Port City Factors and Port Production: Analysis of Chinese Ports

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Abstract

The objective of this article is to analyze port production activities and city factors in port cities. Port activities take place in port cities and the analysis provides a good opportunity to integrate the study of ports and cities. The study uses the economic production equation to analyze the production of China's ports over the time period 1995–2007. Numerous studies have examined general port growth and development on the basis of conceptual discussion. It is generally accepted that the Anyport Model and the Port Generation Model are valuable models for analysis of a port developing into a port city. However, empirical studies on port growth and factors that influence the growth rate are rather few. This study seeks to identify the city factors that are critical in determining port growth and attempts to develop an empirical model in the macroeconomic perspective. Seven major China port cities and their interfaces with their associated ports are studied here. This article attempts to analyze the port activities as economic production outputs and the city factors as inputs. The article provides an empirical analysis of port growth and policy insights on the interdependence between ports and port cities.

Globalization is a trend in the business world. Businesses are all looking globally for effective logistics solutions. In the shipping and port industry, logistics integration is reinforced by globalization. Forming networks with neighbor ports and having strategic alliances with remote destination ports are common practices. The ports can enhance efficiency, strengthen

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competitiveness, and achieve synergy effects and economies of scale. The role of ports is broadened and elaborated from a simple sea-shore interface to a comprehensive logistics center. The port is developed from an isolated facility to a community asset. The port and city are then interrelated and interdependent, and a "port city" is a spatial location having the functions of port and city. A port facilitates the growth of its city and regional economy, whereas the growth of the city pushes the development and evolution of its port. The city and port issues may be complementary as well as contradictory. On the one hand, successful ports around the world are often city ports. On the other hand, the port and city interface is one of the major determinants of the degree of success of modern ports, and therefore the formation of major port cities.

Both ports and cities tend to focus on a global outlook, logistics integration, and transportation networks. Under globalization, there exists a close relationship between port and city developments; city ports (and therefore port cities) serve the global markets with integrated logistics and supply chain flows. In the modern shipping and port industry, in order to facilitate efficiency and trades, globalization encourages standardization in shipments and cargo handling. Containerization is the consequence. Containerization advances the port facilities and develops cities. Major city ports acquire advanced container terminals. The port cities also develop integrated logistical facilities to support the port operations and the city activities.

China is a continuously growing country in terms of economy and world position. The world is now looking into China for opportunities. With the establishment of the China Open-Door Policy in 1978 and the entrance of China into the World Trade Organization (WTO) in 2000, trade plays a crucial role in the growth and development of ports and coastal cities as well as economies in China. In addition to development of the long coastal line, the development of sea-bound international trade in China undoubtedly has a bright future. In order to attract more foreign investment, 14 coastal cities were opened in 1984. There has been rapid growth of port cities in China since the 1990s, particularly after China joined the WTO. China's national throughput increased from 802 million tonnes in 1995 to 3,882 million tonnes in 2007, which represents an average annual growth rate of about 15 percent. Port cities in China are facing a highly dynamic environment, making them a good case to study in carrying out the analysis described here.

For the city development, ports are an important source of employment, both directly and indirectly through associated activities and industries;

ports also constitute a major facility in the commercial development of a city. The effects of city development on the port activities are quite important for planners and managers of the ports and cities to keep in mind. This article aims to explore the economic function of port cities and their evolution by considering the port production versus various factors of port cities.

Literature Review

A substantial body of research in urban development embraces the study of industrial production and urban development, for example, Chapman and Walker (1991); Fleming and Hayuth (1994); Fujita, Krugman, and Venables (1999); Chakravorty, Koo, and Lall (2005); and Vicente and Suire (2007). Previous studies are concerned mainly with the internal structures of cities and the spatial aspects of urban activities. Empirical studies on port growth and factors that influence the growth rate are few.

From the geographical perspective, a port city can be classified into two spatial scales. At a local scale, a port city is the "area in transition" where port and urban jurisdiction and functions interact (Hoyle 1989). At a wider scale, assuming a land-sea connection, a port city is the nodal system as a whole within a regional area, consisting of multiple cities and ports (Ducruet and Jeong 2005). From the economic perspective, a port city is a city with port functions, whereby the city functions and port functions keep a balanced combination of centrality and intermediacy (Ducruet 2005). A port city is a product of the integration of port and city. Not only can it reflect the common characteristics of a general city, but it also has its specific contents and rules of movement (Ducruet and Lee 2006).

There are two hypotheses regarding the evolution of port and city: growth tends to be led by the port and growth tends to be led by the city. In the port-led growth model, port development is described in the Anyport Model with six stages (Bird 1963). Starting from the initial port site with small lateral quays adjacent to the town center, the development of wharfs is the product of evolving maritime technologies and improvements in cargo handling. This stage is also marked by changing spatial relationships between the port and the urban core, as docks are built farther away from the central business district. In the final stages, increased specialization of cargo handling, growing sizes of ships, and ever-increasing demands for space for cargo handling and storage result in port activity being concentrated at sites far removed from the oldest facilities.

The Anyport Model implicates the changing relationship between ports and their host cities. It describes the growing repulsion by the rest of the urban milieu. This aspect has been studied over the last two decades by a number of geographers investigating the redevelopment of harbor land. Hoyle (1989) proposed the Anyport-City Model to emphasize the changing linkages between the port and the city, instead of stressing the port infrastructure development. One of these urban linkages is the redevelopment of old port sites for other urban uses.

The Port Generation Model suggests that a port will experience generations of development (UNCTAD 1992). A port begins as an interface between land and sea transport. A local port grows into a regional port with connections and cooperation with nearby ports, and associated infrastructure develops in order to support the cargo transfer. A port may transform into a global port, which is the fourth generation port. In the aspect of connecting to the rest of the world and being one of the nodes of the global network, containerization, mechanization, and the establishment of the supply chain are crucial. Even more sophisticated transportation and infrastructure are built to cater to the new port production components.

Unlike previous port city studies in the literature, a more quantitative approach—regression analysis—is applied to analyze the ports and cities in which multiple city variables may play a part in port production.

The Port Model of City Factors

Rather than remaining static, a port city may be constantly growing over time. The port growth can be quantified by the port's activities. The port production should be the most remarkable factor of port activities. We consider a port city as a production organization, the port production as the output of the organization, and the city factors as factors of production. In other words, the port factors (port throughput, freight turnover, total trade value) are treated as the port production, which is the combined result of city factors of production (equation 1). The overall production of a port can be represented by Cobb-Douglas production function (equation 2).

(1) production = f (labor, capital, land)
(2) $Y = A\,L^{\alpha} K^{\beta} D^{\gamma}$

where Y = total port production (the monetary value of production in one year); L = labor input; K = capital input; D = land input; A = constant; α, β, and γ = constant output elasticities of labor, capital, and land, respectively.

Output elasticity measures the responsiveness of output to a change in levels of either labor or capital used in production. For example if $\alpha = 0.15$, a 1 percent increase in labor would lead to an approximately

0.15 percent increase in output. Applying to the port city, for example, "land" can be quantified by the "infrastructure," "capital" by "economic" factors and "labor" by "demographic" factors. The city factors affect the port factors and facilitate the port development, and vice versa. The port production is, therefore, the combined result of all the city factors. Presenting the factors by function formula (equation 3), port production is the dependent variable; whereas economic, demographic, and infrastructure factors are independent variables in the given years. For easy comparison and statistical calculation, the factors are transformed into logarithmic form, as shown in equation 4.

(3) port production = f_1(economic, demographic, infrastructure)
(4) ln port production = f_2(ln economic, ln demographic, ln infrastructure)

where port production = port throughput, or freight turnover, or total trade value; economic = g_1 (GDP, GDP per capita); demographic = g_2 (population, total employment, employment in tertiary sector); infrastructure = g_3 (fixed assets investment, contracted foreign direct investment); and ln = log of the figure of the year.

Without loss of generalization, the port production can be physical or economic production in equations 1 and 2. Combining port production and factors of port production, we arrive at equation 5.

$$(5) \quad \ln Y = \ln A + \alpha \ln L + \beta \ln K + \gamma \ln D$$

where ln Y is the factor quantifying the port growth rate. In order to test the robustness of the model, three different quantities will be used to denote port production as the dependent variable.

Data and Analysis

Table 1 summarizes the data collected from *China Statistical Yearbooks* (1996 to 2007). The seven ports are the leading ports in China. The data for the port and data for the city in which the port is located are then collated. The data is collected from both cross-sectional units (i = 1, 2, . . . , N) and over time (t = 1, 2, . . . , T). This type of data is known as panel data or cross-sectional time-series data. The fundamental advantage of a panel data set over a cross-sectional is that the panel data allows greater flexibility in modeling differences across individuals and over time.

The findings are generated by EViews 6 (Startz 2007) and result from analysis of the port growth rate and corresponding city factors of

Table 1/Data on Port and City Factors, 1996–2007

	Production			Economic		Demographic			Infrastructure	
	Port throughput 10k tons	**Freight turnover 100m ton-km**	**Trade value total 100m USD**	**GDP 100m USD**	**GDP per capita**	**Population 10k persons**	**Total employment 10k persons**	**Employment in tertiary 10k persons**	**Investment in fixed asset 100m Yuan**	**Contracted FDI 100m USD**
Dalian	6,417–22,286	307–3,700	57– 363	733–3,131	13,676–51,630	537–578	85–280	42–12	115–1,931	24–59
Tianjin	5,787–30,946	73–14,717	65–716	918–5,018	10,281–45,829	942–1,115	403–614	159–276	393–2,389	35–115
Qingdao	5,103–26,507	1,440–3,648	86–457	710–3,787	10,331–45,399	690–758	103–393	42–254	79–1,635	7–95
Shanghai	16,388–49,227	117–15,789	190–2,830	2,463–12,001	18,943–66,367	1,415–1,858	670–906	284–503	1,602–4,459	15–149
Ningbo	6,853–47,336	95–978	39–565	638–3,435	12,156–66,067	526–565	57–414	30–96	146–1,598	5–45
Xiamen	1,314–8,117	74–519	76–398	308–1,388	19,743–56,188	123–167	49–96	15–32	79–928	7–33
Shenzhen	3,080–19,994	171–772	388–2,875	796–6,802	23,381–79,645	103–212	93–272	41–100	186–1,345	12–86

Source: *China Statistical Yearbooks*, 1997–2008 seven port cities from 1996 to 2007. The correlation test is used to test the correlation between port and city factors. Port factors (i.e., port throughput, freight turnover, and total trade value) are tested with city factors one by one. As shown in table 2, the correlations among port factors and city factors can be statistically supported. Based on the significance of the city factors to port factors, the model specification of Cobb-Douglas production function is then tested.

Table 3 summarizes the pooled ordinary least squares (OLS) regression outputs of the port production and city factors, where each of three models uses one single port factor as port production. The R-squares are 0.933, 0.691, and 0.961, indicating the high explanatory power of the proposed models. Therefore, the city factors can be used to predict the port production. Regarding the level of significance, the factors are statistically and highly significant when the p-value is smaller than 0.01 (**) and are marginally significant when the p-value is smaller than 0.05 (*). If the significant level is larger than 0.05, the independent factor will not be considered significant to the dependent factor. As the three models show similar regression results, the finding is robust and independent of different ways to define the port production. However, there are some discrepancies of variable signs among the three models.

Table 4 shows the estimates of fixed effects model with cross-section fixed. While the pooled regression assumes that there is no difference among port cities, the fixed effects regression includes the constant difference term for each port city. The coefficients are similar for the pooled OLS and fixed effects estimations. The two estimations are reported for comparison only. Discussion is based on the pooled model.

Table 2/Correlation Coefficient (R) of Port Production Versus City Factors

		Port production		
		Throughput	**Freight**	**Trade**
Economic	GDP	0.888**	0.693**	0.824**
	GDP per capita	0.373**	0.188	0.804**
Demographic	Population	0.700**	0.703**	0.025
	Total employment	0.444**	0.613**	0.305**
	Employment in tertiary sector	0.541**	0.642**	0.376**
Infrastructure	Fixed asset investment	0.810**	0.672**	0.771**
	Contracted FDI	0.728**	0.703**	0.693**

Variables in logarithms:
* Correlation is marginally significant if $p < 0.05$ (2-tailed)
** Correlation is statistically significant if $p < 0.01$ (2-tailed)

Table 3/Pooled OLS Estimates of Port Production Versus City Factors

		Port production		
		Throughput	**Freight**	**Trade**
Economic	GDP	1.086** (9.341)	−0.031 (−0.058)	1.280** (10.976)
	GDP per capita	−0.081 (−0.591)	0.782 (1.288)	0.231 (1.696)
Demographic	Population	0.526** (7.966)	1.091** (3.938)	−0.750** (−12.004)
	Total employment	0.063 (0.471)	0.608 (0.991)	0.331* (2.542)
	Employment in tertiary sector	−0.452** (−3.071)	−0.469 (−0.71)	−0.104 (−0.724)
Infrastructure	Fixed asset investment	−0.081 (−1.056)	−0.079 (−0.226)	−0.116 (−1.524)
	Contracted FDI	−0.052 (−0.946)	0.602* (2.604)	0.256** (4.621)
	Constant	1.006 (0.802)	−10.471 (−1.949)	−3.201* (−2.611)
	R^2 Adjusted R^2	0.933 0.927	0.691 0.659	0.961 0.957

Variables in logarithms (t-statistics in parentheses):
* Correlation is marginally significant if $p < 0.05$ (2-tailed)
** Correlation is statistically significant if $p < 0.01$ (2-tailed)

Table 4/Fixed Effects Estimates of Port Production Versus City Factors

		Port production		
		Throughput	**Freight**	**Trade**
Economic	GDP	1.191** (5.681)	1.563 (1.206)	1.569** (5.085)
	GDP per capita	−0.187 (−1.000)	1.111 (0.931)	0.262 (0.917)
Demographic	Population	−0.334 (−0.837)	−1.667 (−0.682)	−1.542** (−2.813)
	Total employment	0.107 (1.342)	−0.185 (−0.334)	0.055 (0.441)
	Employment in tertiary sector	−0.062 (−0.624)	0.346 (0.537)	0.130 (0.843)
Infrastructure	Fixed asset investment	0.002 (0.032)	−0.413 (−1.250)	−0.195** (−2.672)
	Contracted FDI	0.055 (1.662)	−0.194 (−0.898)	0.167** (3.157)
	Constant	3.877 (1.45)	−3.072 (−0.185)	0.481 (0.127)
	R^2 Adjusted R^2	0.985 0.982	0.838 0.804	0.977 0.973

Variables in logarithms (t-statistics in parentheses):
* Correlation is marginally significant if $p < 0.05$ (2-tailed)
** Correlation is statistically significant if $p < 0.01$ (2-tailed)

As can be seen in table 3, economic and demographic factors are highly significant to port throughput in general. In the "throughput" model, the GDP, the population, and the employment in tertiary sector are significant to the port throughput. The "freight" model is least statistically satisfactory, in which only the population and the contracted FDI are significant in the model. The "trade" model shows the most satisfactory results, and the GDP, the population, the total employment, and the contracted FDI are significant to the total trade value.

The significance of economic and demographic factors to port production is understandable. In a port city, the port and city are interdependent and the economic factors will affect the capital input to port and the demographic factors would affect the labor input. Nevertheless, apart from the total trade value, the significance of fixed assets investment (FAI) and contracted FDI are not obvious.

It is believed that the growth in FAI and contracted FDI are compatible with the port production of a port city. The low significance of FAI and contracted FDI may be attributed to not considering the time lags in generating the regression analysis of the economic production model. Investment on fixed assets such as superstructure in port and infrastructure of the city take a long time to complete. The investment decision may be made on the basis of performance of previous years. Similar to investment in fixed assets, the contracted FDI of a year may contribute to the port production in later years. The effect and significance of FAI and contracted FDI to port production cannot be immediately represented well by the annual data. Moreover, the contracted FDI usually involves investing in businesses such as commercial banks and manufacturers, which are not directly related to port production. The contracted FDI is related to the capital input of a city. Therefore, the significance of contracted FDI to port production is also very low.

Table 5 shows the port city means obtained from the fixed effects regression model. Port cities in south China (e.g., Shenzhen, Xiamen) face a lower elasticity of port production to city factors than port cities in northeast China (e.g., Tianjin, Qingdao). As the port production is higher in south China than in northeast China, the finding supports the explanation that the port production faces diminishing returns of city factors.

Discussion and Implications

The port and city interface of the national port cities is identified. The investigation of the port and city interface answers the two fundamental

Table 5/Fixed Effects: Port Production Means

Port City	Port production		
	Throughput	Freight	Trade
Dalian	0.366	0.279	−0.083
Tianjin	0.052	2.496	0.592
Qingdao	0.329	1.865	0.549
Shanghai	−0.139	1.974	0.864
Ningbo	0.668	−0.855	−0.124
Xiamen	−0.382	−2.499	−0.773
Shenzhen	−0.975	−4.231	−1.104

questions: (1) how ports facilitate city functions; and (2) how cities support port functions.

How Ports Facilitate City Functions

Port functions, from a primitive port to a sophisticated port, are direct cargo flows, simple trade, cargo handling, transshipment, warehousing, consolidation and information flow, and other high value adding services. In the parameters of equation 3, the port factors are port throughput, freight turnover, and total trade value. At each enhancement and development of the port, the related city is benefited.

When the port's production increases with more than simple cargo flow and handling (e.g., transshipment), start-up medium-scale trading companies emerge around the port to work with shippers. These trading companies can improve the efficiency of cargo handling and, therefore, increase the freight turnover of port. Meanwhile, around the trading companies, which are sources of goods, markets and trade fairs occur, and formal commercial activities such as banking and financing begin. With commercial activities in the markets, traders and sellers require storage space for incoming or outgoing cargoes and therefore use the port as the warehouse function in a supply chain.

From time to time, when trading is growing around the port and the economy is rising in the city, port throughput can satisfy the growing demand of goods and different commodities. To further facilitate economic activities in the city, infrastructure such as highways and railways are constructed to transport the cargo from the port to the city. Apart from carrying cargo, infrastructure also carries population into the city from other areas.

Meanwhile, the consolidation and value added services provide inducement to traders to stick with the port. With a fully functioning port and well-established commercial activities and infrastructure, ports can attract investment from the region nearby and overseas. In a port city, a productive port with a comprehensive package of services is beneficial and crucial to the development of city functions. The port and city interface helps the economic growth and demographic upgrading of the city.

How City Favors Port Functions

City functions, ranging from a little village to a big city, contribute to improved quality of life of the people who live in the city, for educational, commercial, manufacturing, and political reasons. In the framework of the port model, city factors of a port city are economic factors (GDP and GDP per capita), demographic factors (total employment and employment in the tertiary sector), and infrastructure factors (fixed assets investment and contracted foreign direct investment). For each enhancement of the city, the associated port benefits. The city factors are also statistically significant to the indicators of port productivity.

When markets and trade fairs start to emerge around the port, the cargo at ports can be distributed quickly. The berthing time at a port can be shortened and more trade is attracted, resulting in increased freight turnover. When the commercial activities grow in the city, more goods are unloaded from incoming vessels. Having more port calls can increase the port throughput and the numbers of direct shipments and transshipments. Meanwhile, the rise in commercial activities enhances the economic conditions of the city as the port engages in more trade and the total trade value moving through the port increases.

Moreover, to facilitate trade, infrastructure such as railways, highways, and bridges are built. With these infrastructures, the connectivity between the port and the outer areas of the city can be achieved. The linkage between the port and the entire city and surroundings attract population to the city. The population can be employed in the port-related, value-added, and supporting logistics services, which is the tertiary sector. These services help to make the port more competitive.

As the port production continues to rise, the performance of the port becomes advanced and attracts more capital from the city for port enhancement and expansion. The port can, therefore, become sophisticated and world ranked. In a port city, mature city development is essential and critical to port functions. The port and city interface helps the development and the specialization of the port to be globally competitive.

Conclusions

An economic production model is developed to study port production versus city factors that contribute to port operations. The economic production of ports is specified by the Cobb-Douglas production function. Regression analysis is applied on port production and city factors by assuming a port city as a production organization. It has been recognized that the city economy is the most significant contributor of port production growth, but there are no consistent results about the effects of infrastructure and demographic factors. This study offers statistical evidence supporting the city-led evolution of port cities and provides a solid foundation to derive economic policies of port development.

Previous conceptual discussion and qualitative analysis have been very fruitful in understanding the mechanisms of port city evolution. This article contributes to the issues of the port city development model by using quantitative analysis to analyze the port activities and city factors.

However, further research is needed to compare the port growth models across the world and to explore the explanatory power of various model specifications. A limitation of this study is that it is based on the seven port cities in China. It is possible that the results of this study are affected by the bias of export-oriented ports. China is regarded as one of world's manufacturing centers, and Chinese ports are export-oriented. To overcome this limitation, future research should involve gathering data from ports across the world that are import-oriented or balanced in imports and exports.

Another limitation of this study is that the fourth generation ports may not be associated with physical production. As pointed out by Campbell (1993), in a global port the port and city relations are separated. The global port appears to be a stand-alone asset of a city. Thus, some port activities seem to be not related to its associated city's physical activities, especially ports with high levels of transshipments. Since this article discusses the economic production of port cities, the model should be applicable to transshipment ports. Under the forces of globalization, the structures of port cities will be complicated and diversified. This study should be extended to consider some other city inputs and other modes of port city evolution. This is important because future port city planning should include the port management.

Note

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