AN INTRODUCTION TO THE PORTS GROWTH PERFORMANCE EVALUATION MODEL (PGPE-MODEL)

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Abstract:
This paper will present a new group of indicators to analyze the performance of ports. Hence, this paper is divided into two parts. The first part will present a new model of analysis to evaluate how the port cargo openness, the productivity level, the cargo expansion, and the technological change adaptability can affect directly on the marginal port productivity growth rate performance. This new model of analysis is entitled “the ports growth performance evaluation model (PGPE-Model)”. The objective of the PGPE-Model is to offer policy makers and researchers new analytical tools to study the impact and trend of ports performance from a new perspective. The PGPE-Model application is not limited to the study of a special group of ports. It is not constrained by issued about the geographical area or development stage of the port. The PGPE-Model, in effects, is a simple and flexible scheme.

The second part of this paper shows the results obtained by the application of PGPE-Model on different ports at Singapore, Malaysia, South Korea, Japan and China. The PGPE-Model general objective is to measure the evolution and vulnerability of the ports performance.

Keywords: Ports Productivity, Singapore, Malaysia, China, South Korea, Japan.

JEL Classifications: R40

1. Introduction

The ports growth performance evaluation model (PGPE-Model) is a new analytical model to analyze how the port cargo openness (Ruiz Estrada and Yap, 2006), the productivity level, the cargo expansion, and the technological change adaptability can affect directly on the marginal port productivity growth rate performance, regardless of whether it is a small, middle and large port. There are two general objectives for the proposal of the ports growth performance evaluation model (PGPE-Model): (i) to measure the port cargo openness, the productivity level, the cargo expansion level and the technological changes adaptability level; (ii) to quantify and analyze the marginal port productivity growth rate;
The PGPE-Model will test prove the following two general hypotheses:

1. The marginal port productivity growth performance is directly connected to the efficient coordination of the port cargo openness, the productivity level, the cargo expansion level, and the technological changes adaptability level simultaneously.

2. Basically, the profit of any port is based on how the human capital factor can be adapted anytime to the fast changes in new technologies of ports.

The PGPE-Model is based on a series of steps in its application to study the ports performance:

(i) The total volume cargo of the port per year ($\Psi$) and the total volume cargo of the port per year growth rate ($\Delta\Psi$).
(ii) The total volume of exports/imports cargo operations under the national level ($\lambda$).
(iii) The port cargo openness ($Op$) and the port cargo openness growth rate ($\Delta Op$).
(iv) TFP port level ($T$) and TFP port level growth rate ($\Delta T$).
(v) The marginal port productivity growth rate ($\Pi^*$).
(vi) Measurement of the port cargo openness/FTP growth rate ($\Delta Op: \Delta T$) sensitivity analysis.
(vii) The plotting of ports growth diamond graph.

2. Steps to Apply PGPE-Model

Step-1: The Total Volume Cargo for the Port per Year ($\Psi$) and the Total Volume Cargo of the Port per Year Growth Rate ($\Delta\Psi$)

Initially, the total volume cargo of the port per year ($\Psi$) is equal to the total exports cargo volume ($\alpha'$) plus the total imports cargo volume ($\beta'$). If we build the total volume cargo of the port per year ($\Psi$) then we can proceed to find the total volume cargo of the port per year growth rate ($\Delta\Psi$). The $\Delta\Psi$ can show how the cargo of any port is growing across different periods of time in our case is year by year.

$$\Psi = \alpha' + \beta'$$  \hspace{1cm} (1)

$$\Delta\Psi = \frac{(\Psi')_{\text{final year}} - (\Psi_{\text{last year}}) * 100\%}{(\Psi_{\text{last year}})}$$  \hspace{1cm} (2)

Analysis of $\Delta\Psi$ Results

The results of $\Delta\Psi$ reflect two possible scenarios:
(i) If $\Delta\Psi$ rate is high, then the port experiences strong trade cargo growth.
(ii) If $\Delta\Psi$ rate is low, then the port experiences weak trade cargo growth.
Step-2: The Total Volume of Exports/Imports Cargo Operations under the National Level (λ)

The second indicator in our model is called “The total volume of exports/imports cargo operations under the national level (λ)”. This indicator is responsible to evaluate how much exports volumes and imports volumes are crossing across a port every year. The calculation of is equal to:

\[ \text{Total Exports (γ) + Total Imports (Λ) = Total Trade (Ł)} \]  

(3)

The Total Volume Cargo of the Port per Year (Ψ)/ Total Trade (Ł) *100% = λ  

(4)

Step-3: The Port Cargo Openness (Op) and the Port Cargo Openness Growth Rate (ΔOp)

In case of the port cargo openness formula is equal to:

\[ \frac{Ψ}{\text{GDP}_{\text{real prices}}} = \text{Op} \]  

(5)

In the case of the port cargo openness, this indicator will show the type of international trade policy any country carry such as import substitution industrialization (protectionism) and export oriented (free trade) (Ruiz Estrada, 2004). Hence, we are evaluating how a port is open to the rest of the world. The ΔOp is equal to the port cargo openness rate in a given period (Op') minus the port cargo openness rate of the previous period (Opo) divided by the port cargo openness rate of the previous period (Opo).

\[ \Delta \text{Op} = \frac{\text{Op'} - \text{Opo} * 100\%}{\text{Opo}} \]  

(6)

Analysis of ΔOp Results:

(i) If ΔOp rate is high, then the country experiences strong openness growth
(ii) If ΔOp rate is low, then the country experiences weak openness growth

Step-4: The TFP Port Level (T) and the TFP Port Level Growth Rate (ΔT)

In the case of TFP port level is based on a several number of variables such as education (V1): we are taking the minimum academic level requested by the port authorities; training (V2): Number of training programs annually; diet (calories): average national level of calories (V3); physical condition (V4): basic medical annual checkup per worker; life expectation (V5): average national life expectation; years of experience (V6): average years of working experiences among all staff; ratio of local and foreign workers (V7): we compare the percentage between local and foreign workers; working place security (V8): labor guaranty in the long run; technological management (V9): basic uses of technology in the working place of each worker; incentives programs (V10): allowance and commissions; salaries skills (V11): time and amount of money; retirement programs (V12): social welfare programs; management system (V13): centralized or des-centralized management systems; working hours (V14): number of hours per worker monthly.
\[ T = f(V_1, V_2, V_3, V_4, V_5, V_6, V_7, V_8, V_9, V_{10}, V_{11}, V_{12}, V_{13}, V_{14}) \]
\[ T' = f'(V_1, V_2, V_3, V_4, V_5, V_6, V_7, V_8, V_9, V_{10}, V_{11}, V_{12}, V_{13}, V_{14}) \]
\[ \vdots \]
\[ T^d = f^d(V_1, V_2, V_3, V_4, V_5, V_6, V_7, V_8, V_9, V_{10}, V_{11}, V_{12}, V_{13}, V_{14}) \] (7)

Hence, the TFP Port Level Growth Rate (\( \Delta T \)) is equal to the T in a given period (\( T' \)) minus the TFP of the previous period (\( T_0 \)) divided by the T of the previous period (\( T_0 \)).

\[ \Delta T = \frac{T' - T_0}{T_0} \times 100\% \] (8)

**Step-5: The Marginal Port Productivity Growth Rate (\( \Pi^* \))**

The marginal port productivity growth rate (\( \Pi^* \)) is based on the uses of three co-factors that we like to applied multidimensional partial differentiation simultaneously. The variables are using to measure the \( \Pi^* \) is based on the labor demand growth rate (\( \alpha \)); the equipment and machinery demand growth rate (\( \beta \)) = ratio of container crane(s) by Km²; the ratio of capacity of storage by KM² (\( \theta \)) = ratio of storage space by Km²; the ratio of disembarkation by KM² (\( \Omega \)) = ships space disembarkation; the shipping supply (\( \gamma \)) = the ratio of maintenance services, fuel supply, water and foodstuffs number of suppliers. The construction of the marginal port productivity growth rate (\( \Pi^* \)) is to evaluate the fast changes and adaptability of labor and capital in the process of the port growth expansion (see Figure 1).

\[
\Pi_1 = \left( \frac{\sum \lambda_1 [a_1 + \beta_1]^{\theta+1}}{1 - \lambda_1} \right) \times 100\%
\] (9)

\[
\Pi_1 = \left( \frac{\sum \lambda_1^o [a_1^o + \beta_1^o]^{\theta+1}}{1 - \lambda_1^o} \right) \times 100\%
\]
\[ \Pi_{n} = \left\{ \frac{\sum \lambda_{n} \left[ \theta_{n} + \Omega_{n} \right]^{\theta+1}}{1 - \lambda_{n}} \right\} \times 100\% \]

\[ \Pi_{3} = \left\{ \frac{\sum \lambda_{i} \left[ \gamma_{i} + \Omega_{i} \right]^{\theta+1}}{1 - \lambda_{i}} \right\} \times 100\% \]

\[ \Pi' = \Pi_{1} + \ldots + \Pi_{n} \]
To prove the marginal port productivity growth rate ($\Pi^*$), we will propose our mathematical framework to support our analysis. Additionally, we are going to applied estimation of the coefficients in a multidimensional distributed lag model by Wahba (1969). The main idea is to analyze the behavior the marginal port productivity growth rate ($\Pi^*$) by parts under the application of a large number of partial derivatives see bellow.

The labor demand growth rate ($\alpha$)

$$\alpha' = \frac{\Delta \alpha^*}{\Delta \alpha} \int_{\tau=0}^{\infty} \pi^0 \left( \sum_{i=0}^{n+1} (\Delta \alpha)^{i+1} \right) \times (\Delta \lambda)^{i+1} \int_{\tau=0}^{\infty} \pi^0 \left( \sum_{i=0}^{n+1} (\Delta \alpha)^{i+1} \right) \times (\Delta \lambda)^{i+1} \cdots R_+ \forall \neq 0$$

The equipment and machinery demand growth rate ($\beta$)

$$\beta' = \frac{\Delta \beta^*}{\Delta \beta} \int_{\tau=0}^{\infty} \pi^0 \left( \sum_{i=0}^{n+1} (\Delta \beta)^{i+1} \right) \times (\Delta \lambda)^{i+1} \int_{\tau=0}^{\infty} \pi^0 \left( \sum_{i=0}^{n+1} (\Delta \beta)^{i+1} \right) \times (\Delta \lambda)^{i+1} \cdots R_+ \forall \neq 0$$
Thus, we prove that the profit (\(\pi\)) is represented by

\[
\pi_i (\Delta \Psi^*) \rightarrow \Delta \Psi^* = f(\Pi_1, \Pi_2, \Pi_3) \ldots \ldots R \neq 0
\]  

(17)

\[
\pi_i'(\Delta \Psi) = \left\{ \left[ \frac{\Delta \pi_i^{'(t+1)}}{\Delta \pi_i^t} \right]^{k+1} \left[ \frac{\Delta \pi_i'(\Delta \alpha')^{-1}}{\Delta \pi_i^t} \Delta \beta' \right] \right\}
\]

(18)

Finally, we can prove that the profit and losses of any port is strongly related about the optimum combination between labor (\(\alpha\)) and capital (\(\beta\)). It is possible to be observed in the figure 2 that in the initial state of any port the profit is directly connected to the high intensity of capital (\(\beta\)) at the short run, but in the long run the profit is going to be directly connected to the intensive uses of labor (\(\alpha\)).

**Figure 2:** Ports Profit Analysis

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**Step-6: Measurement of the Port Cargo Openness/FTP Growth Rate (\(\Delta Op: \Delta T\)) Sensitivity Analysis**

This indicator measures the vulnerability of any port growth performance under the analysis of the port cargo openness growth (\(\Delta Op\)) and FTP growth rate (\(\Delta T\)) simultaneously. The main objective is to compares the trend of port cargo openness growth rate (\(\Delta Op\)) and FTP growth rate (\(\Delta T\)) behavior together.

\[
(\Delta Op: \Delta T) = \Delta Op : \Delta T
\]

(19)
Results of ($\Delta$Op: $\Delta$T) Sensitivity Analysis

The ($\Delta$Op: $\Delta$T) sensitivity analysis reflects several possible scenarios:

(i) If $\Delta$Op: $\Delta$T then the ports growth performance has good performance
(ii) If $\Delta$Op: $\Delta$T then the ports growth performance has poor performance
(iii) If $\Delta$Op: $\Delta$T then the ports growth performance has inconsistent performance
(iv) If $\Delta$Op: $\Delta$T then the ports growth performance has inconsistent performance

($\Delta$Op): port cargo openness growth rate $\Delta$: increase
($\Delta$T): FTP growth rate $\Delta$: decrease

Step-7: Plotting of Ports Growth Diamond Graph

The Ports Diamond Graph (Ruiz Estrada, 2007) presents a general idea about the current port development based on a new concept of graphic representation (see Figure 3). This new concept of graphic representation consists of six axes, each of which has only positive values. In the case of this research, the value in four of the axes is represented by the degree of ports growth (openness, productivity, cargo expansion, technological changes). These indexes are independent variables. There can be joined together to create a general area. This general area is called “area of coverage of ports growth performance (ACPG)” This area shows the dimension of ports growth performance from a general perspective. For comparison purposes, ACPG can be applied to different years for one port or two ports. The analysis of the ACPG is based on the comparison of two periods. In the case of this research paper, two periods (i.e. first period and second period) are compared. The total ACPG may present three possible scenarios, namely:

(a) Expansion (ACPG’ first period < ACPG” second period)
(b) Stagnation (ACPG’ first period = ACPG” second period)
(c) Contraction (ACPG’ first period > ACPG” second period)

The fifth and sixth axes are represented by the dependent variables $Y_1$ (port growth rate) and $Y_2$ (income growth rate). They are positioned in the center of the graph which is the meeting point of the other four axes.
3. Application of the Ports Growth Performance Evaluation Model (PGPE-Model)

Initially, the PGPE-Model was applied on twelve ports such as the port of Singapore, Hong Kong, Busan, Shanghai, Tokyo, Kobe, Yokohama, Osaka, Kobe, Ulsan, Incheon, Port Klang at Malaysia respectively (see Table 1). The period of study is between 1970 and 2010. In this period of time was chosen because we are interested to evaluate if exist a strong linkage between the marginal port productivity growth rate and four main variables of analysis. These main four variables in analysis are the port cargo openness, the productivity level, the fast cargo expansion, and the technological change adaptability. The results show that the marginal port productivity growth directly is depend on the efficient coordination of the port cargo openness, the productivity level, the fast cargo expansion, and the fast technological change adaptability. According to the PGPE-Model results is possible to observe that the most high marginal port productivity growth rate among the twelve ports in analysis is the port of Singapore (see Table 1 and Figure 4). It is followed by the port of Hong Kong, Busan, Shanghai, Tokyo, Kobe, Yokohama, Osaka, Kobe, Ulsan, Incheon, and Klang respectively. The last place among the twelve ports is analysis was Port Klang at Malaysia. We can observe a high ports openness, but low cargo expansion, a low productivity, and slow technological change adaptability (see Table 1 and Figure 6). The lower marginal port productivity growth rate in Port Klang request the help from the central government of Malaysia to supply high levels of subsidies to reduce the high cargo costs according to the PGPE-Model.
FIGURE 5: THE PORTS GROWTH DIAMOND FOR PORT OF SINGAPORE

\[ Y^* = \text{The Marginal Port Productivity Growth Rate (} \Pi^* \text{)} \]

FIGURE 6: THE PORTS GROWTH DIAMOND FOR PORT KLANG (MALAYSIA)

\[ Y^* = \text{The Marginal Port Productivity Growth Rate (} \Pi^* \text{)} \]
### Table 1:
Ports Growth Performance Evaluation Model (PGPE-Model) Results

<table>
<thead>
<tr>
<th>PORT</th>
<th>Port Openness</th>
<th>Productivity Level</th>
<th>Cargo Expansion</th>
<th>Technology Change Adaptability</th>
<th>The Marginal Port Productivity Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>0.97</td>
<td>0.95</td>
<td>0.99</td>
<td>0.99</td>
<td>0.975</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>0.95</td>
<td>0.91</td>
<td>0.95</td>
<td>0.99</td>
<td>0.95</td>
</tr>
<tr>
<td>Shanghai</td>
<td>0.90</td>
<td>0.89</td>
<td>0.99</td>
<td>0.90</td>
<td>0.92</td>
</tr>
<tr>
<td>Busan</td>
<td>0.95</td>
<td>0.91</td>
<td>0.89</td>
<td>0.93</td>
<td>0.92</td>
</tr>
<tr>
<td>Tokyo</td>
<td>0.85</td>
<td>0.92</td>
<td>0.91</td>
<td>0.95</td>
<td>0.90</td>
</tr>
<tr>
<td>Klang</td>
<td>0.55</td>
<td>0.35</td>
<td>0.37</td>
<td>0.35</td>
<td>0.40</td>
</tr>
</tbody>
</table>

4. **Conclusion**

Firstly, this paper conclude that to generate a high marginal port productivity rate is necessary to have an efficient coordination of the port cargo openness, the high productivity levels, the fast cargo expansion, and the fast technological change adaptability simultaneously according to PGPE-Model results.

Secondly, the same model shows that a high marginal port productivity level is based on how the human capital factor can be adapted to the fast new maritime and ports technologies changes adaptability. It is possible to be demonstrated by our mathematical modeling that is included in this paper.

5. **References**


