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Path to a multilayered transshipment port system: How the Yangtze River bulk port system has evolved

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A R T I C L E I N F O

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A B S T R A C T

China's steel output has maintained rapid growth over the past twenty years. Due to this, a large number of iron ore ports/terminals have been built along the Yangtze River, and the Yangtze River bulk port system has experienced a unique development in its structure. This paper aims to understand the evolution of this bulk port system.[1] along the Yangtze River. To achieve this objective, first the development phases of the Yangtze River bulk port system are reviewed, taking the theoretical (container) port evolution model as a benchmark. Then several hypotheses addressing certain features of bulk port system development are proposed, followed by using panel data analysis to test these hypotheses. Based on this discussion and analysis, the major driving forces that are reshaping bulk port development along the Yangtze River are then summarized. It is found that evolution of the Yangtze River bulk port system in general follows the port development models in previous literature. However, the trend toward regionalization and an offshore hub have not appeared. Besides this, iron ore transshipment is moving outward both for sea ports and river ports, and few iron ore transshipment gateway hubs are occurring. Furthermore, the transshipment function of a bulk port plays a significant role in port traffic changes, but this role is affecting sea ports differently to river ports. The container throughput of transshipment sea ports has a significant negative effect on bulk traffic, whereas that of transshipment river ports has a positive effect. Geographical conditions, institutional factors and national policy, industry agglomeration, changes in market supply and demand, and technology updates are major factors driving changes to the port system structure. These factors are observed to function either individually or collectively at different development stages.

1. Introduction

China has been the world's leading producer of steel since 1996, and in 2014 its steel production reached 822.7 million tons. This ranked No. 1 in the world, and was almost 8 times that of Japan's production (110.7 million tons), which ranked No. 2 (World Steel Association).

Iron ore is the main raw material needed for steel production, yet China's domestic supply of iron ore is far from meeting the demand for its steel production. Thus, every year China imports massive amounts of iron ore from other countries. For example, 933 million tons were imported in 2014, which accounted for 80.1% of the total demand in China. Since the 1950s, many steel manufacturers have been founded alongside the Yangtze River, and Table 1 lists each major steel manufacturer, together with its year of founding and paired port.

Iron ore is the most important bulk cargo shipped along the Yangtze River. To support such fast growth in imported iron ore along the Yangtze River, over recent decades many bulk ports or terminals have been constructed in this region. Shanghai, Ningbo, Zhoushan and Lianyungang are four sea ports close to the Yangtze River that act as transshipment gateway ports between ocean transportation and river transportation. Due to its unique geographical features, the Yangtze River can be divided into three segments, namely, the mouth of the Yangtze River, the low Yangtze River and the middle and upper Yangtze River, as Fig. 1 shows. Ports at the mouth of the Yangtze River have good water depth, and can accommodate ships of up to 200,000 dwt (Dead Weight Tonnage). The water depths of ports along the lower Yangtze River vary though; for instance, Suzhou and Nantong, which are located at the mouth of the Yangtze River, have a 12.5-meter water

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[1] In this paper, bulk cargo mainly refers to iron ore bulk cargo.

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Table 1
Major steel manufacturers and year of founding.

Port	Steel plants	Year	Port	Steel plants	Year
Shanghai	Baosteel	1985	Suzhou	Sha Steel	1992
Nanjing	Nanjing Steel	1959	Suzhou	Yonggang Steel	1984
Jiangyin	Xingcheng Steel	1993	Ma'anshan	Ma Steel	1993
Jiujiang	Nanchang Steel	2001	Wuhan	Wuhan Steel	1958
Chenglingji	Valin Steel	1997	Chongqing	Chongqing Steel	1997

Sources: Steel manufacturers' web sites.

depth, and can handle ships of 150,000 dwt. The water depths at Jiangyin and Nanjing are approximately 7 to10 meters, and can therefore only accommodate ships of 50,000 to 100,000 dwt, depending on the tide. Ports upstream of Nanjing, such as Ma'anshan, Wuhan and Chongqing, can only be accessed by smaller ships of maximum 10,000 dwt, due to the low height permitted by the Nanjing Yangtze River Bridge. Fig. 1 shows a map of ports along the Yangtze River.

Since 1960, the evolution of port networks has attracted a lot of attention, and in recent years, some researchers have also extended their studies to river port system evolution, such as the Pearl River Delta port system (Wang, 1998; Wang and Slack, 2000; Liu et al., 2013) and the Yangtze River port system (Veenstra and Notteboom, 2011; Wang and Ducruet, 2012; Zheng and Yang, 2016). However, it is noted that all these studies focus only on container ports. Over the past 30 years, though, the bulk port system along the Yangtze River has developed very quickly and experienced dramatic changes. It is therefore of great benefit to investigate the evolution of this bulk port network along the Yangtze River by answering the following questions: What has been the development path of the bulk port system along the Yangtze River? What are the differences between the development path of a container port system and a bulk port system? What are the driving forces that shape the structure of a bulk port system? This paper aims to address these questions by first reviewing the development phases of the bulk port system along the Yangtze River, and then conducting an empirical analysis.

This paper attempts to augment the existing literature on port systems by adapting port development models to river ports, and by adding the development pattern of a bulk port system. In addition, this paper will employ panel data analysis, using a significant amount of data to empirically test several hypotheses that are inspired by the proposed questions. It is believed that this paper will substantially increase the understanding of a theoretical port development model, as well as provide clues that will assist the future development of bulk port systems on inland rivers.

The paper is organized into five sections. Section 2 reviews and summarizes existing literature on port system evolution. Section 3 analyzes the development phases of the Yangtze River bulk port system whilst constantly referring to the theoretical port development model. Section 4 empirically tests several hypotheses regarding certain features of bulk port system development. Based on this analysis, Section 5 summarizes the major driving forces involved, and Section 6 highlights the conclusions that can be drawn.

2. Literature review

Taaffe et al. (1963) initially studied the development of a port transport network in Ghana and Nigeria. Hayuth (1981) put forward the concept of containerization and load centers, and divided the port evolution process into five phases: Conventional ports, container ports, port concentration and inland penetration, load centers, and port decentralization. Notteboom (1997) introduced Hayuth's model when analyzing the port system in Europe, and compared the differences between European and US port systems. He pointed out that the concentration of European ports was a result of container traffic shifting to medium-sized ports, rather than just the challenges from peripheral ports. Later, Notteboom and Rodrigue (2005) added the port regionalization phase to the port development path, which links gateway sea ports to the inland transport network. Rodrigue and Notteboom (2010) extended this conceptual structure by introducing foreland regionalization, which refers to the capture of maritime hinterland by intermediate offshore hubs, and the integration of transshipment hubs into regional shipping networks.

Hayuth and Notteboom's classic port development conceptual models were widely applied in studying regional port systems all over the world, and were adjusted for geographical scale. Notteboom (2006) described port regionalization in the port of Antwerp, which started to develop the hinterland network, including inland terminals and logistic poles. Wilmsmeier and Monios (2013) identified a potential deconcentration of container traffic within the UK port system, with a shift from gateway ports to transshipment hubs. Wilmsmeier et al. (2014) examined the container movements of Latin America and the Caribbean between 1997 and 2012. They performed a detailed analysis of the evolution from mature hub-and-spoke networks and port devolution to the undermining of the hubs and the rise of new secondary hub-and-spoke networks.

The container port system in the Pearl River Delta (PRD) in China has also attracted a lot of attention. Wang (1998) divided the evolution of the PRD port system from the 1970s to 1995 into three stages, during

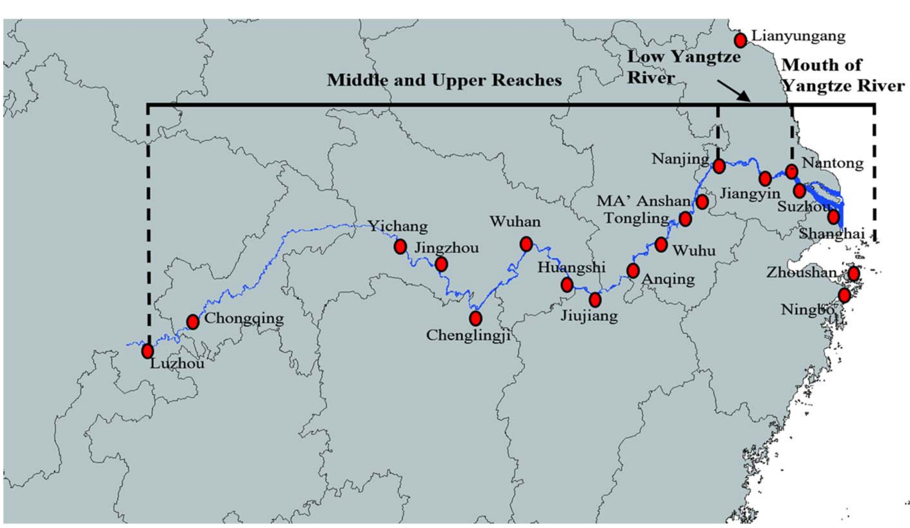

Fig. 1. Main ports and their corresponding steel manufacturers along the Yangtze River.