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The emergence and spatial distribution of Chinese seaport cities

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Michael Funke and Hao Yu: The emergence and spatial distribution of Chinese seaport cities

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Abstract

Seaports have historically played a key role in facilitating trade and growth. This paper is the first attempt in the literature to analyse the formation of Chinese seaport cities and the dynamics that drives it. First, we aim to identify theoretically the emergence of urbanized seaports with the help of a formal economic geography model. Second, employing an empirically plausible parameterisation of the model, we calibrate the evolutionary process and spatial distribution of seaports along the Chinese coastline.

Keywords: Seaports, cities, economic growth, China
JEL-Classification: R11, R12, R41

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Tiivistelmä

Satamakaupungit ovat kautta historian merkittävästi helpottaneet kaupankäyntiä ja talouskasvua. Tämä tutkimus on ensimmäinen, joka analysoi Kiinan satamakaupunkien muodostumista ja niiden muodostumista ajavaa dynamiikkaa. Formaalilla talousmaantieteellisellä mallilla identifioidaan teoreettisesti urbaanien satamakaupunkien synty. Lisäksi käyttämällä empiirisesti mahdollisia parametriarvoja tutkimuksessa kalibroidaan satamakaupunkien kehitys ja alueellinen jakautuminen Kiinan rannikkoalueella.

Avainsanat: satamakaupungit, kaupungit, talouskasvu, Kiina.
JEL-koodit: R11, R12, R41.

1 Introduction

In a rapidly globalising world, the maritime sector has been a significant factor in facilitating the integration of markets for manufactured goods, with seaports operating a natural gateway to countries across the globe. Since world trade grows significantly faster than world output, foreign trade plays an increasingly important role in the development of national economies. Particularly in East and South East Asia, the enormous industrial success has been closely linked to the development of intermodal transport and has led to Asian dominance in container traffic. In fact, seaports constitute the backbone of the transport network without which today's global economy could not exist in its present form. It should be noted that, of the top 25 seaports in the world port traffic league ranked by containers handled 1999-2003, 15 form what can be likened to a string of pearls, stretching from Singapore to Tokyo. In all, 7 of these seaports are located in China.[1]

The new economic geography, new trade theory, and endogenous growth models have highlighted the nexus between geographic location and economic growth. Conclusions emanating from this line of inquiry are: (a) landlocked regions and countries trade less with coastal regions or countries, and (b) coastal regions and maritime countries on average post higher growth than landlocked regions and countries. For example, Démurger (2001) and Démurger et al. (2002) have demonstrated that transport facilities are a key differentiating factor in explaining regional growth disparities across China. Bruinsma et al. (2000) find that transport infrastructure is a significant determinant of the location decisions of footloose multinational firms, and that these firms tend to locate in particular high-value-added sectors in close proximity to a seaport. Furthermore, Kawakami and Doi (2004) have presented empirical evidence that seaport capital has Granger-caused economic development in Japan.

The tremendous explosion of foreign trade has also created a situation wherein ports today are not only redistribution centres but also generate a wide range of commercial activities and become entrepôts, i.e. commercial centres with related industries. Given these developments and their immense economic importance, it is a surprising omission in the literature that the emergence and growth of seaport cities in China has not been studied in greater detail. In order to fill this gap and explore this unchartered territory, the present paper will employ a theoretical modelling framework that facilitates rigorous investigation of the hypothesis that seaports are a fertile ground for indus-

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[1] Arguably, this development of waterborne container traffic illustrates the shift in the gravity centre of global economic activity. The emergence, and now dominance, of Asia in container traffic stands out.

trial concentrations. The geographical economics modelling approach laid out below incorporates location, increasing returns to scale, imperfect competition, and transport costs, in conjunction with mobility of factors of production. These modelling ingredients enable us to discover what allocation of seaport cities in China has been the most efficient.

The remainder of the paper is divided into three parts. Section 2 provides the historical context for the subsequent analysis. Section 3 is devoted to the modelling, which serves to map out the formation of Chinese seaports with a developed industrial urban character. In Section 4 we present some model simulation results. Finally, some conclusions are given in Section 5.

2 Historical background

China before the First Anglo-Chinese War (1839-42), popularly known as the "Opium War" was closed to the West, and foreign trade was strictly controlled by the Chinese government. Ultimately, this was much more than a war about opium trade. Rather, the fundamental change which brought confrontation was the Industrial Revolution. Technological innovations, advances in communication and improvements in organisational capacities in Europe had enabled Britain, as the leading European nation, to capture markets and project power overseas.

Brought about by the insulate attitude of the Chinese Empire, late imperial China exercised strict control over its foreign trade. External trade was organized by the "Guangzhou Trade System", since only the seaport of Guangzhou in southern China was open to foreign trade.[2] Having reached Guangzhou, the Western merchants could only deal with a group of government appointed merchants that had a monopoly on the trade with the West. The volume of the trade and the prices were also regulated.

After its defeat in the Opium War, China was forced to open up. The unequal Treaty of Nanjing (August 1842) and subsequent treaties signed after the war were the primary means of opening China along with its markets and resources. They radically increased China´s trade openness and opened additional treaty seaports, including Shanghai. Under the Treaty of Nanjing, China also ceded the island of Hong Kong. In the 1850s, the western countries grew increasingly dissatisfied with both the terms of their treaties with China, and the Qing Government's failure to adhere to them. The British forced the issue by attacking the Chinese port cities of Guangzhou and Tianjin in

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[2] Additionally, Portugal had established a foothold in Macau in 1557 and other nations were allowed to trade with China through the seaport of Macao.

the second Opium War (1857-1860). In 1860 a combined British French army attacked Beijing and burned down the Old Summer Palace. The Treaty of Tianjin signed after the war granted the western countries further rights and privileges. The number of treaty seaports increased further, with new ports opened to Western trade along the Chinese coast, and along the Yangtze River in the interior.

On the economic side, the opening-up of the country meant that China had lost its own economic protection against the influx of cheap foreign goods. The domestic handicraft industry was hard hit, and this engendered social and economic dislocations in China. But new technologies also arrived in China - the railroad, the telegraph - along with new administrative technologies and new ways of organizing financial institutions. The Chinese were quick to take advantage of these opportunities, and a tide of modernization and integration was on the rise.[3] In other words, the Industrial Revolution changed the landscape.[4] Small towns grew into huge cities, and urbanized seaports began to develop. A schematic spatial mapping of Chinese seaports at that time is given in Figure 1.

Figure 1 Formation and location of urbanized Chinese seaports

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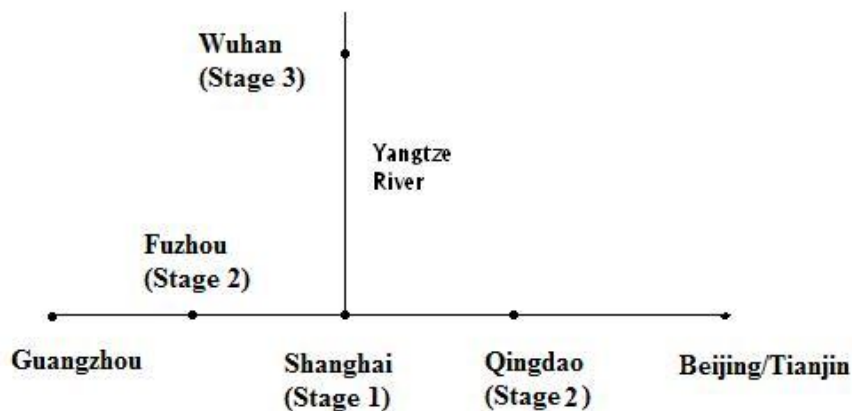
[3] One indication of China´s increasing economic integration was price convergence. For example, by the end of the 1880s, the price of rice in Shanghai was linked to the price of rice all along the Yangtze River Valley and to the international price [Shiue and Keller (2007)].

[4] An interesting question is why the Industrial Revolution did not take place in China although China was clearly the world leader in scientific developments, production technologies and administrative organization until around the 16th century. And once there was an Industrial Revolution, why did it take so long to get to China? Many economists favour institutional explanations of growth and stagnation around the time of the Industrial Revolution. The account has at its core the hypothesis that China was unable to break through the institutional and structural barriers to the industrial-scientific revolution. See, for example, Lin (2008). For a textbook treatment of institutions, economic growth and high-level equilibrium traps, see Aghion and Howitt (2009), pp. 237-264.

The emergence of Chinese seaports took place in various stages and was shaped by the Opium Wars. Originally, the corner pillars Guangzhou and Tianjin served as the main ports. Guangzhou´s natural advantages - its location and its local topography - gave it the preferred position on China´s southeast coast for foreign trade. By the start of the Qing dynasty, Tianjin had become the leading economic centre of North China because of its nearby capital city, Beijing, and its location at the northern terminus of the Grand Canal. Historically, the Grand Canal was the designated channel for the transport of tribute-grain from the south and the east to the imperial capital. Tianjin Port grew rapidly as a port and commercial centre, and it became the chief storage, transfer, and distribution point for grain and other foodstuffs from central and southern China.[5] After the two Opium Wars, further treaty seaports were gradually opened. Among them was the conveniently located seaport of Shanghai, with its easy access to the Yangtze waterway and other main trading routes. Further coastal cities opened up to foreign trade included Fuzhou and Qingdao and the port of Wuhan on the Yangtze River. The mighty Yangtze River was the most important waterway for trade and communications in the richest part of China. We will argue below that this historical context offers an unprecedented and so far unexplored event to analyse the explanatory power and guidance of regional economics modelling frameworks.

3   Seaport cities´ genesis - tools and applications

The focus of this section is to understand the interplay of seaport development and city growth.[6] The basic hypothesis is that the role of seaports goes far beyond the nautical dimension. Seaports were trade centres that generated a wide range of economic activities. First, we will develop a modelling framework to understand the formation and expansion of Chinese seaports and their connectivity with the hinterland. Let us describe the conceptual framework informally. The new economic geography research agenda fills the gap left by traditional trade theories, as it describes the formation of economic agglomerations in geographic space [Fujita et al. (1999) and Fujita and Krugman (2004)]. The rationale behind regional economic imparity is that agglomeration creates growth, and

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[5] Although it became a port during the Tang Dynasty (618-907AD), the history of Tianjin Port can be traced back to the Han Dynasty (206 BC-220 AD).

[6] Despite widespread agreement that industrial co-location can generate positive economic externalities, academics and policymakers still strive for a thorough understanding of the mechanisms through which clusters can be expected to deliver economic growth. Nevertheless, clustering has become a policy panacea for many governments, and international agencies that see clusters as drivers of regional and national competitiveness and growth. We do not deal explicitly here with the subtle policy implications of the formal model.

certain regions experience forces that encourage agglomeration and others experience the reverse forces. Fujita and Mori (1996) analyse the role of seaports in the development of cities with a developed industrial urban character. Their evolutionary model of spatial economic development explains how agglomeration economies and the hub-effect of seaports interplay in the making of successful cities. The bottom line is that agglomerations and seaports arise from the interaction of random historical events, increasing returns, transport costs, and seaborne trade. Below we analyse in detail the mechanisms underlying the formation and growth of urbanized Chinese seaports during the Industrial Revolution.

3.1   Basic framework

We begin with a sketch of the seaport model with non-neutral space.[7] For simplicity, the quality of land is the same everywhere and all non-land factors are mobile. Labour is assumed to be the only mobile factor of production and each worker is endowed with one unit of labour. Workers can change jobs and locations. Consumers derive utility from consumption; and there are two types of consumption goods, a homogeneous agricultural good (*A*) and differentiated manufactured goods (*M*).[8] Preferences are represented by the Stone-Geary utility function

(1) $U = A^{1-\mu}M^{\mu}$,

where the expenditure share of manufactured goods (μ) is strictly between 0 and 1. The CES aggregator of differentiated manufacturing goods is given by

(2) $M = \left[\int_0^n m_i{}^{\rho} di\right]^{1/\rho}$,

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[7] The model is adapted from Fujita and Mori (1996). An entirely different game-theoretic approach analysing the seaports projects and the subsequent investment in port facilities has been presented by Anderson et al. (2008). They apply their model to the competition between the ports of Busan and Yangshan (Shanghai).

[8] Defining two sectors as being agriculture and manufacturing is arbitrary. The main point is that one sector employs an immobile factor of production producing a homogeneous good that is freely tradable under perfect competition, and that the other sector employs a mobile factor of production, producing heterogeneous varieties that are costly to trade between regions under monopolistic competition.

where n is the range of manufacturing varieties and $0 < \rho < 1$. The utility function exhibits the feature that, ceteris paribus, the larger the variety of differentiated manufacturing goods, the greater the utility. The budget constraint of consumers is

$$(3) \qquad p^A A + \int_0^n p_i m_i \, di = Y \ ,$$

where p^A is the price of food and Y is income. The solution to this program leads to the demand functions for food and for manufacturing good i:

$$(4) \qquad A = \frac{(1-\mu)Y}{p^A}$$

$$(5) \qquad m_i = \frac{\mu Y \, p(i)^{-\sigma}}{G^{-(\sigma-1)}} \ ,$$

where $\sigma \equiv 1/(1-\rho)$ is the price elasticity of differentiated manufacturing goods and

$$(6) \qquad G = \left[\int_0^n p_i^{1-\sigma} \, di \right]^{1/(1-\sigma)}$$

is the price index for manufacturing goods. We now turn to the supply side. The agricultural-good production is subject to constant returns to scale, requiring one unit of land and one unit of labour. The production of differentiated manufactured goods exhibits increasing returns such that labour input l^M for producing q^M manufactured goods is given by

$$(7) \qquad l^M = F + c^M q^M \ ,$$

where F represents a fixed input and c^M is the variable labour input.[9] We impose symmetry across varieties by assuming the same inputs across varieties. Producers set a price that maximises instantaneous profits:

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[9] This issue will become important below. The Marshallian externalities arise from three sources: labour market pooling, the creation of specialised suppliers, and the emergence of knowledge spillovers.

(8) $\pi = p^M q^M - w^M \left(F + c^M q^M \right),$

where w^M is the wage in the manufacturing industry. Free entry implies zero profits. In turn, this implies that the price for manufactured goods is

(9) $p^M = \dfrac{c^M w^M}{\left(1 - 1/\sigma\right)}.$

The resolution of this program leads to the following equilibrium output and input of manufacturing goods:

(10) $q^* = \dfrac{F(\sigma - 1)}{c^M}$

(11) $l^* = F\sigma$

The equilibrium number of varieties is then determined by equating the profits of the marginal firm to zero. Denoting the endogenously determined variety by n^*, we have

(12) $n^* = \dfrac{L^M}{l} = \dfrac{L^M}{F\sigma}$

We assume that the transport cost of each good takes Samuelson´s iceberg form. This allows us to model transport costs without including a transport sector. The "deglaciation" of goods shipped over distance d follows the exponential function $e^{-\tau^i d}$ ($i = A, M$), where τ^i is a positive constant.[10] Thus the delivered price of manufacturing goods produced at location s and consumed at location r is $p^M(r)e^{-\tau^{Mi}|r-s|}$. Substituting this price in (6) yields the manufactured good price index at location r:

(13) $G(r) = \left\{ \displaystyle\int_{s \in R} n(s) \left[p^M(s) e^{\tau^M |r-s|} \right]^{1-\sigma} ds \right\}^{\frac{1}{1-\sigma}},$

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[10]The cost of transport is assumed to be a constant. Alternatively, one could assume economies of transport density. The average cost of processing freight may fall with the quantity processed at a particular port, creating economies of transport at seaports and river junctions with access to the sea. This leads to circular causation: processing industries prefer agglomerations and this leads to some reinforcing force due to an endogenous improvement in the efficiency of transport. For a geographic economy model with such economies of transport density, see Mori and Nishikimi (2002).

where R is the geographic range of the economy. Following (5), the consumption demand at location for a certain manufacturing variety produced at r is

$$(14) \qquad m_i(s) = \mu Y(s) \left[p^M(r) e^{\tau^M |r-s|} \right]^{-\sigma} G(s)^{\sigma-1} ,$$

where $m_i(s)$ and $Y(s)$ denote demand for manufacturing variety i and total income at location s, respectively. In order to supply amount $m_i(s)$ of product to location s, the amount $m_i(r) e^{-\tau^{Mi}|r-s|}$ should be produced at r. The total sales of manufacturing variety i at location r, denoted $q^M(r)$, thus amounts to

$$(15) \qquad q^M(r) = \mu \int_{s \in R} Y(s) \left[p^M(r) e^{\tau^M |r-s|} \right]^{-\sigma} G(s)^{\sigma-1} e^{\tau^M |r-s|} ds .$$

Next, nominal wages can be determined. By the zero profit condition equilibrium output is equal to

$$(16) \qquad q^* = \mu \int_{s \in R} Y(s) \left[p^M(r) \right]^{-\sigma} e^{-(\sigma-1)\tau^M |r-s|} G(s)^{\sigma-1} ds .$$

Reverse engineering of (16) yields

$$(17) \qquad \left[p^M(r) \right]^{\sigma} = \frac{\mu}{q^*} \int_{s \in R} Y(s) e^{-(\sigma-1)\tau^M |r-s|} G(s)^{\sigma-1} ds .$$

Substituting this equation for p^M into equation (9), yields the nominal wage of a manufacturing worker at location r:

$$(18) \qquad w^M(r) = \left(\frac{\sigma-1}{\sigma \cdot c^M} \right) \left[\frac{\mu}{q^*} \int_{s \in R} Y(s) e^{-(\sigma-1)\tau^M |r-s|} G(s)^{\sigma-1} ds \right]^{\frac{1}{\sigma}} .$$

Without loss of generality, we assume

$$(19) \qquad c^M = \frac{\sigma-1}{\sigma} .$$

This definition simplifies the notation in the equations below. It follows that $p^M = w^M$ and $q^* = l^*$. For further simplification we assume

(20) $\qquad F = \mu/\sigma$.

It can be easily verified that the equilibrium number of firms in each location [equation (12)] is constant:

(21) $\qquad n^* = \dfrac{L^M}{\mu}$.

Accordingly, the equilibrium output level at which firms make zero profit becomes

(22) $\qquad q^* = l^* = \mu$.

Finally, the price index and the wage can be written as

(23) $\qquad G(r) = \left\{ \int_{s \in R} n(s) \Big[p^M(s) e^{-\tau^M |r-s|} \Big]^{1-\sigma} ds \right\}^{\frac{1}{1-\sigma}} = \left\{ \dfrac{1}{\mu} \int_{s \in R} L^M(s) \Big[w^M(s) e^{-\tau^M |r-s|} \Big]^{1-\sigma} ds \right\}^{\frac{1}{1-\sigma}}$

(24) $\qquad w^M(r) = \left(\dfrac{\sigma-1}{\sigma \cdot c^M} \right) \left[\dfrac{\mu}{q^*} \int_{s \in R} Y(s) e^{-(\sigma-1)\tau^M |r-s|} G(s)^{\sigma-1} ds \right]^{\frac{1}{\sigma}} = \left[\int_{s \in R} Y(s) e^{-(\sigma-1)\tau^M |r-s|} G(s)^{\sigma-1} ds \right]^{\frac{1}{\sigma}}$.

Thus, the model is fully determined and we can now obtain the spatial equilibrium and the emergence of Shanghai as a further seaport city.

3.2   Monocentric spatial equilibrium

Armed with this framework, we can now turn to our specified abstract Chinese economy. Space is one-dimensional and stretches between the two peripheral seaport cities Beijing/Tianjin and Guang-

zhou (see Figure 1).[11] The entire production of manufacturing goods is assumed to take place in both cities, and the surrounding agricultural area extends from each of the peripheral cities towards the central region (hub).[12] One question is how to draw the catchment areas and hence the borders of both peripheral cities. Another question is whether a new seaport city will emerge over and above one of the existing cities.[13] Suppose that initially the population size is small and therefore only one city (either Beijing/Tianjin or Guangzhou) has already emerged at location 0. This city is specialised in manufacturing goods and exports manufactures for agricultural goods.

Next, assume that the economy grows. This leads to a larger city, and more manufactured varieties will be produced, leading to increasing returns at the city level. As the city population grows, further farmland has to be developed to support the growing city.[14] Eventually, as long as the population keeps growing, manufactured goods and agricultural products will be transported over increasing distances, leading to a dissemination of growth benefits across the country. Finally, beyond some adjacent catchment area, a new seaport city will emerge from the seaport-hinterland dynamics. In the course of this process, the trigger point for the emergence of a new agglomeration is where the cost of setting up production in a new city is less than that of transporting goods.

To clarify, we have depicted the geometry of our stylised Chinese economy in Figure 2.[15] In our abstract schematic graph, Shanghai is at the location of the hub, and the branch stretching in direction *bz* from the hub is the Yangtze River Valley, the longest inland river in China. To make the presentation comprehensible, we denote the line extended from the segment of the centre city to the hub, or *Obx*, as baseline; the branch on this line, *bx*, therefore is the baseline branch. All the other branches are nonbaseline branches. The number of nonbaseline branches at the hub is *k*. Without loss of generality, we assume *k* =1.

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[11] One must bear in mind that the model makes a number of simplifications. One limitation is the implicit assumption that the coastline is uniform, i.e. we don´t model coastlines with different water depths. This may lead to limited coastline resources with deep water, which is critical to constructing port facilities.

[12] Due to the geographic restriction, the farm hinterland of Guangzhou and Beijing/Tianjin can only stretch in one direction. This is different from Fujita and Krugman´s (1995) monocentric equilibrium model, where farm hinterland develops symmetrically at both sides of the centre city.

[13] New cities need not be seaport cities. Self-organizing forces may also lead to new non-port cities in the municipal area of the existing city. But a seaport city has the natural advantage of being a transport node for trade. Shiue and Keller (2007) estimated the current relative costs ratio of sea transport vs. inland water transport vs. overland transport in China at 1:2.7:9.5. Thus, seaports had an eminent comparative advantage in transport. Needless to say, the comparative advantage of navigable waterways is not just the result of geography but also of investment in seaport facilities and port expansion programmes.

[14] Traditionally, seaports have offered connectivity towards land- and ocean-side. In the current globalised world, container ports are part of a larger logistic chain, i.e. a global distribution channel.

[15] The implicit assumption in Figure 2 is that the farm hinterlands of the existing two cities do not overlap and so there is no economic integration between the two peripheral cities. Numerical simulations of the model in Section 4 support this assumption.

Figure 2 Genesis of Shanghai
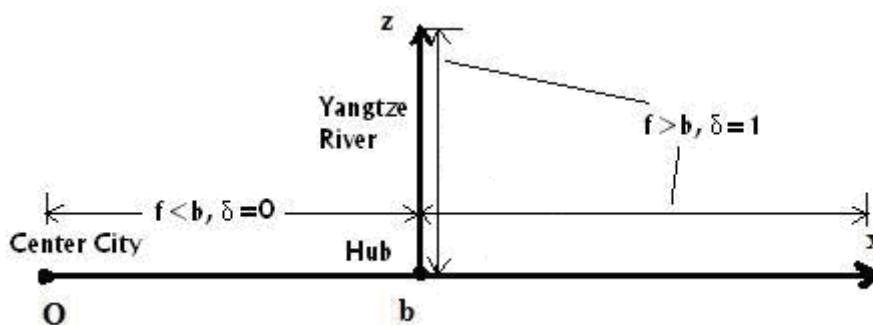
The above intuitive explanation is inaccurate because it is not clear when the new city will emerge. To answer this question precisely, we introduce a new variable δ to indicate whether the farm hinterland reaches the existing hub location.

$$(25) \qquad \delta = \begin{cases} 0 & f \leq b \\ 1 & f > b \end{cases}$$

The economic distance between the marginal farmland and the peripheral city is denoted by f and there is a hub at location b. For $f \leq b$, the hub is beyond the existing city´s sphere of influence and therefore no new city will emerge. On the contrary, for $f > b$ the necessary condition for the emergence of a new city at the Yangtze River Valley hub is fulfilled. The apparent next step is to determine the critical value of f. Suppose that the agricultural good has to be transported from the hinterland to the city. At each location r in the hinterland, it must hold that

$$(26) \qquad p^A(r) = p^A e^{-\tau^A r}.$$

By the zero-profit condition, the land rent and agricultural wage at each location r in the hinterland are given by

$$(27) \qquad R(r) = p^A(r) e^{-\tau^A r} - c^A w^A(r)$$

and

$$(28) \qquad w^A(f) = \frac{p^A e^{-\tau^A f}}{c^A},$$

respectively. Turning to manufacturing, let $p^M(0) = w^M(0) = 1$ be the price of manufactured goods at the central location. From equation (23) we obtain the price index for location r:

$$(29) \qquad G(r) = \left(\frac{L^M}{\mu}\right)^{1/(1-\sigma)} e^{\tau^M r}$$

where $L^M = N - c^A(f + \delta k(f - b))$ is the labour force working in the manufacturing sector, which is equal to the total workforce less the number of farmers.[16]

Let us now define the supply-demand relationship determining f. The urban worker´s income share spent on food is $1-\mu$. Total food demand in the city is therefore $D^A = (1-\mu)w^M L^M / p^A$. Likewise, farmers consume the fraction $1-\mu$ of their harvest and transport the remaining part μ to the city. Therefore, food supply in the city is $S^A = \mu\left(\int_0^f e^{-\tau^A s}ds + \delta k\int_b^f e^{-\tau^A s}ds\right)$. Market clearing $D^A = S^A$ implies

$$(30) \qquad p^A = \frac{(1-\mu)[N - c^A(f + \delta k(f - b))]}{\mu A(f)},$$

where $A(f) = \int_0^f e^{-\tau^A s}ds + \delta k\int_b^f e^{-\tau^A s}ds$. Finally we must ensure that the real wages of farmers in the hinterland and manufacture workers in the city are identical. This requirement leads to another equilibrium relationship of p^A with f. The real wage at each location r is proportional to the nominal wage deflated by the cost-of-living index, $G(r)^\mu[p^A(r)]^{1-\mu}$. Therefore we can solve for the real wage of farmers at the fringe of farm hinterland:

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[16] The cultivated area on the baseline is always equal to f, while in every nonbaseline branche it is $\delta k(f\text{-}b)$. The total cultivated area is therefore $f + \delta k(f\text{-}b)$.

(31) $\qquad \omega^A(f) = w^A(f)[G(f)]^{-\mu} \left[p^A(f)\right]^{-(1-\mu)} = \dfrac{1}{c^A} \left(p^A\right)^{\mu} G^{-\mu} e^{-\mu\left(\tau^M + \tau^A\right)f}$.

Since manufacturing is geographically concentrated in the city, the manufacturing real wage is

(32) $\qquad \omega^M = G^{-\mu} \left(p^A\right)^{-(1-\mu)}$.

The requirement of real wages of farmers and manufacturing workers being equal implies the no-arbitrage condition:

(33) $\qquad p^A = c^A e^{\mu\left(\tau^A + \tau^M\right)f}$.

The above information is enough to determine the equilibrium. We can readily see that (30) and (33) together uniquely determine the equilibrium farm hinterland range f, as well as the agricultural good price in the city, p^A.

3.3   Market potential function and possible emergence of new urbanized seaports

In this subsection we derive a condition for alternative equilibrium configurations. To this end, let us define the market potential function for manufacturing firms, which was introduced by Fujita and Krugman (1995). The market potential function $\Omega(r)$ measures the relative real wage of manufacturing workers and farmers at a certain location r:

(34) $\qquad \Omega(r) = \dfrac{\left[\omega^M(r)\right]^{\sigma}}{\left[\omega^A(r)\right]^{\sigma}}$,

where $\omega^M(r)$ and $\omega^A(r)$ denote the real wage of manufacturing workers and farmers at location r, respectively, and $\sigma \equiv 1/(1-\rho)$ is the price elasticity for differentiated manufacturing goods defined above. The market potential function measures the relative profitability at each location r for manufacturing firms. Hence, the location moncentric (single-city) equilibrium requires that market potential function does not exceed 1 anywhere in the economy, i.e.

(35) $\qquad \Omega(r) \le 1$

for all *r*. In other words, for $\Omega(r) < 1$ the centripetal force created by the existing city is so strong that no new city can emerge. Put differently, for $\Omega(r) > 1$ manufacturing workers would be attracted to location *r*, triggering a self-enhancing feedback effect of spatial agglomeration there. It is straightforward to show that

(36) $\qquad \Omega(r) = \dfrac{\left[\omega^M(r)\right]^\sigma}{\left[\omega^A(r)\right]^\sigma} = \dfrac{\left\{w^M(r)G(r)^{-\mu}\left[p^A(r)\right]^{-(1-\mu)}\right\}^\sigma}{\left\{w^A(r)G(r)^{-\mu}\left[p^A(r)\right]^{-(1-\mu)}\right\}^\sigma} = \dfrac{\left[w^M(r)\right]^\sigma}{\left[w^A(r)\right]^\sigma} = \left[w^M(r)\right]^\sigma e^{\sigma\left[(1-\mu)\tau^A - \mu\tau^M\right]r}$.

Recalling the definition of $w^M(r)$ in equation (24), we can decompose the wage into three parts as follows:

(37) $\qquad \begin{aligned} \left[w^M(r)\right]^\sigma &= L^M w(0)e^{-(\sigma-1)\tau^M r}\left[G(0)\right]^{\sigma-1} + \int_0^f p^A(s)e^{-(\sigma-1)\tau^M|r-s|}\left[G(s)\right]^{\sigma-1}ds \\ &\quad + \delta k \int_b^f p^A(s)e^{-(\sigma-1)\tau^M d(r,s)}\left[G(s)\right]^{\sigma-1}ds \end{aligned}$,

where *d(r,s)* is the distance of farmers from the baseline, given by

(38) $\qquad d(r,s) = \begin{cases} s-r & f \le b \\ (r-b)+(s-b) & f > b \end{cases}$.

In equation (38) we divide the whole economy visualised in Figure 2 into three segments: the original city, the segment from the centre city to the edge of the hinterland on the baseline *obx*, and the farm hinterland on the nonbaseline branch starting from junction point *b*. Substituting (26) and (30) into (37) yields

(39) $\qquad \left[w^M(r)\right]^\sigma = \mu e^{-(\sigma-1)\tau^M r} + \left(\dfrac{\mu p^A}{L^M}\right)\left[\int_0^f e^{-\tau^A s}e^{(\sigma-1)\tau^M(s-|r-s|)}ds + \delta k \int_b^f e^{-\tau^A s}e^{(\sigma-1)\tau^M(s-d(r,s))}ds\right]$.

It follows straightforwardly from (31) that $\mu p^A / L^M = (1-\mu)/A(f)$. Let us repeat the dynamic system we have arrived at. The potential function $\Omega(r)$ is a piecewise function to the left-hand side and to the right-hand side of the hub as follows:

$$(40) \qquad \Omega(r) = \begin{cases} \Omega_1(r) & \text{for } r \leq b \\ \Omega_2(r) & \text{for } r > b \end{cases},$$

where the potential functions for the two regions can be solved as

$$(41) \qquad \Omega_1(r) = e^{\sigma[(1-\mu)\tau^A - \mu\tau^M]r} \left[\mu e^{-(\sigma-1)\tau^M r} + \psi(r,f)(1-\mu)e^{(\sigma-1)\tau^M r} \right] \qquad \text{for } r \leq b$$

and

$$(42) \qquad \begin{aligned} \Omega_2(r) &= e^{\sigma[(1-\mu)\tau^A - \mu\tau^M]r} \{ \mu e^{-(\sigma-1)\tau^M r} + \psi(r,f)(1-\mu)e^{(\sigma-1)\tau^M r} \\ &- (1-\mu)\phi(f)e^{(\sigma-1)\tau^M r} \left[1 - e^{-2(\sigma-1)\tau^M(r-b)} \right] \} \end{aligned} \qquad \text{for } r > b,$$

where $\phi(f) = \delta k \int_b^f e^{-\tau^A s} ds / A(f)$ and $\psi(r,f) = 1 - \int_0^r e^{-\tau^A s} \left[1 - e^{-2(\sigma-1)\tau^M(r-s)} \right] ds / A(f)$, and $A(f)$ is defined above in equation (30).

   The model considered in this section has an obvious merit. Once the $\Omega(r)$ bifurcation criterion is established for the emergence of further seaports, we can calibrate possible equilibrium configurations. Thus, we can examine whether new hubs will be formed and therefore whether the framework is important for explaining the observed geographic dispersion of further Chinese seaports. Or to put it somewhat differently: The calibrations will shed light on whether the initial seaport hierarchy in the Beijing/Tianjin - Guangzhou range is likely to be challenged.

4 Spatial dynamics in the Beijing/Tianjin - Guangzhou range

Section 3 developed and discussed the main features of the model and paved the way for the numerical analysis. The next task is to simulate the emergence of urbanized Chinese seaports in the

setup and to explore the sensitivity of the results to changes in the parameters.[17] This allows to get a feel for the model and the space-time dynamics.

Before initiating the model calibrations, the slope of the potential function at the centre city ($r = 0$) is calculated from (41) as

$$(43) \qquad \frac{d\Omega_1(0)}{dr} = \sigma\left[(1-\mu)\tau^A - (2\rho\mu + \mu - \rho)\tau^M\right].$$

The stability of the moncentric equilibrium requires that the slope of the potential function is negative, i.e. $d\Omega_1(r)/dr < 0 \Leftrightarrow (1-\mu)\tau^A < (2\rho\mu + \mu - \rho)\tau^M$. Otherwise, the relocation of an arbitrarily small number of manufacturing firms would lead to the formation of a new city. On the other hand, a new city will emerge only when the farm hinterland of the city exceeds a critical threshold f. From equation (41), the limit of the potential function for $f \to \infty$ can be derived as

$$(44) \qquad \overline{\Omega}_1(r) = \Omega_1(r,f)|f \to \infty = Ke^{\sigma(\rho-\mu)\left(\tau^A + \tau^M\right)} + (1-K)e^{-\left[(1-\mu)(\sigma-1)\tau^M - d\Omega_1(0)/dr\right]r},$$

where K is a positive constant, and $\overline{\Omega}_1(r)$ is thus the upper limit of potential curve $\Omega_1(r)$. It can be verified that the condition $\overline{\Omega}_1(r) > 1$ for $f \to \infty$ is that $\rho > \mu$.

Given that these conditions are met, the historical evolution of Chinese port cities can be simulated. How useful is the theoretical modelling framework for China´s economic history? Can the framework be (loosely) fitted to a variety of different circumstances? These questions are addressed below. Rather than presupposing the existence of seaports, we simulate the spatial arrangement endogenously. Our mode of conduct is straightforward: First, we calculate the potential function $\Omega(r)$ for given parameter values. Once the maximum value of the potential function exceeds 1, a bifurcation occurs and a new city emerges. Because methodological issues related to calibration are not the focus of this paper, a pragmatic stance is taken. The coastline between Guangzhou and Shanghai is approximately 1200 kilometres long, and the coastline distance between Beijing/Tianjin and Shanghai is about 1800 kilometres long. Therefore we assume the corresponding lengths of these two coastlines are 0.8 and 1.2, respectively. Hence, in Figure 3 Guangzhou locates at the ori-

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[17] Perhaps one might object that the dynamics of the model are rather mechanical. However, one should keep in mind that more sophisticated firm behaviour - intermediate products, horizontal and vertical integration, etc. - would merely enrich the linkages, which are of primary importance in the geographical economy model. In other words, more complicated models do not change the conclusions in principle, although the details depend, of course, on the precise structure of the framework.

gin, Shanghai at $b = 0.8$ and Beijing/Tianjin at $r = 2$. The remaining parameters, which were chosen for realism, are $\sigma = 4$, $\mu = 0.55$, $\tau^A = 1.2$, $\tau^M = 1.4$, $C^A = 0.6$, $N_G = 2.1$, and $N_B = 1.8$. Before the Opium War, the Chinese population was unevenly distributed. Therefore we assume that the population parameter for Guangzhou city and its periphery (denoted by N_G) is 2.1 while that for Beijing/Tianjin and its periphery (N_B) 1.8. During the Qing Dynasty, agricultural production was believed to be a fundamental prerequisite. On the contrary, higher taxes and tariffs were levied on manufacturing products and trade. Therefore we assume the transporting cost parameter of manufacturing goods ($\tau^M = 1.4$) to be higher than for food ($\tau^A = 1.2$). The spending ratio on manufactured goods is assumed to be $\mu = 0.55$.[18] Given these parameters, the parameter constraints in equations (43) and (44) are satisfied.[19]

Armed with an empirically plausible parameterisation of the model and given the two initial peripheral cities, the key question is where are new seaport cities likely to emerge? There are several noteworthy features represented in Figure 3. To begin with, the solid line on the left indicates the baseline potential curve for Guangzhou, while the dashed curve starting from the right side represents the potential curve for Beijing/Tianjin. For robustness checks, we have also drawn both potential curves for smaller population sizes (solid and dashed thin lines for $N_G = 1.8$ and $N_B = 1.37$; all other parameters as in the baseline case). As expected, both curves shift downward as population size decreases. As shown in Figure 3, irrespective of the assumed population size, the potential curve for Guangzhou exceeded the $\Omega(r) = 1$ threshold. Thus, the calibrations indicate the emergence of another urbanized seaport along the southern coastline. However, due to the Qing government´s closed-door policy and attempts to limit contacts with the outside, no further seaport cities emerged at first.

As soon as the population size increased to $N_G = 2.1$, the area $\Omega(r) > 1$ comprehended the location of Shanghai ($b = 0.8$). Accordingly, the emergence of Shanghai as a seaport city was within the realm of possibility and finally occurred once the Qing government ended its policy of seaport closings. Its location at the mouth of the Yangtze River Delta initially led to its development as a

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[18] We have Estimated Engel coefficients (proportion of processed and non-processed food expenditure in consumer expenditure) only for urban Chinese residents in the 1970s, about 55 percent. Contingent on the share of processed food, this translated into a reasonable spending ratio for manufactured goods, $0.45 < \mu < 0.65$. Given the unavailability of historical estimates, we used $\mu = 0.55$. The motivation is that Chinese GDP per capita in the 19th century remained unaltered, in stark contrast to elsewhere in the world [Maddison (2002), p. 43)].

[19] The parameter constraints are fulfilled for $0.45 < \mu < 0.75$. It may be noteworthy that the calibrations primarily serve as a communication device. The modelling approach introduced in this paper goes some way towards achieving the purpose of understanding the dynamics of the theoretical framework. Yet we do not claim empirical accuracy for the model, which we use rather for qualitative features and predictions.

coastal trade port. After Shanghai became an international treaty trade port in 1842, foreign ships, shipyards and related business increased rapidly and finally Shanghai developed into an international transportation hub. Industry was another of the impetuses for urban development in Shanghai with most industries being distributed along the Huangpu river. All these developments were interdependent and interactive, but the development of the seaport has been and still is one of the important dynamics of urban expansion in Shanghai.[20] On the other hand, $\Omega(r)$ for Beijing/Tianjin is always smaller than 1. This implies that the lock-in effect of Beijing/Tianjin prevented the formation of a further seaport city along the northern coastline at that time.[21]

Figure 3: Potential curves for Guangzhou and Beijing/Tianjin
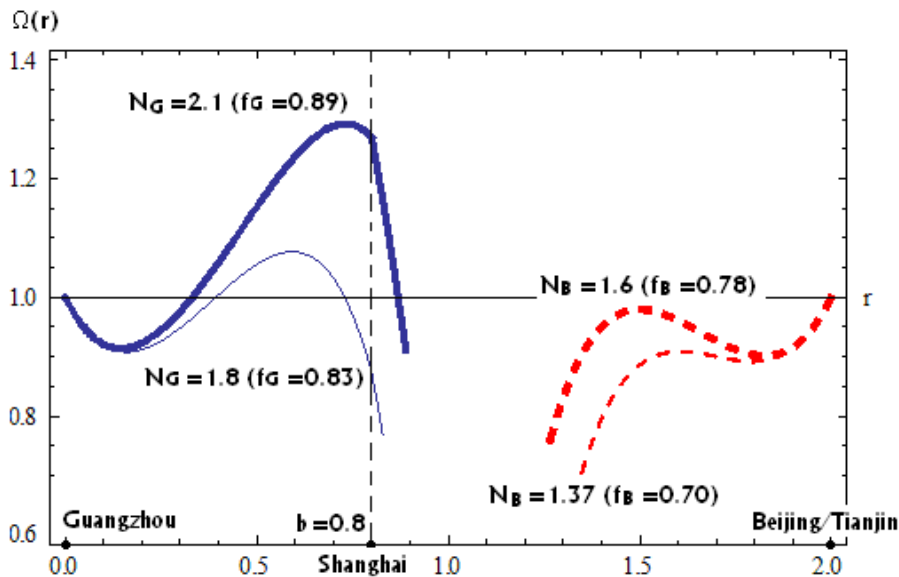
Given this evolutionary process, the additional potential function for Shanghai, denoted as $\Omega_S(r)$, can be derived in line with (41) and (42) as follows:[22]

(45)
$$\Omega_S(r) = e^{\sigma\left[(1-\mu)\tau^A - \mu\tau^M\right]r} \left\{ \left[\frac{1+\mu}{2} - \frac{(1-\mu)\phi_S(f)}{2} \right] e^{-(\sigma-1)\tau^M r} + \psi_S(r,f)\left(\frac{1-\mu}{2}\right)e^{(\sigma-1)\tau^M r} \right. $$
$$\left. - (1-\mu)\phi_S(f)e^{(\sigma-1)\tau^M r}\left[1 - e^{-2(\sigma-1)\tau^M(r-b)} \right] \right\},$$

---

[20] A comprehensive review of Shanghai´s port origin and city formation is provided in Zhongmin and Jianzhong (1990).
[21] It is worth mentioning that due to $f_G + f_B = 1.67 < 2$, the farm hinterlands of the two peripheral cities indeed do not overlap. This fact validates our previous assumption that the two monocentric cities co-exist.
[22] Contrary to both peripheral cities, Shanghai had three directions to extend its hinterland: along the northern and southern coastline and along the Yangtze River Valley. To get the potential curves for this special case, set $b = 0$ and $k = 2$. Note that the potential curves in Figure 4 only typify the stretch-out along the northern and southern coastline. In other words, the potential curve along Yangtze River is not depicted. For this point, see Figure 5 below.

where $\quad \phi_S(f) = \int_0^f e^{-\tau^A s} ds / A_S(f), \quad \psi_S(r, f) = 1 + \phi_S(f) - 2 \int_0^r e^{-\tau^A s} \left[1 - e^{-2(\sigma-1)\tau^M (r-s)} \right] ds / A_S(f), \quad$ and

$A_S(f) = 3 \int_0^f e^{-\tau^A s} ds$. The population size of Guangzhou, Shanghai (denoted by NS) and Beijing/Tianjian at this historical stage is assumed to be NG = 1.7, NS = 0.8 and NB = 1.8. All remaining parameters are the same as in Figure 3. Again we present the outcomes graphically instead of with unreadable, large tables. The new potential curves after the development of Shanghai are provided in Figure 4.

As before, the solid and dashed lines represent the potential curves for Guangzhou and Beijing/Tianjin, respectively. The tapered dotted line represents the potential curve for Shanghai. The significance of the diagram is that along the northern coastline a new seaport was likely to emerge in the range of $1.2 < r < 1.6$. It is particularly noteworthy that this calibration result is consistent with the formation of Qingdao as a further seaport city. Before the 17th Century, the Port of Qingdao was little more than a small fishing village. In 1891, the Qing Dynasty government began to extend and fortify the seaport of Qingdao. In 1898, the German navy overcame these defenses, and the city was ceded to Germany. They made the Port of Qingdao a free port in 1899. As a result, the the economy swelled and the city was undergoing a period of rapid growth based upon light manufacturing industries.

Figure 4 Potential Curves for Guangzhou, Shanghai and Beijing/Tianjin
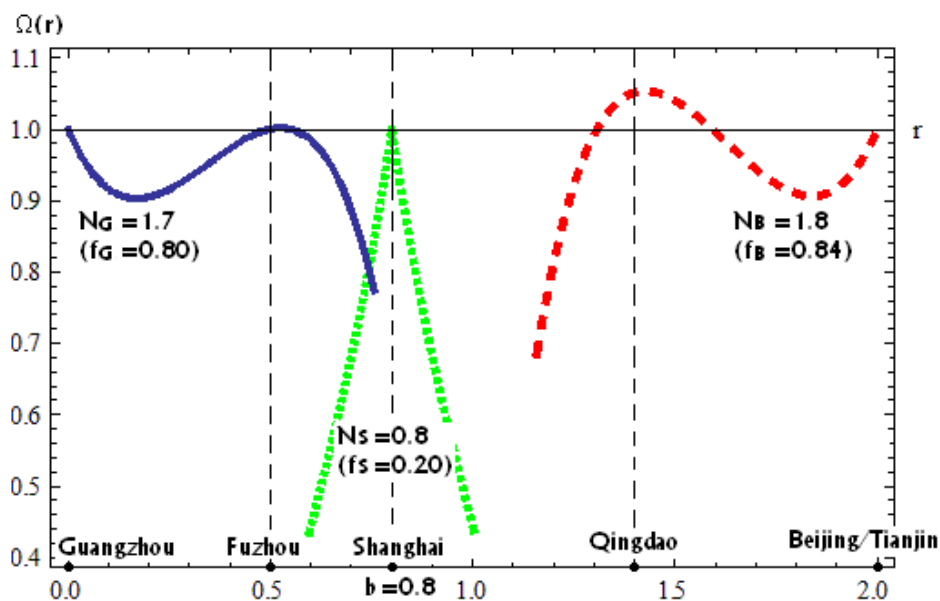
Along the southern coastline, Guangzhou´s potential curve touched $\Omega(r) = 1$ near to $r = 0.5$. Thus it was advantageous to establish a new seaport city there. This new seaport was Fuzhou, which was opened to foreign trade after the Opium War, in 1842, as one of the five unequal treaty ports. Fuzhou immediately benefited from this and became the chief port for tea trade. The opening also enhanced the development of Fuzhou´s urban market economy.[23]

A final issue concerns the emergence of inland ports. From the mid 19th Century to 1900, the population of Shanghai more than doubled to over 1 million, with an expanding international community. After 1900 Shanghai was characterised by further remarkable growth. In 1920 the total population was already estimated at 2 million, a census then showing 950,000 in the International Settlement and French Concession. Among other things, Shanghai´s growth as a shipping hub was linked to the needs of the Yangtze River Valley. As Shanghai developed rapidly, the city´s farm hinterland extended further and further along the Yangtze River. As a result, the emergence of new inland port cities along the Yangtze River Valley became a possibility.

To shed some light on this issue, the same modelling framework as above can be used to calibrate the emergence of such inland port cities. Given Shanghai´s rapid population growth, $N_S = 9$ is assumed. Furthermore, given the interim technological progress in agriculture, a technological parameter $C^A = 0.4$ is assumed. Figure 5 shows the in-depth numerical exercise results for the branch along Yangtze River Valley, i.e. we limit our analysis to bz in Figure 2.

Figure 5 Potential curve for emergence of port cities in the Yangtze river valley

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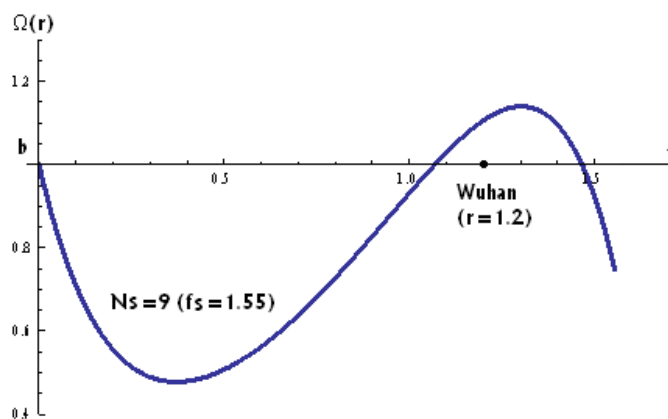
[23] Fuzhou´s port history goes back to the northern Song Dynasty (960-1127). Shipping routes from Fuzhou to Japan and to Arabic countries were established. During the Yuan Dynasty Marco Polo passed through Fuzhou. During the Ming Dynasty, the famous Chinese navigator, Zhenghe, called at the port of Fuzhou. However, as recently as the Opium War, the traditional connection between seaports and hinterlands began to change. Openness and trade led to an increase in the division of labour and major changes in the organisation of production.

As explained before, where the potential curve hits the threshold 1 a new city will eventually emerge in the evolutionary process, due to the bifurcation of the spatial system. One can readily see that the likely emergence of an inland port city and hub occurs in the range $1.2 < r < 1.4$. This coincides with the development of Wuhan as an industrial agglomeration inland port city. Lying where the Han and Yangtze Rivers meet, it was formed in 1949 from the consolidation of three cities: Wuchang, Hanyang, and Hankou. Located centrally between Beijing/Tianjin and Guangzhou and between Shanghai and Chongging, it is sometimes called the "thoroughfare of nine provinces".[24] The port is accessible to oceangoing ships. The city of Wuhan is China´s traditional manufacturing industry base, and one of the origins for China´s modern industry.

All in all, one may say that while the calibration evidence shown in this section is merely suggestive, it is consistent with the predictions of the modelling framework and the above-mentioned historical facts.

5 Conclusions

The miracle of China´s growth based on exporting of manufactures is above all a maritime one and it would have been inconceivable without the ship-borne container. Urbanization also took place differently along the coast, with cities growing more rapidly than in the interior.25 In this paper we have therefore tried to motivate a focus of attention on the genesis of urbanized seaports in China using the analytical modelling tools of economic geography. A fascinating feature of the underlying economic geography modelling framework is that seaport city growth is path-dependent, but the path does not seem to be entirely determined by sheer luck but is rather constrained by the geographic economic conditions, as mentioned above. The model makes no presumption on which location might become an urbanised seaport, but once a location gets a headstart via the initial emergence of a seaport, the process of cumulative causation begins to unfold. What were initially small GDP per capita differences across locations can evolve over time into large income differences.

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[24] Prior to that, Hankou was already a designated treaty trading port for western powers after the 2nd Opium War.

[25] Not all ports are of equal stature and their success has been variable over time. As trade shifts, so does the fortune of ports. Changes in the seaport sector are the result both of new technologies and of structural shifts in the world's trading patterns. The increasing concentration of traffic in a few giant ports has been a part of this development. Furthermore, institutional, regulatory, and government policies can help promote sea transport services. for example, the decentralisation reforms adopted in China after 2001 provide strong incentives for local authorities to commit more emphasis upon seaport development and the necessary institutional framework.

In other words, the interaction of agglomeration and spreading forces implies that history is decisive. [26]

Let us conclude our journey into the economics of Chinese seaport cities by pointing out what we have learned. In a nutshell, we have demonstrated that the spatial distribution of Chinese seaport cities in modern times can be explained in the context of a new economic geography model framework, even though the emergence of Chinese seaports took place under very special circumstances. While being an incomplete summation of the full range of issues related to the emergence and growth of Chinese seaport cities, they form a useful point of departure for future work on model formulation, calibration, and interpretation.

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[26] The model of Fujita and Mori (1996) also entails the lock-in effect of agglomerating forces. In other words, seaport cities continue to prosper even after their initial geographic advantage has ceased to play an important role.

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