COLOMBO SEAPORT - SCALE OF OPERATION, PROFITABILITY AND CAPACITY UTILIZATION

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Summary - After brief introduction, this paper deals with the scale of operation, profitability based on the productivity and the capacity utilization aspects to get more insights into the recent growth of the Colombo seaport. It concludes that after the 1977 policy reforms in Sri Lanka, the operation of the Colombo seaport increasing returns to scale, sustainable nature of productivity based profitability and the high rates of capacity utilization. Furthermore, this paper has emphasised that seaport growth and further expansion may be judged based on the scale of operation, productivity based profitability and the high rate of actual to preferred capacity utilization to yeild the sufficient returns to the investments and to overcome the provision of over-capacity.

Sri Lanka (formerly Ceylon), a sea-locked (island) nation, is strategically located in the South Asian main sea routes as a gateway to the Far-East, the Middle-East, Europe, Africa and Australia[1]. This supreme strategic hub location created commendable achievements in seaports in different magnitudes. More specifically, after 1977 economic policy reforms[2], the Colombo seaport has earned the reputation as the best managed and the most efficient hub port in the South Asia and the major transhipment centre in the Indian Ocean (Lloyd's Shipping Economist, October 1984 and UNCTAD, 1990). This success further strengthened by the liberalization of shipping in 1990[3] which was the landmark of changing the fundamentals of the Sri Lankan shipping and ports related activities. In terms of future prospects of transhipment activities in South Asia, it can be estimated that, with the size of vessels growing on the main routes, there will be a concentration of transhipment activities on a very limited number of strategically located hub ports equipped to cope with future generation of vessels requirements and ensuring excellent working conditions. UNCTAD (1990 ibid) has more frankly emphasised that Colombo's qualifications are deemed fit to become one of these major hub in the South Asia. In this context, the recent growth of the Colombo seaport is analyzed by using production function, profitability and capacity utilization approaches to get more insights into the seaport operation and to find the possibilities for further expansion[4]. First, this paper presents the scale of operation in three major seaports (Colombo, Galle and Trincomalee) and later more exclusively the situation of the Colombo seaport. Second, it presents the profitability of the operation of the Colombo seaport based on the productivity analysis. Third, the actual to preferred capacity utilization analysis is presented. Finally, the conclusions are presented.

Scale of Operation Analysis

The following conventional Cobb-Douglas production function is used as the main tool of this section which generally captures the basic ingredients of seaport operations.

$Q = AK^aL^be^{z(T/L)}$; Where, Q = Output (gross port revenue[2], 1980 prices),

K = Capital inputs (capital employed book value, 1980 prices), L = Labour inputs (wages and salaries paid, 1980 prices), a and b = capital and labour

ratios, $e^{(T/L)}$ = proxy for technological improvement; T = Total tonnage

handled, L = number of employees, (T/L) = tonnage per unit of labour. Using natural log (=ln) form, this production function can transform into econometric model by introducing error term (U) as follows[3]:

$\ln Q = \ln A + a \ln K + b \ln L + (T/L) \ln e^z + U$ ....(1)

$\ln Q = A + a \ln K + b \ln L + U$ ....(2)

These two models are estimated in two stages. First for three major Sri Lankan seaports (Colombo, Galle and Trincomalee). Second, only for the Colombo seaport.

Estimation of the Production Function for Major Sri Lankan Seaports

Model (1) for major Sri Lankan seaports is estimated by using the OLS method. The results as follows:

$$\ln Q = 2.6042 + 0.1049\ln K + 0.4302\ln L + 0.7055(T/L) \quad \ldots\ldots (1)$$

t = (2.85) (3.09) (2.69) (3.27)

Se = (0.91) (0.03) (0.15) (0.21)

n = 1980-93 (13), R^2 = 0.989, Adj.R^2 = 0.986, DW = 1.759, F = 308

Statistical interpretation of this results may be summarised in the ensuing forms: Partial coefficients including intercept are significant at 0.05% level, standard errors are very low, more than 98% of variation of seaport output is explained by the variations of explanatory variables, the F statistic is significant at 0.05% level, the DW statistic significant at 0.01% level which indicates that the absence of first order serial correlation. The economic interpretation of this results as follows: The partial slope coefficient of 0.1049 measures the partial elasticity of the output with respect to the labour and technological change. Specifically, this number states that, holding the labour and technological change constant, if the capital input increases by 1 percent on the average, the output goes up by 0.10 percent. Likewise, holding the capital inputs and technological change constant, if the labour input increases by 1 percent on the average, output goes up by 0.43 percent. If we add the two output elasticity coefficients of factor inputs, we obtain an economically important parameter called the returns to scale parameter, which gives the response of output to proportional change in inputs. The sum of two elasticity coefficients of capital and labour is 0.5351, suggesting that the Sri Lankan major seaports (Colombo, Galle and Trincomalee) decreasing returns to scale - doubling the inputs less than doubles the output. However, this tentative conclusion has some effect from the technological proxy which is explicitly assumed that all seaports have the same traffic structure especially, the same capital/labour ratios over time. Therefore, this proxy has dropped in order to see the direct relationship between inputs and outputs in major seaports of Sri Lanka. The following results are estimated after dropping the proxy for technological development[4].

$$\ln Q = 0.0732 + 0.1101\ln K + 0.9320\ln L \quad \ldots\ldots (2)$$

t = (0.10) (2.37) (15.04)

Se = (0.66) (0.04) (0.06)

R^2 = 0.977, Adj.R^2 = 0.973, DW = 1.274, F = 242

Statistically these results may be interpreted as follows: Partial coefficients of capital and labour are significant at 0.05% level but intercept has 0.28 probability for significance. Standard errors are very low, the F statistic is significant at 0.05% level, the variation of 97% of seaports output is explained by the variation of explanatory variables. The DW statistic significant at 0.01% level which indicates that the absence of first order serial correlation. An economic interpretation of this results as follows: The partial slope coefficient of 0.1101 measures the partial elasticity of the output with respect to the capital inputs (K). This number indicates that, holding the labour input constant, if capital input increases by 1 percent on the average, the seaport output goes up by 0.11 percent. Likewise, holding the capital input constant, if the labour inputs increases by 1 percent on the average, output goes up by 0.93 percent. This interpretation gives an important policy message that is labour has more responsiveness to output rather than the capital in Sri Lankan seaports which is very much compatible with the factor endowments of the country. The sum of capital and labour elasticity coefficients is 1.0421, suggesting that Sri Lankan major seaports displayed an increasing returns to scale during 1980-93 period. According to the results of these regressions the productivity growth in the seaports were quite fast. This fast growth indicates that demand for the seaports' services have being increasing during the past decade and in turn it shows, there are more possibilities to expand seaport facilities in order to reduce the seaport congestion which automatically creates by excess demand. However, this fast growth mainly came from the Colombo seaport rather than Galle or Trincomalee. Therefore, to analyze the situation in the Colombo seaport, these two models are estimated to the Colombo seaport the below.

Estimation of Models for the Colombo Seaport

First model is estimated through OLS method to the Colombo seaport, the results as follows:

$$\ln Q = 2.2532 + 0.1173\ln K + 0.04747\ln L + 0.6337(T/L) \quad \ldots\ldots (1)$$

t = (2.99) (3.72) (3.32) (3.29)

Se = (0.75) (0.03) (0.14) (0.19)

R^2 = 0.989, Adj.R^2 = 0.986, DW = 1.758, F = 320

Statistically these results may be interpreted as: Labour and capital partial coefficients and intercept are significant at 0.05% level, standard errors are very low, more than 98% of variation of seaport output is explained by the variation of explanatory variables, the F statistic is significant at 0.05% level, the DW statistic is significant at 0.01% level which indicates that the absence of positive first order serial correlation. Economically these results may be interpreted as: holding the labour and technological change constant, if the capital input increases by 1 percent on the average, the output goes up by 0.11 percent. And holding the capital inputs and technological change constant, if the labour input increases by 1 percent on the average, output goes up by 0.04 percent. Sum of these capital and labour elasticity coefficients is 0.5920 which suggesting that the Colombo seaport in decreasing returns to scale during 1980-93 period. But the government heavily invested in the Colombo seaport in order to cope with the increasing traffic which caused the rapid changes in the capital-output ratios over time. Therefore, by dropping the technological proxy, second model is estimated to the Colombo seaport in order to ascertain the direct relationship between inputs and outputs.

$\ln Q = 0.3102 + 0.1077 \ln K + 0.9222 \ln L$ ....(2)

t = (0.48) (2.49) (15.41)

Se = (0.64) (0.04) (0.05)

$R^2 = 0.978$, Adj.$R^2 = 0.974$, DW = 1.2781, F = 250

Statistically these results may be interpreted as: capital and labour partial coefficients are significant at 0.05% level but intercept has 0.638 probability to significance. Standard errors are very low and the F statistic is significant at 0.05% level. More than 97% of variation of output is explained by the variation of explanatory variables. The DW statistic significant at 0.01% level which indicates that the absence of the first order serial correlation. Economically these results may be interpreted as: holding the labour input constant, if the capital input increases by one percent on the average, output goes up by 0.10 percent. Likewise, holding the capital input constant, if the labour inputs increases by one percent on the average, output goes up by 0.92 percent. The sum of labour and capital partial coefficients is 1.0299 which suggesting that the operations of the Colombo seaport shows increasing returns to scale during the recent past.

Productivity based Profitability Analysis in the Colombo Seaport

The following max-min model is used to show the sustainable nature of profitable operation in the Colombo seaport based on the productivity analysis.

Maximize: $Q = wL + rK$

Subject to: $Q = AK^aL^b$

Where, Q = Gross revenue from port activities (1980 prices), w = Average

annual total earning per employee (1980 prices), K = Net assets (book values, 1980 prices), L = Number of employees, a and b = capital and labour coefficients, r% = Rate of return on capital; (Q-wL)/K.

Solving this model by using the Lagrange multiplier:

$w = y1\,(b.Q/L) = y1$ MPPl in Rupee value

$r = y2\,(a.Q/K) = y2$ MPPk in per cent terms

where y1 and y2 = Lagrange multipliers for labour and capital, MPPl = Marginal Physical Productivity of Labour (APl*b), MPPk = Marginal Physical Productivity of Capital (APk*a), APl = Average Productivity of Labour (Q/L), APk = Average Productivity of Capital (Q/K), MRPl = Marginal Revenue Product of Labour (MPl*w), MRPk = Marginal Revenue Product of Capital (MPk*r%).

The results of this max-min model presents in table 1.

Table 1 shows the productivity based profitable operation in the Colombo seaport during 1980-93 period. Assuming that labour and capital coefficients had remained constant during the sample period, the marginal productivities of labour and capital obtained by multiplying input coefficients to their respective average productivities. The Lagrange multiplier (y1, y2) measures the deviation of returns to input factors from their marginal productivities which is derived by dividing returns to inputs factors by their marginal productivities. Economically important two main profitability measures are well above the acceptable level -that is- the average marginal revenue product of port labour are well above the average wage rate paid for the port labour, (w = 18545) < (MRPl = 849298) and the average marginal revenue product of capital employed in the port are well above the average interest rate paid for the port development loans, (r% = 10.68) < (MRPk% = 21.80). The average interest rate on the government bonds during 1980-93 period 14% which is well below the MRPk% (Central Bank of Sri Lanka, 1994) however, majority of port development loans come from the concessionary sources such as government guaranteed development cooperation rather than the real commercial origin. Wages in the Colombo seaport are mainly determined by labour market and trade unions actions exogenous to the labour productivity of the seaport operation. Speed up money collection is widespread practice among the port labour which may be the indirect compensation for the low wage level. Therefore, capital always yield high profitability for the investment. The average Lagrange multiplier for labour (y1) equals to 0.02327 and capital (y2) equals to 0.58436 which indicate the relative stability of returns to input factors from their marginal productivities over time. But in accounting terms, the lion share of the gross port profit of the Colombo seaport is paid as tax revenue to the government and to subsidise the losses of other major seaports which are under the SLPA. Therefore, Colombo seaport does not have sufficient surplus in their hand to re-invest for the development. This may be the main reason for Colombo to heavily depends on the development cooperation sources for its development.

Capacity Utilization Analysis in the Colombo Seaport

Capacity utilization is the ideal measure to show the proportion of seaport productive capacity currently utilised from the available maximum port capacity. This is a good indicator to determine the future expansion of seaport facilities without creating the problem of over-capacity. Often the excess demand for the seaport services may lead to expand seaport facilities without proper assessment of the utilization of the available capacity. Therefore, before expansion of the existing seaport facilities, it is preferable to carry-out a capacity utilization analysis. The estimation of the ratios of capacity utilization in the Colombo seaport based on the actual tonnage handled and the preferred tonnage[5]. By assuming that preferred tonnage indicates the preferred level of capacity utilization, the ratios of actual to preferred tonnage of the port of Colombo is derived in the following sequences. First, the port capacity function specify as:

T = f(Time, H) Where, T = Actual tonnage handled, H = Dummy variable for peak tonnages. After identifying the trend line of the actual tonnage handled, the following function is specified.

$T = a + b\,\text{time} + c\,(\text{time})^2 + d\,H$, t^2 has introduced after identifying the quadratic behaviour of actual

Table 1 - Profitability analysis in the Colombo seaport, 1980-93

Year	Wage = w (Rs)	MRPl = MPl*w	yl = w/MRPl	r% = Q-wL/K	MRPk= MPk*r%	y2 = r / M P P k
1980	16432	515646	0.03186	05.3059	05.8635	0.90489
1981	15662	525473	0.02980	06.1088	07.0578	0.86554
1982	15506	548584	0.02826	07.2238	09.4334	0.76576
1983	16490	618833	0.02664	08.3962	12.7658	0.65771
1984	14598	552310	0.02643	09.8018	16.0638	0.61017
1985	16136	688605	0.02343	09.7061	15.5790	0.62303
1986	15265	706392	0.02161	11.0027	18.7396	0.58714
1987	16172	732106	0.02209	11.2184	20.2140	0.55498
1988	19917	949446	0.02097	12.0321	25.3660	0.47433
1989	19645	966855	0.02031	09.1346	14.2225	0.64226
1990	18637	990451	0.01881	17.3070	47.6802	0.36298
1991	22303	1150805	0.01938	14.5171	37.7430	0.38462
1992	23323	1237134	0.01885	14.4673	37.9191	0.38153
1993	29541	1707527	0.01730	13.4081	36.6250	0.36609
Average	18545	849298	0.02327	10.6878	21.8052	0.58436
S.Deviation	4160	343014	0.00456	03.4384	13.1939	0.17894

Source: Calculation is based on the unpublished data obtained from the Financial Division of the Sri Lanka Ports Authority

tonnage over time. First, this function is estimated through OLS method, and later first order auto correlation removed through first order auto-regressive process [ar(1)].

$T = 3861.22 + 170\ time + 23.87\ (time)^2 + 844.48\ H$ ....(3)
Se = (957) (110) (10) (235)
t = (4.03) (1.80) (2.29) (3.58)
$R^2 = 0.976$, Adj.$R^2 = 0.967$, DW = 1.82, F = 113, n = 1977-93 (17)

In the estimated model, partial coefficients including intercept are significant at 0.05% level, 95% of variation of preferred tonnage is explained by the variation of the explanatory variables, the F statistic is significant at 0.05% level and the DW statistic significant at 0.05% level which indicates the absence of first order auto-correlation. This equation shows the annual rate of increase of tonnage at the port of Colombo has been positive one, and the rate has increased at an increasing rate over time - that is - $dT/d(time) = 170 + 47.74\ time$; $d^2T/d^2(time) = 47.74 > 0$, which is very much compatible with the analysis of section 5.1.2 of this chapter. Based on the equation (3) the preferred tonnage (PT) can specify as:

$PTi = 3861.22 + 170\ time + 23.87\ (time)^2 + 844.48\ H$,

Where i = from 1977 to 1993 and H = 1. Following this definition, preferred tonnage for the 1977-93 period are computed from PTi equation by plugging into the equation the time variable and H = 1 for every period. The derived ratios of actual to preferred tonnage presents table 2.

Table 2 shows the average rate of capacity utilization around 95% in the Colombo seaport during 1977-93 period. In years like 1978, 88 and 93 the capacity utilization reached over 100% which is a good sign of heavy congestion, long waiting queues for ships and all the ships arrived could not be served efficiently and by-pass rate is very high with respect to the main lines.

The main contents of this analysis may be finalised in the following form of conclusions.

1) The analysis based on the Cobb-Douglas production function has shown that the operation of the Colombo seaport increasing return to scale during the recent past. The returns to scale depends to a larger extent upon changing demand for seaport services and corresponding development to cope with this demand. In view of the rapidly rising tonnage handled and the other services provided for ships and the related other business activities by the Colombo seaport afer the 1977 policy reforms, as explained in the third chapter, has

reasonable evidences to find increasing returns to scale in our estimated models even with some what ambiguous data set.

2) The analysis of the section 5.2 is elaborated the profitable operation of the Colombo seaport based on the productivity analysis. The average profitability measures such as W<MRPI and r% < MRPk% are well above the acceptable limits. The sustainable nature of profitable operation well elaborates with little fluctuation of Lagrange multipliers over time.

3) The section 5.3 analyzed the capacity utilization aspects of the Colombo seaport during the recent past. This analysis shows the annual rate of increase of tonnage at the Colombo seaport has been positive and, the rate has increased at an increasing rate over time. Finally, it shows the high rate of actual to preferred capacity utilization which can be used as a basis to expand seaport facilities without creating the problem of overcapacity.

Table 2 - Capacity utilization in the Colombo seaport, 1977-93

Year	Actual Tonnage (T)	Preferred Tonnage (PT)	Capacity Utilization (T/PT)%
1977	4637000	4899570	94.64
1978	5498000	5141180	106.94
1979	4982000	5430530	91.74
1980	5711000	5767620	99.01
1981	5186000	6152450	84.29
1982	5831000	6585020	88.54
1983	6090000	7065330	86.19
1984	7044000	7593380	92.76
1985	7743000	8169170	94.78
1986	8518000	8792700	96.87
1987	8798000	9463970	92.96
1988	11469000	10182980	112.62
1989	10429000	10949730	95.24
1990	11706000	11764220	99.50
1991	12282000	12626450	97.27
1992	11957000	13536420	88.33
1993	14712000	14494130	101.50
Average	83878200	87420000	95.48

Source: Actual tonnage data has obtained from the Port Statistics Series, 1977-95

Notes

1) The theoretical defects of port impact and cost/benefits studies are very much controversial issue in seaport literature. For details of theoretical defects of these studies, see Waters (1977 ibid); Chang (1978 a,b); Peter and Rose (1995 ibid). For details and shortcomings of the port impact studies based on the Input-Output technique, see Davis (1983 ibid); Braun (1990 ibid) and Moon (1995 ibid).

2) The product of seaport is very much debatable issue which consist of pilotage, towage, berthing, cargo handling, warehousing and other modern port activities related to distribution, transport and property trading and other activities. However, gross port revenue or income generated through the cargo handling are the famous port output among the port and shipping community. Sri Lanka's seaports are not land lord ports but they are service ports. Therefore, port charges are more or less in-line with the cost.

3) Standard definition of a production function is that it gives the maximum possible output for a given set of inputs. This is a different concept than the regression function, which gives mean output for a given set of inputs (Cornwell and Schmidst, 1996). For the calculation of this chapter, most of the unpublished data have obtained from the Accounts Division of the Sri Lanka Ports Authority, Colombo.

4) Generally, technological change measures by introducing time variable to general production function. Our first model is using per-capita tonnage as proxy for the technological change which in-line with the assumption of the labour-augmenting Harrod's neutral technological progress because capital-output ratio of Sri Lanka's seaports showed a relatively stable picture during 1980-93 period. In our model, Harrod and Hicks neutral assumptions on technological progress are equivalent because elasticity of substitution is unitary even returns to scale is not unitary. Generally, the Cobb-Douglous production function is embedded with the technological progress therefore a separate proxy is not necessary. For given values of K and L, the magnitude of A (intercept) will proportionately affect the level of Q. Hence A may be considered as an efficiency parameter, i.e., as an indicator of the state of technology. For more details of this, see Chang (1974). Therefore, included techological proxy has dropped from our model because of this reality. For details about the various specification forms of Cobb-Douglas production function, see Zellner, Kementa and et.al., (1966); Mundlak and Hoch (1965).

5) Capacity output and capacity utilization are very difficult to measure in seaports. The most popular capacity utilization measures are Wharton school index based on Klein

and Preston method (1966) and Tally method (1988 ibid 1994). Available other capacity utilization measures are well elaborated by Morrison (1985); Caves and et.al (1981). Wharton school index is constructed by marking off cyclical peaks of production and then computing ratios of actual to the linear trend line fitted through these peaks. This method assumes that cyclical peaks represent the full capacity utilization. Tally method measures full capacity utilization in engineering point of view. Two types of engineering optimum outputs were introduced. First, the theoretical optimum engineering output which is the maximum (designed) throughput of a port when it is operating at its maximum rate of efficiency. Second, the optimum empirical engineering output which is the estimated maximum throughput based upon actual port data. However, most of the seaport' capacity utilization studies were used 'actual' and 'preferred' capacity utilization rather than 'full' capacity utilization. For details see Chang (1978ab ibid); Berndt and Morrison (1981).

Notes

1) Sri Lanka, by virtue of its mid-way position in the Indian Ocean, has been throughout her history a famous meeting place of foreign merchants and travellers. Arab coasters, Greek and Roman galleys as well as Persian merchants visited the ancient harbours of the Sri Lanka to rendezvous with vessels form the East for trading purposes. Therefore, economic and cultural inter-changes, trade links, colonization, roots of industrialization, urban and commercial centres and most of the imports and exports based modern business activities have emerged through the seaports (Ibn Batuta's travel documents translated by Gibbs, 1936 and Warmington, 1928). The development of major seaports in Sri Lanka under the Portuguese (1505-1658), Dutch (1658-1796) and the British (1796-1948) colonial regimes explained by Panditharathna (1960), ECAFE (1966) and Dharamesena (1980). At present, Sri Lanka has four major international seaports (Colombo, Galle, Trincomalee and Kankasanturai) however, Colombo (commercial capital city of the island) is the most developed one which handles over 90% of the country's sea-borne trade. This seaport has a water area of 224 hectares, and 20 alongside berths (including 6 container berths) with modern cargo handling equipments. At present, the Colombo seaport is 29th container port of the World (Containerization International, 1994) and among the developing countries it ranks as a seventh container port (UNCTAD, 1994).

2) This economic policy reforms mainly included:

a) Liberalization of most of imports and exchange payments.

b) Abolition of most price controls while keeping a system of administered prices for certain products of importance in the society's consumption pattern and grant of greater autonomy to public corporations for more realistic pricing policies in order to help them to achieve commercial viability.

c) Attempts to reduce budgetary expenditure on account of food subsidies by introducing a system of 'food stamps' whereby stamps of a given value were issued to low income families and market forces were allowed generally to determine the prices of commodities purchasable with these stamps (safety net with market forces).

d) Promotion of private enterprises, including direct foreign investment through a wide array of fiscal, infrastructural and other incentives.

e) Restraint in granting wage demands in general and those within the public sector in particular along with repressive measures on the trade union movements.

f) An appearance of restrictiveness in monetary measures marked by unprecedented high interest rates and intermittent credit squeezes imposed on commercial bank lending. Apart from short periods of these credit squeezes, however, private and public sectors do not seem to have encountered much difficulty in obtaining the required bank credit. In that respect, easy money conditions have been maintained.

g) Sharp increases in government capital expenditure, particularly on infrastructure and housing project, despite the fact that this necessitated the running of large budget deficits, even if they had to be bridged through inflationary finance.

h) Search for increasing volumes of foreign aids, loans and grants.

i) Sharp (Mono) devaluation of currency.

j) Measures to promote economic activities earning foreign exchange (export-oriented industry, export crops, tourism, labour migration for foreign jobs etc). Hence the claim of the proponents of the 'open economy' that their strategy is one of 'export-led growth'. More details of this policy reforms, see Lall and Rajapathirana (1990).

3) The major changes introduced under the liberalization of shipping are: from Central Freight Bureau (CFB) regulations to liberalization, from a pivot of cargo monopsony to ship owner competition, from national line priority to foreign line precedence, from CFB negotiated rates to free market prices, from a lean sailing regime to prolific service oriented regime, from dominance of the CFB to the resurrection of the Ceylon Association of Steamer Agents (CASA) and Shipping Council, from a Central Freight Booking Office to primacy of Colombo hub port, and promotion of private foreign and local investment to different areas in the maritime industry.

4) The theoretical defects and abuse of studies of port impact and cost/benefits are very much controversial issue in seaport literature. For details see Waters (1977); Chang (1978ab, ibid), and Peter and Rose (1995). Port impact and cost/benefits studies are different from the studies of port performance and efficiency. Seaport performance and efficiency are mainly related with

stevedores (equipments and labour related), shipping lines (turn around time) and port itself (facility utilization and throughput). The various advantages and disadvantages of these indicators are explained by Takel (1994, ibid). The most important determinants of the seaport performance and efficiency are explained by Tongzon (1995). However, the most acceptable single seaport performance indicator is shadow price based port throughput per profit unit.

5) Generally, technological change measures by introducing time variable to general production function. Our first model is using per-capita tonnage as proxy for the technological change which in-line with the assumption of the labour-augmenting Harrod's neutral technological progress because capital-output ratio of Sri Lanka's seaports showed a relatively stable picture during 1980-93 period. In our model, Harrod and Hicks neutral assumptions on technological progress are equivalent because elasticity of substitution is unitary even returns to scale is not unitary. It is generally belived that the Cobb-Douglas production function is embodied with the technological progress therefore a separate proxy is not necessary.

6) Production function and max-min model estimated for the period of 1980-93. Before 1979, the Colombo seaport was administered by Colombo Port Commission, Port Tally and Protective Corporation and Port (Cargo) Corporation. In 1979, by amalgamating these three, Sri Lanka Ports Authority established by the government. Thereafter data available under the single Authority. Data used for the calculation of this paper can be collected from the author.

7) Capacity output and capacity utilization are very difficult to measure in seaports. The most popular capacity utilization measures are Wharton school index based on Klein and Preston method (1966) and Tally method (1988 and 1994). Wharton school index is constructed by marking off cyclical peaks of production and then computing ratios of actual to the linear trend line fitted through these peaks. This method assumes that cyclical peaks represent the full capacity utilization. Tally method measures full capacity utilization in engineering point of view. Two types of engineering optimum outputs have been introduced. First, the theoretical optimum engineering output which is the maximum (designed) throughput of a port when it is operating at its maximum rate of efficiency. Second, the optimum empirical engineering output which is the estimated maximum throughput based upon actual port data. However, most of the seaport' capacity utilization studies have been used 'actual' and 'preferred' capacity utilization rather than 'full' capacity utilization. For details see Chang (1978ab) and Douglas and et.al (1981).

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