as 'principal component analysis') (PCA) is employed, from which the weights of the respective factors follow [19].

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 point in time. The rationale for using principal component analysis is that it helps one to reach an aggregative representation from various individual port performance indicators. Its broader objective is quite *pari pasu* with homogenizing the overall requirements for the individual indicators across the ports. The worldwide globalization programme makes it almost mandatory for researchers to apply this normalization technique not only across regions within a country but also across ports in different countries located in a particular geographical block of the globe.

2.2. *Construction of PPI*

Values of eight port performance variables from 1985–1999 across 12 major ports were available. The details of the factor loadings (weights) derived from the PCA of these performance variables and their corresponding ranks are presented in tables 1 and 2. The estimated PPI and rank of ports in terms of PPI are given in tables 3 and 4, respectively. PPI is a linear combination of the unit free values of the individual indicators such that

$$PPI_{ij} = \sum W_{kj} X_{kij} \quad (1)$$

where PPI_{ij} = port performance index of the ith port in jth time, W_{kj} = weight of kth indicator in jth time, and X_{kij} = unit free value of the kth indicator for the ith port in jth time. Each individual indicator was made unit free dividing by the standard deviation across the ports. A few observations are worth noting here.

First, the authors have not found a single variable that has emerged as the most influential factor in all the years. The variables which have emerged as influential determing factors before 1991 come out as less important factors in the post-liberalization period. However, looking at the overall consecutive good rankings of BOR, BTR and PBWT during the period, it is felt that these variables have played an influential role in determining the performance of individual ports.

Secondly, PBWT, BOR, TRT and BTR have been found to be important determinants of performance in the post-liberalization period during 1991–1992 to 1999–2000. Thus, two each of the operational performance indicators (TRT and PBWT) and asset performance indicators (BTR, BOR) have emerged as decisive factors in determining the PPI in the post-liberalization period.

Thirdly, in the post-liberalization period, India has witnessed a rise in her overseas trade volumes, particularly between 1993–1994 and 1996–1997. A substantial part of this overseas trade has passed through the ports, and this is directly reflected in the port capacity utilization rate. During the period from 1991–1992 to 1999–2000, Indian ports have been over-utilized. Port congestion is quite likely to prevail in the coming years, if this rate of progression continues. Broadly speaking, when there is high congestion at a port, performance is influenced by coordination among different processes as well as the speed of clearance of vessels from the berth. In the short run when capacity is over-utilized, coordination among various intra-port outfits and speed of clearance of vessels are the only ways out for tackling congestion. As a matter of fact, this has been reflected in the year 1999–2000 when two of the operational performance indicators (PBWT and TRT), and one asset performance indicator (BOR) became the first three important factors in terms of weights in determining performance of an individual port.

Fourthly, unlike popular belief, financial performance indicators like PTOS and RRI have emerged as factors of low importance in determining PPI in the post-liberalization era. However, these two financial performance variables played key roles in determining PPI in the pre-liberalization period.

Fifthly, table 3 presents the values of the performance index of 12 major ports over the 15 year period. The coefficient of variation (CV) of PPI substantially declined in 1999–2000 (0.24) even after rising from 0.52 in 1985–1986 to 0.68 in 1990–1991. Thus, there has been a tendency toward equalization of inter-port performance index after liberalization. In some sense, this may be interpreted as reflecting a rise in competitiveness among Indian ports in the post-reform period.

Sixthly, it is noted that those ports which are performing better are attached to economically prosperous hinterland and *vice versa*. It is argued that, since overall performance of states like Gujarat, Tamil Nadu, Andhra Pradesh, Goa and Maharastra are much better than that of West Bengal, Orissa, Karnataka and Kerala [20–25], performance of ports of the first group of states is ahead of those in the second group. In order of ranking, these ports are Chennai (in Tamil Nadu), Kandla (in Gujarat), Vizag (in Andra Pradesh), Mormugao (in Goa) and Mumbai

Table 1. Weights of port performance indicators.

Year	TRT	PBWT	PITTWB	OSBD	BOR	BTR	PTOS	RRT	Eigen value[a]	EV[b]
1985–1986	−0.539	0.417	−0.604	0.876	0.580	0.636	0.803	0.893	3.782	0.533
1986–1987	−0.503	0.381	−0.683	0.950	0.271	0.658	0.077	0.383	2.425	0.403
1987–1988	−0.781	−0.110	−0.520	0.873	−0.260	0.696	0.408	0.682	2.839	0.455
1988–1989	0.584	0.906	0.054	0.142	0.867	0.651	−0.281	0.756	3.010	0.496
1989–1990	−0.329	−0.396	0.603	0.701	0.432	0.763	0.401	0.629	2.445	0.406
1990–1991	−0.393	−0.074	0.299	0.824	0.160	0.881	−0.690	0.625	2.597	0.425
1991–1992	−0.171	0.514	−0.507	0.763	0.671	0.766	−0.636	0.299	2.663	0.433
1992–1993	0.128	0.834	−0.419	0.806	0.849	0.762	−0.511	0.462	3.312	0.504
1993–1994	0.130	0.780	−0.695	0.673	0.768	0.576	−0.514	0.731	3.282	0.510
1994–1995	0.672	0.767	−0.741	−0.065	0.811	0.208	0.348	0.870	3.173	0.497
1995–1996	0.877	0.853	−0.899	0.194	0.729	0.539	0.109	0.619	3.559	0.515
1996–1997	0.728	0.912	−0.686	0.033	0.822	0.457	−0.458	0.154	2.950	0.439
1997–1998	0.615	0.794	−0.241	0.654	0.790	0.680	−0.689	−0.050	3.061	0.493
1998–1999	0.782	0.892	0.138	0.248	0.891	0.446	−0.520	0.283	2.831	0.422
1999–2000	0.753	0.939	0.144	0.243	0.865	0.522	0.197	0.266	3.081	0.500

[a] The factor loading of the eight port performance indicators for three different years is derived by the formula eigen vector = (factor loading)/$\sqrt{}$(eigen value). Eigen value is the first value of the 'variance explained' column in the unrotated factor loading (pattern).
[b] Explained variance as % of total.

Table 2. Rank of weights of port performance indicators: PCA.

Year	TRT	PBWT	PITTWB	OSBD	BOR	BTR	PTOS	RRT
1985–1986	7	6	8	2	5	4	3	1
1986–1987	7	4	8	1	5	2	6	3
1987–1988	8	5	7	1	6	2	4	3
1988–1989	5	1	7	6	2	4	8	3
1989–1990	7	8	4	2	5	1	6	3
1990–1991	7	6	4	2	5	1	8	3
1991–1992	6	4	7	2	3	1	8	5
1992–1993	6	2	7	3	1	4	8	5
1993–1994	6	1	8	4	2	5	7	3
1994–1995	4	3	8	7	2	6	5	1
1995–1996	1	2	8	6	3	5	7	4
1996–1997	3	1	8	6	2	4	7	5
1997–1998	5	1	7	4	2	3	8	6
1998–1999	3	1	7	6	2	4	8	5
1999–2000	3	1	8	6	2	4	7	5

(in Maharastra). These five ports together contribute more than 65% of total Indian port traffic in recent periods (see table 5).

To conclude, according to the PPI in 1999–2000, the three best performing ports are Chennai, Kandla and Vizag, and the worst three ports are New Mangalore, Cochin and Jawarlal Nehru. To be more specific, values of these scores are much more important than mere ranking. High variance in both PPI and indvidual factors, among other things, represent the level of differential inter-port performance. Except the first three ports, lower scores for the remaining ports represent their potential for further rise. To understand the nature of data, it may be useful to review the inter-port variations of each of the eight performance variables as they are given in the

Table 3. Port performance index (PPI): PCA.

Year	Kandla	Mumbai	JN	Mormugao	NM	Cochin	Tuticorin	Chennai	Vizag	Paradip	Calcutta	Haldia	Mean	SD[1]	CV[2]
1985–1986	13.30	8.05	*	11.06	4.65	2.66	6.27	9.16	7.85	3.37	0.88	9.25	6.96	3.61	0.52
1986–1987	5.87	1.58	*	5.60	0.83	−1.14	0.42	2.39	3.48	1.36	−1.63	3.04	1.98	2.31	1.17
1987–1988	1.66	−3.80	*	4.01	−1.30	−1.45	−1.67	0.13	0.16	0.77	−6.84	−0.35	−0.79	2.71	−3.43
1988–1989	14.79	13.93	*	12.51	15.88	7.30	9.17	12.65	9.14	9.60	6.95	10.38	11.12	2.87	0.26
1989–1990	4.22	3.50	−0.10	8.82	8.62	6.47	4.98	5.83	5.05	4.60	2.81	6.25	5.09	2.34	0.46
1990–1991	5.08	2.08	0.38	8.24	7.10	3.40	3.75	4.54	4.06	2.62	−1.22	3.97	3.67	2.48	0.68
1991–1992	9.96	2.35	2.80	9.71	7.48	2.36	4.53	5.27	6.70	4.58	−0.30	4.09	4.96	2.94	0.59
1992–1993	14.46	7.47	6.22	14.51	8.58	5.41	8.81	9.17	10.75	8.40	3.13	8.73	8.80	3.17	0.36
1993–1994	12.74	6.96	2.95	10.66	6.50	2.37	6.90	7.88	8.89	7.13	1.50	6.43	6.74	3.14	0.47
1994–1995	16.47	12.08	14.13	8.72	7.42	4.70	8.38	11.38	10.74	11.00	7.62	10.77	10.29	3.04	0.30
1995–1996	14.84	7.39	9.93	7.84	2.84	2.19	5.58	6.03	8.76	8.52	2.63	6.31	6.90	3.41	0.49
1996–1997	12.81	8.21	5.29	6.95	2.76	2.76	5.51	8.04	6.85	5.07	2.15	4.75	5.93	2.83	0.48
1997–1998	14.05	8.40	4.11	12.40	6.07	5.57	7.15	10.22	9.90	7.52	4.53	7.13	8.09	2.93	0.36
1998–1999	16.95	10.55	6.89	12.65	8.81	7.34	10.61	14.05	11.66	9.03	8.15	9.98	10.56	2.80	0.27
1999–2000	15.34	12.77	6.95	12.79	9.13	7.98	11.13	15.67	12.80	9.89	9.22	10.68	11.20	2.64	0.24

SD = Standard deviation. CV = Coefficient of variations.
*Not in operation.
JN and NM represent Jawarlal Nehru and New Mangalore ports, respectively.

Table 4. Rank of ports in PPI.

Year	Kandla	Mumbai	JN	Mormugao	NM	Cochin	Tuticorin	Chennai	Vizag	Paradip	Calcutta	Haldia
1985–1986	1	5	*	2	8	10	7	4	6	9	11	3
1986–1987	1	6	*	2	8	10	9	5	3	7	11	4
1987–1988	2	10	*	1	7	8	9	5	4	3	11	6
1988–1989	2	3	*	5	1	10	8	4	9	7	11	6
1989–1990	9	10	12	1	2	3	7	5	6	8	11	4
1990–1991	3	10	11	1	2	8	7	4	5	9	12	6
1991–1992	1	11	9	2	3	10	7	5	4	6	12	8
1992–1993	2	9	10	1	7	11	5	4	3	8	12	6
1993–1994	1	6	10	2	8	11	7	4	3	5	12	9
1994–1995	1	3	2	8	11	12	9	4	7	5	10	6
1995–1996	1	6	2	5	10	12	9	8	3	4	12	7
1996–1997	1	2	7	4	10	11	6	3	5	8	11	9
1997–1998	1	5	12	2	9	10	7	3	4	6	11	8
1998–1999	1	6	12	3	9	11	5	2	4	8	10	7
1999–2000	2	5	12	4	10	11	6	1	3	8	9	7

*Not in operation.

form of raw data over time. The values of mean, SD and CV of the raw indicators of port performance are given in appendix 3. Except OSBD, BTR, PTOS, and RRT, the coefficients of variation (CV) for the rest of the variables have been rising over the years. Among these four variables, only RRT has become more equitable across the ports over time. That is, the value of CV of this variable has fallen from 0.64 in 1985–1986 to 0.41 in 1991–1992 to 0.38 in 1999–2000. In contrast to this, PBWT displays the highest disparity—more than doubling from 0.33 in 1985–1986 to 0.63 in 1999–2000. This being a reasonably good indicator of port congestion suggests that there has been high variance in congestion across the ports.

Therefore, from the forgoing analysis, it may not be out of merit to find a causal relationship between performance and traffic. This may be helpful in formulating the sequential priority of port policy and its overall direction.

3. Cointegration and causality between performance and traffic

To judge the nature and strength of the causal relationship between performance and traffic, unit root tests, cointegration tests, and Granger causality tests are conducted in a sequential manner.

The analysis proceeds sequentially in several steps. Since standard Granger causality tests presuppose that the data are stationary, investigating data stationarity properties constiutes the first phase of the analysis. If the data are non-stationary, they must be differenced enough to achieve stationarity. The specific form of the Granger causality test also depends on whether the data are cointegrated. For example, if the data series in a specific case are cointegrated, then an error correction model is an appropriate model of short run dynamics [26]. In this case, the Granger causality test must include an error correction term as an explanatory variable. This error term restores relevant information that has been lost due to differencing the data and represents the error from a model using non-differenced data. However, if the data are non-stationary but not cointegrated, then Granger causality tests only require that the data be differenced sufficiently to achieve stationarity. Hence, to test the direction of causal relationship between performance and traffic of Indian ports, one shall first test the order of integration of the variables and then perform Granger causality test.

3.1. *Unit root tests*

In order to test the order of integration of the variables, three simple relations that may be used to represent many economic time series are the random walk, random walk with a drift and trend-stationary processes. All these three models are nested in the equation

$$\Delta Y_t = \mu + \beta t + (\rho - 1)\, Y_{t-1} + e_t \tag{2}$$

which is used for the Dickey-Fuller unit root test. Under the null hypothesis of a unit root, if ρ is close to unity, then the coefficient $(\rho - 1)$ will not be significantly different from zero. If there is no unit root, Y is said to be stationary in the levels, or integrated of order zero (denoted by $I(0)$). If there is a unit root, but differencing the series once makes it stationary, then it is said to be integrated of order one, denoted by $I(1)$. The critical t-values, for the tsts, were calculated by Monte Carlo simulation in Fuller [27], because the distribution is not standard. In addition to testing for the unit root, equation (2) will establish if there is a deterministic trend $(\beta \neq 0)$ and/or a drift $(\mu \neq 0)$. The error term, e_t, represents white noise. If Y_t is a

Table 5. Share of major ports in total Indian port traffic (%).

Year	Kandla	Mumbai	JN	Mormugao	NM	Cochin	Tuticorin	Chennai	Vizag	Paradip	Calcutta	Haldia
1985–1986	13.78	20.32	*	13.47	3.08	4.41	3.53	15.17	13.30	2.78	3.48	6.66
1986–1987	13.02	20.17	*	12.00	4.37	5.53	3.32	15.90	12.09	3.90	3.26	6.45
1987–1988	13.43	21.97	*	9.90	4.54	5.05	3.16	16.95	11.42	3.86	3.26	6.45
1988–1989	12.11	19.95	*	10.47	4.82	5.32	3.49	16.22	13.85	4.10	2.95	6.72
1989–1990	12.82	18.80	0.47	9.60	5.19	4.82	3.61	16.22	14.31	4.19	2.94	7.01
1990–1991	12.96	19.02	1.33	9.81	5.28	4.79	3.34	16.14	12.78	4.53	2.72	7.31
1991–1992	13.41	16.76	1.78	9.64	5.28	4.78	3.75	15.99	13.74	4.66	2.66	7.56
1992–1993	13.76	17.39	1.81	9.80	4.26	4.79	3.74	15.21	13.67	4.56	3.10	7.92
1993–1994	13.69	17.05	1.89	10.46	4.82	4.26	3.74	14.83	14.30	4.65	2.89	7.43
1994–1995	13.53	15.66	2.56	9.64	4.09	4.41	4.10	15.04	15.33	5.17	2.96	7.52
1995–1996	14.10	15.76	3.19	8.41	4.13	5.34	4.32	14.28	15.25	5.23	2.84	7.15
1996–1997	14.84	14.84	3.55	7.62	5.48	5.17	4.04	14.01	15.18	5.10	2.65	7.52
1997–1998	15.46	12.76	3.54	8.42	6.07	4.90	3.97	14.12	14.31	5.29	3.16	8.03
1998–1999	16.14	12.30	4.66	7.16	5.65	5.03	4.03	13.98	14.16	5.21	3.64	8.03
1999–2000	17.03	11.18	5.51	6.70	6.47	4.71	3.68	13.77	14.53	5.02	3.79	7.61

*Not in operation.

first order autoregressive process (AR(1)), then the single lagged value of the dependent variable will be sufficient to ensure this condtion. If the process is not AR(1), then m additional difference terms will need to be added to (2) to make e_t white noise. Thus, the new equation becomes

$$\Delta Y_t = \mu + \beta t + (\rho - 1)\, Y_{t-1} + \sum_{j=1}^{m} \rho_j\, \Delta Y_{t-j} + e_t \tag{3}$$

which is the equation of the Augmented Dickey-Fuller (ADF) test.

In the pertinent case, the ADF test is used to test the null hypothesis (H_0: Y_t non-stationary) of a unit root for each of the major ports except Jawarlal Nehru for the 15 year period from 1985–1986 to 1999–2000 on the considered data series, namely port performance index and port traffic [28]. This test involves a regression of the variable in a series (here traffic and PPI) against their lagged values, lagged difference terms and, as an option, a time trend. The test is carried out on traffic and PPI separately at level, and then at first difference, and so on. The null hypothesis of a unit root is rejected if the parameter $(\rho - 1)$ is negative and significantly different from zero. Estimated test results are reported in table 6. Although this particular case considers the parametric test, Phillips-Perron test results are given in appendix 4 for comparison [29]. Test results for all major ports in the case of performance overwhelmingly reject the null hypothesis of a unit root. This clearly shows that this data series are stationary at level $I(0)$ with varied levels of significance. However, opposite results are obtained in the case of port traffic. Here, test results fail to reject the null hypothesis of a unit root except Mumbai and Vizag at the level, and this indicates that traffic of major ports of India are non-stationary at level, except Vizag and Mumbai. As a corollary, a regression of the first difference of this particular data series was done and it was found that the null hypothesis of a unit root is rejected for all the ports at first difference and, hence, there is no requirement for further differencing of the data series.

To conclude, port performance data series are stationary at $I(0)$, or integrated of order zero with varied levels of significance, whereas port traffic series are non-stationary at $I(0)$ but stationary at first differences, or integrated of order one, $I(1)$.

Based on this battery of stationarity tests, it would appear that cointegration analysis is appropriate in all cases except Mumbai and Vizag.

3.2. *Cointegration tests*

For ports with non-stationary data, the next stage of the testing procedure is sought to detect whether there is a common stochastic trend for the data series involed [30]. The Johansen and Jesulius [31] method is applied to compute values for the trace statistics. If these values are significant, a common stochastic trend among the variables exists and the series are cointegrated. This implies that the existence of a long-run equilibrium relationship between the variables be tested. If the variables are cointegrated, then an error correction term must be included as an explanatory variable in any subsequent causality test. The error correction term will represent an error term obtained from the estimated long run relationship between variables.

This cointegration tests for the two variables are shown in table 7. Test statistics show the existence of a cointegrating vector across the two variables (PPI and traffic) in 11 ports of India. The statistics in the first column test the null hypothesis that

Table 6. Results of augmented Dickey-Fuller (ADF) test: Indian ports.

Ports	ADF[a]	MCV[b]	LD[c]	ADF[d]
Port performance				
Kandla	−3.845*	−3.382	1	−4.188**
Mumbai	−4.242**	−3.873	1	—
Mormugao	−4.240**	−3.873	1	—
New Mangalore	−5.593***	−5.115	2	—
Cochin	−4.137**	−3.927	2	—
Tuticorin	−3.734*	−3.411	2	−4.389**
Chennai	−4.566**	−3.927	2	—
Vizag	−3.949**	−3.873	1	—
Paradip	−4.481**	−3.873	1	—
Calcutta	−4.658**	−3.927	2	—
Haldia	−3.456*	−3.411	2	−3.912**
Port traffic				
Kandla	−3.611	−3.410	2	−4.099**
Mumbai	−4.317**	−3.995	3	—
Mormugao	−3.465	−3.382	1	−4.202**
New Mangalore	−3.762	−3.382	1	−4.176**
Cochin	−3.551	−3.410	2	−4.343**
Tuticorin	−3.570	−3.446	3	−4.288**
Chennai	−3.566	−3.446	3	−4.187**
Vizag	−4.748**	−3.995	3	—
Paradip	−3.501	−3.446	3	−4.002**
Calcutta	−3.494	−3.446	3	−4.122**
Haldia	−3.872	−3.446	3	−4.154**

[a] ADF at level.
[b] MacKinnon critical values (MCV) for rejection of hypothesis of a unit root. Value refers to same order of significance level of corresponding ADF statistic.
[c] Lagged differences (LD) of independent variables.
[d] At first difference.
Statistics with *, ** and *** indicate rejection of null hypothesis at the 10%, 5% and 1% confidence level. When the null hypothesis is rejected no differencing is required to obtain stationary data. Equation considered both trend and intercept terms at level.

there are no cointegrating vectors, $N = 0$, against the alternative hypothesis that there exists one cointegrating vector, $A = 1$. The second column tests one cointegrating vector, $N = 1$, against two cointegrating vectors, $A = 2$, and so on. Each row reports the trace statistic for each port. For comparison, critical values corresponding to each column are presented at the head of table 7. Note that critical values have been taken for the trace statistic (at the 5% and 1% levels) reported by Osterwald-Lenum [32], not those tabulated in Johansen and Juselius [30]. When the test statistic exceeds the table value, the null hypothesis is rejected. Column 1 of table 7 shows that null hypothesis is rejected for seven and three ports at 5% and 1% significance levels, respectively, thereby indicating the presence of one cointegrating vector across the data series. However, test statistics of all the ports fail to reject the null hypothesis in the second column. Hence, there is the presence of one cointegrating vector among the variables.

The foregoing cointegration test clearly ascertains the need for inclusion of an error correction term in the causality tests. This term represents an error obtained from a model representing the relationship among the variables, and is considered a

Table 7. Cointegration test: Indian ports.

Ports	NR = 0 AR = 1	NR = ⩽ 0 AR = 2
Critical value (5%)	19.96	9.24
Critical value (1%)	24.60	12.97
Kandla	23.31	3.35
Mumbai	24.93	3.49
Mormugao	16.82	1.69
New Mangalore	12.20	1.74
Cochin	22.49	2.26
Tuticorin	16.57	5.84
Chennai	20.00	5.08
Vizag	14.15	3.61
Paradip	24.73	7.71
Calcutta	23.24	7.15
Haldia	31.23	9.01

The statistics in the first column test the null hypothesis that there are no cointegrating vectors, $n = 0$, against the alternative hypothesis that there exists one cointegrating vector, $A = 1$. The second column tests one cointegrating vector, $n = 1$, against two cointegrating vectors, $A = 2$, and so on.

Critical values for the trace statistic (at 5% and 1% level) reported by Osterwald-Lenum [32], not those tabulated in Johansen and Juselius [31].

When the test statistic exceeds the table value, the null hypothesis is rejected.

measure of the long-run relationship among levels of the variables. Coefficients of this model also represent a cointegrating vector. In most cases, the number of cointegrating vectors is greater than zero but less than the number of variables. This indicates that subsequent causality test statistics should be viewed as the best available approximation to the true statistic [33].

3.3. *Granger causality tests*

Cointegration says nothing about the direction of the causal relationship between the variables, but if two variables are found to be cointegrated, it follows that there must be Granger causality in at least one direction. The Granger [34] approach to the question of whether X causes Y is to see how much of the current Y can be explained by past values of Y and then to see whether adding lagged values of X can improve the explanation. Y is said to be Granger-caused by X if X helps in the prediction of Y, or equivalently if the coefficients on the lagged X's are statistically significant. Note that two-way simultaneous causation is frequently the case; X Granger causes Y and Y Granger causes X [35]. To test whether X causes Y, parameters of the equation

$$Y_t = \sum_{j=1}^{m} \alpha_j Y_{t-j} + \sum_{i=1}^{m} \beta_i X_{t-i} + e_t \tag{4}$$

are estimated and the causality test determines if the β_j's are jointly different from zero.

This standard Granger causality test is performed for cases where the variables are not cointegrated and also the corresponding data series are stationary. When the two variables are cointegrated, an error correction term, representing the error term from the non-differenced cointegrated relationship, would be included in the equations. The reported F-statistics are the Wald statistics for the joint hypothesis

$$\beta_1 = \cdots = \beta_j = 0$$

for each equation. The null hypothesis is, therefore, that X does not Granger-cause Y in the first regression and that Y does not Granger-cause X in the second regression.

Hence, causality is tested by specifying two equations similar to equation (4) on two variables, namely port performance and port traffic for all the 11 ports. Thus, the equations may be rewritten as

$$\Delta PPI_t = \sum_{j=1}^{m} \alpha_j \Delta PPI_{t-j} + \sum_{i=1}^{m} \beta_i \Delta \text{Traffic}_{t-i} + u_t \quad (5)$$

$$\Delta \text{Traffic}_t = \sum_{j=1}^{m} \delta_j \Delta \text{Traffic}_{t-j} + \sum_{i=1}^{m} \varphi_i \Delta PPI_{t-i} + v_t \quad (6)$$

For there to be unidirectional causality from traffic to PPI, the estimated coefficients on lagged traffic in equation (5) should be significantly different from zero as a group ($\sum \beta_i \neq 0$) and the set of estimated coefficients on lagged $PPI(\sum \varphi_I)$ in the second equation should not be significantly different from zero. Bilateral causality (or what may be called simultaneity) is suggested when both $\sum \beta_i \neq 0$ in (5) and $\sum \varphi_i \neq 0$ in (6) and independent when both sets of coffients are not significantly different from zero.

Results of the causality tests are given in table 8. The test was performed considering 1 and 2 year lags for all the ports involving both 'without error correction term' and 'with error correction term'. Although one test is applicable for each port, performing both types of tests is useful for comparison. At the 5% confidence level, the relatively larger ports like Kandla, Mumbai, Chennai, Vizag support the hypothesis that performance causes traffic. Using a more liberal 10% confidence level, Tuticorin is also consistent with the causality from performance to traffic hypothesis. When an error correction term is included, causality between performance and traffic in Cochin becomes significant at the 5% confidence level. Table 9 represents the above results briefly. Evidence from this cointegration test indicates that these results may be slightly biased. Even taking this bias into consideration, these results clearly imply that efforts to adopt performance augmenting technologies or performance improvement measurements will have some positive influence on port traffic.

While more ports provide evidence in favour of the performance causes traffic hypothesis, only one port confirms the simultaneous relationship that is Haldia, which is an estuarine port located in the eastern part of the country. This may be due to the fact that the port of Haldia is served by a larger hinterland; it has rather a mixed industrial feedback generated from the very industrial township of Haldia and captive bulk cargo. Interestingly, no port confirms the reverse hypothesis, i.e. traffic causes performance. Even inclusion of an error correction term fails to reverse the general outcomes. No significant relationship has been found in the cases of New Mangalore, Mormugao and Paradip. These are the ports which are especially equipped to handle bulk cargo, either bulk solid and bulk liquid, and focus less on performance augmenting factors due to static captive demand/supply of this traffic in overseas and/or local markets. Moreover, these ports serve largely local and well-defined hinterlands and face little competition. Finally, the role of these ports in Indian total port traffic has not been significant over the last two decades.

The results from this paper demonstrate that, even in the presence of cointegration among a set of variables, inclusion of an error correction term in the Granger test has little empirically observable effect on the results. It may be concluded that, to attain higher traffic, ports obviously should give highest priority to their performance by improving operational performance factors like PBWT, TRT, and asset performance indicators like BOR and BTR. These four most important determinants of port performance appeared in the post-liberalization period from principal component analysis and are related to the degree of port congestion. Hence, for attracting higher traffic, policy towards performance augmenting facilities shall be given priority, so that higher efficiency induces higher traffic.

4. Conclusions

The major finding of this paper is that in no port does traffic cause performance and most of the ports provide evidence towards the fact that performance causes traffic in India. Hence, it should not be surprising that performance does lead to increased traffic in a liberal economic regime. This paper uses some individual port performance indicators, which are largely internal to each of the ports, for finding causal relationship with port throughput. If a port performs better by improving its operational and asset performance, then it is likely to get higher traffic.

Policies to increase efficiency have been pursued in the port sector in many countries by changing the structure and institutional framework of this industry. The changes have been introduced across the globe by such measures as privatization and deregulation so that the role of governments has been reduced significantly. The countries in which the policy changes have been greatest are those in which national policies exerted a strong influence on port performance. The more competitive environment has implications for national port policies and for port management. The India government has taken some discrete initiatives in the recent period for expanding their port capacity. However, no comprehensive policy has yet been announced for augmenting port performance [36]. The improvement of operational performance of Indian ports has been a priority policy objective for many years but, notwithstanding the vast technical assistance provided by international organizations and various countries, the results have often been disappointing. According to a study of the Government of India [37], approx. US$4.5–5.5 billion is required to invest by 2005–2006 to provide an adequate port facility in this country. Realizing the urgent need for inter-port and intra-port competition to attain a higher performance level, the Union Government has invited the private sector to finance new port facilities [38]. However, success to date has been very limited. This has led to the realization that substantial improvement will remain out of reach until a fundamental restructuring and changes in management culture are implemented, and will, therefore, take a considerable time to achieve. Hence, there is an urgent need for a comprehensive policy which will strongly influence on port performance and will be consistent with the globalization programme.

Questions may also be raised as to the usefulness of a port performance index derived from PCA. Notwithstanding the specific roles played by various individual

Table 8. Granger causality test: Indian ports.

Ports	Null Hypothesis	W/O EC *F*-Statistic	With EC *F*-Statistic	W/O EC *F*-Statistic	With EC *F*-Statistic
	Number of lags	1	1	2	2
	Critical value (at 5%)	3.71	3.71	3.84	3.84
	Critical value (at 1%)	6.55	6.55	7.01	7.01
Kandla	Traffic does not Cause Performance	7.089***	7.934***	3.986**	4.054**
	Performance does not Cause Traffic	0.565	0.588	0.957	1.320
Mumbai	Traffic does not Cause Performance	8.712***	8.933***	4.167**	4.342**
	Performance does not Cause Traffic	0.022	0.176	1.885	1.944
Mormugao	Traffic does not Cause Performance	0.002	0.003	0.045	0.034
	Performance does not Cause Traffic	0.068	0.189	0.337	0.672
New Mangalore	Traffic does not Cause Performance	0.650	0.744	0.162	0.203
	Performance does not Cause Traffic	1.160	1.452	0.361	0.388
Cochin	Traffic does not Cause Performance	2.112	2.542	4.340**	4.986**
	Performance does not Cause Traffic	0.312	0.567	0.206	0.332
Tuticorin	Traffic does not Cause Performance	3.584*	3.664*	1.458	1.893
	Performance does not Cause Traffic	0.023	0.099	0.030	0.098
Chennai	Traffic does not Cause Performance	10.491***	13.452***	5.488**	6.554**
	Performance does not Cause Traffic	0.236	0.398	0.294	0.302
Vizag	Traffic does not Cause Performance	4.097**	4.002**	1.321	1.340
	Performance does not Cause Traffic	0.207	0.205	0.132	0.198
Paradip	Traffic does not Cause Performance	2.604	2.675	1.629	1.657
	Performance does not Cause Traffic	0.001	0.001	0.697	0.762
Calcutta	Traffic does not Cause Performance	5.735**	6.670***	3.114	3.965**
	Performance does not Cause Traffic	0.301	0.430	1.301	1.340
Haldia	Traffic does not Cause Performance	3.474*	4.330**	3.967**	4.872**
	Performance does not Cause Traffic	3.385*	5.340**	1.593	1.672

The reported *F*-statistics are the Wald statistics for the joint hypothesis.
W/O EC and With EC mean Without error correction terms and With error correction terms, respectively.
Cause means 'Granger Cause'.
Statistics with *, ** and *** indicate rejection of null hypothesis at the 10%, 5% and 1% confidence level.
Significance of a variable demonstrates causality.

Table 9. Direction of causal relationship.

Ports	Causal relationship
Kandla	Performance ⇒ Traffic
Mumbai	Performance ⇒ Traffic
Mormugao	*
New Mangalore	*
Cochin	Performance ⇒ Traffic[a]
Tuticorin	Performance ⇒ Traffic[a]
Chennai	Performance ⇒ Traffic
Vizag	Performance ⇒ Traffic
Paradip	*
Calcutta	Performance ⇒ Traffic
Haldia	Performance ⇒ Traffic[b]

[a] Weak relation.
[b] Simultaneous relation.
* No causal relation.

port performance indicators, it cannot be denied that some judicious combinations of these factors lead to perfect coordination for maximizing over all port efficiency. As there is no other rationale method for doing so; one cannot but use the indexation method described in this paper. Above all, such a weighting mechanism will help the policy-makers to strengthen the weaker factors for improving the overall performance index.

The limitations of this study are briefed below. First, one has not considered here the spatial concentration of manufacturing activities in and around the ports, differential geographical attributes, logistics networks, and differential nation-wide infrastructure stocks associated with each region which may have very substantial bearings on port traffic. The findings of this paper may be further substantiated incorporating these exogenous factors. Secondly, implication of this study might have been stronger if some external factors which have direct bearings on port traffic and performance, like depth of the navigational channel, nature of shipping routes and vessel sizes, level of technologically advanced equipment, etc. were considered. Thirdly, given the aggregate nature of the performance index, there is some potential for obtaining biased results. Fourthly, the Granger causality test considers long time period properties. For this reason, conclusions obtained in this paper are subject to revision if conducted by tests based on a larger period.

Future work can attempt to measure causal relationship between cargo-specific performance and traffic for each port and then perform the procedures described in this paper. The reason for this is that most of the Indian ports are designed to handle specific categories of cargo which have declined over time, while other types of traffic have gained importance. However, the port's berth configurations have not yet adjusted to the new categories of cargo. In this backdrop, such an analysis can lead to distinct results for each cargo basket in each port.

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Notes and references

1. Public capital in the port sector such as radio wireless station, pilot vessels, mooring boats, tugs, cranes and trailers of various types, warehousing and storage facilities, water supply and energy facilities, fire fighting utilities, conservancy, etc., could be viewed as inputs in the service process which contribute independently to the cargo handling. Under the present institutional set-up, the role of private capital in Indian ports is very limited. Yet, it is generally taken for granted that decades of 'sheltered market' phenomenon have not created among Indian industrialists any 'outward looking' tendency. Moreover, high 'gestation lag' in the port sector is believed to be the main cause for low level of private capital in this sector, even under the selective liberalization initiated by the Government in the post-1991 period.
2. Juhel, M. H., 1999, Global challenges for ports and terminal in the new era. *Ports and Harbors*, March, 17–27.
3. Rauch, J. E., 1991, Comparative advantage, geographic advantage and the volume of trade. *The Economic Journal*, 101.
4. Marjit, S. and Roychaudhury, A., 1997, *Indian Export: An Analytical Study* (New Delhi: Oxford University Press).
5. Export–Import Bank of India, 1998, Transaction cost of Indian exports: an analysis. *Occasional paper no. 64* (Mumbai).
6. Estache, A. and Carbajo, J., 1997, Competing private ports: lessons from Argentina. In: *The Private Sector in Infrastructure: Strategy, Regulation, and Risk*, edited by K. Tilmes (Washington DC: The World Bank), pp. 129–132.
7. Bollard, A. and Pickford, M., 1998, Deregulation and competition policy in the transport sector in New Zealand. *Journal of Transport Economics and Policy*, **3**, 267–276.
8. However, there is also a result in the opposite direction. Coto-Millan *et al.* [39] have shown that greater autonomy in management has generated greater economic inefficiency in Spanish ports during the period 1985–1989.
9. Ghosh, B. and De, P., 2000, Impact of performance indicators and labour endowment on traffic: empirical envidence from Indian ports. *International Journal of Maritime Economics*, **2**, 259–281.
10. Ghosh, B. and De, P., 2000, Indian ports and globalisation: need for new policy initiatives. Mimeo, Indian Statistical Institute, Calcutta. *Economic and Political Weekly*, **36**, 3271–3283.
11. De Monie, G., 1995, The problems faced by Indian ports today. *Maritime Policy & Management*, **22**, 235–238.
12. Peters, H. J., 1997, Reforming India's port system: a position paper. *Paper presented at the Follow up Workshop on the Power and Transportations Sector: India*, Japan Chamber of Commerce and The World Bank, Tokyo.
13. Haralambides, H. E. and Behrens, R., 2000, Port restructuring in a global economy: an Indian perspective. *International Journal of Transport Economics*, **27**, 19–39.
14. Infrastructure Development Finance Company Limited, 2001, *India Infrastructure Report 2001* (New Delhi: Oxford University Press).
15. Hicks, J., 1979, *Causality in Economics* (Oxford: Basil Blackwell).
16. Let's take an example: the study of the past, with the object of finding out not only what has happened, also helps one understand why it has happened. If the study is successful, one may be able to state a 'cause': A caused B, i.e. in historical series, A is prior to B; but this is not absolute. There are four distinguishable elements in the assertion of (separable) causation of B by A: (1) A existed (2) B existed (3) the hypothetical situation in which A did not exist, *ceteris paribus*, can be constructed (4) if that situation existed, at time T_a, B would not have occurred.

17. In India, there are 12 major ports in total, namely Kandla, Mumbai, Jawarlal Nehru, Mormugao, Cochin, New Mangalore, Chennai, Tuticorin, Paradip, Vizag, Calcutta, and Haldia. See Appendix 1 for classification of Indian ports and their institutional set-up.
18. India followed the strategy of planning ever since the first 5-year plan (1951–1956). 1991 (July) marks the beginning of the era of market economy away from centralized planning. The new economic policy became effective from this year. The salient features of this policy, to start with, were as follows: (i) To allow direct foreign capital in industries, trading companies and banking up to 51% of share capital (in some cases 100%); (ii) Automatic clearance for capital goods import; (iii) Automatic approval of foreign technology agreements in high priority areas; (iv) setting up of Foreign Investment Promotion Board for negotiating with MNCs and granting single point clearance; (v) Permission of private sector banking; (vi) Other measures include the abolition of industrial licensing except limited areas, abolition of MRTP and FERA, closing down of chronically sick public sector units etc. Yet, no major fundamental policy change pertaining to the port sector could be visualized in 1991.
19. Fruchter, B., 1967, *Introduction to Factor Analysis* (New Delhi: Affiliated East West Press).
20. Dutt, G. and Ravallion, M., 1998, Why have some Indian states done better than others at reducing rural poverty, *Economica*, 65.
21. Ghosh, B., Marjit, S. and Neogi, C., 1998, Economic growth and regional divergence in India: 1960–1995. *Economic and Political Weekly*, **33**, 1312–1321.
22. Ghosh, B. and De, P., 1998, Role of infrastructure in regional development: a study of India over the plan period. *Economic and Political Weekly*, **33**, 3039–3048.
23. Ghosh, B. and De, P., 2000, Linkage between infrastructure and income among Indian states: a tale of rising disparity since independence. *Indian Journal of Applied Economics*, **8**, 391–431.
24. Ghosh, B. and De, P., 2000, How do economic and social infrastructure facilities affect regional economic performance: an investigation with major Indian states. *Proceedings of the National Conference on India Rural Infrastructure Report*, National Council of Applied Economic Research, New Delhi.
25. Rajiv Gandhi Institute of Contemporary Studies, 2000, *How are the States Doing?* (New Delhi).
26. Engle, R. and Granger, C. W. J., 1987, Cointegration and error correction: representation, estimation, and testing. *Econometrica*, **55**, 251–276.
27. Fuller, W. A., 1976, *Introduction to Statistical Time Series* (New York: John Wiley and Sons).
28. Jawarlal Nehru has not been considered in this causality test because the port has only been operational since 1989, whereas all other ports were functioning before 1985–1986.
29. Phillips and Perron [40] propose a non-parametric method for controlling higher-order serial correlation in a series.
30. An alternative test is the cointegrating regression Durbin-Watson (CRDW) proposed by Sargan and Bharagava [41], providing a table of critical values. This is performed simply by regressing Y, the variable of interest, on a constant C. If Y is random walk then disturbance, e, will have a unit root. The null hypothesis that e has a unit root is tested against the alternative that it follows a stationary first-order Markov process, using the conventional DW statistic. However, the power of these tests to discriminate between unit roots and borderline-stationary processes is weak [42] and the small sample properties are poor. They also start from a single equation OLS basis. Hence, an alternative test, which is more powerful and not based on regression residuals, has been proposed by Johansen. The Johansen Maximum Likelihood estimation method [31, 43, 44] is based on the estimation of all the cointegrating vectors.
31. Johansen, S. and Juselius, K., 1990, Maximum likelihood estimation and inference on cointegration—applications to the demand for money. *Oxford Bulletin of Economics and Statistics*, **52**, 169–210.
32. Osterwald-Lenum, M., 1992, A note with quantiles of the asymptotic distribution of the maximum likelihood cointegration rank test statistics. *Oxford Bulletin of Economics and Statistics*, **54**, 461–472.

33. It has been argued that while cointegrating measures long-run relationships among variables, causality applies to short-run relationships [43]. No such claim is made here. While evidence favouring cointegration can influence the method of testing for causality between variables, this evidence is not informative about their causal relationship.
34. Granger, C. W. J. 1969, Investigating causal relations by econometric models and cross-spectral methods. *Econometrica*, **37**, 424–438.
35. It is important to note that the statement 'X Granger causes Y' does not imply that Y is the effect or the result of X. Granger causality measures precedence and information content but does not by itself indicate causality in the more common use of the term.
36. Rail India Technical and Economic Services Limited, 2000, *Indian Ports in the New Millennium* (Vision 2020 Report), New Delhi.
37. Government of India, 1996, *The India Infrastructure Report: Policy Imperatives for Growth and Welfare* (New Delhi: National Council of Applied Economic Research).
38. Government of India, 1999, *Plan Document: Ninth Five Year Plan (1997–2002)* (New Delhi: Planning Commission).
39. Coto-Millan, P., Banos-Pino, J. and Rodriguez-Alvarez, A., 2000, Economic efficiency in Spanish ports: some empirical evidence. *Maritime Policy & Management*, **27**, 169–174.
40. Phillips, R. C. B. and Perron, P., 1988, Testing for a unit root in time series regression. *Biometrika*, **75**, 335–346.
41. Sargan, J. D. and Bhargava, A., 1983, Testing residuals from least squares regression for being generated by the Gaussian random walk. *Econometrica*, **51**, 153–174.
42. Bannerjee, A., Dolado, J., Galbraith, J. and Hendry, D., 1993, *Co-integration, Error-Correction, and the Economic Analysis of Non-stationary Data* (London: Oxford University Press).
43. Johansen, S., 1988, Statistical analysis of cointegrating vectors. *Journal of Economic Dynamics and Control*, **12**, 231–254.
44. Johensen, S., 1995, *Likelihood-based Inference in Cointegrated Vector Autoregressive Models* (London: Oxford University Press).
45. Marin, D., 1992, Is the export-led growth hypothesis valid for industrialized countries? *The Review of Economics and Statistics*, **74**, 678–688.

Appendix 1

India is endowed with an extensive coastline of about 6000 km along nine coastal states. These states are Gujarat, Maharsatra, Karnataka, Goa, Kerala (west coast) and Tamil Nadu, Andhra Pradesh, Orissa, West Bengal (east coast). These nine states have in total 12 major and 180 minor ports. Ports in India are classified as 'Major Ports' and 'Other (minor) Ports'. Major ports come under the jurisdiction of the Central government and Other (minor) ports are under the control of the State governments. Among these 12 major ports, six are located in the west coast (Kandla, Mumbai, Jawarlal Nehru, Mormugao, Cochin, New Mangalore) and six in the east coast (Chennai, Tuticorin, Paradip, Vizag, Calcutta, Haldia). Four of the major ports (Calcutta, Mumbai, Chennai, and Mormugao) are more than 100 years old. Cochin and Vizag ports have recently celebrated their golden jubilee. The ports of Kandla, Tuticorin, New Mangalore and Paradip came into existence after independence. Jawarlal Nehru port became operational only after 1989. Ennore (in Tamil Nadu) is the first corporate port of India, having come into existence in 2000.

Out of 180 minor ports including 13 non-working ports, 120 ports belong to the west coast, comprising 67% of total Indian minor ports, 25 ports belong to east coast and the rest (35) belong to Union territories. Due to the lack of overseas cargo, some maritime states like Andhra Pradesh and Kerala closed down a few minor ports, which are called non-working ports. Maharastra has the highest number of ports—

two major and 53 minor. Next to it is Gujarat, where one major and 40 minor ports are situated.

Appendix 2

(1) *Ship turn-round time* is the duration of the vessel's stay in port and is calculated from the time of arrival to the time of departure.
(2) *Pre-berthing waiting time* is the time a ship has to wait before getting entry into a berth.
(3) *Percentage of idle time at berth to time at working berth* is the ratio of total idle time to total working time while a ship is in the port.
(4) *Output per ship berth day* means total tonnage handled, or distributed over the total number of ship berth days.
(5) *Berth throughput* means total cargo handled by a berth in a port.
(6) *Berth occupany rate* is the time that a berth is occupied by ships.
(7) *Operating surplus per ton of cargo handled* derives from total operating surplus divided by total tonnage of cargo handled by the port.
(8) *Rate of return on turnover* derives from operating surplus divided by operating income of a port.

Appendix 3. Port performance indicators: mean, SD and CV.

Performance variables	1985–1986 Mean	1991–1992 Mean	1999–2000 Mean	1985–1986 SD	1991–1992 SD	1999–2000 SD	1985–1986 CV	1991–1992 CV	1999–2000 CV
TRT (days)	10.27	6.37	5.45	2.75	1.82	1.66	0.27	0.29	0.30
PBWT (days)	2.92	1.46	1.80	0.97	0.74	1.14	0.33	0.51	0.63
PITTWB (%)	35.73	34.17	32.19	11.74	11.66	11.26	0.33	0.34	0.35
OSBD (tones)	3073.45	4458.42	5683.58	1773.89	2506.94	2532.79	0.58	0.56	0.45
BOR (%)	70.40	66.87	74.00	8.34	12.73	14.45	0.12	0.19	0.20
BTR (%)	126.48	155.91	166.29	108.05	124.90	107.15	0.85	0.80	0.64
PTOS (Indian Rs.)	1.21	2.34	5.54	0.97	1.27	4.30	0.81	0.54	0.78
RRT (%)	27.07	27.47	35.84	17.33	11.33	13.75	0.64	0.41	0.38

SD = standard deviation, CV = coefficient of variation.

Appendix 4. Results of unit root: Phillips-Perron (PP) test.

Ports	PP	MCV[1]	LD[2]
Port performance			
Kandla	−5.365***	−4.887	1
Mumbai	−4.975***	−4.887	2
Mormugao	−3.402*	−3.359	2
New Mangalore	−3.429*	−3.359	2
Cochin	−3.386*	−3.359	2
Tuticorin	−3.412*	−3.359	2
Chennai	−4.818**	−3.829	2
Vizag	−4.568**	−3.829	2
Paradip	−3.573*	−3.359	2
Calcutta	−3.368*	−3.359	2
Haldia	−4.766**	−3.829	2
Port traffic			
Kandla	−3.622	−3.359	2
Mumbai	−3.362*	−3.359	2
Mormugao	−3.811*	−3.359	2
New Mangalore	−3.662	−3.359	2
Cochin	−3.438	−3.359	2
Tuticorin	−3.621	−3.359	2
Chennai	−3.419	−3.359	2
Vizag	−3.385*	−3.359	2
Paradip	−5.540***	−4.887	2
Calcutta	−3.369	−3.359	2
Haldia	−3.693*	−3.359	2

MOV = MacKinnon critical values for rejection of hypothesis of a unit root. Value refers to same order of significance level of corresponding PP statistic.
LD = Lagged differences of independent variables. Here lag truncation for Bartlett kernel taken at 2 year period for most of the pairs except Kandla.
Statistics with *, ** and *** indicate rejection of null hypothesis at the 10%, 5% and 1% confidence level. When the null hypothesis is rejected no differencing is required to obtain stationary data. Equation considered both trend and intercept terms at level. Data were taken at logarithms form.