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. This supreme strategic hub location created commendable achievements in seaports in different magnitudes. More specifically, after 1977 economic policy reforms, 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 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.

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.

\[ Q = AK^bL^a(T/L)^{e-1/v} \]

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:

\[ \ln Q = \ln A + a \ln K + b \ln L + (T/L) \ln e^{(T/L)} + U \]

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:
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) decrease traffic structure especially, the same capital/labour ratios over time. Therefore, 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 partial 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.

\[
\ln Q = 2.6042 + 0.1049\ln K + 0.4302\ln L + 0.7055(T/L) \quad (1)
\]
\[
t = (2.85) (3.09) (2.69) \\
(3.27) \quad (0.15) \quad (0.21)
\]
\[
n = 1980-93 (13) \quad R^2 = 0.989, \text{Adj} R^2 = 0.986, \text{DW} = 1.759, \quad F = 308
\]

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 seaport 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 been 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:

\[
\ln Q = 2.2532 + 0.1173\ln K + 0.04747\ln L + 0.6337(T/L) \quad (2)
\]
\[
t = (2.99) (3.72) (3.32) \\
(3.29) \quad (0.75) \quad (0.03) \quad (0.14)
\]
\[
R^2 = 0.989, \text{Adj} R^2 = 0.986, \quad \text{DW} = 1.758, \quad F = 320
\]

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 presence 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 0.93 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.
In Q = 0.3102 + 0.1077 InK + 0.9222 InL .......... (2)
\[ t = (0.48) (2.49) (15.41) \]
\[ \text{Se} = (0.64) (0.04) (0.05) \]
\[ R^2 = 0.978, \text{Adj.R}^2 = 0.974, \]
\[ DW = 1.2781, F = 250 \]

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 increase 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: \( Q = AK^L \)

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, \( r\% = \text{Rate of return on capital; } (Q-wL)/K. \)

Solving this model by using the Lagrange multiplier:

- \( w = y1(b,Q/L) = y1\text{ MPP1} \)
- \( r = y2(a,Q/K) = y2\text{ MPPk} \)

where \( y1 \) and \( y2 \) = Lagrange multipliers for labour and capital, \( \text{MPP1} = \text{Marginal Physical Productivity of Labour (API*1b)} \)

\( \text{MPPk} = \text{Marginal Physical Productivity of Capital (APk*a)} \)

\( r = \text{Average Productivity of Capital (Q/K)} \)
\( \text{MPRI} = \text{Marginal Revenue Product of Labour (MPI*w)} \)
\( \text{MRPk} = \text{Marginal Revenue Product of Capital (MPk*r\%)} \)

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

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, \((w = 18545) < (\text{MRP1} = 849298)\) 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, \((r\% = 10.68) < (\text{MRPk}\%) = 21.80.\) The average interest rate on the government bonds during 1980-93 period 14% which is well below the \(\text{MRPk}\%\) (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 union 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 Utilisation 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. 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, \( T = \text{Actual tonnage handled, } H = \text{Dummy variable for peak tonnages. After identifying the trend line of the actual tonnage handled, the following function is specified.} \)

\[ T = a + b \text{ time} + c(\text{time})^2 + d \]

\( H, t^2 \) has introduced after identifying the quadratic behaviour of actual
Table 1: Profitability analysis in the Colombo seaport, 1980-93

<table>
<thead>
<tr>
<th>Year</th>
<th>Wage (w) (Rs.)</th>
<th>MRPl = MPI'w</th>
<th>y1 = w/MRPl</th>
<th>r% = Q-wL/K</th>
<th>MPk = MPk*r%</th>
<th>y2 = r / MPPk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>16432</td>
<td>515564</td>
<td>0.03186</td>
<td>05.3059</td>
<td>05.8635</td>
<td>0.90489</td>
</tr>
<tr>
<td>1981</td>
<td>15662</td>
<td>525473</td>
<td>0.02980</td>
<td>06.1088</td>
<td>07.0578</td>
<td>0.86554</td>
</tr>
<tr>
<td>1982</td>
<td>15506</td>
<td>548584</td>
<td>0.02826</td>
<td>07.2238</td>
<td>09.4334</td>
<td>0.76576</td>
</tr>
<tr>
<td>1983</td>
<td>16490</td>
<td>618833</td>
<td>0.02664</td>
<td>09.1088</td>
<td>12.7658</td>
<td>0.65771</td>
</tr>
<tr>
<td>1984</td>
<td>16590</td>
<td>618833</td>
<td>0.02643</td>
<td>09.8018</td>
<td>16.0638</td>
<td>0.61017</td>
</tr>
<tr>
<td>1985</td>
<td>16136</td>
<td>686605</td>
<td>0.02343</td>
<td>09.7061</td>
<td>15.5790</td>
<td>0.62303</td>
</tr>
<tr>
<td>1986</td>
<td>15265</td>
<td>706392</td>
<td>0.02161</td>
<td>11.0027</td>
<td>18.7396</td>
<td>0.58714</td>
</tr>
<tr>
<td>1987</td>
<td>16172</td>
<td>732106</td>
<td>0.02209</td>
<td>11.2184</td>
<td>20.2140</td>
<td>0.55498</td>
</tr>
<tr>
<td>1988</td>
<td>19917</td>
<td>949446</td>
<td>0.02097</td>
<td>12.0321</td>
<td>25.3660</td>
<td>0.47433</td>
</tr>
<tr>
<td>1989</td>
<td>19645</td>
<td>968655</td>
<td>0.02031</td>
<td>09.1346</td>
<td>14.2225</td>
<td>0.64226</td>
</tr>
<tr>
<td>1990</td>
<td>18637</td>
<td>900451</td>
<td>0.01881</td>
<td>17.3070</td>
<td>47.6802</td>
<td>0.36298</td>
</tr>
<tr>
<td>1991</td>
<td>22303</td>
<td>1150805</td>
<td>0.01938</td>
<td>14.5171</td>
<td>37.7430</td>
<td>0.38462</td>
</tr>
<tr>
<td>1992</td>
<td>23323</td>
<td>1237134</td>
<td>0.01885</td>
<td>14.4673</td>
<td>37.9191</td>
<td>0.38153</td>
</tr>
<tr>
<td>1993</td>
<td>29541</td>
<td>1707527</td>
<td>0.01730</td>
<td>13.4081</td>
<td>36.6250</td>
<td>0.36609</td>
</tr>
<tr>
<td>Average</td>
<td>18545</td>
<td>849298</td>
<td>0.02327</td>
<td>10.6878</td>
<td>21.8052</td>
<td>0.58436</td>
</tr>
<tr>
<td>S.Deviation</td>
<td>4160</td>
<td>343014</td>
<td>0.00456</td>
<td>03.4384</td>
<td>13.1939</td>
<td>0.17894</td>
</tr>
</tbody>
</table>

*Source: Calculations based on unpublished data obtained from the Financial Division of the Sri Lanka Ports Authority.*

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.
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 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.

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-Douglas 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 technological 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).
tion, urban and commercial centres emerged through the seaports (Ibn and most of the imports and exports colonization, roots of industrializa­
trading purposes. Therefore, economic
harbours of the Sri Lanka to rendez­
Persian merchants visited the ancient
mid-way position in the Indian Ocean,
utilization. For details see Chang
mid-maximum throughput based upon actual port data. However, most of the sea­
port' 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).

2) This economic policy reforms mainly included:

a) Liberalization of most of im­
ports and exchange payments.

b) Abolition of most price con­
trols while keeping a system of admin­
istered prices for certain products of importance in the society's consump­
tion pattern and grant of greater au­
tonomy 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 subsi­
dies 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 enter­
prises, including direct foreign invest­
ment through a wide array of fiscal, infrastructural and other incentives.

e) Restraint in granting wage de­
mands 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 in­
frastructure and housing project, de­
spite the fact that this necessitated the running of large budget deficits, even if they had to be bridged through in­
flationary finance.

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

i) Sharp (Mono) devaluation of currency.

j) Measures to promote eco­

Notes

1) Sri Lanka, by virtue of its
mid-way position in the Indian Ocean, has been throughout her history a fa­
nous meeting place of foreign mer­
chants and travellers. Arab coasters, Greek and Roman galleys as well as Persian merchants visited the ancient harbours of the Sri Lanka to rendez­
vous 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 Dharmasena (1980). At present, Sri Lanka has four major international seaports (Colombo, Galle, Trincomalee and Kankasapurui) how­
ever, 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 con­
tainer berths) with modern cargo han­
dling equipments. At present, the Co­
ombo seaport is 29th container port of the World (Containerization International, 1994) and among the devel­
oping countries it ranks as a seventh container port (UNCTAD, 1994).

3) The major changes intro­
duced under the liberalization of ship­
ing are: from Central Freight Bureau (CFB) regulations to liberalization, from a pivot of cargo monopoly to ship owner competition, from na­tional line priority to foreign line pre­
cedence, from CFB negotiated rates to free market prices, from a lean sail­
ing regime to prolific service oriented regime, from dominance of the CFB to the resurrection of the Ceylon As­

sociation of Steamer Agents (CASA) and Shipping Council, from a Cen­
ral Freight Booking Office to primacy of Colombo hub port, and promo­tion of private foreign and local in­
vestment to different areas in the mari­
time industry.

4) The theoretical defects and abuse of studies of port impact and cost/benefits are very much contro­
versial issue in seaport literature. For details see Waters (1977); Chang (1978ab, ibid), and Peter and Rose (1995). Port impact and cost/ben­
efits studies are different from the studies of port performance and effi­
ciency. 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 believed 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 seaports' capacity utilization studies have been used 'actual' and 'preferred' capacity utilization rather than 'full' capacity utilization. For details see Chang (1978ab) and Douglas et al. (1981).

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