The London School of Economics and Political Science

# Historical Transportation Systems and Economic Geography in China Across Seven Millennia

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# Declaration

I certify that the thesis I have presented for examination for the MPhil/PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).



I declare that my thesis consists of approximately 42,000 words.

# Abstract

The evolution of transportation networks and their relationship with urban development is critical to understanding the rise of civilizations. This thesis investigates this dynamic through three interconnected studies, focusing on China' s historical context. First, I reconstruct the transportation network of late imperial China using a GIS-based approach, estimating historical transportation speeds and costs, and compare it with England. Second, I analyze how natural endowments influenced the spatial distribution of ancient settlements and historical cities, revealing patterns of human interaction with their environment over time. Third, I explore how institutional contexts shaped the value of natural endowments for city locations across dynastic cycles.

In paper two and paper three, my findings demonstrate that economic activities were initially concentrated in areas with convenient road access, but this relationship weakened approximately 4,500 years ago during a major global climatic event (Holocene Event 3). This disruption, likely driven by a climate shock triggering a Malthusian trap, persisted for nearly a millennium before being resolved through the formation of China' s first territorial state, aligning with the circumscription hypothesis. Following China' s unification, the relationship between city locations and natural endowments fluctuated with dynastic cycles, driven by governance strategies and taxation structures.

This research contributes to three key areas of scholarship. First, it offers new insights into the Great Divergence by demonstrating that transportation conditions in late imperial Yangtze China were comparable to those in England until 1700, when England experienced a transformative transportation revolution that did not occur in China. Second, it advances economic geography by providing novel empirical evidence on how institutional settings mediate the value of natural endowments for city locations. Finally, it uncovers a previously undocumented historical pattern linking ancient settlement locations to road accessibility, informed by a newly developed terrain based

road suitability index based on Digital Elevation Model data and data from the China Archaeological Database (CADB) Project.

# Acknowledgements

Pursuing a PhD at LSE has been one of the most extraordinary experiences of my life. Before joining the Department of Economic History, I knew little about economics and even less about economic history. What drew me here was the rare opportunity to study history through a quantitative lens. I am profoundly grateful to the department for giving me this chance and allowing me to spend four wonderful years in such a vibrant and supportive community. My deepest gratitude goes to my main supervisor, Professor Joan Rosés, who guided me from being a novice with almost no knowledge of economics or economic history to becoming a scholar capable of independently completing a PhD thesis in this field. I am equally thankful to my secondary supervisor, Professor Kent Deng, whose profound expertise in Chinese economic history provided crucial insights during moments when I struggled to discern historical patterns, helping me find the right direction.

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# Chapter 1

# Introduction

This thesis examines the historical economic geography of China over the past seven millennia, spanning from the origins of civilization to the complex society we live in today. By focusing on the relationship between transportation networks and urban development, it provides insights into the long-term dynamics that shaped China's economic spatial patterns.

To achieve this, the research begins with an exploration of historical transportation conditions in China. Specifically, it reconstructs the transportation networks of the 14th to 19th centuries using travel route books published during that period. By evaluating transportation costs and speeds, the thesis compares these metrics with contemporary data from England. The findings reveal that, prior to the 18th century, transportation conditions in both regions were broadly similar. However, the advent of the Turnpike Trusts and the Canal Revolution in England during the 18th century led to significant reductions in transportation costs and increases in speed. This divergence aligns with the timeline proposed by Pomeranz (2000); Broadberry and Gupta (2006); Broadberry (2013) for the "Great Divergence."

The thesis then leverages data from the China Historical GIS (CHGIS) and the China Archaeological Database (CADB) to reconstruct the spatial distribution of economic activity, focusing on cities and settlements over the past 7,000 years. It explores the relationship between settlement locations and natural endowments for transportation networks, such as terrain suitability for roads, navigable rivers, and estuaries. These natural endowments serve as exogenous proxies for transportation infrastructure, addressing the limitations of relying solely on endogenous road networks, which are only reliably documented in detail from the Ming and Qing dynasties onward.

The analysis reveals that over the past two millennia, the marginal effect of natural endowments on transportation networks has not been constant; rather, it fluctuates with the dynastic cycle. This suggests that the value attributed to natural endowments in determining the location of cities varies under different institutional settings. Through historical case studies, I argue that key institutional mechanisms driving these variations include the taxation structure (direct versus indirect taxation), governance strategies (centralized versus delegated governance), and the influx of Arab and European merchants.

When extending the timeline to the five millennia before the Common Era, the findings show that the elasticity of settlement locations to terrain suitability for roads also fluctuated. After humans settled in China 7,000 years ago, economic activities were initially concentrated in regions with convenient road access, suggesting strong spatial interactions, especially trade. Around 4,500 years ago, however, this relationship declined significantly and was followed by a slow recovery that remained subdued for nearly a millennium. This downturn coincided with a major global climatic event (Holocene Event 3) (Xu et al., 2010; Wang et al., 2005; Bond et al., 1997, 2001), potentially suggesting that a climate shock may have triggered a Malthusian trap, followed by prolonged conflicts. This period of environmental stress likely spurred prolonged conflicts that were ultimately resolved through the formation of a unified "Empire" with large territory (3500 BP). In this sense, the climate shock may have set in motion the process described by the circumscription hypothesis Carneiro (1970).

From this point onward, the elasticity of settlement locations to transportation endowments began to correspond with dynastic cycles. During the early stages of dynasties, newly established regimes enhanced spatial economic interactions by centralizing power and stabilizing transportation networks. This trend persisted through the dynastic midpoints but declined sharply during periods of political collapse and warfare, as economic activities shifted away from areas of better connectivity.

Overall, in the 7,000-year trajectory of human development in China, only three factors have significantly influenced economic geography: climate shocks, institutional changes, and technological innovation. While climate shocks have played a substantial role in human history, their impact on economic activities occurred only once, serving as a critical trigger that transitioned human societies from chiefdoms to territorial states. Subsequently, humans demonstrated remarkable adaptability to later climate shocks, which no longer significantly altered the configuration of economic geography.

After the establishment of large-scale sovereign states, particularly during the era of unified empires, the layout of economic geography was increasingly shaped by institutional factors. This study identifies taxation strategies and governance strategies as key institutional determinants. Finally, over the past century, the introduction of advanced Western technologies has driven a rapid transition in China from traditional transportation modes (packhorses and sailing ships) to modern systems (railways, highways, and motorized vessels). As hypothesized by Krugman's New Economic Geography framework (Krugman, 1991), these technological advancements have led to significant changes in the configuration of economic geography.

This thesis contributes to several fields, including economic history, economic geography, and archaeology.

In economic history, it engages with the Great Divergence debate. Since Pomeranz (2000) proposed the hypothesis of the Great Divergence, it has become one of the most significant discussions in the field. The first paper of this thesis offers a new perspective on this debate by focusing on transportation. As Adam Smith emphasized in *The Wealth of Nations* (Smith, 1776), the level of transportation technology determines the scale of markets and, ultimately, the potential for economic development. By comparing the transportation conditions of the Yangtze China and England, this research evaluates and contrasts market integration in the two regions.

In economic geography, this thesis contributes to the ongoing debate about the relative roles of "first nature" (natural endowments) and "second nature" (human decisions) in shaping spatial economic outcomes. Davis and Weinstein (2002), in their seminal study on the spatial distribution of economic activities in Japan over the past 10,000 years, argue that the distribution of economic activities has remained remarkably stable throughout this period. Even shocks as severe as the atomic bombings of Hiroshima and Nagasaki during World War II, as well as widespread bombings across Japan, did not lead to long-term shifts in the location of economic activities. Based on this evidence, they conclude that "first nature" factors—such as natural endowments and locational fundamentals—are the primary determinants of economic activity locations.

However, this perspective has been challenged by subsequent literature. For example, Bleakley and Lin (2012) demonstrate that some locations maintain their size and importance even after losing their initial locational advantages, highlighting the role of path dependency in spatial economic outcomes. They also critique Davis and Weinstein's conclusions, suggesting that Japan is a unique case due to its highly constrained geography. With limited land suitable for development, economic activities in Japan are naturally locked into specific locations. They liken this to California's Bay Area: if all economic activities in the Bay Area were wiped out and the region were to redevelop, it is highly likely that the spatial distribution of economic activities would resemble its current form. This is because the availability of land suitable for economic activity in the Bay Area is extremely limited, effectively anchoring development to specific sites.

Given these critiques, testing such hypotheses requires studying a region that is broader, more geographically diverse, and relatively self-contained over an extended period. China, with its vast territory, diverse terrain, and rich historical records, presents an ideal case for such research. This thesis leverages China's unique characteristics —including its vast territory, climatic diversity, and complex topography—to re-examine the balance between "first nature" and "second nature" factors in shaping long-term spatial economic outcomes, offering fresh perspectives on this enduring debate.

Finally, in archaeology, this thesis advances the field of settlement archaeology by utilizing innovative datasets and introducing economic methodologies, including econometric analysis. By integrating spatial data from the China Archaeological Database (CADB) with econometric methods, it reveals novel spatial characteristics of ancient settlements in Neolithic China.

A more detailed discussion on each topic will be delivered in each chapter. This introduction contextualizes the thesis'three substantive papers, emphasizing their unifying themes and specific contributions. It outlines the motivations for the research, its engagement with existing literature, and its broader implications for understanding the long-term evolution of China's economic geography.

## 1.1 Why Historical Economic Geography and Why China

The emergence of cities represents a transformative milestone in human history, marked as the birth of civilization and serving as hubs of economic, political, and cultural exchange. Roads have played a central role in amplifying this importance, connecting cities to one another and enabling the flow of information, goods, and ideas. Together, cities and roads form the backbone of human civilization, shaping patterns of interaction, trade, and technological exchange.

Understanding the spatial relationship between cities and roads over thousands of years provides critical insights into societal development and the evolution of economic geography. Roads have not only facilitated urban growth but also influenced how civilizations emerged, expanded, and interacted with their environments. Examining these dynamics across time is crucial to situating contemporary economic systems within a broader historical framework.

However, research on the ultra-long-term relationship between transportation networks and urbanization faces three significant challenges. First, long-term studies are often hindered by the scarcity of data on urban settlements and transportation systems, particularly in prehistoric periods. Second, disentangling the interaction between cities and roads from other influencing factors—such as climate shocks, institutional changes, or technological advances—requires clean and well-defined test conditions. Lastly, many ancient civilizations, including those in Mesopotamia, Egypt, Mesoamerica and the Indus

Valley, experienced substantial disruptions that fragmented their historical continuity, making them less suitable for ultra-long-term studies.

China, in contrast, offers a unique opportunity to overcome these challenges. As one of the few civilizations with a continuous and independent development trajectory spanning thousands of years, China provides an exceptional case for exploring the long-term interplay between roads and cities (including ancient settlements). Its relative isolation, minimal external disruptions, extensive historical records and abundant archaeological evidence in recent years make it an ideal context for studying how roads or spatial interaction shaped human development across millennia.

### 1.1.1 New Possibilities in Historical Data and Archaeological Data

In recent years, with the increasing discovery and analysis of historical and archaeological materials, historical economic geography has emerged as a significant subfield within economic geography. By utilizing long-term data on cities, these studies have provided new insights into urban development that were previously unobserved.

In the Bronze Age, Barjamovic et al. (2019) employed cuneiform tablet records from the Assyrian Empire to construct a gravity model, identifying potential locations of lost cities that existed historically but have yet to be discovered. Similarly, Bakker et al. (2021) developed an accessibility index to explore the relationship between Mediterranean trade networks and city locations during the Iron Age. Their findings suggest that the Phoenicians'early open-sea crossings in the Mediterranean played a causal role in linking geographic connectedness to economic development. This is evidenced by a higher concentration of archaeological sites in well-connected coastal areas during the Iron Age—a pattern that holds at a global scale.

In the medieval period, Bosker et al. (2013) analyzed urban development in Europe and the Middle East between 800 and 1800 AD. Their research shows that while urban growth initially flourished in the Islamic world, Europe eventually outpaced it due to differences in religious orientations, transportation modes (camel-based versus maritime trade), and the rise of more autonomous and participatory local governments. Further, Bosker and Buringh (2017) demonstrated that in medieval Europe, a location's physical geography—particularly access to water or land-based transportation and proximity to existing urban centers—was the key determinant of urban development. Cermeno and Enflo (2019) examined Swedish towns founded by the Crown in the early modern period, showing that although these towns were initially situated in suboptimal locations and only temporarily boosted local production and population without increasing per capita productivity, they later thrived following industrialization. This was largely due to the lasting effects of royal support and the benefits of agglomeration economies. Michaels and Rauch (2018) argues that while natural geographic features matter, historical events can lock towns into suboptimal locations for centuries—as seen in how the collapse of the Western Roman Empire led to French towns persisting in less favorable Roman-era sites, whereas Britain's urban network was reset to take advantage of navigable waterways.

Following the Industrial Revolution, advances in transportation technology led to significant shifts in urban spatial structures, prompting a wave of research on these transformations. In Sweden, Berger and Enflo (2017) found that the first wave of railroad construction led to substantial, long-term increases in town populations, primarily by redistributing economic activity. These early shocks created a path-dependent spatial distribution of economic growth, resulting in persistent differences in town sizes over time. In England, You et al. (2022) demonstrated that the introduction of railways in 1851 significantly boosted local population growth and shifted occupational structures away from agriculture in England and Wales. Additionally, railways reinforced existing urban hierarchies, contributing to greater spatial divergence in economic development.

In the case of China, Düben and Krause (2023) found that while lower-tier market towns in imperial China were primarily shaped by local geographical features, higher-level cities depended more on institutional factors such as administrative centrality. Interestingly, many historically significant political cities continue to hold special status today. Bai and Jia (2023) demonstrated that China's political hierarchy, shaped by regime changes between 1000 and 2000 CE, played a crucial role in regional development. The rise and fall of prefectures were largely determined by shifts in provincial capital status, with economic advantages disappearing once a city lost its administrative role.

These benefits flowed through both public employment and infrastructure investments, particularly in transportation. Finally, Ioannides and Zhang (2017) developed a model using newly compiled historical data to examine the determinants of city wall dimensions in Ming and Qing China. Their findings suggest that city wall sizes were shaped by local economic, geographic, demographic, and security factors, with larger walls indicating greater population sizes and higher risks of attack. Moreover, historically walled cities continue to exhibit distinctive size distributions and higher modern employment and population densities.

### 1.1.2 China's Advantage

China's written historical records are among the most comprehensive and continuous in the world, offering unprecedented opportunities to gain invaluable insights into the evolution of economic geography. Spanning over three millennia, these records provide detailed documentation of socioeconomic and geographic parameters. Digital humanities projects, such as the China Historical Geographic Information System (CHGIS), enable researchers to map city locations across dynasties and reconstruct historical spatial dynamics. Through meticulous analysis of historical documents, historians have extracted critical data on population distribution, taxation systems (including land, poll, and commercial taxes), and ideological structures (e.g., temples and academies) across different periods of Chinese history.

Unlike many regions where historical data is fragmented, China's centralized and stable governance ensured the consistent collection and preservation of records. This wealth of information allows researchers to reconstruct historical transportation systems, evaluate their efficiency, and trace their impact on urbanization patterns over time. However, historical records alone are insufficient for understanding the deeper temporal and spatial dynamics of city development. Many early settlements predate written history or fall outside the administrative scope of recorded documents, underscoring the need to complement historical sources with archaeological data.

Over the past four decades, China has emerged as a global leader in archaeological research, driven by significant government investment and the application of advanced technologies. This "archaeological golden age" has produced one of the most systematic and data-rich records of prehistoric and early historic settlements worldwide. Cutting-edge techniques, such as radiocarbon dating, isotopic analysis, and molecular anthropology, have provided precise and reliable data on settlement patterns, resource use, and population movements.

Archaeological datasets, such as the Archaeology Database Project (CADB), now encompass tens of thousands of rigorously validated sites, ranging from Neolithic villages to early imperial cities. These datasets form a critical foundation for exploring settlement distributions before the advent of written records. Unlike regions where archaeological research has stagnated due to conflict or resource limitations, China's archaeological record continues to expand, benefiting from robust domestic initiatives and international collaboration. This ongoing progress solidifies China's position as a leader in interdisciplinary research on human history.

### 1.1.3 Key Definitions in This Thesis: Roads, Cities and Acient Settlments

In this study, I define roads or routes as a broad transportation network encompassing all major land routes, waterways, and multimodal transport systems that integrate both land and maritime connections. This network includes not only officially designated roads but also key routes frequently used by merchants, providing a comprehensive view of historical transportation flows.

The definition of *cities*, however, presents a more complex challenge due to the vast temporal span of the analysis and the changing nature of available data sources. Ideally, a consistent definition of the basic unit of analysis across all periods would enhance comparability and minimize classification bias. However, the significant differences between archaeological and historical records—especially in terms of data granularity and institutional context—necessitate a flexible approach[1].

[1] The use of different definitions for "city" across historical periods is driven by the nature of available data—archaeological versus documentary—and the institutional contexts they reflect. This inconsistency may introduce bias when comparing urban patterns over time, particularly in measuring city size distributions, centrality, or density. For example, administrative cities in the historical period are

In Chapter 4, which focuses on the Common Era, I rely on data from the China Historical GIS (CHGIS) project. Here, cities are defined as settlements that served as administrative seats of at least a county-level unit. These urban centers typically exhibit characteristics such as:

- Larger population sizes with higher densities relative to the surrounding region;
- Clearly structured urban morphology, including administrative, commercial, and religious cores;
- Physical enclosures (e.g., city walls), reflecting the military and political significance of such locations.

For periods before the Common Era, I rely on archaeological data from the China Archaeological Database (CADB). In this context, the definition of cities becomes problematic. Archaeological sites are classified based on material remains and radiocarbon dating, but often lack information about long-term continuity or the administrative function of settlements. Moreover, estimating stable population size or the permanence of site boundaries is inherently difficult. A site may span 2 square kilometers at one point, but its spatial extent and status could have fluctuated over time.

Given these limitations, I adopt a more cautious classification for prehistoric periods, referring to these sites as *ancient settlements* rather than *cities*, even if some may have housed several thousand inhabitants and featured defensive structures. This terminological distinction is made to avoid retroactively imposing later administrative categories on fundamentally different socio-political contexts.

I acknowledge that this variation in definitional criteria may introduce inconsistencies across chapters. Nonetheless, the criteria employed within each period are applied systematically and transparently. Where comparisons across periods are made, I explicitly account for these definitional shifts and discuss potential sources of bias. While not ideal, this approach represents a pragmatic solution to working with fundamentally heterogeneous datasets and institutional landscapes.

more likely to be documented and thus overrepresented, whereas prehistoric settlements may be underrepresented due to data loss or excavation bias. While these definitional differences are addressed systematically within each period, readers should exercise caution in interpreting long-run trends, especially those involving cross-period comparisons.

### 1.1.4 Research Questions

The integration of China's extensive historical and archaeological data, combined with advanced analytical tools, provides a unique opportunity to explore fundamental questions about human civilization. With unparalleled continuity and rich records, China serves as an exceptional case study for understanding the interplay between geography, infrastructure, and societal development. This thesis focuses on three key questions:

***The Origins of States and Civilizations.***

What drives the origins of complex societies and states? What role did human's spatial interactions play in this transformative process? This thesis investigates the foundational mechanisms that facilitated the rise of governance systems and complex social structures. It critically evaluates competing theories, proposing that a climate-triggered Circumscription Hypothesis offers a more compelling explanation for state formation, while rejecting the Hydraulic Hypothesis and Trading Hypothesis as primary drivers.

***The Long-Term Evolution of Economic Geography and Human Spatial Interaction.***

How has China's economic geography evolved over the past 7,000 years? What were the patterns of human spatial interaction at different stages of civilization, and what were the key determinants driving changes in economic geography over time? This thesis examines the long-term dynamics of spatial development, tracing how factors such as climatic shifts, institutional changes, and technological advancements have shaped the distribution of economic activities across regions. By analyzing these transformations, this study provides empirical insights into the determinants of economic geography and contributes to broader economic theories on the location of economic activity.

***Transportation and The Great Divergence.***

What were the conditions of transportation in pre-industrial China, and how did they compare to those in European countries during the same period? How did differences in transportation technologies contribute to the Great Divergence? By leveraging rich historical sources, such as China's merchant route books, this thesis reconstructs the transportation conditions in pre-industrial China and contrasts them with European counterparts. This comparison offers new perspectives on the role of infrastructure and technology in the divergent economic trajectories of the East and the West.

## 1.2 Literature Review

This thesis is related to multiple fields, including economic history, historical geography, economic geography, and archaeology. In this section, I will provide a comprehensive survey of the relevant literature across these domains. The section is structured as follows: The first part reviews the literature on China's historical transportation geography. The second part examines the body of work on the Great Divergence debate. The third part discusses the key contributions from economic geography. Finally, the last part surveys the literature in archaeology, with a particular focus on studies related to the origins of civilization.

### 1.2.1 Historical Geography: Transportation in Historical China

Historical geography, as an academic discipline, has a long tradition in China, with its research generally focused on two main directions: (1) the study of historical administrative divisions in China[2] and (2) the historical study of population in China[3]. In contrast, historical transportation geography remains a marginal field within Chinese historical geography, with systematic studies on historical transportation networks being exceedingly rare. Among the few comprehensive works is Yang Gengwang's *Tang Dynasty Transportation Study* (Yan, 1985), where Yan Gengwang meticulously reconstructed the transportation network of the Tang dynasty, covering not only official roads but also

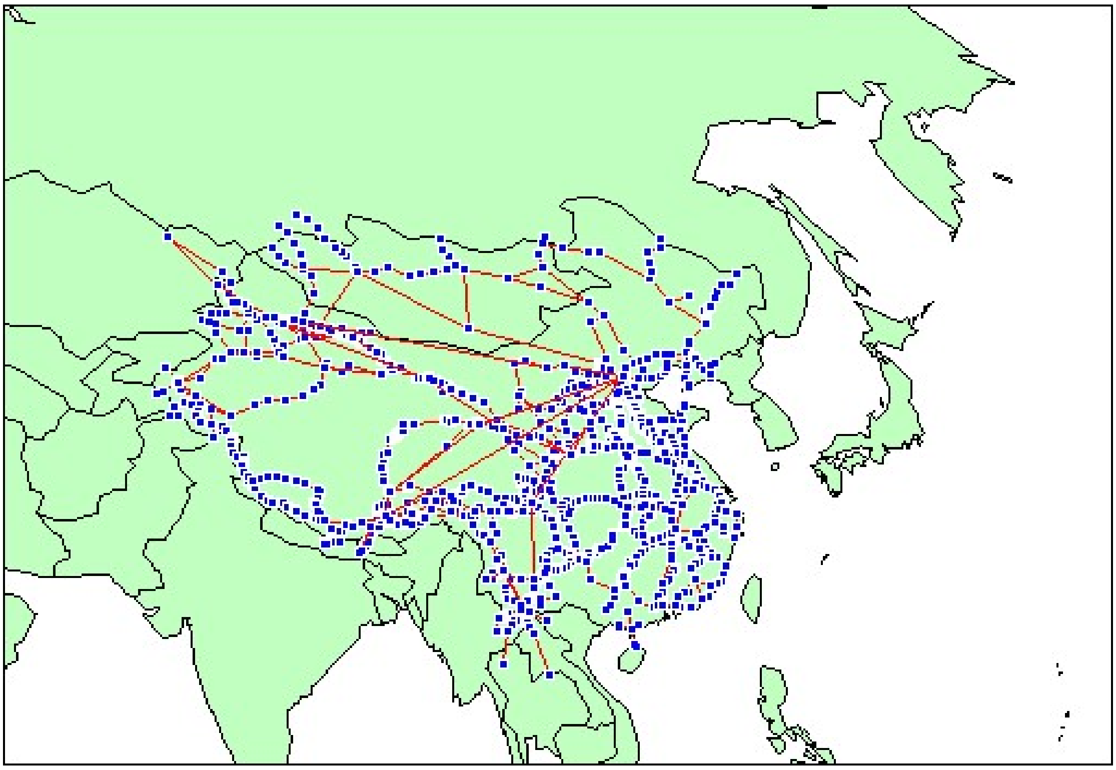
[2]For example, the series The Comprehensive History of China's Administrative Divisions published by the Historical Geography Research Institute of Fudan University, which thoroughly examines the evolution of administrative divisions and urban layouts from the unification of the Qin and Han dynasties onward.(Guo and Jin, 2007; Fu and Zheng, 2007; Li, 2007; Zhou and Li, 2009; Shi, 2009; Li and Xue, 2009; Yu, 2012; Guo, 2012; Fu et al., 2013; Hu et al., 2014; Li, 2014; Mu et al., 2016; Zhou et al., 2016)

[3]For instance, the series A History of the Chinese Population published by the same institute, which systematically examines population dynamics and their implications from the unification of the Qin and Han dynasties onward.(Cao, 2000, 2001)

some informal routes. However, Yan passed away before completing the series, leaving the study unfinished. As a result, while we have a relatively detailed understanding of the transportation network in northern China during the Tang dynasty, our knowledge of the southern network, particularly its waterways, remains limited.

In addition to Yan's work, other scholars have conducted regional studies on historical transportation networks in China. For example, Zeng (1987) examined major roads leading into Lingnan (modern-day Guangzhou) during the Tang dynasty; Lan (1989) studied the main transportation routes in Sichuan; and Yang (2006) reconstructed the official transportation network of the Ming dynasty based on an analysis of postal station locations. However, these studies are often confined to specific regions or official roads and rarely include informal transportation networks. Many journal articles focus on re-examining the routes of specific historical transportation networks for particular periods, but lack a systematic and comprehensive approach.

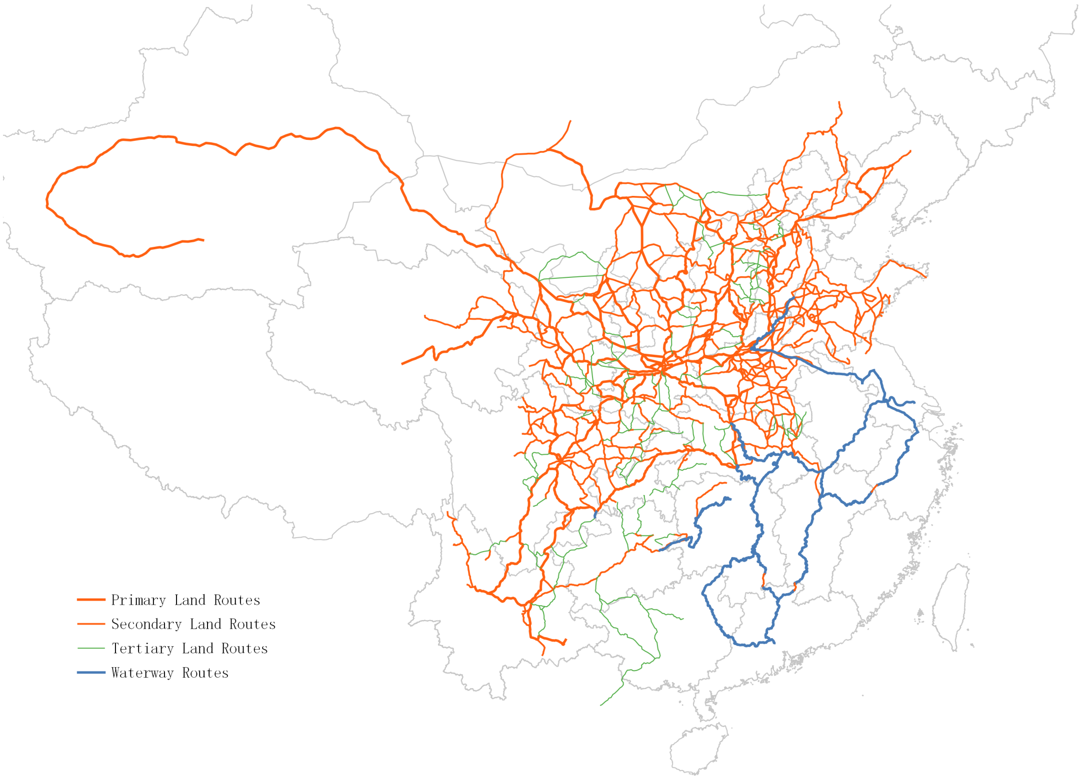
FIGURE 1.1: *China Dataset, Old World Trade Routes (OWTRAD) Project*



*Note:* see Ciolek (2024)

In recent years, advancements in GIS technology have facilitated a "spatial turn" in historical studies, allowing historians to visualize the spatial attributes of historical events

FIGURE 1.2: *Transportation Routes in Tang China*




*Note:* Reconstructed with Yan (1985), Zeng (1987) and Zhu (2014). The national transportation network in Tang China (7th century) remains largely unknown, as Yan passed away before completing his study of the entire network.

more intuitively (Bol, 2013). Some scholars have attempted to use GIS to reconstruct historical transportation networks. For instance, the Old World Trade Routes (OWTRAD) Project (Ciolek, 2024) used GIS to reconstruct the transportation networks of the Ming and Qing dynasties, based on the earlier work of Hoshi (1971). However, as with the aforementioned studies, Hoshi (1971) was limited in scope and less detailed even compared to the Ming dynasty's official postal network. Similarly, Zhu (2014) used Google Maps API to reconstruct the transportation network of the Tang dynasty, building on Yan (1985) and supplementing it with Zeng (1987) and the *Shenbao maps* (申报地图) published in 1934 (Ding et al., 1934). While this research highlights the path dependency of transportation networks and provides theoretical insights, the approach raises questions about its rigor. The *Shenbao maps*, published more than 1,100 years after the Tang dynasty, may not accurately reflect the earlier network. In a more recent study, Jian et al. (2022) reconstructed the main transportation routes from Hangzhou to Fujian during the Ming and Qing dynasties using merchants' travel permits, literary works, and poetry. This research stands out for its meticulous analysis and rigorous examination of details, offering a valuable contribution to the field of historical transportation geography.

While numerous studies have examined aspects of China's historical courier systems (Yang, 2006) and grain transport systems (Li and Jiang, 2008), it is surprising that very few have explored historical transportation costs in China. Notable exceptions include Kiyokoba (1996, 1991), who investigated transportation costs during the Tang Dynasty using legal documents, and Liu (2012), who estimated transportation costs during the Song Dynasty based on official records. Beyond these few studies, however, our knowledge of historical transportation costs and speeds in China remains extremely limited, with no comprehensive ability to estimate them.

This study makes two primary contributions to this field:

1. By leveraging Ming and Qing route books (路引), it uses GIS technology to reconstruct the transportation network of these periods comprehensively.

2. Using transportation times and costs recorded in private travel route books, combined with official archival data, it estimates transportation costs during the Ming and Qing periods. Furthermore, by integrating these estimates with previous research on Tang and Song Dynasty transportation costs, this study constructs a continuous dataset of transportation costs spanning from the Tang Dynasty to the late Qing Dynasty.

### 1.2.2 Economic History: The Great Divergence

The Great Divergence has arguably been one of the most important debates in economic history over the past two decades. Since Pomeranz (2000) introduced the concept, it has been hypothesized that, until 1800, the levels of development in Western Europe and the Yangtze region of China were comparable. However, since then, Western Europe, particularly England, achieved rapid economic development, while China experienced prolonged economic stagnation. Pomeranz proposes that the key factors driving this divergence were England's abundant coal resources and its advantageous geographic location.

Overall, this hypothesis raises two central issues: (1) Given China's vast territory, any meaningful comparison must focus on its most developed region, namely the Yangtze Delta, alongside Western Europe; (2) The core question is why Western Europe achieved sustained economic growth while China failed to do so.

The proposal of this hypothesis has sparked two major debates: (1) When exactly did the Great Divergence take place? (2) What were the fundamental causes behind this divergence?

To address the first debate, scholars have compared various indicators including GDP, wages, and living standards between England and the Yangtze region. Broadberry and Gupta (2006) analyzed wages, prices, and economic development in Europe and Asia between 1500 and 1800. They found that while China remained relatively stagnant, Western Europe, particularly England, experienced a significant economic acceleration during the seventeenth and eighteenth centuries, suggesting that the Great Divergence may have begun in the late seventeenth century. Broadberry et al. (2018) and Broadberry et al. (2021) examined historical national accounts from 980 to 1850, concluding that China's economy peaked during the Song dynasty but began to stagnate after the twelfth century, whereas Europe, especially England, saw gradual growth from the fourteenth century onward. Their findings support the notion that the divergence may have started around 1700. Allen et al. (2011) focused on wages, prices, and living standards, comparing China's Yangtze Delta with Europe, Japan, and India. They showed that the Yangtze region's living standards were comparable to those in advanced parts of Europe until the mid-eighteenth century, after which the gap widened significantly, indicating that the divergence likely occurred in the late eighteenth to early nineteenth centuries. Similarly, Li and Van Zanden (2012) compared the Yangtze Delta and the Netherlands at the beginning of the nineteenth century, highlighting significant differences in agricultural productivity, market integration, technological application, and institutional efficiency. Their findings reinforce the idea that the Great Divergence became evident by the late eighteenth or early nineteenth century.

For the second debate, in a survey of the great divergence, Parthasarathi and Pomeranz (2019) proposes that the Great Divergence was the result of multiple interconnected factors, including environmental advantages, technological innovations, institutional differences, and historical contingencies. Pomeranz (2000) highlights Britain's ability to alleviate land constraints by substituting coal for wood and importing raw materials from the Americas. This ecological relief gave Britain an advantage over the Yangzi Delta, which, despite its high agricultural productivity, faced challenges in accessing its remote coal reserves. Similarly, Parthasarathi (2011) underscores the importance of resource scarcity, noting that ecological factors became critical for Britain in the 19th century but were less relevant for India, which did not experience the same pressures.

Technological and organizational innovations, especially in textiles, also played a significant role. Britain's response to competition from Indian cotton producers, coupled with protectionist policies, fostered breakthroughs in manufacturing. In contrast, the absence of similar competitive pressures in India and China limited their incentives for innovation (Parthasarathi, 2011). Science further shaped this divergence. While Allen (2009) and Pomeranz (2000) argue that early industrialization relied more on artisanal knowledge than formal science, Jacob (2014) and Mokyr (2011) emphasize the unique contributions of 18th-century European science to production processes.

Institutional differences also mattered. Europe's fiscal systems and ability to mobilize resources for large-scale public investments offered long-term advantages. Although Chinese institutions supported market efficiency, they did not facilitate the kind of state-driven resource mobilization seen in Europe, especially in the 19th century (Pomeranz, 2000). Finally, labor productivity differences were crucial. The Yangzi Delta's labor-intensive agricultural model, while highly efficient, restricted the release of surplus labor for industrialization, contrasting with Europe's transition to a more mechanized economy (Huang, 1990; Pomeranz, 2000).

### 1.2.3 Economic Geography: Marshall externalities or First and Second Nature

Why are economic activities distributed unevenly across space? What determines the sizes and locations of cities? These fundamental questions in economic geography have been addressed by three main strands of literature.

The first is the Urban System Model, introduced by Henderson (1974), which attributes spatial agglomeration to external economies of scale. That is, texternal economies external to the industry but internal to the city. The second strand focuses on location fundamentals, emphasizing the role of institutions—such as the protection of private property and legal systems (Acemoglu et al., 2001; North, 1990)—and natural endowments, including climate and physical geography (Davis and Weinstein, 2002), in shaping the location and performance of economic activities. The third strand is New Economic Geography, which highlights increasing returns to scale as the key driver of spatial concentration and economic disparities (Krugman, 1991; Redding, 2010).

In recent decades, an increasing number of studies have utilized historical data to revisit and address these central questions in economic geography (Heblich and Hanlon, 2020). In this section of the literature review, I will critically examine these three strands and their contributions to our understanding of the uneven spatial distribution of economic activities.

#### 1.2.3.1 Urban System Model

The Urban System Model (USM), first proposed by Henderson (1974), addresses key questions in economic geography: Why are economic activities concentrated in certain areas, and why do cities vary in size? According to this model, the answer lies in intra-industry externalities. The concept of external economies, introduced by Marshall (1890), explains the concentration of industries through three mechanisms: (1) knowledge spillovers, (2) advantages of thick markets for specialized skills, and (3) the backward and forward linkages associated with large local markets (Krugman et al., 1999). This concept was later formalized by Arrow (1962), Romer (1986), and Glaeser et al. (1992) as the Marshall-Arrow-Romer (MAR) model, which posits that knowledge spillovers occur predominantly within the same industry (Van der Panne, 2004).

City size is influenced by two opposing forces: centripetal forces, which encourage agglomeration and city growth, and centrifugal forces, which limit growth due to urban diseconomies such as congestion costs (Krugman, 1999). According to the USM, centripetal forces arise from MAR externalities, while centrifugal forces stem from urban diseconomies. The model, grounded in neoclassical economics, suggests that city size reaches equilibrium when these forces balance out. Since knowledge is industry-specific in this framework, there are no production benefits to hosting multiple industries within one city. In fact, doing so would increase overall production costs. As a result, cities are expected to specialize in one specific industry to maximize welfare. Different industries, with their distinct scales of intra-industry externalities and capacities to handle congestion costs, lead to variations in city sizes and specializations. In essence, cities produce distinct sets of goods, optimize production-scale economies differently, and achieve varying sizes to maximize worker output.

Empirical studies support these theoretical claims. Henderson (2003), using data from the U.S. machinery and high-tech industries, demonstrates significant productivity effects in high-tech industries driven by local knowledge spillovers but not in machinery industries. This finding highlights the differing external economies of scale across industries and supports the USM's prediction that cities specialize by industry, with their optimal size determined by industry-specific externalities. Similarly, Henderson et al. (1995) provides evidence for both MAR externalities and Jacobs externalities. While MAR externalities emphasize industry-specific spillovers, Jacobs externalities suggest that knowledge may spill over between complementary industries, enabling innovations to transfer across sectors. Their analysis of U.S. manufacturing industries in the 1970s shows evidence of MAR externalities in mature capital goods industries, while high-tech industries exhibit both MAR and Jacobs externalities. This supports the notion that high-tech industries thrive in larger, diversified cities, whereas conventional production industries flourish in smaller, specialized cities.

In China, Au and Henderson (2006) estimate urban agglomeration economies to assess cities' optimal sizes based on their functions. Their findings reveal that most Chinese cities are undersized due to restrictive migration policies, while some favored cities are oversized. These policies have resulted in significant welfare losses across cities. Additional studies highlight other factors influencing spatial economic concentration. For instance, Chen, Henderson, and Chen et al. (2017) demonstrate that cities supported by political factions experience better growth due to lower capital costs. Henderson and

Wang (2007) show that democratization and technological advancements influence city growth: larger cities benefit more from technology, while smaller cities benefit from democratization. Henderson et al. (2017) explore the impact of climate on urbanization in Sub-Saharan Africa, finding that manufacturing cities experience increased urbanization in response to drier climates as people migrate to escape negative climate shocks.

Despite its contributions, the Urban System Model has notable limitations. First, it overlooks the role of intercity transportation costs (Krugman, 1999; Henderson, 1996). Second, external economies are treated as a "black box," making them difficult to quantify or model (Krugman, 1999). Third, the model fails to explain the rise of megacities in developing nations during recent decades of rapid urbanization. Finally, while USM offers insights into variations in city sizes, its explanation of economic activity locations relies heavily on traditional natural advantage theories. To address these shortcomings, Krugman (1991), building on his new trade theory, provides an alternative framework that incorporates transportation costs and spatial considerations to better explain the location and size of economic activities and cities.

#### 1.2.3.2 New Economic Geography and the Role of Market Access

In contrast to the Urban System Model (USM), which attributes agglomeration forces to Marshallian externalities, the New Economic Geography (NEG)—an extension of the New Trade Theory (NTT)—posits that increasing returns to scale and economies of scale are the primary drivers of centripetal forces (Krugman, 1991). This framework suggests that economic activities benefit more as the scale of economic activity increases. Consequently, even if two regions possess similar initial factor endowments, the agglomeration forces driven by scale economies will eventually concentrate economic activities in one region, provided that spatial transaction costs—typically transportation costs—are not sufficiently high to fragment the market (Krugman, 1993a,b). The dominant region is often determined by historical accidents, such as wars, political upheavals, or natural disasters.

NEG offers two key predictions. First, economic activities tend to concentrate in areas with greater market access. As market access improves, economic activities further consolidate, leading to a redistribution of their spatial location (Krugman et al., 1999). Second, secondary natural or man-made advantages significantly influence the location of economic activities. These contribute to persistent spatial path dependency and the existence of multiple stable spatial equilibria (Krugman, 1993b).

In empirical applications, four main factors are typically used to operationalize the NEG framework: local market size, labor resources, the number of local firms, and transportation costs. Together, these determine how market access affects the location decisions of firms and workers. Increasing returns and reduced transportation costs drive firms to concentrate production near large markets, which subsequently raises local wages and attracts more population. This feedback loop is often referred to as the "home market effect" (Redding, 2010). NEG effects can be estimated using simplified market potential functions (Helpman, 1998) or more structured market access models (Donaldson and Hornbeck, 2016).

Numerous studies have demonstrated the empirical relevance of market access in shaping the spatial distribution of economic activities. For example, Hanson (2005), using U.S. census data from 1970 to the 1990s, found a strong correlation between market access and nominal wages. He compared results from a simple market potential function and an augmented version based on Helpman (1998), discovering that the latter provided greater explanatory power. Similarly, González-Val et al. (2017) studied city growth in Spain from 1860 to 1960 and revealed that market potential positively correlates with city growth, although this elasticity varied over time. Notably, market potential growth after 1900 had a significant influence on city growth. Bakker et al. (2021) demonstrated a causal relationship between geographic connectedness and regional development, using trade expansion in the Mediterranean during the Iron Age as a case study. Rosés (2003) also confirmed that NEG provides a compelling explanation for the spatial distribution of economic activities during early industrialization in 19th-century Spain.

Beyond static correlations, many studies have examined how changes in market access —often induced by transportation infrastructure—reshape the geography of economic activity. For instance, Donaldson and Hornbeck (2016) developed a structural market access model and found that the expansion of American railways in the 19th century significantly altered regions' market access. Regions with greater increases in access experienced corresponding rises in agricultural land prices. Similarly, Fenske et al. (2023), using newly collected city population data, examined the relationship between railway expansion and early urbanization in 19th-century India. They found that railway connectivity spurred urbanization, especially benefiting smaller, previously remote cities. Banerjee et al. (2020) identified moderate positive causal effects of railway expansion on China's economic performance, while Berger and Enflo (2017) observed population growth in towns gaining railway access, primarily due to the redistribution of economic activities. Conversely, Faber (2014) found that although the expansion of China's highway system had positive economic effects on metropolises, it negatively affected non-targeted peripheral counties, largely due to industrial output shifting to larger cities. NEG provides a consistent framework to interpret these outcomes, emphasizing the importance of market access in shaping urban and regional development.

A major challenge in isolating the role of market access lies in disentangling it from other contributing factors such as institutions, culture, and geography. Natural experiments offer a solution. Hanson (1997) analyzed trade liberalization in Mexico, showing that under a closed economy, industries were concentrated in Mexico City. After trade reforms, industries shifted toward the U.S.-Mexico border. Manufacturing wages also decreased with distance from both Mexico City and the U.S. border. Similarly, Redding and Sturm (2008a) examined the division of Germany and found that cities in West Germany near the East-West border experienced population declines due to reduced market access, with smaller cities facing greater reductions. Lee (2018) observed that economic sanctions concentrated economic activities near trade hubs, borders, and manufacturing centers in China, indicating that severe changes in market access can reshape the spatial distribution of economic activities. Lastly, Fajgelbaum and Redding (2022), studying Argentina's integration into international markets, discovered that regions with better international market access exhibited higher population densities, urban population shares, relative prices of non-traded goods, and land prices relative to wages.

#### 1.2.3.3 Location Fundamentals and Increasing Returns: Substitutes or Complements?

A central question in economic geography concerns the respective roles of location fundamentals and increasing returns to scale in determining the spatial distribution of economic activity. This is often framed as a dichotomy between natural endowments (first-nature advantages) and man-made agglomeration effects (second-nature advantages). However, recent scholarship suggests that this distinction may be overstated, and that the two forces often act as complements rather than substitutes. While location fundamentals—such as topography, climate, and proximity to trade routes—offer initial advantages, these are frequently reinforced and locked in by increasing returns to scale, leading to persistent spatial patterns. As argued by Plöchl and Severnini (2022), ignoring the interaction between these forces risks oversimplifying the mechanisms behind long-run spatial inequality.

The New Economic Geography (NEG) framework highlights that increasing returns and transportation costs can produce multiple stable spatial equilibria (Krugman, 1993b). Initial advantages, whether geographic or historical, may determine which equilibrium is realized. Once an agglomeration emerges, path dependency and scale effects perpetuate its dominance, even in the absence of the original advantage. In other words, location fundamentals can shape the "initial condition," while increasing returns provide the "amplifier."

Empirical work supports this view. Allen and Donaldson (2022) developed a theoretical and empirical model to explore under what conditions history matters for the spatial distribution of economic activity. Simulations based on U.S. county-level data from 1800 to 2000 revealed that even small historical shocks can have persistent spatial consequences. Bleakley and Lin (2012) examined U.S. portage cities that initially benefitted from river transport but later lost this advantage due to the rise of railroads. Despite the disappearance of their first-nature advantage, many of these cities retained their economic prominence—evidence of agglomeration economies reinforcing past conditions.

Similarly, Jia (2014) showed that China's treaty port cities maintained their economic momentum even after the treaty system was abolished in 1942. Cermeno and Enflo (2019) found that townships established by royal decree in medieval Europe continued to outperform neighboring areas despite losing exclusive trading rights. Jedwab and Moradi (2016); Jedwab et al. (2017) highlighted how colonial railroads in Africa gave rise to cities that remained spatially advantaged even after independence and institutional change. Henderson et al. (2018) drew attention to how early industrialized countries, which developed under high transportation costs, retained dispersed economic centers, whereas recently modernized economies—emerging under low transportation costs—exhibit higher urban concentration along coasts.

***Empirical Evidence for Spatial Path Dependency***

Allen and Donaldson (2022) developed a theoretical and empirical model to explore the conditions under which history matters for the location of economic activities. Simulations using U.S. county data from 1800 to 2000 showed that even minor historical variations can have significant long-term consequences for the spatial distribution of economic activities. Bleakley and Lin (2012) examined portage cities in the U.S. Midwest and found that despite losing their initial advantages due to the shift from river to railway transport, these cities have retained their spatial advantages. Similarly, Jia (2014) studied treaty port cities in China and observed sustained economic advancement even after the treaty port system was abolished in 1942. These cities continue to exhibit high economic growth today.

Cermeno and Enflo (2019) found that townships established by royal decree in medieval Europe still experience high economic growth despite losing their historical trade monopolies. Similarly, Jedwab et al. (2017) and Jedwab and Moradi (2016) investigated the impact of colonial railways in Africa, finding that cities emerging from railway expansion during the colonial era retained their spatial advantages even after independence and the decline of railway systems. Henderson et al. (2018) explored differences in spatial distributions between early industrialized and recently modernized nations, finding that early industrialization created dispersed economic centers due to higher transportation costs in the 19th century. In contrast, modernized nations exhibit concentrated economic activity in coastal megacities, reflecting the influence of low transportation costs on market access.

#### *Challenges to the Path Dependency Argument*

While many studies support spatial path dependency, a competing strand of literature argues that natural advantages predominantly determine the spatial distribution of economic activities. Davis and Weinstein (2002) examined Japan's economic geography before and after the devastating bombings during World War II, including the atomic bombings, and found no significant long-term change in the spatial distribution of economic activities. Similar findings were observed for bombing campaigns in Germany (Brakman et al., 2004) and Vietnam (Miguel and Roland, 2011). Cavallo et al. (2013) further demonstrated that even severe natural disasters have little long-term impact on a nation's economic geography unless accompanied by events such as civil wars or revolutions. Similarly, Elliott et al. (2015) found that even destructive typhoons had no measurable effect on regional long-term economic development.

#### *Reconciling the Two Strands*

Why do these two strands of literature produce conflicting conclusions? Recent research provides insights into this question. Kocornik-Mina et al. (2020) studied the long-term effects of floods and found that while floods do not alter the spatial distribution of economic activities in well-established regions, they can significantly impact newly urbanized areas. Hanlon (2017) examined the impact of the U.S. Civil War on cotton supplies and found that English textile cities faced a permanent decline in growth rates, leading to long-term changes in population levels. Similarly, Redding et al. (2011) investigated the aviation industry in Germany, finding that the division of Germany caused a permanent shift in the country's aviation hub from Berlin to Frankfurt, facilitated by a series of temporary shocks.

These studies suggest that only permanent shocks that fundamentally alter regional market access can result in the redistribution of economic activities. Temporary shocks, while impactful in the early stages of economic development, fail to influence spatial distributions once spatial path dependency is established. This reconciles the two strands of literature, highlighting the conditions under which natural advantages or increasing returns to scale dominate in determining economic geography.

### 1.2.4 Archaeology: The Origin of Civilization

The emergence of cities or large settlements is often seen as a marker of civilization. In this section I review three main hypotheses on the origin of civilization: the Circumscription Hypothesis (Carneiro, 1970), the Hydraulic Hypothesis (Wittfogel, 1957), and the Neolithic Revolution Hypothesis (Childe et al., 1940; Childe, 1950). Theoretically, the non-concentrated settlement patterns should align with the Neolithic Revolution Hypothesis. In contrast, both the Circumscription and Hydraulic Hypotheses should result in concentrated settlement patterns, though for different reasons. The Circumscription Hypothesis attributes this to resource competition and conflict, while the Hydraulic Hypothesis points to the need for large-scale water management and centralized control.

#### 1.2.4.1 Carneiro: The Circumscription Hypothesis

The circumscription theory was initially introduced by Robert Carneiro in the 1970s. In his article published in *Science* in 1970 (Carneiro, 1970), he used the coastal valleys in Peru and the Amazon region to illustrate the role of environmental boundaries, population growth, and engage in conflict and conquest once population expansion covers the entire area and resources become scarce. According to his coercive theory, in areas with clear environmental boundaries and limited resources, such as the coastal valleys of Peru and the Nile River Basin, tribes will engage in conflict for conquest after population expansion covers the entire area to compete for limited resources. Eventually, one tribe will dominate the entire valley and establish a state. Over time, this state will surpass physical barriers and expand to other valleys, ultimately forming a country that spans multiple valleys.

It is important to note that this mechanism is mainly present in areas with well-defined environmental boundaries, such as valleys, basins, and oases in deserts. In contrast, in areas without clear environmental boundaries, such as the Amazon region (plains with abundant resources), conflicts are more likely to occur in the form of revenge. This is because in these areas, a defeated tribe can choose to migrate from the region, making it challenging for the victor to conquer the defeated tribe. Consequently, the role of war is merely to create greater distance and autonomy between settlements. Conversely, in areas with clear environmental boundaries, the defeated tribe has no choice but to be conquered, allowing the victor to acquire significant benefits and drive further war, ultimately ruling the entire area.

According to this hypothesis, in areas with well-defined environmental boundaries and limited resources, a tribe will eventually emerge and unify the entire region through warfare over time. As a result, resources will be highly concentrated in this region, leading to a settlement cluster distribution characterized by a single center or a highly hierarchical structure.

The empirical assessment for this hypothesis is Schönholzer and François (2023). [4] They develop an algorithm to measure the level of Circumscription. They use data from the Atlas of World Archaeology and Seshat: Global History Databank.

#### 1.2.4.2 Wittfogel: The Hydraulic Hypothesis

The hydraulic hypothesis was proposed by Wittfogel (1957), which suggests that the demand for managing and regulating irrigation systems is the reason behind the emergence of states. In some arid or semi-arid regions, such as ancient Egypt and Mesopotamia, the growing population needed to obtain more food from limited land, which led humans to collaborate in constructing large-scale hydraulic engineering facilities to boost food production. The construction, maintenance, and management of these facilities require a high level of social organization and relatively centralized power. Therefore, the establishment of a power authority that can organize and train labor is inevitable during the construction of hydraulic facilities.

In the context of this hypothesis, the emergence of large settlements is closely related to highly centralized power. After the first settlement with a hydraulic system is completed,

[4] link: https://www.davidschonholzer.com/.

it has significantly higher welfare than other settlements, leading to higher population growth and attracting more migration. Moreover, sunk investments and good welfare encourage people to expand the existing hydraulic facilities in this settlement, rather than establishing new settlements with hydraulic facilities in other places. This leads to the first settlement with a hydraulic system having a higher initial advantage and becoming the center of agglomeration. This means that if the emergence of a large settlement in a region follows the path of the hydraulic hypothesis, the settlement pattern of the region should also be a centralized model with one or a few centers.

This hypothesis has been empirically tested in Allen et al. (2023). They used the systemic archaeological survey in Mesopotamia in the 1980s, which is very detailed, comprehensive, and credible.

#### 1.2.4.3 Childe: The Neolithic Revolution Hypothesis

During the 1930s to 1940s, Childe presented the "Neolithic Revolution" hypothesis, which suggests that after humans settled down to engage in agricultural production, the population grew as agriculture provided a more dependable food source. With population growth, agricultural societies became more intricate, settlement sizes increased, and social hierarchies began to emerge. Agricultural production also resulted in surpluses, enabling some individuals to work in non-agricultural sectors, leading to the emergence of specialization, exchange of goods, and trade.

Under this hypothesis, the division of labor leads to the exchange of goods and the emergence of trade. Therefore, we can anticipate that under conditions of exorbitant transportation costs, economic activities will exhibit polycentricity, where several cities of comparable size serve as regional centers. As a result, we can expect to observe multiple large settlements of similar size coexisting within the same region, leading to a non-centralized settlement distribution.

#### 1.2.4.4 Characteristics of three hypotheses

In this section, I reviewed the three prevailing hypotheses for the origin of complex societies: Carneiro's Circumscription Hypothesis, Wittfogel's Hydraulic Hypothesis, and Childe's Neolithic Revolution Hypothesis. These hypotheses present three distinct paths towards complex societies, each with unique prerequisites and resulting in different settlement distribution patterns. Carneiro's Circumscription Hypothesis is contingent on a circumscribed environment, such as a basin, valley, or oasis in a desert. Wittfogel's Hydraulic Hypothesis necessitates an area with hydraulic facilities that can significantly increase agricultural productivity or ensure normal agricultural production. In contrast, Childe's Neolithic Revolution Hypothesis does not require any environmental prerequisites. The potential settlement distribution patterns resulting from these hypotheses are also markedly different. Carneiro's Circumscription Hypothesis and Wittfogel's Hydraulic Hypothesis would lead to a centralized settlement distribution pattern, while Childe's Neolithic Revolution Hypothesis would result in a non-centralized settlement distribution pattern.

## 1.3 Sources and Data

The three chapters of this thesis each utilize distinct data sources to reconstruct historical transportation networks and the spatial distribution of cities or settlements in China.

To reconstruct historical transportation routes, I employed a variety of official and unofficial route books from the Ming and Qing dynasties (14th to 18th centuries) as well as archival records on government transportation (further details in chapter 2). For the spatial distribution of cities in China's history, I relied on the *China Historical GIS (CHGIS)* project, developed jointly by Harvard University and Fudan University, which documents the locations of Chinese cities over the past 2,000 years in detail.

For the pre-Qin (pre-221 BCE) period, information on the locations of cities or settlements is less thoroughly researched, and systematic studies are scarce. To address this gap, I used data from the *China Archaeology Database (CADB)* project. This dataset includes all publicly available archaeological reports published up to 2020. This means that, as of 2020, all archaeological sites that have undergone systematic excavations or regional surveys are included in the database. Specifically, the dataset contains records for over 10,000 archaeological sites, spanning from the Neolithic period (approximately 10,000 years ago) to the unification of China during the Qin and Han dynasties.

In this section, I will provide a detailed introduction to these three datasets, discussing their origins, reliability, and the extent of their coverage.

### 1.3.1 Travel Route Books: Travel in Ming-Qing China

Traveling in Ming-Qing China was considerably more complex than it is today. The first challenge appeared to be identifying the direction of the way. *Xu Hongzu* 徐弘祖, renowned as *Xu Xiake* 徐霞客, a prominent traveler and geographer, addressed this issue by carrying a copy of the *Ming Yitongzhi* (*Ming National Gazetteer* 明一统志), which consisted of a cumbersome ninety volumes (Brook, 1981). These extensive volumes were far from being portable or practical for the average traveler. To bridge this gap, a more accessible guide was published in the late 16th century, the *Yitong Lucheng Tuji* (*Comprehensive Illustrated Route Book* 一统路程图记) (hereafter YTLC). This guide was specifically crafted for merchants and ordinary travelers. *Huang Bian* 黄汴, the author of YTLC and a merchant from Huizhou—present-day Anhui, China—recognized the challenges of traversing the vast Chinese Empire, particularly the absence of a practical, comprehensive route book for common use. In response, he authored YTLC to serve as a reference for future travelers. In the preface of the book, he notes:

> *My family resides in the mountainous region of Huizhou, an area known for its challenging transportation and limited educational opportunities. Despite the scarcity of flat land, it remains densely populated. These conditions have compelled many locals to pursue merchant trade as a means of survival. At the age of twenty, I began to travel with my father and brothers. Our journey took us from Hongdu to Changsha, and along the way, we explored the scenic landscapes of Dongting Lake. We then journeyed along the Yangtze River,*

*stopping at Huaiyin and Yangzhou, before ultimately reaching our final destination, Beijing.*

*I am anxious to return home as soon as possible during my trip from Yanzhou to Xuzhou, but the road ahead is murky indeed. I am troubled with asking the direction and realized that many travelers suffer the same difficulty of missing the direction of the way as I did.*

*Later, when I was living in Suzhou, I collected several route maps from merchants who traded in both capitals, all thirteen provinces, and the border regions. I examined them closely, compared their differences, then collated all the material. It took me twenty-seven years to work it into book form.*

*This book is formed into eight volumes and each volume has its specialized region. Once the reader read it, one can know the direction and distance of routes, the steepness of mountains and rivers, and the potential dangers of robbery. One can gain insights into various fields in various regions, just like the whole of China is displayed in one's hand. I sincerely write this book and hope this book could provide references to officials'tours, merchants'trends, and ordinary people's trips.*

In the post of the book, it writes:

*Should gentry obtain this book, it will help them carry out the emperor's sagely commands, and should merchants obtain it, it will inform them about the characteristics and difficulties of local area*[5]*.*

Indeed, Huang's YTLC achieved the impact he anticipated, gaining popularity towards the end of the Ming Dynasty. The book offers comprehensive details on 158 routes across China, alongside insights into the scenery, specialties, security, and cultural aspects of various regions. However, by the late 17th century, a new guide, *Shi Wo Zhou*

[5]Translation from (Brook, 1981)

*Xing* (*Traveling Everywhere on My Own* 示我周行) (hereafter SWZX), eclipsed Huang's YTLC in popularity. Unlike Huang's guide, which typically summarizes regional situations in one or two sentences, SWZX provides extensive descriptions in full paragraphs. It includes meticulous details on practical matters such as hiring vehicles and pack mules, paying commercial taxes, finding lodgings, and offers specific information and precautions for different areas. Due to its thoroughness, SWZX was reprinted multiple times in the 18th century and continued to be a valued reference well into the late 19th century (Jian et al., 2022).

These route books provide a vivid depiction of Ming-Qing China as an empire with a well-developed transportation network, encompassing a variety of transport modes and extensive routes covering the majority of China proper. The books detail extensive waterway networks, where people traveled using different types of ships on canals, lakes, major rivers, and creeks. Depending on the waterway, ships varied greatly in capacity, ranging from a few piculs to hundreds of piculs.

For land routes, travelers commonly journeyed on foot, often with their belongings transported by pack horses or mules, especially for long-distance treks that could extend over thousands of kilometers. In flatter regions, different sizes of wheeled vehicles were available for shorter trips. Notably, near Beijing, one could hire vehicles for transporting goods from Tongzhou, the northern terminus of the Grand Canal, to the capital. A large vehicle could carry up to 2000 *jin* of goods but might face congestion in Beijing's city center, whereas a smaller vehicle, carrying up to 1000 *jin*, could offer greater maneuverability.

In the Yangtze Delta, stage ships provided continuous day and night service, connecting cities and towns. These ships are meticulously detailed in the route books. In YTLC, the book has described the stage ships in Suzhou as follows:

> *For trips north of Suzhou cities, ships run only during the days; For trips south of Suzhou city, ships run both day and night. One can take ships to Huzhou from both Meidu Bridge and Pingwang in Suzhou City, ships for this route run both day and night. Both day and night ships from Jiangxing to*

> *Pinghu should be boarded at Dongzhakou. Ships from Jianxing to Songjiang only run during the day but not at night.*

For Huzhou, it writes that one can take night ships to Suzhou from the east gate; night ships to Jian from the west gate; night ships to Hangzhou, Wukang county, and Deqing county from the south gate; and night ships to Yixing county from the north gate. At the end of the instruction, it concludes that:

> *All stage ships from Huzhou to other places run at night only. Two exceptions are stage ships to Zhengze and Wuzhen, which there are also days ships available.*

While China has a long history of prosperous long-range naval trade with Southeast Asia and Japan (Brook, 2017; Wang, 2018; Ding, 1997). Surprisingly, route books in Ming-Qing China rarely mentioned traveling through sea routes. It seems that worries about the risk of naval journeys have hindered its role in travelers, especially merchants'trips. Huang's YTLC has negatively commented on a route traveling from Haizhou to Huaian Fu through seaway as follows:

> *It is uncertain whether there is wind available for a naval trip. A tailwind would make the journey easier but also riskier. If the wind is unavailable, it would be hard to know how long the journey would become. Under this circumstance, one should seek another route. ⋯Even though there is wind available for the naval journey, one also might lose their way at sea and end up drifting further south to Taicang. Those travelers who take care of their safety should not choose this route.*

A meticulous examination of these route books reveals a distinct spatial concentration of commentary on routes and places, particularly in southern China, with significant focus on areas such as the Yangtze Delta, Huguang, and Fujian. In contrast, the routes in western and northern China receive comparatively less attention, featuring fewer comments and descriptions. This uneven distribution of detailed information in the route books suggests that southern China may have experienced higher levels of transportation and trade activities than northern China during the Ming and Qing periods.

### 1.3.2 China Historical GIS (CHGIS) Project

#### 1.3.2.1 A Brief History of CHGIS

In 1957, after the establishment of the People's Republic of China, Chairman Mao expressed a desire to create a historical geography atlas showcasing China's history. This ambitious task was entrusted to Professor Tan Qixiang (谭其骧) at Fudan University, who subsequently founded the Institute of Historical Geography to fulfill Chairman Mao's directive. However, the project was extraordinarily time-consuming and labor-intensive. It was only in the 1980s, several years after Chairman Mao's passing, that the work was completed, culminating in the publication of the *Historical Atlas of China* (Tan, 1982). The atlas spans eight volumes, covering the period from prehistoric times to the Qing Dynasty, and features 304 maps illustrating administrative divisions at the first and second levels for specific years in Chinese history. However, it does not reflect historical events.

Around the early 2000s, Peter Bol, then a professor at Harvard University in the Department of East Asian Languages and Civilizations, initiated discussions with Professors Man Zhimin and Wu Songdi from Fudan University's Institute of Historical Geography. Together, they decided to digitize Fudan's *Historical Atlas of China* using GIS technology. Originally, the project was expected to take only one year. However, the Fudan team aimed to go beyond the atlas by leveraging GIS capabilities to create a continuous dataset of China's cities and administrative boundaries over the past two millennia, rather than providing only a few cross-sectional snapshots. This ambition significantly delayed the project, which ultimately took 17 years to complete.

Many members of the Fudan team were scholars who had assisted Professor Tan Qixiang during the production of the original atlas. These seasoned researchers meticulously reconstructed administrative boundaries and city locations, starting with the early Republican period in 1910 and working backward to the Qin and Han Dynasties. As a result, they produced a comprehensive dataset of county-level administrative units and their boundaries spanning over two millennia.

Today, the CHGIS project is jointly managed by Fudan University's Institute of Historical Geography and Harvard University's Center for Geographic Analysis (CGA).

#### 1.3.2.2 Coverage and Reliability of CHGIS Data

CHGIS data is freely available for download from its official website and can be categorized into five main components:

- (1) Administrative unit locations
  - Including prefecture and county seats over the past two millennia.
- (2) Administrative boundaries
  - Providing fairly complete prefecture-level boundaries up to the Ming Dynasty, with significant gaps for earlier periods.
- (3) Market towns of 1820.
- (4) The Hartwell dataset on administrative divisions during the Tang and Song Dynasties.
- (5) The Ming Dynasty postal station network.

Among these, components (1) and (2) are the core datasets. The administrative unit locations dataset consists of two main data subsets: a cross-sectional dataset for 1820 and a time-series dataset covering the period from the unification of China under the Qin Dynasty in 221 BCE to the fall of the Qing Dynasty in 1911. Both subsets include two further datasets—prefecture-level administrative unit locations and county-level locations. The data is available in GIS-compatible point format (SHP files), providing detailed attributes such as the unit's name, administrative level, type (e.g., prefecture, county, military region), establishment and abolition dates, and precise modern-day locations.

The administrative boundaries dataset (2) offers polygon data for both the 1820 cross-section and the time-series dataset. However, due to the challenges of historical reconstruction, reliable polygon data extends only as far back as the Ming Dynasty. Earlier periods contain significant gaps. As a supplementary resource, the Hartwell dataset provides boundaries for the Tang and Song Dynasties. However, users should exercise caution as these boundaries were extrapolated using 1990 administrative boundaries, historical administrative seats, and gazetteer records, making them less reliable. A better alternative for earlier periods is to use administrative seat point data to construct Thiessen polygons for boundary approximations.

The market town dataset (3) for 1820, compiled by Fudan University's team, presents significant limitations in its coverage and accuracy due to constraints in historical records. This raises concerns about its randomness and representativeness, necessitating careful consideration when utilizing the data.

For instance, as elaborated in Chapter 1 of this thesis, the dataset only covers approximately 20% of the market towns mentioned in Ming and Qing route books, highlighting substantial gaps. Furthermore, the dataset exhibits distinct regional inconsistencies, particularly in Northeast China. In this region, the distribution of market towns aligns closely with major transportation routes, with no market towns recorded outside areas covered by the transportation network. This raises an important question: does the absence of recorded market towns outside the transportation network imply that such areas genuinely lacked market towns, or is this simply a reflection of incomplete historical documentation?

These issues underscore the need for cautious interpretation, as the dataset's limitations could impact the broader analysis of historical market town distributions and their relationship with transportation networks.

Lastly, the Ming Dynasty postal station network (5) relies heavily on a 1915 postal map and covers only about 400 of the over 1,000 stations documented in the *Da Ming Hui Dian (大明会典)*. This reliance results in an incomplete and potentially inaccurate representation of the network. Routes are represented as direct lines between stations, without reconstructing actual pathways. Moreover, the heavy dependence on the 1915 postal map introduces discrepancies with the Ming-era network. A more reliable alternative is the reconstructed data presented in Chapter 2 of this thesis.

#### 1.3.2.3 Summary of Section

Overall, the CHGIS datasets, particularly the point data and polygon data on administrative unit locations and boundaries, are highly reliable. Their creation dates back to 1957 when Professor Tan Qixiang began work on the *Historical Atlas of China*, a project supported by a large, professionally trained team of historical geographers over nearly seven decades.

However, the polygon data for periods prior to the Ming Dynasty remains incomplete due to difficulties in historical reconstruction. The Hartwell dataset serves as a supplement for Tang and Song administrative boundaries but is less reliable due to its reliance on modern extrapolation methods. For pre-Ming periods, a better approach is to use point data of administrative seats and construct boundaries using Thiessen polygons (as suggested by professor Peter Bol, who initiated this Project).

The market town dataset for 1820 reflects significant limitations and biases due to the scarcity of historical records, requiring cautious use. Similarly, the Ming postal station network is incomplete and somewhat inconsistent. For a more accurate representation, the reconstructed data in Chapter 2 of this thesis offers a superior alternative.

### 1.3.3 China Archaeological Database (CADB) Project

The **China Archaeological Database (CADB)** project, led by Professor Chen Zhiwu from the University of Hong Kong, was a collaborative effort aimed at digitizing all available archaeological materials excavated in China as of 2020. The database framework was developed by Yu Xiao, then a PhD student in political science at Tsinghua University, who also recruited a team for data entry. The project's primary goal was to create a comprehensive electronic record of all published archaeological reports in China.

The database is divided into four sections: Archaeological Site Information, Tomb Information, Artifacts Information, and Settlement Site Information. The first three sections are structured as a relational SQL database, linked by unique IDs. The fourth section, being more independent, focuses specifically on settlement sites and serves as the primary data source for settlement studies, including this research.

The first section, **Archaeological Site Information**, documents the location of sites, their chronological identification, excavation area, estimated total area, the number of tombs discovered, cultural periods, and the sources of the data.

The second section, **Tomb Information**, provides details about the tombs found within archaeological sites. It records the associated site name, the chronological period of the tomb, and the total number of individuals interred. Additionally, it includes detailed information about the deceased, such as their height, gender, age, injuries, and diseases. The burial posture (e.g., prone, lateral, supine, extended, or flexed positions) is also noted, along with details of any coffins or burial chambers, including the number of layers, dimensions, and materials used. The burial pit area and references to the source material are also documented.

The third section, **Artifacts Information**, records the artifacts excavated from tombs and sites. It includes the associated site and tomb, the specific name and type of the artifact, its material, dimensions (length and width), color, weight, and the source references.

The fourth section, **Settlement Site Information**, focuses on settlement data. It documents the location, chronological period, and excavation status of each site (e.g., fully excavated, partially excavated, or surveyed systematically). It also provides information on the excavation area, the estimated total area, and the presence of enclosure features such as city walls or moats, with the type of moat (dry or water-filled) and its dimensions noted. Furthermore, it details subsistence strategies (e.g., gathering, hunting, fishing, farming, or pastoralism), settlement patterns (e.g., permanent or seasonal), estimated population size, evidence of fire usage, presence of central buildings, functional zoning, and the source references.

The CADB database includes approximately 10,000 pre-Qin archaeological sites. These sites are supported by systematic archaeological reports and have undergone professional excavations, ensuring a high degree of data reliability compared to other sources.

## 1.4 Structure

The thesis is structured around three substantive articles and is organized as follows. Chapter 1 offers an introduction, including a comprehensive review of the related literature. This is followed by the three core articles presented in Chapters 2, 3, and 4, each addressing a specific aspect of the research. Finally, Chapter 5 summarizes the key findings, discusses the study's limitations, and outlines potential directions for future research.

# Chapter 2

# Transportation Cost in the Great Divergence: Yangtze China VS. England

# Abstract

The Great Divergence has arguably been one of the most important debates in the field of economic history over the past two decades. This article contributes to this ongoing discussion from a novel perspective, specifically focusing on transportation conditions. Utilizing travel route books published since 16th century China, I reconstructed the national trade transport network of China during the Ming and Qing dynasties (14th to 19th centuries) and estimated transport costs and speeds in the Yangtze region during the late 17th and 18th centuries. These estimates were then compared with those of England for the same period. The findings reveal that, in the late 17th century, transport costs and speeds in the Yangtze region of China were comparable to those in England. However, a divergence emerged after 1700. This timing of divergence in transportation between the Yangtze region and England supports the strand of literature proposing that The Great Divergence began around 1700.

## 2.1 Introduction

Since Pomeranz (2000) proposed the concept of the Great Divergence[1], discussions on this topic have remained among the most significant debates in the field of economic history. A key aspect of this debate revolves around the specific timing of the divergence. One strand of literature, by reconstructing and comparing economic development indicators such as GDP, wages, and living standards between Western Europe and Yangtze China, finds that by 1800, there were already significant differences in development levels. This body of work further proposes that the Great Divergence occurred around 1700. (Broadberry and Gupta, 2006; Broadberry et al., 2018, 2021; Li and Van Zanden, 2012; Broadberry, 2013)

This article approaches the debate from a different perspective, focusing on the transportation condition. It is widely acknowledged that the progressive reduction in transport costs has been a crucial driver of long-term economic growth since the days of Adam Smith (Smith, 1776; North, 1958). Recent empirical studies further reveal the causal connections between the development of transport infrastructures and economic growth (Donaldson and Hornbeck, 2016).

Yet, very few studies have focused on the great divergence from the perspective of the availability of transportation. There are rich studies on transportation in 18th century England. These studies has shown that the turnpike trust revolution, beginning around 1700, significantly improved transportation infrastructure and contributed to subsequent economic expansion (Bogart, 2005; Bogart et al., 2023, 2022). However, there has been a lack of systematic studies exploring the transportation conditions in China during the same period. To address this gap, this study examines transport cost, speed and network in late 17th century China and compares them with those in England during the same timeframe.

[1] The Great Divergence hypothesizes that until 1800, the development levels of Western Europe and the Yangtze China were comparable. Such a hypothesis raises two important issues: (1) Given China's vast territory, the comparison should focus on the most developed regions: Western Europe and Yangtze China. (2) The central concern of this hypothesis is why Western Europe achieved economic development while China experienced economic stagnation.

Specifically, by following merchant travel route books published since the 16th century, I reconstructed the national trade transport network of China during the Ming and Qing dynasties (14th to 19th centuries) and estimated transport costs and speeds in the Yangtze region during the late 17th and 18th centuries. My findings indicate that historically, China had a highly developed national transportation network capable of supporting a nationwide prosperous market[2]. By comparing the transportation costs and speeds in the Yangtze China with those of England, it is evident that up until 1700, the transportation costs and speeds were similar between the two regions. However, starting from 1700, England underwent a transportation revolution that significantly reduced transportation costs and increased speeds[3], leading to a clear divergence from the Yangtze Delta. Considering that transportation condition is a crucial determinant of an efficient market, it can be speculated that until around 1700, the market performances of the Yangtze Delta and England were comparable, but they began to diverge in the 18th century[4].

To gain these insights, I begin by examining several historical archives and popular travel route books used by merchants[5]. Using these sources, I reconstruct the commercial transport network and estimate the passenger and freight travel speeds and costs, both over land and via rivers, across various regions in late 17th century China. I then compare this new evidence with transportation situation in late 17th century England.

This study reveals that in Yangtze China, passengers and freight could travel as fast as 55 km per day through canals and minor rivers. On major rivers like the Yangtze, with tailwinds, ships could achieve speeds up to 65 km per day even while traveling

[2] This aligns with the findings of Shiue (2002), which, through the analysis of correlation in grain prices, identified the existence of a historical nationwide market in China that performed better than traditionally believed.

[3] see (Gerhold, 2014) and (Bogart, 2005)

[4] This corresponds with the findings of Shiue and Keller (2007), which discovered that by the mid-18th century, England's performance was noticeably superior to that of continental Europe, while the performance across continental Europe was on par with that of Yangtze China. This aligns with the historical fact that England was the first in Europe to undergo a transportation revolution.

[5] I have used several route books in this study. A majority of quotations I get for transport cost and speed are from *Shi Wo Zhou Xing* (*Traveling Everywhere on my own* 示我周行) (hereafter SWZX). This route book is first published in 1694, it can be expected the book reflects the transport situation in the 1680s. Brook (1981, 2002)

upstream[6]. In mountainous areas, small ships on creeks could travel downstream at speeds of up to 80 km per day, but upstream travel was much slower, around 28 km per day. For overland journeys, merchants using packhorses could cover 45 km per day in flat regions and approximately 30 km per day in hilly areas.

When these travel speeds are compared to those in late 17th century England, it becomes evident that the Yangtze Delta in China had transport speeds comparable to those of England during the same period. However, the situation in England changed dramatically with the turnpike revolution in the 18th century, which significantly increased both passenger travel and land freight speeds (Gerhold, 2014; Bogart, 2005). Unlike England, China did not undergo a similar transformative increase in transportation speeds.

This study estimates that the average cost of traveling through waterways was 0.021 silver taels[7] per 100 kilograms per 100 kilometers, while land shipments cost 0.213 silver taels per 100 kilograms per 100 kilometers. For passenger trips within the core Yangtze region, the average price was 0.022 silver taels per 100 kilometers. Traveling in periphery part of Yangtze Delta was considerably more expensive, costing nearly four times as much.

Compared to England, the transport costs in these two regions were similar in magnitude in the late 17th century when adjusted for unskilled wages. However, during the 18th century, England saw a 50% reduction in land transport costs and a three-fold increase in travel speed, while China's transport efficiency remained unchanged throughout the century.

### 2.1.1 Related Literature

This study contribute to several strands of literature. It first contribute to the debate in level of market integration in historical China. It is generally agreed that the progressive reduction in transport costs has been a crucial driver of long-term economic growth.(Smith, 1776; North, 1958) However, this perspective was challenged by Shiue

[6]Sources from SWZX do not provide a downstream travel speed along major rivers. However, considering the flow speed in the middle and lower part of the Yangtze River is very slow, it can be expected the speed between upstream and downstream would be close if there is a tailwind.

[7]Detail for measuring and currency unit see table 1

(2002) and Shiue and Keller (2007). Utilizing a grain price correlation method, they demonstrated that Yangtze China had achieved an integrated market whose performance was comparable to that of continental Europe until the late 18th century, while England was achieving better market performance during the same period. They argue that these findings indicate that although strong market performance is necessary, it is not sufficient for sustained economic growth.

Their argument, however, has been questioned by economic historians, who point out that grain prices were heavily regulated by the government in historical China, leading to a "false market integration." (Li, 2000; Deng, 2011; Von Glahn, 2016; Ni and Uebele, 2019). Therefore, the level of market integration derived from government-controlled prices would be too optimistic. In this study, I explore the factors that constitute market performance from another perspective: the availability of transport. Specifically, I examine the transport condition in late 17th century China and compare it with that of England during the same period. Surprisingly, my findings largely align with those of Shiue (2002) and Shiue and Keller (2007), suggesting that Yangtze china do obtained comparable transportation infrastructure to support a efficient market that comparable to England until 1700.

This study also contributes to the literature on the Great Divergence. There has been an ongoing debate on the timing of the Great Divergence. While some world historians argue that the divergence occurred only after 1800 (Pomeranz, 2000; Parthasarathi, 1998, 2001; Frank, 1998), another strand of literature proposes that such divergence had already happened during the 18th century (Broadberry and Gupta, 2006; Broadberry et al., 2018, 2021; Li and Van Zanden, 2012; Broadberry, 2013). Utilizing Chinese historical route books, this study compares the transportation conditions between the Yangtze region in China and England during the 18th century. My findings support the hypothesis that the Great Divergence began since 1700.

Finally, this study contributes to the literature on Chinese historical geography, with a focus on transportation in historical China. Research on historical transportation routes in China is relatively scarce. Systematic studies are limited, with only a few such as the study on Tang Dynasty Transportation Network by Yan (1985). Unfortunately, Yan passed away before completing this work, leaving us without a comprehensive and reliable study of China's historical transportation network. Moreover, research on transportation costs and speeds in historical China is also extremely limited. Some preliminary explorations, such as those by Liu (2012); Kiyokoba (1991, 1996), have only addressed specific periods. This study, based on travel route books from the Ming and Qing dynasties and supplemented by various official archives, utilizes GIS technology to reconstruct the commercial transportation network and estimates transportation costs and speeds during historical China.

The rest of this article is organized as follows: Section two reconstructs the transportation network and estimates the transport costs and speeds in late 17th century China. Section three compares the transportation situation in England with that in the Yangtze region of China since the late 17th century. Finally, Section four concludes the article.

## 2.2 The Transport Revolution in 18th century England

Since Adam Smith's *The Wealth of Nations*, the improvement of transportation infrastructure has been recognized as a crucial driver of long-term economic growth. Recent studies have revealed that a significant transformation in England's transportation infrastructure occurred during the 18th century, laying the groundwork for the country's subsequent economic expansion.

Around 1700, the establishment of Turnpike Trusts marked the beginning of a concerted effort to improve the nation's roadways. These trusts, funded by tolls collected from road users, maintained and upgraded key routes as well as constructing new turnpike roads. By the mid-18th century, the network of turnpike roads had expanded significantly, covering several thousand miles. The impact of these improvements was profound: road conditions improved substantially, resulting in a marked decrease in land transportation costs and a significant increase in travel speeds(Alvarez-Palau et al., 2017; Bogart, 2019). As shown in Table 7, the cost of transporting goods overland in 1830 was considerably lower than in 1680.

In addition to road improvements, the latter half of the 18th century saw a boom in canal construction. This expansion further transformed England's transportation landscape by enhancing connectivity between regions. While canal construction did not directly reduce the cost or speed of water transport, it significantly lowered overall trade costs by linking major industrial centers with cheaper water routes.

The cumulative effect of these infrastructure improvements on accessibility and economic activity was profound. By 1830, before the railway revolution, the accessibility of different regions in England had improved dramatically compared to 1680, facilitating greater economic integration and growth(Alvarez-Palau et al., 2017). Such improvement in accessibility also facilitates economic growth from several perspectives. Recent studies suggest that the 18th-century transportation revolution was closely linked to the spread of steam engines(Bogart et al., 2017), the process of urbanization(Alvarez-Palau et al., 2020), and changes in occupational structures (Bogart et al., 2022).

However, as Needham (1974) famously questioned in his "Needham Puzzle", despite China's early technological advances, it did not undergo an industrial revolution like England. This puzzle extends to transportation as well. While England experienced substantial transportation reforms in the 18th century, China did not see a similar transformation until the late 19th century with the arrival of railroads and steamships.

To better understand why China did not follow the same path as England in transportation, a comparison between the two regions is crucial. Such an analysis could shed light on the broader Needham Puzzle and the differing roles of infrastructure in driving economic development.

## 2.3 *Status Quo Ante* of Transportation in 17th Century China

To enable the comparison between England and Yangtze China, the transport condition in historical China should be reconstructed. In this study, I reconstructed the national transportation network of Ming-Qing China and analyzed the transportation costs and speeds from the late 17th to the 18th century using historical sources. An overview of all the historical sources used in this study along with their abbreviations has been provided in table 2.2 and more detail in Appendix E. Detail information on units of distance, weight and currency used in this study are reported in table 2.1.

### 2.3.1 Transport Network

Routes in Ming-Qing China can be classified into two categories, official routes, and commercial routes. Official routes are the routes constructed and maintained by the government, which in most cases were part of the national official courier system. The courier system served to deliver official documents, public servants trips, transporting government supplies, military marches, and other government-related matters. Courier stations were set up on side of courier routes for a fixed range, providing services including accommodations and supplies[8]. Due to its official characteristics, the courier routes roads connected the national capital to the provincial capitals of each province, and from the provincial capitals to the important prefecture cities.

In addition to the official roads, well-developed commercial routes were also an important part of the transport networks in Ming-Qing China. The courier route system, designed for all-season accessibility, often did not offer the lowest transport costs or the shortest distances[9]. These commercial routes were often with shorter distances, lower costs, and relatively same or shorter travel time. However, their quality were not as good as official routes. In a sense, the official routes formed the backbone of the road network in Ming-Qing China, while the commercial routes served as crucial branches connecting various regions.

[8]According to the types of routes that stations were serving, they could be classified as land stations, waterway stations, and amphibious stations.

[9]A typical example is a path from Wuhan to Kaifeng. The courier routes detour upstream through the Han River to Xiangyang and then head to Kaifeng by land. The commercial route, however, heads directly to the destination in a nearly straight line from the present-day Zhumadian. It would take roughly 940 km trips through courier routes, but only 460 km for commercial routes. One possible explanation for the courier route detour is that the commercial road is subject to flooding in the Huai River basin during the summer, which may cause the route to be disrupted. Since the official routes have high demands for on-road stability, the official routes prefer roads that were more stable for all-seasonality even with more distance. While commercial routes were more of a product of merchants'choice for transportation cost minimization.

This study start with a GIS reconstruction on official routes or courier system in Ming-Qing China. In Ming Dynasty, there are more than 1000 courier stations, located already in Yang (2006). Using this information, I geo-located a total of 1,025 courier stations from the Ming Dynasty, with their spatial distribution illustrated in Figure 2.4. These courier stations were then connected using the routes described in *Comprehensive guide to worldwide routes* (*Huanyu Tongqu*, hereafter HYTQ[10]).

For commercial routes, this study incorporates data from two prevalent route books, *The comprehensive illustrated routebook]* (*Yitong Lucheng Tuji*, hereafter YTLC) and *Traveling everywhere on my own]* (*Shiwo Zhouxing*, hereafter SWZX), which together catalog over 300 routes, although some overlap. Notably, SWZX provides more granular details, including accommodations and logistical advice. One challenge is that many locations mentioned in the route books have either disappeared or changed names over the centuries. To address this, the locations of prefecture and county-level cities, as well as courier stations, were identified using the CHGIS database (CHGIS, 2024). The village-level locations cited in historical route books were then manually matched to contemporary names and similar pronunciations through Google Map. Ultimately, approximately 50% of the locations mentioned in the route books were identified and geo-located[11].

Figure 2.1 shows the resultant transportation network, which encompasses 38,245 kilometers of land routes and 20,518 kilometers of waterway routes.

### 2.3.2 Travel Speed

The route book SWZX contains 22 observations[12] regarding travel times, primarily derived from comments about specific route segments or locations. These comments typically provide details about the trip's origin, destination, travel method, distance,

[10]HYTQ is a official route book published in 1394, more detail see Appendix E

[11]Nearly five centuries have passed since these travel route books were published, and during this time, place names have undergone significant changes. Approximately 15% of the place names perfectly match the originals, but in many cases, the spelling of the place names has changed while their pronunciation remains similar. Therefore, if I relax the search criteria and looking for places with similar pronunciations, about 50% of the place names can be reasonably matched to corresponding locations.

[12]Detail of these 22 observations is demonstrated in table 2.10

required travel days, and sometimes costs. This information is invaluable for approximating travel speeds in late 17th-century China. One notable challenge in analyzing this data arises from the inaccuracies in the distances recorded, a consequence of the rudimentary cartography technology available in China at that time. As such, distances noted in SWZX tend to be overestimated. Recent studies by Jian et al. (2022) utilized GIS tools to recalibrate these measurements. They focused on a specific route from Fuzhou in Fujian province to Hangzhou in Zhejiang province. Their geoprocessing revealed that while 1 *li* during the Qing dynasty should correspond to 576 meters, the actual measurement for much of this route was slightly less than 500 meters.

To address inaccuracies in reported distances, I extracted data on trips with documented travel times from the Ming-Qing transport network GIS dataset constructed in this paper and converted to today's real equivalents. Employing this method, I identified an average discrepancy of approximately 20% between the recorded and actual distances. This discrepancy is often more pronounced in mountainous regions, affecting measurements for both land and waterway routes. The spatial distribution of these 22 observations, illustrated in Figure 2.2, provides a visual representation of the variances across different regions and route types, indicating a concentration of observations in the Yangtze Delta, Fujian, and Huguang. These data encompass a range of transportation methods tailored to diverse geographical conditions[13].

In late 17th-century China, transportation methods were predominantly categorized by waterways or land routes. Waterways are subdivided into three classifications based on geographical features: major, secondary, and tertiary. Major waterways include significant rivers such as the Yangtze and its major tributaries. Secondary waterways consist of narrower rivers like the Great Canal, the Fuchun River, and secondary tributaries of large rivers. Tertiary waterways, the narrowest, typically include creeks in mountainous areas. Land routes are classified into flat and mountainous, reflecting the terrain they traverse.

[13]It includes waterway trips on major rivers like yangtze River, trips on secondary rivers such as the grand cannal and trips on creeks in mountain regions. For land routes, it includes trips on flat and hill lands through pack horse, human labor and sedan.

The effect of traveling upstream versus downstream does not significantly alter travel speeds on major and secondary rivers. With a tailwind, ships on major rivers can maintain speeds up to 65 km per day, irrespective of the direction. Speed on secondary rivers is around 55 km per day. However, in mountainous regions, where streams are narrower and terrain influences water flow, the speed difference between upstream and downstream travel is substantial. In the cases of Fujian and Zhejiang, upstream travel speeds are approximately 28 km per day, while downstream can reach a speed of about 70 km per day. On land routes, travel speeds in flat regions are typically around 43 km per day, comparable to modern walking speeds, whereas in mountainous areas, speeds decrease to approximately 30 km per day. The detailed approximation of travel speed for 17th century China are presented in table 2.3 and their original cases in table 2.10. The reliability of these estimations is high, as data from both commercial travel routes books and official documents yield consistent speed estimations.

### 2.3.3 Freight and Travel Cost

Compared to the recorded information on transportation speed in SWZX, there is relatively little information on transportation costs, with only 11 entries. Given the limited data on transportation costs in SWZX, this study further compiles transportation cost data from 18th-century Qing Dynasty official historical documents. The DQHD records the transportation prices paid by provincial governments for grain transport across the country in the 18th century, totaling 92 entries.

By comparing the transportation costs recorded in SWZX, a commercial source, with those in DQHD, an official source from the Yangtze region of China, this study finds a high degree of consistency between the two data sources. This consistency indicates that the transportation cost information for the Yangtze region derived in this study is relatively reliable. The specific results are shown in Table 2.32.4. In the remainder of this section, I will detail the recorded transportation costs from SWZX and DQHD, as well as the process of reconstructing these costs. For raw data of SWZX, see table 2.11 and raw data fro DQHD see table 2.14.

#### 2.3.3.1 Data from Travel Route Books

SWZX has reported 11 cases for transportation cost, with 5 of them passenger cost and 6 of them freight cost. All of these cases were from a broader definition of Yangtze China.

***Passenger Fares in Travel Route Books***

As mentioned in the previous section, passenger trips in the Lower Yangtze Delta mainly rely on stage ships. One route recorded in SWZX states that a trip of approximately 100 km from Hangzhou to Huzhou costs about 2 *fen* per person. For a journey of 34 km from Nanxun to Huzhou, it costs about 8 *li* if one boards the stage ship halfway. Another record shows that a 45 km trip from Huzhou to Meixi costs around 1 *yin* per person. By calculating the costs of these journeys, I find that the transportation cost of a stage ship in the late 17th century in the Yangtze Delta was about 0.02 silver taels per passenger per 100 km.

Interestingly, the YTLC also records information on passenger ship business in the Yangtze Delta. It notes that in Suzhou, a passenger can travel 20 *li* by boat for 2 wen. In Yangzhou, 3 *wen* allows a passenger to take a small boat for a trip to Guazhou, covering 18 km. In the Hangzhou area, an 80 km stage-ship ride from Xixing (now Xiaoshan, Zhejiang) to Dongguanyi (now Shangyu, Zhejiang) costs 2 *fen* per person. These records indicate that in the mid-16th century, when YTLC was written, the cost of stage-ship travel in the Yangtze Delta was around 0.02 silver taels per passenger per 100 km, which is very close to the late 17th-century prices.

For areas outside the Yangtze Delta, SWZX records a case stating that it costs 3 *qian* per person for a 250 km boat ride along the Fuchun River from the mountainous area of Zhejiang to the Yangtze Delta.With a 30% discount for using higher quality silver, the cost reduces to 2.1 *qian*. Assuming the journey costs 2.1 *qian*, the transportation cost is 0.084 silver taels per passenger per 100 km, which is about four times that of the Yangtze Delta.

SWZX also records the cost of passenger trips on land routes using a sedan chair. For a 39 km journey on flat land in Zhejiang, it cost 750 wen to hire a sedan chair. This equates to approximately 0.75 silver taels per passenger per 100 km.

#### ***Freight Cost in Travel Route Books***

For freight cost, SWZX contains two records of the cost of shipping by waterway. The first is for the journey from Hangzhou to Yangzhou. For this 336 km trip along the Grand Canal, crossing the Yangtze River, it is noted that the cost of hiring a boat, though influenced by the type and size of the boat, was roughly 2 to 3 silver taels. This translates to a cost of 0.6 to 0.89 taels per 100 km. The second record is from the Jiangxi region, stating that for a journey from Tingzhou, Fujian, to Quzhou, Zhejiang, via Jiangxi, a traveler could hire a boat at Dengjiabu (now Yingtan, Jiangxi) for 1200 wen to travel upstream along the Xinjiang River to Yushan County, a distance of about 200 km. This sets the cost of hiring a boat in Jiangxi at 600 wen, or 0.6 silver taels, per 100 km.

Although these two locations are about 300 km apart, the cost of hiring a boat in both places is roughly the same. However, knowing the price of hiring a ship alone is insufficient for estimating waterway freight costs. I need to determine the loading capacity of the ships to assess the cost of waterborne freight in the lower Yangtze River region in the late 17th century. Two records in SWZX mention the type of ship but not its loading capacity. To address this, I referenced detailed descriptions of various ship types from Worcester (2020) and SGBL, a route book published in 1792. According to these descriptions, the capacity of the vessels in the two cases is approximately 40 to 60 piculs. Assuming a loading capacity of 40 piculs (1 picul is approximately 84 kg in Qing dynasty), I estimate that in the late 17th century, the transport cost on secondary rivers was about 0.021 silver taels per 100 kg per 100 km.

The route book has four records for land transport costs. The first two records are from a journey in the Jiangxi region, detailing transport costs using pack mules and wheeled vehicles. To complete this 56 km trip on flat land, it cost 100 wen to hire a mule and 220 wen for a wheeled vehicle. Assuming a mule can carry about 100 kg of freight on flat terrain, the freight cost for a pack mule is about 0.213 silver taels per 100 kg per 100 km. The route book does not specify the load capacity of a wheeled vehicle. Assuming the capacity of a wheeled vehicle in Jiangxi is similar to that in Beijing, which can carry 1000 *jin*, the freight cost for the wheeled vehicle is approximately 0.078 silver taels per 100 kg per 100 km. The last two records from the route in Zhejiang province detail the cost of hiring laborers to carry goods. Assuming one laborer can carry 0.4 *shi*, the cost is approximately 1.594 silver taels per 100 kg per 100 km.

A summary to transport cost accroding to SWZX is reported in table 2.4, and their original cases are reported in table 2.11.

#### 2.3.3.2 Data from Historical Archives

As a supplement to observations from SWZX, this article incorporates data on transportation costs from official archives. The DQHD provides 92 records of grain transport costs across various provinces, spanning the period from 1738 to 1776. The raw data is demonstrated in table 2.14. The price are spatially different, a spatial distribution on official downstream waterway freight cost is shown in figure 2.5. A statistic table of All records in Yangtze China has been shown in table 2.5.

Official records in Yangtze China mostly align with my estimations based on travel route books for transportation costs in the Yangtze Delta during 18th century. One exception is the transport cost for major rivers in 1776. Records from Jiangxi and Zhejiang provinces suggest a 50% reduction in major river transport costs. However, this reduction is questionable for there were no major technological changes in transportation in 18th-century China[14]. Given the lack of corroborating records from other sources, I treated these records as unreliable.

[14]Given the fact that there were no transportation revolution in 18th century China and the fact that transport cost remained at same level when comparing transport cost in 1890s with 1690s, therefore it is likely that such drop is a political action but not able to reflect real market value.

#### 2.3.3.3 To what extend could we trust the data

One of the key challenges faced in this study is how to justify the reliability of the estimated transportation costs given the limited amount of available data. Two main strategies are employed to address this issue: (1) cross-validation between data from official and non-official sources—specifically, DQHD and SWZX—and (2) an examination of whether transportation cost data remain stable across multiple revised editions of the SWZX, despite substantial changes in other parts of the text.

First, a comparison of transportation costs recorded in DQHD and SWZX reveals a remarkable degree of consistency, with discrepancies generally within 10%. Given that DQHD is an official source and SWZX is a widely circulated civilian travel manual, this high degree of alignment strongly suggests that the transportation costs derived from these two types of sources are credible.

Second, SWZX underwent multiple reprints throughout its circulation history. The earliest known edition, dated 1684, is held in the British Library. Later editions, such as the 1738 version (preserved in the Toyo Bunko, Japan) and the 1778 version (held in institutions including the Yenching Library, the National Library of Australia, and the Berlin State Library), were widely disseminated. These versions are not identical; rather, each reprint involved substantial updates. For instance, the 1684 edition begins with a route from Fuzhou to Beijing, while the 1738 edition starts in Hangzhou, relegating the Fuzhou–Hangzhou segment to a later section. Another significant revision involves the Grand Canal route, which was updated in response to changes in place names along the waterway. In addition to these major alterations, numerous smaller editorial changes are found across versions.

Despite these structural and geographical modifications, the transportation cost data recorded in the SWZX remain notably stable across all versions. This consistency suggests that price fluctuations in transportation at the time were relatively limited and also indicates a degree of editorial intentionality in preserving this information. Given SWZX' s large print volume, broad readership, and practical role as a travel guide, it is reasonable to conclude that its transportation cost data—though limited in quantity—are highly reliable and suitable for historical economic analysis.

#### 2.3.3.4 Transport Cost Conclusion

Combining these materials, this article estimates the transport costs in China proper, particularly for the middle and lower reaches of the Yangtze River, in the late 17th and 18th centuries. Detailed transport costs are reported in Table 2.6. In early and mid-Qing China, waterway freight costs were about one-tenth of mule-pack-based land transport costs, consistent with Kiyokoba's (1996) estimation for Song China. Passenger trips in the Yangtze Delta were reasonably cheap, at approximately 0.02 silver taels per passenger per 100 miles. Waterway freight costs in the Grand Canal and upstream of the Xinjiang River were slightly higher compared to downstream trips along the Yangtze River.

Given the similar travel speeds for upstream and downstream trips in the lower Yangtze River and its tributaries, it is likely that transport costs were not significantly affected by the direction of water flow due to the slow speed. Evidence from DQHD supports this suggestion, showing that the Qing government paid the same price for upstream and downstream trips in secondary rivers of the Yangtze Delta. Price differences between upstream and downstream transport were only observed in mountainous regions (tributary river), with a ratio usually at 1:1.5.

## 2.4 Comparing Transportation Cost between Yangtze China and England in 18th century

### 2.4.1 Area and unit for comparison

By the 17th century, China had developed an extensive transportation system. But how did this system's performance compare with that of Western Europe, particularly England, which later became the birthplace of the Industrial Revolution in the 18th century? Alvarez-Palau et al. (2017) summarize the speed and cost of both freight and passenger transportation in England and Wales in 1680 and 1830. Using this dataset and my estimates of transportation cost and speed in China at the end of the 17th century, this article compares the transportation situations in England and the Yangtze Delta region at that time.

The Yangtze Delta was chosen for comparison with England based on several considerations. As Pomeranz (2000) argues in *The Great Divergence*, even within China proper, there are huge cultural and economic differences, making it inappropriate to compare China as a whole with England. The Yangtze Delta has long been the most developed region in China and is comparable in geographical size to England, making it a more suitable basis for comparison.

One potential issue is the geographical distinction between the Yangtze Delta and England. While both areas have large plains, none of the rivers in England are comparable to the Yangtze River. The Thames, for instance, can only be classified as a secondary river by the standards used in this article. Major canal construction in England did not begin until the 1750s (Bogart, 2013), so waterway transport in late 17th-century England relied heavily on natural rivers. Therefore, the waterway transport in England is more comparable to transport on secondary rivers in the Yangtze Delta rather than primary rivers like Yangtze River.

As a result, this paper focuses on comparing transport costs on flat lands and secondary rivers in both regions.

### 2.4.2 Similar transport situation between Yangtze China and England in late 17th century

#### 2.4.2.1 A comparison in transport speeds

As shown in Table 2.7, transport speeds for both waterways and land were similar between the Yangtze Delta and England in the late 17th century. After converting all units to miles per day, the transport speed via waterways in the Yangtze Delta was about 34.4 miles per day, and on flat land, it was about 26.9 miles per day. In England, waterway transport speed was about 38.4 miles per day, while land transport speed was 24 miles per day (Alvarez-Palau et al., 2017; Bogart, 2019). The differences in travel speeds between the two regions are relatively small and fall within the margin of error.

The main difference appears in passenger travel speeds. In the Yangtze Delta, passengers typically traveled on stage-ships that operated day and night. Therefore, to compare passenger travel speeds, we should compare stage-ships in the Yangtze Delta with stagecoaches in England. It seems that in the late 17th century, passenger travel speed in England was about 40% faster than in the Yangtze Delta.

#### 2.4.2.2 A comparison in transport cost

It is challenging to compare transportation costs between different countries historically. Although both late 17th century Yangtze China and England used silver as their primary currency[15], making direct comparison possible, the different purchasing power of their currencies makes such a comparison imprecise.

One approach is to use the Consumer Price Index (CPI) for comparison. Allen et al. (2011) constructed a bare-bones consumption basket to estimate the CPI in Western Europe and China from 1730 to 1925. For the CPI series before 1730 in China, I use the consumer price index constructed by Peng (2006) as a supplement. However, a potential issue with using the Allen basket is that housing prices constitute a significant portion, which is unrelated to transportation costs, potentially diminishing the deflation effect.

A better approach is to use unskilled labor wages as the basis for deflation. This study uses Liu (2024) estimation of wages during the Ming and Qing dynasties, approximating that the nominal wage for unskilled labor was 0.06 silver taels per day at the end of the 17th century. For wage levels in England, this paper uses Allen (2001) estimate of the nominal unskilled labor wage in London.

[15] Silver taels were used as the main currency during the Ming and Qing dynasties. One silver tael contained 37.3 grams of silver (Lin, 2006). Currencies in the late 17th century England were also made of precious metals. In the late 17th century, one penny contained 0.464 grams of silver (Allen, 2001; Feavearyear, 1932).

The results, measured in silver, CPI, and unskilled labor wages, are presented in Table 2.8 and Figure 2.3.

***Freight Cost Comparison***

As shown in Table 2.8, both England and the Yangtze Delta maintained a ratio of approximately 1:10 between water and land transport costs at the end of the seventeenth century. When compared directly in terms of silver grams, the cost of water transport in the Yangtze Delta was approximately 0.125 grams of silver per ton-mile, and the cost of land transport was 1.254 grams of silver per ton-mile. In England, the cost of water transport was 0.464 grams of silver per ton-mile, and the cost of land transport was 4.965 grams of silver per ton-mile. Overall, the freight cost in the Yangtze Delta was about a quarter of the cost in England.

When deflated by the unskilled wage in the 1680s, the cost of shipping one ton of goods for a mile by water in the Yangtze Delta was 0.056 days of unskilled wage. In England, the cost was 0.05 days of unskilled wage, which is almost the same as in the Yangtze Delta. Land freight costs were also similar between England and the Yangtze Delta in the late 17th century, costing 0.56 days of unskilled labor wage in the Yangtze Delta and 0.535 days in England. This indicates that transport costs in the Yangtze Delta were comparable to those in England in the late 17th century when measured through unskilled labor wages.

When comparing based on CPI, Allen et al. (2011) estimated the CPI for both the Yangtze Delta and England from 1730 to 1925. Since this CPI does not cover the late 17th century, I adjusted their CPI estimates for the two regions using other consumption index estimates for England (Allen et al., 2011) and the Yangtze Delta (Peng, 2006), which provide longer coverage. The comparison shows that transport costs in the Yangtze Delta were around one-third of those in England in the late 17th century. As I have mentioned before, this discrepancy is likely because Allen's basket includes items such as housing prices, which are not directly related to transportation costs. This inclusion makes it less appropriate to use Allen's basket for deflating transport costs.

*Passenger Fares Comparison*

Passenger travel fares, however, show some different characteristics from freight costs. In the Yangtze Delta, people typically traveled on stage ships that operated both day and night. In contrast, travelers in England preferred stagecoaches due to the lack of a comprehensive river network comparable to that of the Yangtze Delta in the 17th century. However, if the origin and destination were connected by rivers, waterway travel was still an option in England. Thus, I included waterway travel in England for comparison.

In terms of silver grams, the cost of a stage ship in the Yangtze Delta was only 1% of the cost of a stagecoach in England and 7% of the cost of a waterway trip. In terms of unskilled labor wages, the cost of a stage ship in the Yangtze China was 6% of the cost of a stagecoach in England and one-third of the cost of waterway trips. Considering that passenger fares outside the core region of Yangtze China were four times higher than within the region, passenger transport costs via waterways were quite similar between England and periphery regions of Yangtze China.

Using the Consumer Price Index (CPI), the cost of a stage ship in the Yangtze China was 1.5% of the cost of a stagecoach in England and 8.5% of the cost of waterway trips. Overall, passenger travel fares were lower in the Yangtze China regardless of the comparison method.

#### 2.4.2.3 Conclusion to the Comparison

The comparison reveals that, in terms of freight transport, both the speed and cost were quite similar between England and the Yangtze Delta in the late 17th century when evaluated through unskilled wages. However, the situation differed significantly for passenger transport. The speed of stagecoaches in England was about twice that of stage ships in the Yangtze Delta. Despite this speed advantage, the cost of passenger travel by stagecoach in England was 16 times higher than that of travel by stage ship in the Yangtze Delta.

### 2.4.3 The divergence since 1700

It is often assumed that the transport revolution in England occurred after the invention of railways around the 1840s. However, recent studies have found that England had already experienced a transport revolution centered on turnpike trusts before the advent of railways (Bogart, 2013). The most significant changes occurred in the 1750s and 1760s, during which over 300 turnpike trusts were established along 10,000 miles of road. By 1800, around 1,000 turnpike trusts managed over 20,000 miles of road (Bogart, 2005). This expansion was accompanied by significant improvements in the overall condition of England's roads Bogart et al. (2023). Passenger travel speed increased fourfold, and long-distance services increased from 63 services per week in the first half of the 18th century to over 4,000 services per week in the 1830s (Gerhold, 2014). For freight, the construction of canals and turnpikes reduced overall transport costs in England by 40% and nearly doubled the speed of transport (Alvarez-Palau et al., 2017).

In contrast, the transport situation in the Yangtze Delta showed little change over the same period. As shown in table 2.8, by comparing transport prices in the Yangtze Delta at various time periods, it can be observed that the cost of transport remained relatively constant from the end of the seventeenth century to the late eighteenth century. Transport costs in Zhili province in 1816 (Li, 2000) and the Yangtze Delta in 1890 (Fan, 1992; Kingsmill, 1898) were similar to those of the early eighteenth century. Given the lack of a transport technology revolution in China, it is likely that transport costs in the Yangtze Delta did not change significantly over nearly two centuries from the late seventeenth century to the first half of the nineteenth century. The nearly unchanged travel time for the same distance in Fujian over different eras suggests that the speed of transport in China remained constant throughout the Qing dynasty (Jian et al., 2022).

This indicates a divergence in transportation infrastructure developments between the Yangtze Delta and England starting around 1700. The timing of such divergence is interesting, as it coincident with the starting time of great divergence proposed by one strand of literature. Although there is much academic debate about the exact timing of the Great Divergence[16], recent wage data and GDP estimates for England

[16] Pomeranz (2000) proposed the starting time point for great divergence in 1750

and the Yangtze Delta suggest that the Great Divergence most likely occurred in the early eighteenth century, around 1700 (Broadberry and Gupta, 2006; Broadberry et al., 2018, 2021). Such coincidence in time raises the question of whether England's transport revolution is inextricably linked to the broader economic and technological divergence.

### 2.4.4 Level of market integration

On the other hand, the divergence in transportation infrastructure starting in 1700 likely led to a divergence in the level of market integration between the two regions. Using a grain price approach, Shiue (2002) and Shiue and Keller (2007) found that: (1) the level of market integration in ancient China was higher than previously thought; and (2) in 1750, the level of market integration in the Yangtze region of China was comparable to that of Europe but lower than that of England. However, this grain price-based approach has been criticized by historians, as they proposed that the grain market in Qing China was not a free trade market, and the government strongly intervened in grain prices. Therefore, a grain-based approach might overestimate the level of market integration in 18th century China (Li, 2000; Deng, 2011; Von Glahn, 2016; Ni and Uebele, 2019).

This study evaluates and compares one of the foundational elements of market performance, transport costs, in both regions. The findings reveal that while England started its transportation revolution in the 1700s, China saw hardly any significant changes in transport technology and networks. According to the law of one price, the price difference for the same commodities in two markets should be equal to or less than the transport cost between these two markets. If the price gap is higher than the transport cost, trade would occur and reduce the gap. This law provides the theoretical foundation for the potential connection between changes in market integration and the development of transport infrastructure. Thus, the comparison of transportation conditions between the two regions makes it reasonable to suspect that, by the late 17th century, the level of market integration in England and the Yangtze region of China was similar. However, the divergence in transportation developments starting from 1700 likely led to a divergence in market integration levels between the two regions.

This conclusion aligns with the findings of Shiue (2002) and Shiue and Keller (2007), further indicating that using the grain price approach to assess the level of market integration in historical China is, to some extent, reliable.

## 2.5 Conclusion

Through historical commercial route books and official archives, this paper reconstructs the transportation network of China during the Ming and Qing dynasties and evaluates the transport costs and speeds in the Yangtze region at the end of the 17th century. The paper then compares the transport costs and speeds in the Yangtze region from the late 17th to the 19th century with those of England during the same period. The comparison shows that in the late 17th century, the transport costs and speeds in both regions were very similar. However, starting from 1700, England underwent a transport revolution, marked by the turnpike trust revolution and canal revolution, which significantly improved its transportation infrastructure, reduced transport costs, and increased speeds (Bogart, 2005, 2013, 2019). Meanwhile, China did not experience any significant transportation technology revolution during the same period. This indicates that starting from 1700, there was a divergence in transportation conditions between the Yangtze region of China and England. This timeline aligns with one strand of literature estimate for the occurrence of the Great Divergence (Broadberry and Gupta, 2006; Broadberry et al., 2018, 2021), suggesting a potential link between the transport revolution and the Great Divergence.

Additionally, the comparison suggests that, by the late 17th century, the level of market integration in England and the Yangtze China was similar. However, the divergence in transportation developments since 1700 likely led to a divergence in market integration levels between the two regions. This inference aligns with the conclusions of Shiue (2002) and Shiue and Keller (2007), further indicating that using the grain price approach to assess market integration in historical China is, to some extent, reliable.

## 2.6 Tables

TABLE 2.1: *Unit Conversion for Late 17th and 18th century China*

| | |
|---|---|
| ***Measure and weights*** | |
| 1 *li* 里 (Chinese miles) | 500 meters |
| 1 *jin* 斤 (catty) | 600 grams |
| 1 *shi* 石 (picul, weight) | 84 kilograms |
| ***Currencies*** | |
| 1 *tael* 两 | approx. 37.31 grams of silver |
| 1 *qian* 钱 (mace) | 1/10 of a tael |
| 1 *fen* 分 (candareen) | 1/100 of a tael |
| 1 *li* 厘 | 1/1000 of a tael |
| 1 *wen* 文 (coppers) | assume 1/850 of a tael |

*Source:* *Jin* and *shi* sourced from Peng (1965). *li* see text. Currency conversion ratio from Lin (2006) and Antony (2016).

TABLE 2.2: *Abbreviations to primary sources*

| Name | Chinese | Abbreviations |
|---|---|---|
| *Shiwo Zhouxing* | 示我周行 | SWZX |
| *Zhouxing Beilan* | 周行备览 | ZXBL |
| *Yitong Lucheng Tuji* | 一统路程图记 | YTLC |
| *Shanggu Bianlan* | 商贾便览 | SGBL |
| *Huanyu Tongqu* | 寰宇通渠 | HYTQ |
| *Qingding Daqing Huidian* | 钦定大清会典事例 | DQHD |

*Notes:* More detail in appendix E

TABLE 2.3: *An estimation to travel speed in late 17th century China*

| Travel Method | Speed *km/day* |
|---|---|
| Primary River | 65 |
| Secondary River | 55 |
| Tertiary - Downstream | 66.5 |
| Tertiary - Upstream | 28 |
| Flat Land | 43 |
| Land-Hill | 30 |

*Source:* Sourced from SWZX. Original cases see table 2.10.

Table 2.4: *Transport cost in late 17th century China from Commercial Route Books*

| Travel Method | Cost |
|---|---|
| ***Freight Cost*** | *silver taels/100kg/100km* |
| Secondary River | 0.021 |
| Flat Land - mule/packhorse | 0.213 |
| Flat Land - wheeled vehicle | 0.077 |
| Flat Land - labor | 1.594 |
| ***Passenger Cost*** | *silver taels/pax/100km* |
| Waterway - stageship (core Yangtze) | 0.022 |
| Waterway - stageship (periphery Yangtze) | 0.084 |
| Flat Land - sedan | 0.750 |

*Source:* Sourced from SWZX. Original cases see table 2.11.

Table 2.5: *Freight Cost in 18th century Yangtze China from Official archive*

| **Travel method** | **Avg** | **Std** | **n** |
|---|---|---|---|
| | *silver taels/100kg/100km* | | |
| Primary river | 0.015 | 0.002 | 6 |
| Secondary river | 0.023 | 0.003 | 12 |
| Tertiary river - upstream | 0.043 | 0.006 | 4 |
| Tertiary river - downstream | 0.035 | 0.010 | 5 |
| Flat Land | 0.229 | 0.022 | 11 |
| Hill Land | 0.452 | 0.103 | 14 |

*Source:* Sourced from DQHD. Original cases see table 2.14.

Table 2.6: *An estimation to transport cost in late 17th century China*

| Travel Method | Cost |
|---|---|
| ***Freight Cost*** | *silver taels/100kg/100km* |
| Primary River | 0.016 |
| Secondary River | 0.021 |
| Tertiary - upstream | 0.043 |
| Tertiary - downstream | 0.035 |
| Flat Land - mule/packhorse | 0.213 |
| Flat Land - wheeled vehicle | 0.077 |
| Flat Land - labor | 1.594 |
| Hill Land | 0.452 |
| ***Passenger Cost*** | *silver taels/pax/100km* |
| Waterway - stageship (core Yangtze) | 0.022 |
| Waterway - stageship (periphery Yangtze) | 0.084 |
| Flat Land - sedan | 0.750 |

*Source:* Sourced from SWZX and DQHD.

Table 2.7: *Transport Speed in Yangtze China and England*

| | **Units** | **Yangtze 1680s** | **England 1680** | **England 1830** |
|---|---|---|---|---|
| *Passenger speed* | | | | |
| Waterway | mpd | 34.4 | 38.4 | 30 |
| Land | mpd | 26.9 | 48 | 208.8 |
| *Freight speed* | | | | |
| Waterway | mpd | 34.4 | 38.4 | 30 |
| Land | mpd | 26.9 | 24 | 48 |

*Source:* For Yangtze Delta see text. For England see Alvarez-Palau et al. (2017)
*Notes:* mpd for miles per day

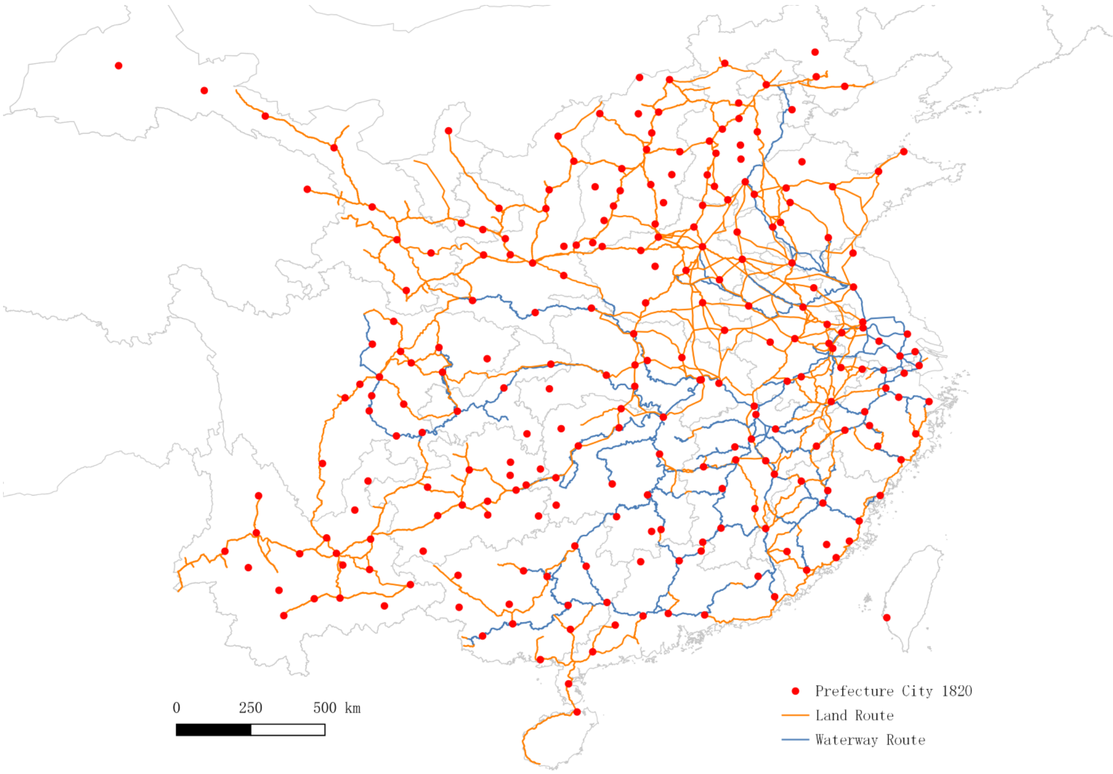
Table 2.8: *Transport Cost in Yangtze China and England*

| **Region** | **Freight** | | **Passenger** | |
|---|---|---|---|---|
| | *Waterway* | *Land* | *Waterway* | *Land* |
| *Silver grams* | | | | |
| Yangtze –1680s | 0.125 | 1.272 | 0.013 | |
| England –1680 | 0.464 | 4.965 | 0.186 | 1.021 |
| Zhili –1812 | 0.213 | 1.421 | | |
| England –1830 | 0.631 | 4.467 | 0.486 | 1.457 |
| France –1830 | 0.742 | 3.191 | | |
| Jiangsu –1890 | 0.260 | 3.924 | | |
| *Deflate by Wage (days)* | | | | |
| Yangtze - 1680s | 0.056 | 0.568 | 0.006 | |
| England - 1680 | 0.050 | 0.535 | 0.020 | 0.110 |
| Zhili - 1812 | 0.071 | 0.476 | | |
| England - 1830 | 0.036 | 0.256 | 0.028 | 0.083 |
| France - 1830 | 0.082 | 0.355 | | |
| Jiangsu - 1890 | 0.045 | 0.675 | | |
| *Deflate by CPI (Allen Basket)* | | | | |
| Yangtze - 1680s | 0.325 | 3.295 | 0.034 | |
| England - 1680 | 0.825 | 8.827 | 0.330 | 1.815 |
| Zhili - 1812 | 0.333 | 2.219 | | |
| England - 1830 | 0.676 | 4.785 | 0.520 | 1.560 |
| France - 1830 | 0.873 | 3.753 | | |
| Jiangsu - 1890 | 0.157 | 2.374 | | |

*Notes:* Unit in ton/pax mile. Transport cost for China see text, for England see Alvarez-Palau et al. (2017), for France in 1830s see Ejrnaes and Persson (2000). Wage and CPI data from Liu (2024), Allen (2001), and Allen et al. (2011). CPI in China before 1730 is adjusted by CPI constructed in Peng (2006). Wage data is in days, therefore it stands for to what extend could 1 day wage transport (in ton/mile).

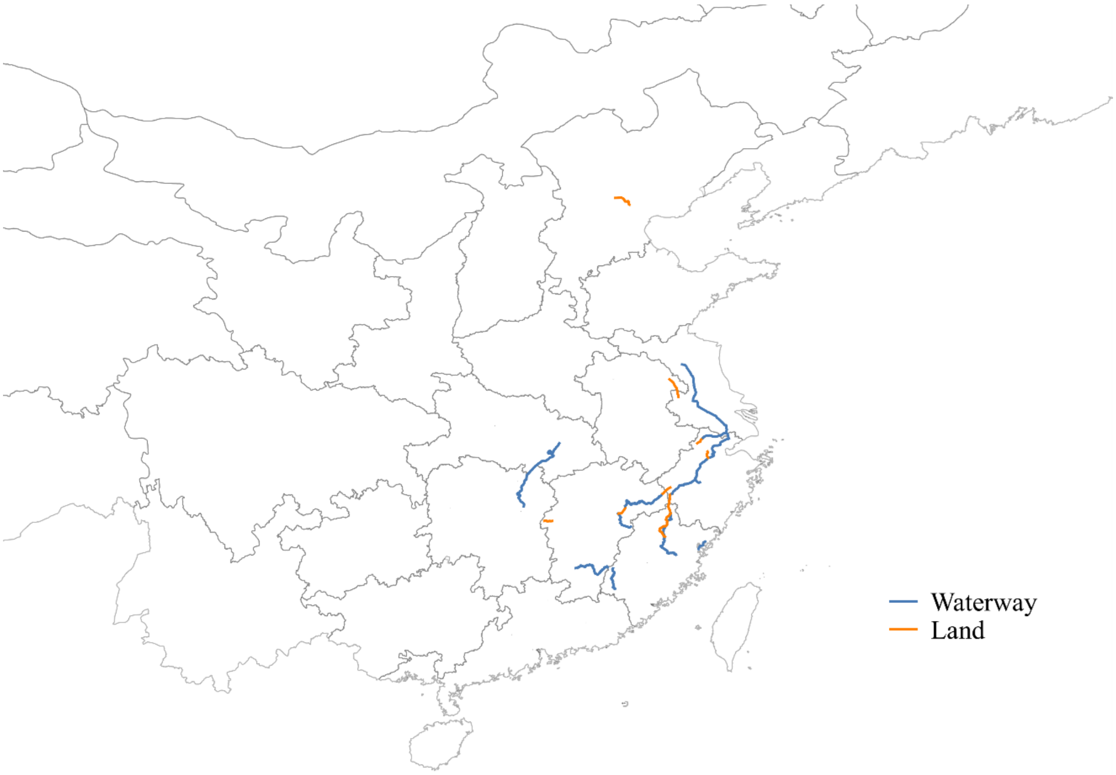
## 2.7 Figures

Figure 2.1: *Transportation Network in Ming-Qing China*



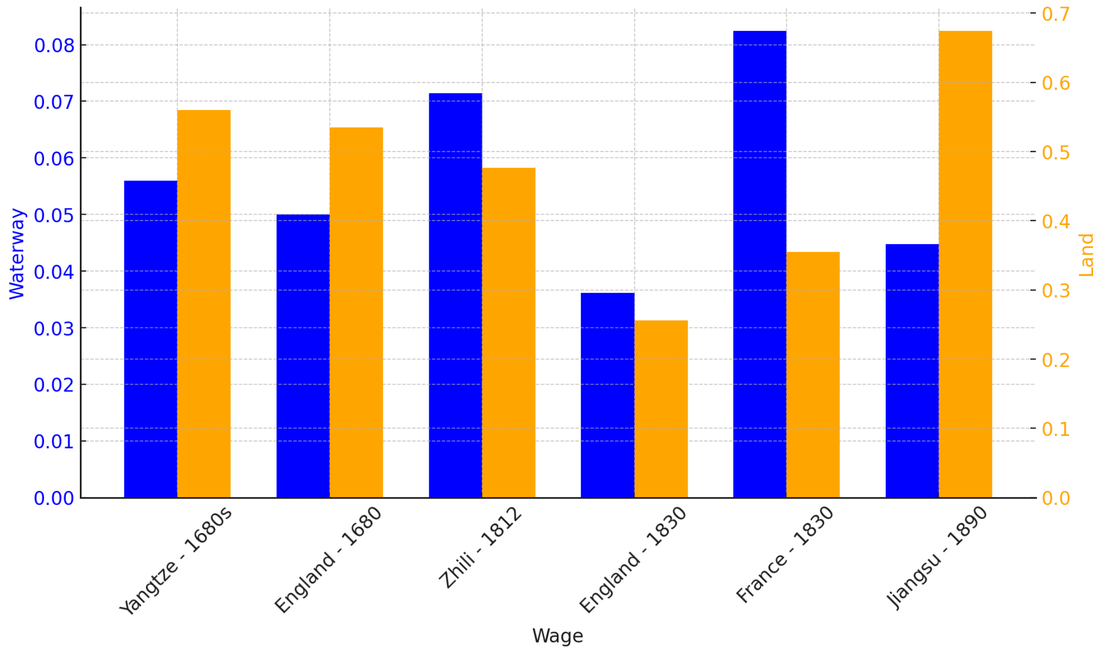

*Note:* GIS reconstruction of transportation network in ming-qing China. Using source from Yang (2006), SWZX and YTLC. Detail for construction see text. Prefecture seats location from CHGIS.

FIGURE 2.2: *Spatial distribution of quoted routes in SWZX*




*Note:* This graph shows all quoted routes used for transport cost and speed estimation from SWZW. A majority of sources are from Eastern China in Jiangsu, Zhejiang, Fujian, Jiangxi, and Huguang Province.

FIGURE 2.3: *Comparing Transport cost in England and Yangtze China*




*Source:* see table 2.8.

## 2.8 Appendix A. Additional Table

Table 2.9: *Transport cost in historical China*

| Time | Travel Method | Nominal Price | Silver Grams | Grain Liter |
|---|---|---|---|---|
| | | *Copper Coin/100kg/100km* | | |
| Tang (738) | Land | 498.00 | - | 149.40 |
| | Waterway | 165.84 | - | 49.75 |
| Song (1202) | Land | 336.02 | 3.84 | 8.41 |
| | Waterway | 33.60 | 0.38 | 0.84 |
| Song | Land | - | 10.13 | 18.39 |
| (1100 price) | Waterway | - | 1.01 | 1.84 |
| | | *Zhongtong Chao/100kg/100km* | | |
| Yuan (1288) | Land | 0.328 | 12.50 | 32.05 |
| | Waterway | 0.020 | 0.75 | 1.92 |
| | | *Silver Taels/100kg/100km* | | |
| Qing (1694) | Land | 0.213 | 7.95 | 24.66 |
| | Waterway | 0.016 | 0.60 | 1.85 |
| Qing (1890) | Land | 0.654 | 24.39 | 27.18 |
| | Waterway | 0.044 | 1.63 | 1.81 |

*Source:* All data here are for Yangtze China. Song (1100 price) is the transport cost from Song (1202) but deflating through grain and silver price in 1100. Tang and Song data are from Kiyokoba (1991), Kiyokoba (1996), and Liu (2012), Yuan data from *Da De Dian Zhang* (大德典章), Qing (1694) data see text, and Qing (1890) data from Fan (1992) and Kingsmill (1898) and. All grain price and silver price (excpet Yuang Dynasty) are sourced from Peng (1965) (grain price in 8th century from p218, Song price from pp313, Yuan price from pp403 and Qing price from pp560). Silver conversion ratio are from Peng (1965) as well (Song ratio from pp330, Yuan ratio from pp447 of 2020 edition). Qing Dynaty is then using Silver as its main currency.

Table 2.10: *Speed observations in route books*

| **Obs.** | **Region** | **Travel Method** | **Route condition** | **Time Taken** | **Distance *km*** | **Speed *km/day*** |
|---|---|---|---|---|---|---|
| 1 | Fujian | waterway | Creek - upstream | 16 days | 400 | 25 |
| 2 | Fujian | waterway | Creek - downstream | 4 - 5 days | 400 | 80 |
| 3 | Fujian | land | Hill | 3 days | 105 | 35 |
| 4 | Zhejiang | waterway | Rivers - upstream | 6 days | 330 | 55 |
| 5 | Zhejiang | waterway | Rivers - downstream | 6 days | 330 | 55 |
| 6 | Jiangsu | waterway | Canal | 5 - 6 days | 350 | 60 |
| 7 | Jiangsu | waterway | Canal | 3 days | 170 | 55 |
| 8 | Jiangsu | land | Flat | 4 days | 170 | 43 |
| 9 | Zhili | land | Flat | 2.5 days | 117 | 45 |
| 10 | Zhili | land | Flat | 1 day | 29 | 29 |
| 11 | Huguang | waterway | Major Rivers - upstream | 5 - 6 days | 380 | 65 |
| 12 | Huguang | land | Hill | 1 day | 31 | 31 |
| 13 | Fujian | waterway | Creek - upstream | 5 days | 135 | 27 |
| 14 | Fujian | waterway | Creek - downstream | 2.5 days | 135 | 67.5 |
| 15 | Huguang | waterway | River - downstream | 2 days | 128 | 64 |
| 16 | Fujian | land | Hill | 4 days | 170 | 42.5 |
| 17 | Jiangxi | waterway | Secondary Rivers - downstream | 6 days | 270 | 45 |
| 18 | Zhejiang | waterway | Creek - downstream | 0.5 day | 26 | 52 |
| 19 | Zhejiang | stage ship | Rivers | 1 night | 34 | 34 |
| 20 | Fujian | waterway | Coast | 1 tide | 43 | 43 |
| 21 | Fujian | waterway | Creek - upstream | 6 days | 190 | 32 |
| 22 | Jiangsu | land | Flat | 2 days | 83 | 41.5 |

*Notes:* All sourced from SWZX

Table 2.11: *Cost observations in route books*

| Obs. | Region | Travel Method | Route condition | Price | Distance | Capacity | Transport cost |
|---|---|---|---|---|---|---|---|
| *Freight Cost* | | | | | | | *taels/100kg/100km* |
| 1 | Yangtze Delta | Waterway | Canal | 2 - 3 taels | 336 km | 40 piculs | 0.018 - 0.026 |
| 2 | Jiangxi | Land-mule pack | Flat | 100 wen | 56 km | 100 kg | 0.212 |
| 3 | Jiangxi | Land-wheeled vehicle | Flat | 220 wen | 56 km | 1000 jin | 0.078 |
| 4 | Jiangxi | Waterway | River-upstream | 1200 wen | 200 km | 40 piculs | 0.021 |
| 5 | Yangtze Delta | Land-labor | Flat | 2 qian | 55 km | 25 kg | 1.455 |
| 6 | Yangtze Delta | Land-labor | Flat | 1.3 qian | 30 km | 25 kg | 1.733 |
| *Passenger Cost* | | | | | | | *taels/pax/100km* |
| 7 | Yangtze Delta | Stageship | Canal | 2 fen | 100 km | 1 pax | 0.02 |
| 8 | Yangtze Delta | Stageship | Canal | 8 li | 35 km | 1 pax | 0.023 |
| 9 | Yangtze Delta | Stageship | Canal | 1 fen | 45 km | 1 pax | 0.022 |
| 10 | Zhejiang | Waterway-pax | River-downstream | 2.1 qian | 250 km | 1 pax | 0.084 |
| 11 | Jiangxi | Land-sedan chair | Flat | 750 wen | 39 km | 1 pax | 0.882 |

*Notes:* All sourced from SWZX

TABLE 2.12: *Cost observations in Kingsmill (1898)*

| **Region** | **Land** | **River** | **Land Silver** | **River Silver** | **Land Grain** | **River Grain** |
|---|---|---|---|---|---|---|
| | *Cash/catty/li* | | *Grams/100kg/100km* | | *100L/100kg/100km* | |
| Shansi | 0.0400 | - | 32.514 | - | 36.240 | - |
| Shensi | 0.0200 | - | 16.257 | - | 18.120 | - |
| Kansu | 0.0200 | - | 16.257 | - | 18.120 | - |
| Ningshia | 0.0300 | - | 24.386 | - | 27.180 | - |
| Tsinghai to Kansu | 0.0200 | - | 16.257 | - | 18.120 | - |
| Shensi to Kansu | 0.0200 | - | 16.257 | - | 18.120 | - |
| Szechwan | 0.0500 | - | 40.643 | - | 45.299 | - |
| Yunnan | 0.0300 | - | 24.386 | - | 27.180 | - |
| Kwangsi | 0.0400 | - | 32.514 | - | 36.240 | - |
| Hupeh to Honan | 0.0300 | - | 24.386 | - | 27.180 | - |
| Kiangsu to Anhwei | - | 0.0030 | - | 2.439 | - | 2.718 |
| Kiangsu to Honan | - | 0.0020 | - | 1.626 | - | 1.812 |
| Kiangsu | 0.0300 | 0.0008 | 24.386 | 0.650 | 27.180 | 0.725 |
| Chekiang | 0.0300 | - | 24.386 | - | 27.180 | - |
| Honan to Shansi | 0.0200 | - | 16.257 | - | 18.120 | - |
| Honan | - | 0.0040 | - | 3.251 | - | 3.624 |
| Hopei | 0.0300 | 0.0080 | 24.386 | 6.503 | 27.180 | 7.248 |
| Shantung | 0.0300 | - | 24.386 | - | 27.180 | - |
| Manchuria | 0.0400 | - | 32.514 | - | 36.240 | - |

*Notes:* Sourced from Kingsmill (1898). According to Fan (1992), this should be a survey on the transport price in China at 1890 conducted by Royal Asiatic Society. Grain Price is sourced from Peng (1965) (pp 676). Exchange ratio between copper coin and silver is derived from Lin (2006).

TABLE 2.13: *Cost observations in Yuan Dynasty*

| **Location** | **Method** | **Year** | **Nominal** *Zhongtong Chao /1000 jin/100 li* | **Silver** *taels /100kg/100km* | **Grain** *liters /100kg/100km* |
|---|---|---|---|---|---|
| ***Origin Plan*** | | | | | |
| National | Land-hill | 1288 | 12 | 0.39 | 38.5 |
| | Land-flat | | 10 | 0.33 | 32.1 |
| | Waterway-downstream | | 0.6 | 0.02 | 1.9 |
| | Waterway-upstream | 1292 | 1.2 | 0.04 | 3.8 |
| ***New Plan*** | | | | | |
| Zhejiang | Land-hill | 1300 | 15 | 0.49 | 48.1 |
| | Land-flat | | 12 | 0.39 | 38.5 |
| | Waterway-Yangtze-downstream | | 0.7 | 0.02 | 2.2 |
| | Waterway-Yangtze-upstream | | 0.8 | 0.03 | 2.6 |
| | Waterway-upstream | | 1 | 0.03 | 3.2 |
| | Waterway-downstream | | 0.7 | 0.02 | 2.2 |
| Jiangxi | Land-flat | 1301 | 17 | 0.56 | 54.5 |
| Henan | Land-hill | 1301 | 15 | 0.49 | 48.1 |
| | Land-flat | | 12 | 0.39 | 38.5 |
| | Waterway-upstream | | 1 | 0.03 | 3.2 |
| | Waterway-downstream | | 0.6 | 0.02 | 1.9 |

*Source:* Sourced from *Da De Dian Zhang* (大德典章), can be found in *Yong Le Da Dian Can Juan* (永乐大典残卷), volume 15950. Also can be found in *Yuan Dian Zhang* (元典章), volume 26. Grain price sourced from Peng (1965) (pp486-481). In Yuan Dynasty, 1 *jin* equals to 610 grams, 1 *jin* equals to 16 taels and 1 tael equals to 38.125 grams.(Yang, 2001)(pp401-402).

Table 2.14: *Cost observations in DQHD*

| **Obs.** | **Year** | **Region** | **Method** | **Sub-condition** | **Unit cost** | **Silver grams /100kg/100km** | **Silver grams /ton/mile** |
|---|---|---|---|---|---|---|---|
| 1 | 1738 | Hunan | waterway | secondary | 0.01 taels/shi/100 li | 0.888 | 0.142 |
| 2 | 1738 | Jiangsu | waterway | secondary | 0.008 taels/shi/100 li | 0.711 | 0.114 |
| 3 | 1738 | Jiangsu | waterway | secondary | 0.01 taels/shi/100 li | 0.888 | 0.142 |
| 4 | 1738 | Jiangsu | land | flat_labor | 0.0015 taels/shi/li | 13.325 | 2.132 |
| 5 | 1743 | Guangxi | waterway | secondary | 0.015 taels/shi/100 li | 1.333 | 0.213 |
| 6 | 1743 | Guangxi | waterway | tertiary | 0.02 taels/shi/100 li | 1.777 | 0.284 |
| 7 | 1743 | Guangxi | land | flat | 0.001 taels/shi/li | 8.883 | 1.421 |
| 8 | 1743 | Guangxi | land | hill | 0.002 taels/shi/li | 17.767 | 2.843 |
| 9 | 1743 | Sichuan | waterway | primary-downstream-normal | 0.007 taels/shi/100 li | 0.622 | 0.099 |
| 10 | 1743 | Sichuan | waterway | primary-upstream-normal | 0.014 taels/shi/100 li | 1.244 | 0.199 |
| 11 | 1743 | Sichuan | waterway | primary-downstream-dry | 0.009 taels/shi/100 li | 0.800 | 0.128 |
| 12 | 1743 | Sichuan | waterway | primary-upstream-dry | 0.016 taels/shi/100 li | 1.421 | 0.227 |
| 13 | 1743 | Sichuan | waterway | tertiary-downstream | 0.016 taels/shi/100 li | 1.421 | 0.227 |
| 14 | 1743 | Sichuan | waterway | tertiary-upstream | 0.032 taels/shi/100 li | 2.843 | 0.455 |
| 15 | 1743 | Sichuan | land | flat | 0.0015 taels/shi/ li | 13.325 | 2.132 |
| 16 | 1743 | Sichuan | land | slope | 0.0022 taels/shi/ li | 19.543 | 3.127 |
| 17 | 1743 | Sichuan | land | hill | 0.003 taels/shi/ li | 26.650 | 4.264 |
| 18 | 1743 | Zhili | waterway | secondary | 0.00015 taels/shi/li | 1.333 | 0.213 |
| 19 | 1743 | Zhili | land | flat | 0.001 taels/shi/li | 8.883 | 1.421 |
| 20 | 1743 | Shandong | waterway | secondary | 0.02 taels/shi/100 li | 1.777 | 0.284 |
| 21 | 1743 | Shandong | land | flat | 0.1 taels/shi/100 li | 8.883 | 1.421 |
| 22 | 1743 | Fengtian | land | flat | 0.0012 taels/shi/li | 10.660 | 1.706 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23 | 1743 | Zhejiang | land | flat | 0.0007 taels/shi/li | 6.218 | 0.995 |
| 24 | 1743 | Zhejiang | land | hill | 0.0015 taels/shi/li | 13.325 | 2.132 |
| 25 | 1743 | Zhejiang | waterway | secondary | 0.001 taels/shi/10 li | 0.888 | 0.142 |
| 26 | 1743 | Zhejiang | waterway | tertiary | 0.0015 taels/shi/10 li | 1.333 | 0.213 |
| 27 | 1743 | Shanxi | land | flat | 0.1 taels/shi/100 li | 8.883 | 1.421 |
| 28 | 1743 | Jiangxi | waterway | secondary-downstream | 0.01 taels/shi/100 li | 0.888 | 0.142 |
| 29 | 1743 | Jiangxi | waterway | secondary-upstream | 0.012 taels/shi/100 li | 1.066 | 0.171 |
| 30 | 1743 | Jiangxi | waterway | primary-downstream | 0.0058 taels/shi/100 li | 0.515 | 0.082 |
| 31 | 1743 | Jiangxi | waterway | primary-upstream | 0.00696 taels/shi/100 li | 0.618 | 0.099 |
| 32 | 1743 | Henan | waterway | secondary | 0.01 taels/shi/100 li | 0.888 | 0.142 |
| 33 | 1743 | Henan | land | flat | 0.14 taels/shi/100 li | 12.437 | 1.990 |
| 34 | 1743 | Hubei | waterway | easy | 0.007 taels/shi/100 li | 0.622 | 0.099 |
| 35 | 1743 | Hubei | waterway | hard | 0.012 taels/shi/100 li | 1.066 | 0.171 |
| 36 | 1743 | Hubei | land | easy | 0.001 taels/shi/li | 8.883 | 1.421 |
| 37 | 1743 | Hubei | land | hard | 0.0015 taels/shi/li | 13.325 | 2.132 |
| 38 | 1743 | Hunan | waterway | primary-downstream | 0.005 taels/shi/100 li | 0.444 | 0.071 |
| 39 | 1743 | Hunan | waterway | primary-upstream | 0.007 taels/shi/100 li | 0.622 | 0.099 |
| 40 | 1743 | Hunan | waterway | tertiary-downstream | 0.007 taels/shi/60 li | 1.036 | 0.166 |
| 41 | 1743 | Hunan | waterway | tertiary-upstream | 0.01 taels/shi/60 li | 1.481 | 0.237 |
| 42 | 1743 | Hunan | waterway | tertiary-downstream-extream | 0.01 taels/shi/60 li | 1.481 | 0.237 |
| 43 | 1743 | Hunan | waterway | tertiary-upstream-extream | 0.012 taels/shi/60 li | 1.777 | 0.284 |
| 44 | 1743 | Hunan | land | flat__labor | 0.05 taels/0.4shi/60 li | 18.507 | 2.961 |
| 45 | 1743 | Hunan | land | hill__labor | 0.06 taels/0.4shi/60 li | 22.208 | 3.553 |
| 46 | 1743 | Hunan | land | hill-hard__labor | 0.07 taels/0.4shi/60 li | 25.910 | 4.146 |
| 47 | 1743 | Anhui | waterway | primary | 0.00651 taels/shi/100 li | 0.578 | 0.093 |
| 48 | 1743 | Anhui | waterway | secondary | 0.01 taels/shi/100 li | 0.888 | 0.142 |
| 49 | 1743 | Anhui | waterway | tertiary-shallow | 0.018 taels/shi/100 li | 1.599 | 0.256 |

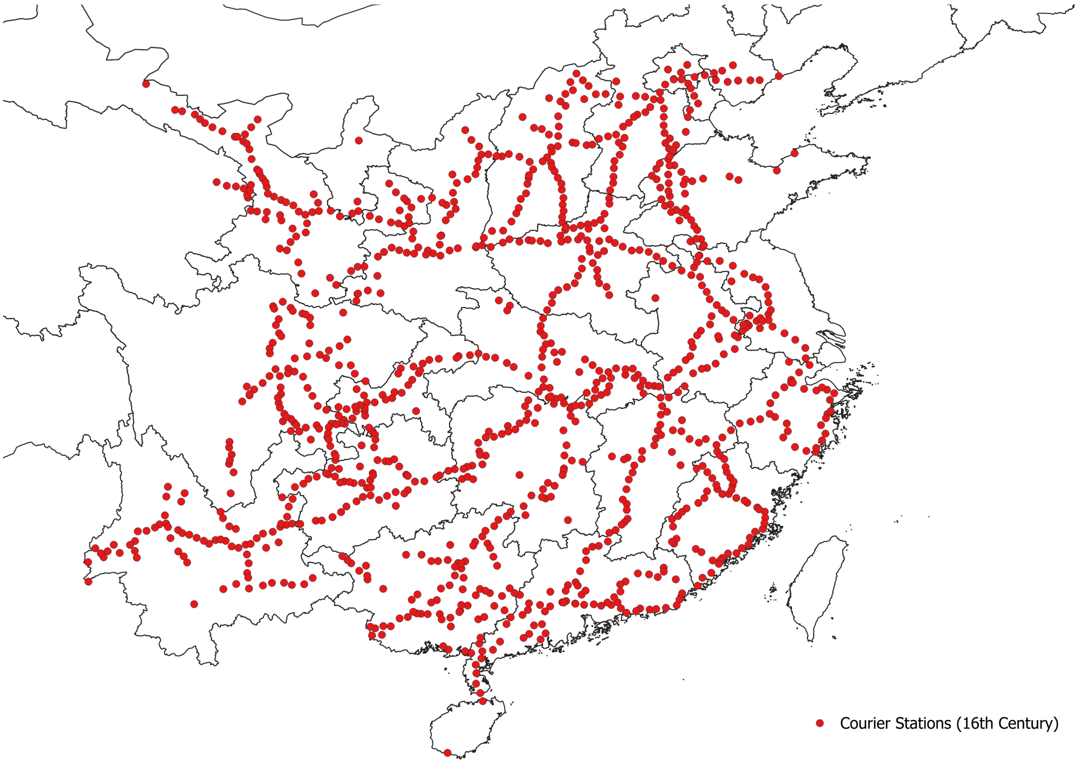
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 50 | 1743 | Anhui | waterway | tertiary-extream | 0.02 taels/shi/100 li | 1.777 | 0.284 |
| 51 | 1743 | Anhui | land | flat | 0.001 taels/shi/li | 8.883 | 1.421 |
| 52 | 1743 | Anhui | land | slope | 0.0015 taels/shi/li | 13.325 | 2.132 |
| 53 | 1743 | Anhui | land | hill | 0.002 taels/shi/li | 17.767 | 2.843 |
| 54 | 1743 | Anhui | land | hill-hard | 0.003 taels/shi/li | 26.650 | 4.264 |
| 55 | 1744 | Shaanxi | waterway | | 0.04 taels/shi/100 li | 3.553 | 0.569 |
| 56 | 1744 | Shaanxi | land | flat | 0.1 taels/shi/100 li | 8.883 | 1.421 |
| 57 | 1744 | Shaanxi | land | hill | 0.16 taels/shi/100 li | 14.213 | 2.274 |
| 58 | 1744 | Gansu | land | | 0.13 taels/shi/100 li | 11.548 | 1.848 |
| 59 | 1744 | Yunnan | land | flat | 0.12 taels/shi/100 li | 10.660 | 1.706 |
| 60 | 1744 | Yunnan | land | hill | 0.2 taels/shi/100 li | 17.767 | 2.843 |
| 61 | 1744 | Guizhou | land | flat | 0.001 taels/shi/li | 8.883 | 1.421 |
| 62 | 1744 | Guizhou | land | hill | 0.0018 taels/shi/li | 15.990 | 2.558 |
| 63 | 1744 | Guangdong | land | flat | 0.003 taels/shi/li | 26.650 | 4.264 |
| 64 | 1744 | Guangdong | land | hill | 0.004 taels/shi/li | 35.533 | 5.685 |
| 65 | 1744 | Guangdong | land | by vehicle | 0.001 tales/shi/li | 8.883 | 1.421 |
| 66 | 1744 | Guangdong | waterway | downstream | 0.007 taels/shi/100 li | 0.622 | 0.099 |
| 67 | 1744 | Guangdong | waterway | upstream | 0.01 taels/shi/100 li | 0.888 | 0.142 |
| 68 | 1744 | Guangdong | seaship | | 0.07 taels/shi/100 li | 6.218 | 0.995 |
| 69 | 1744 | Fujian | waterway | tertiary-downstream | 0.001 taels/shi/10 li | 0.888 | 0.142 |
| 70 | 1744 | Fujian | waterway | secondary-downstream | 0.008 taels/shi/100 li | 0.711 | 0.114 |
| 71 | 1744 | Fujian | waterway | tertiary-upstream | 0.0015 taels/shi/10 li | 1.333 | 0.213 |
| 72 | 1744 | Fujian | land | flat | 0.001 taels/shi/li | 8.883 | 1.421 |
| 73 | 1744 | Fujian | land | hill | 0.0015 taels/shi/li | 13.325 | 2.132 |
| 74 | 1776 | Fengtian | land | | 0.0012 taels/shi/li | 10.660 | 1.706 |
| 75 | 1776 | Fengtian | waterway | | 0.00014 taels/shi/li | 1.244 | 0.199 |
| 76 | 1776 | Fengtian | seaship | | 0.14 taels/shi/500km | 1.244 | 0.199 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 77 | 1776 | Zhili | waterway | | 0.00015 taels/shi/li | 1.333 | 0.213 |
| 78 | 1776 | Jiangxi | land | hill | 0.001 taels/100 jin/li | 12.437 | 1.990 |
| 79 | 1776 | Jiangxi | waterway | primary | 0.003 taels/shi/100 li | 0.267 | 0.043 |
| 80 | 1776 | Jiangxi | waterway | secondary-downstream | 0.003 taels/shi/100 li | 0.267 | 0.043 |
| 81 | 1776 | Jiangxi | waterway | secondary-upstream | 0.003 taels/shi/60 li | 0.444 | 0.071 |
| 82 | 1776 | Fujian | seaship | | 0.09 taels/shi/800km | 0.500 | 0.080 |
| 83 | 1776 | Fujian | seaship | | 0.0748 taels/shi/700km | 0.475 | 0.076 |
| 84 | 1776 | Zhejiang | land | flat | 0.001 taels/shi/li | 8.883 | 1.421 |
| 85 | 1776 | Zhejiang | waterway | primary | 0.00005 taels/shi/li | 0.444 | 0.071 |
| 86 | 1776 | Zhejiang | waterway | tertiary-hill | 0.0002 taels/shi/li | 1.777 | 0.284 |
| 87 | 1776 | Yunnan | land | flat | 0.135 taels/shi/100 li | 11.993 | 1.919 |
| 88 | 1776 | Yunnan | land | flat-horse | 0.18 taels/shi/100 li | 15.990 | 2.558 |
| 89 | 1776 | Yunnan | land | hill | 0.165 taels/shi/100 li | 14.658 | 2.345 |
| 90 | 1776 | Yunnan | land | hill-horse | 0.2 taels/shi/100 li | 17.767 | 2.843 |
| 91 | 1776 | Yunnan | waterway | tertiary-wide | 0.0004 taels/shi/li | 3.553 | 0.569 |
| 92 | 1776 | Yunnan | waterway | tertiary-narrow | 0.0005 taels/shi/li | 4.442 | 0.711 |

*Notes: All sourced from DQHD*

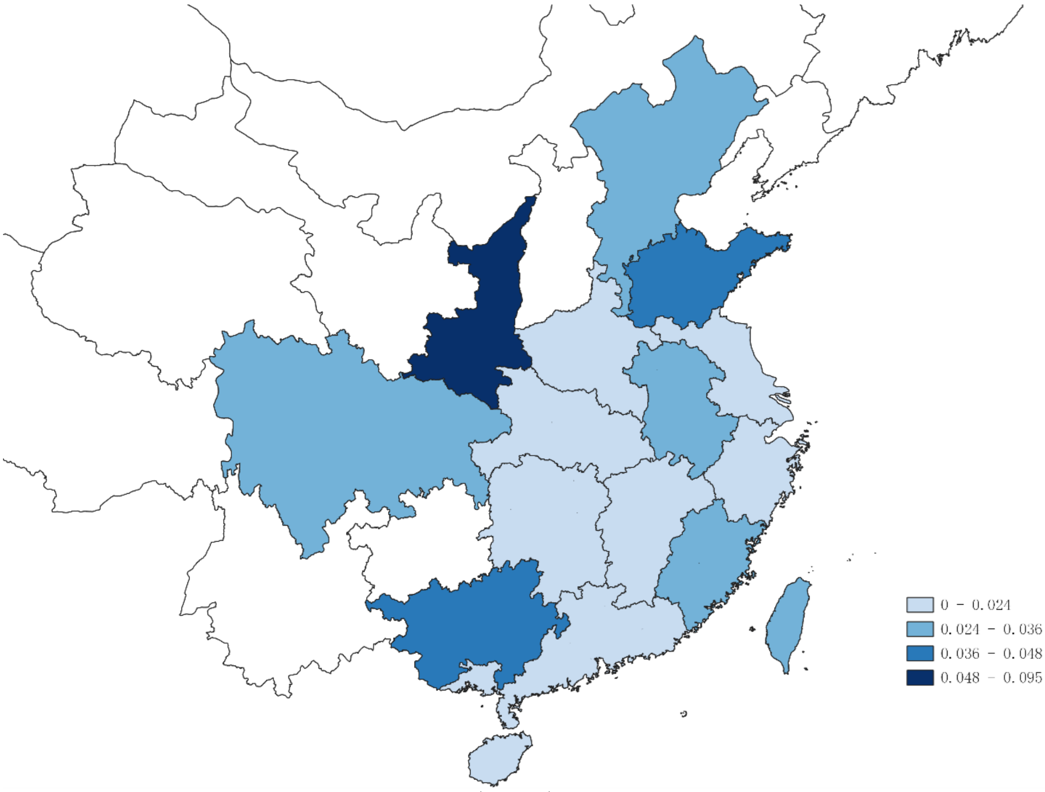
## 2.9 Appendix B. Additional Figure

FIGURE 2.4: *Courier Stations in Ming China*



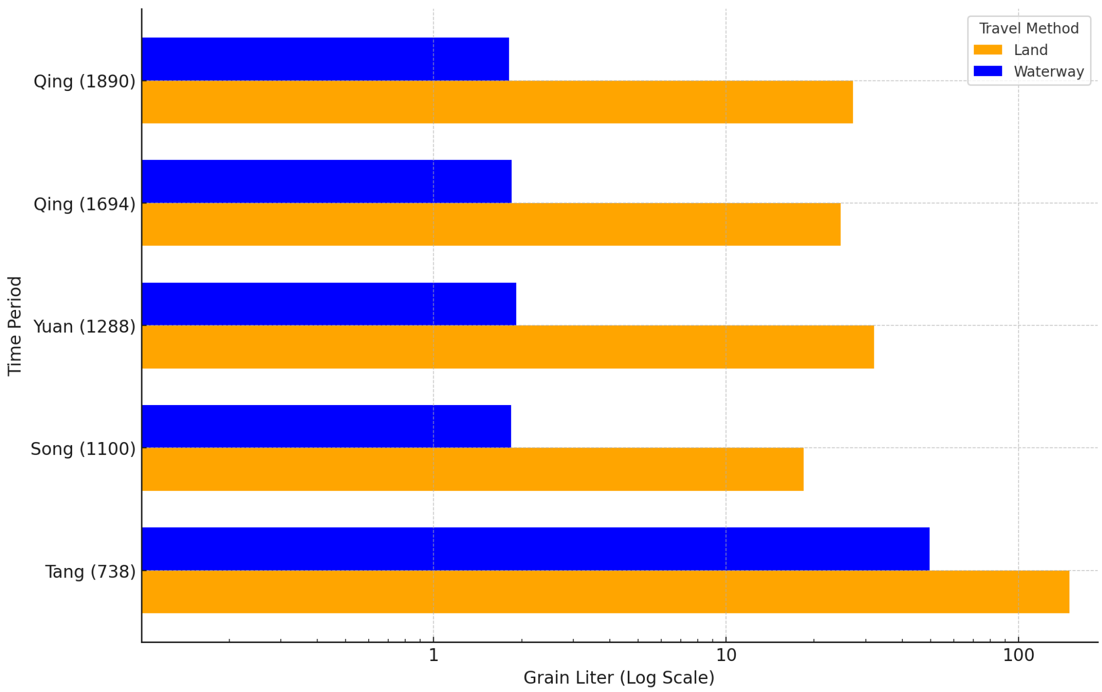

*Note:* Source from Yang (2006).

FIGURE 2.5: *Official downstream waterway transport costs in 1740s*




*Note:* Sourced from DQHD. Unit in silver taels/100kg/100km It can be observed waterway transport costs were diverse in 1740s China. In general, it cost higher in western and northern China. Regions that are plains or with comprehensive waterways obtained lower waterway transport costs in 1740s.

FIGURE 2.6: *Transport Costs over Different Dynasties in Historical China*




*Source:* see table 2.9

## 2.10 Appendix C. A comparison on Transportation Cost in Chinese History (6th to 20th century)

In this section, I compare my estimation of transportation costs in 17th and 18th-century China with those of other periods in Chinese history. Through comparison, it could be found that there was a significant decrease in transport cost from the Tang Dynasty (7th century) to the Song Dynasty (12th century). However, from the Song Dynasty onward, until the late Qing Dynasty (19th century), transport coast remained relatively stable.

### C.1 Tang and Song (7th to early 13th century)

Research on transportation costs in Chinese history is relatively scarce. One of the few studies on it is Kiyokoba (1991, 1996), which estimated transportation costs during the Tang and Song (8th and 12th century). Using official regulations quoted in *Da Tang Liu Dia* (*The Six Statutes of the Tang Dynasty* 大唐六典), Kiyokoba (1991) estimated transportation costs in 8th century China (Tang Dynasty). According to his estimation (see Table 2.9), land transportation by horse or mule pack ranged from 80 to 150 wen per 100 jin per 100 li. For waterway transportation, an upstream trip cost around 150 wen per 100 jin per 100 li, while a downstream trip cost only 50 wen per 100 jin per 100 li. This indicates that land transportation costs were similar to upstream waterway costs, and there was a 1:3 cost ratio between downstream and upstream waterway transportation in 8th century China (Tang Dynasty).

Using records from the official compendium of the Song dynasty, *Qingyuan Tiaofa Shilei* (*Laws and Regulations of the Qingyuan Period* 庆元条法事类), Kiyokoba (1996) estimated that land transportation cost 100 wen per 100 jin per 100 li. For waterways, the cost was 30 wen per 100 jin per 100 li upstream and 10 wen per 100 jin per 100 li downstream. As a supplement, Liu (2012) found an official price case from 1079 in historical archives[17], which revealed that transportation costs at that time were consistent with those recorded in *Qingyuan Tiaofa Shilei*. This consistency indicates that these

[17] Sourced from *Xu zizhi tongjian changbian* (续资治通鉴长篇), *juan* 297.

transportation costs represent the situation throughout the 11th, 12th, and early 13th centuries. A comparison of nominal transportation costs indicates an evolution from the Tang Dynasty to Song Dynasty in Chinese history. While land transportation costs remained relatively stable, nominal waterway transportation costs reduced by approximately 80% during the Tang-Song transition. Considering differences in measurement units and inflation over these five centuries, this reduction should be even higher (Liu, 2012).

## C.2 Yuan (late 13th to early 14th century)

Currently, there is no estimations on the transportation costs during the Yuan Dynasty. In the *Da De Dian Zhang* (大德典章), I discovered records detailing the official transportation costs of that era. These records has been listed in Table 2.13. They document changes in transportation costs during Yuang Dynasty. In 1288, the central government of the Yuan Dynasty established a standardized transportation rate across the nation. However, due to severe inflation, these initial rates soon became inadequate. Consequently, various regions requested price increases, which the central government approved to a certain extent.

It is crucial to note that the rampant inflation throughout the Yuan Dynasty complicates direct price comparisons over time. To address this inflation, the Yuan government introduced a new currency, the *Zhiyuan Chao*, in 1287, replacing the previously used *Zhongtong Chao*. With the launch of the new currency, the government also established guidelines on the purchasing power of the *Zhiyuan Chao*[18], providing the cases in 1288 (the original plan) a reliable reference for comparing Yuan Dynasty transportation costs with those of other periods in Chinese history (Peng, 1965).

## C.3 Late Qing (late 19th century)

In 1890, the Royal Asiatic Society conducted a systematic and comprehensive survey of the transportation situation in China. This survey provided detailed information on

[18] 10 taels of *Zhongtong Chao* is equal to 2 guan of *Zhiyuan Chao* and equal to 1 taels of sterling silver. (Peng, 2020)(pp447)

freight costs across various parts of China at that time (Fan, 1992; Kingsmill, 1898). A table listing all the cases is provided in Table 2.12. Here I use the waterway price for *Kiangsu to Honan* and the land price for *Kiangsu* as reference prices for comparing transportation costs in this study. I do this because: (1) it reflects the prices in the Yangtze China, and (2) the waterway trip from *Kiangsu* to *Honan* primarily relies on the Grand Canal, consisting with the criteria used for other periods'observations.

As discussed in Fan (1992), it is evident that freight rates by land are fairly consistent across different regions. For instance, the difference in transportation costs between Yunnan, a less developed and mountainous region, and the lower Yangtze, a well-developed and relatively flat area, is minimal. The highest land freight rate is only 2.5 times greater than the lowest. This indicates that commercial land transport faced similar challenges in both developed and underdeveloped areas and also, the presence of a competitive market. In contrast, land and river freight rates show significant disparities. When comparing the cost of transporting goods by junk from Kiangsu to Honan via the Grand Canal and Huai River with land freight costs, the ratios range from 1:10 to 1:25. In Kiangsu, the ratio can be as low as 1:37.5. This reflects the extensive local water routes in the lower Yangtze delta, where low water freight costs highlight the development of an efficient water transport network.

### C.4 Deflate with grain price

By summarizing the transportation costs across various periods in Chinese history, I am able to estimate changes in historical transportation costs. However, a potential issue on comparing these data is that different currencies were used in different periods of Chinese history. Copper coins were mainly used in the Tang and Song Dynasties, paper money in the Yuan Dynasty, and silver in the Ming and Qing Dynasties. Additionally, the purchasing power of these currencies varied, making direct comparisons using nominal prices impossible. Therefore, to make transportation cost in different time period comparable, sort of deflating is needed. Here, I use grain prices for deflation. Grain is a basic necessity for human survival and a key component in constructing the Consumer Price Index (CPI) in various studies (Allen et al., 2011; Liu, 2024; Peng, 2006). Further, grain itself also has monetary attributes and has long been the most important trade commodity in historical China.[19]

Peng (1965) provides data on grain prices throughout Chinese history. In the first half of the 8th century during the Tang dynasty, the price of grain was about 330 wen per 100 liters (Peng, 1965)(pp218). In 1200, during the Southern Song dynasty, the grain price was 3039 wen per 100 liters (Peng, 1965)(pp313). An estimate for the Yuan dynasty puts the grain price at 39 grams of silver per 100 liters (Peng, 1965)(pp403)[20][21]. In 1680, during the early Qing dynasty, the grain price was 32.22 grams of silver per 100 liters, and by 1890, in the late Qing dynasty, it had risen to 89.37 grams of silver per 100 liters (Peng, 1965)(p560).

Considering the high grain prices during the Southern Song period after the Jingkang Incident[22], which may not accurately reflect the real purchasing power, and given Liu (2012)'s indication that nominal transportation costs remained roughly unchanged from the 11th to early 13th centuries, I have also provided deflated transportation cost estimates for the Northern Song period around 1100. These estimates are based on 1100 grain prices (1827 *wen* per 100 liters (Peng, 1965)(pp313)) and the 1202 transportation costs.

I have also prepared silver price based deflation for comparisons. Peng (1965) does not provide the exchange rate between silver and copper coins during the Tang dynasty. Around 1104 in the Song dynasty, the exchange rate was 1250 *wen* of copper coins per tael of silver, and by 1200, the rate had changed to 3300 *wen* of copper coins per tael of silver (Peng, 1965)(pp329-330). During the Yuan dynasty, the newly issued *Zhiyuan Chao* in 1287 had an official exchange rate, with 2 *guan* of *Zhiyuan Chao* equivalent to

[19] While the wage of unskilled labor might be a better choice due to its lower volatility compared to grain prices, existing research on Chinese unskilled labor wages primarily focuses on the period after the 15th century. Historical records of unskilled labor wages before the 15th century are very limited, making it extremely difficult to use unskilled labor wages as a method for deflation.

[20] It is important to note that the 1965 edition listed this as 29 grams of silver per 100 liters, but the 2020 revised edition updated it to 39 grams of silver per 100 liters. Therefore, the 2020 edition data is used here. All other periods'data are consistent between the two editions.

[21] Due to severe inflation during the Yuan dynasty, only the transportation cost in 1288, when new currency was issued with a clear silver exchange rate, is used here.

[22] During which the Song empire is invaded by Jin and Song empire lost all of its territory in north China.

10 taels of *Zhongtong Chao* or 1 tael of silver (Peng, 1965)(pp447). In the Ming and Qing dynasties, silver taels were directly used as the circulating currency.

### C.5 A comparison

Table 2.9 and Figure 2.6 display the transportation costs in the Yangtze China across different historical periods. Observations reveal a significant reduction in transportation costs between the Tang and Song dynasties. For waterway freight costs, the nominal price decreased by approximately 80%. When deflated by grain prices, the decrease exceeds 95%, surpassing the reduction in transportation costs brought by the 19th-century railway revolution in Britain (Bogart, 2013).

Furthermore, when comparing grain price-deflated freight costs across different eras, it is evident that from the Yuan dynasty to the late 19th century of the Qing dynasty, waterway freight costs remained relatively stable. Although land freight costs fluctuated, they were also relatively consistent. Comparing the grain price-deflated freight costs of the Yuan, Ming, and Qing dynasties with those of the Song dynasty (1202), it is evident that waterway freight costs during the Song dynasty were about half of those in the later dynasties.

Given that 1202 was during the Southern Song Dynasty after the Jingkang Incident, when grain prices were consistently high due to the loss of northern territories and frequent wars, this may potentially distort the effect of deflation. Given Liu (2012)'s argument that the nominal transportation costs during the Song dynasty remained relatively stable from the 11th century to the early 13th century, using grain prices from the relatively peaceful period of 1100 as the deflation basis suggests that waterway freight costs in Song Dynasty were roughly on par with those in the Yuan, Ming, and Qing dynasties, while land freight costs were about 60% of those during the Yuan, Ming, and Qing periods.

It is challenging to provide credible explanations for such a trend. One potential hypothesis is that the taxation structure among different dynasties played an essential role. The Song dynasty was unique in Chinese history. It was not only the only dynasty founded on indirect taxation but also the first sustainable tax state in global history (Liu 2015). In the Northern Song dynasty, around 40% of tax revenue came from commercial taxes. By the Southern Song dynasty, this ratio had increased to 84.7% (Gu 2003). In contrast, the Tang, Ming, and early Qing dynasties mainly relied on direct taxes such as land and poll taxes.

This difference in tax sources led the Song Empire have more incentive to maintain an efficient market, as more commercial activities meant higher tax revenues. This focus was demonstrated through massive investments in transport infrastructure, particularly canals. Many canals used in the Ming and Qing dynasties were initially constructed during the Song dynasty, and large-scale construction and maintenance projects were rare in the Ming and Qing periods. In fact, most construction projects during the Ming and Qing dynasties focused on maintaining existing canals rather than building new ones (Fan, 1992). As a result, commercial activities were more prosperous in regions once governed by the Southern Song dynasty during the Ming and Qing periods.

In general, the sources of state tax revenue determined policy focus and attitudes toward the construction of new transport infrastructure. These differences could potentially contribute to the trends in transport costs observed in Chinese history.

## 2.11 Appendix D. Primary Sources and their abbreviations used in this study

- *Shiwo Zhouxing* (SWZX) 示我周行 [Traveling everywhere on my own]
    - Author: anonymous
    - Type: Merchants' route book
    - Edition: 1694 (British Library), 1774 (Berlin State Library), 1784 (Library of Congress, Washington)
    - Note: 144 routes. The 1774 edition was the most widely circulated route book. (Brook, 1981)
- *Zhouxing Beilan* (ZXBL) 周行备览 [Ready reference for traveling everywhere]
    - Author: anonymous
    - Type: Merchants' route book

  - Edition: 1738 (Institute for Advanced Studies on Asia, The University of Tokyo)
  - Note: A 1738 reprint of SWZX, with a few difference on sequences of route.

- *Yitong Lucheng Tuji* (YTLC) 一统路程图记 [The comprehensive illustrated route-book]
  - Author: Huang Bian 黄汴
  - Type: Merchants' route book
  - Edition: 1570 (Naikaku Bunko (Cabinet Library), National Archives of Japan, Tokyo)
  - Modern reprint: Yang (2019a)
  - Note: 158 routes. The first national route book published by merchants.

- *Shanggu Bianlan* (SGBL) 商贾便览 [A convenient handbook to merchants]
  - Author: Wu Zhongfu 吴中孚
  - Type: Merchants' route book
  - Edition: 1792 (National Library of China, Beijing)
  - Modern reprint: Yang (2019b)
  - Note: 75 routes abridged from SWZX. One section provide a detail description on boats all over China.

- *Huanyu Tongqu* (HYTQ) 寰宇通渠 [Comprehensive guide to worldwide routes]
  - Author: Ming Government
  - Type: Official route book
  - Edition: 1394 (National Library of China, Beijing)
  - Modern reprint: Yang (2019c)
  - Note: A collection of all courier routes in early Ming Dynasty.

- *Qingding Daqing Huidian Shili* (DQHD) 钦定大清会典事例 [The official statutes and precedents of the Qing Empire]
  - Author: Qing Government
  - Type: Official achieves
  - Edition: 1812

# Chapter 3

# Path Toward Civilization: Natural Roads, Trade Potential and the Location of Economic Activities in Pre-historical China (7000 BP –2000 BP)

# Abstract

This chapter aims to analyse the correlation between trade potential and the evolution of civilisation in the Neolithic era and how that changes over five millennia from 7000 BP to 2000 BP in China. The first step of this research is to assess the natural routes across the country using a topography-based metric. It then investigates the relationship between these natural routes and the local economic activities, measured through the presence of archaeological sites in an area. This inquiry reveals a significant connection between higher natural route scores and the number of archaeological sites at 5000 BP. Further econometric examination of the relationship between market potential and archaeological sites provides additional evidence of the crucial role of trade in the Neolithic era. Lastly, the paper examines how this relationship evolved over five millennia computing the elasticities between economic activity and natural roads. Interestingly, the elasticities were not constant. I find that since humans settled down 7000 years ago, economic activities have generally concentrated around regions with convenient natural road access. However, approximately 4,500 years ago, this relationship declined significantly and remained low for nearly half millennium. This trend reversed with the emergence of the first territorial states 4000 years ago, after which the elasticities fluctuated in alignment with dynastic cycles.

## 3.1 Introduction

A significant body of literature recognises trade as a crucial driver of economic growth. This idea can be traced back to the works of the classical economist Adam Smith (1776). Recent empirical studies have found evidence of the relationship between trade and economic development in various parts of the world across different historical periods (Acemoglu et al., 2005; Bosker et al., 2013; Bosker and Buringh, 2017; Michaels and Rauch, 2018). These periods can reach as far back as the Iron Age Mediterranean 2750 years ago (Bakker et al., 2021) and the Bronze Age Assyria Empire 3900 years ago (Barjamovic et al., 2019). However, the connections between trade and economic development identified in the aforementioned literature all occurred after the establishment of states and complex institutions. Our understanding of the role of trade in economic development among pre-state communities is still markedly limited.

To overcome such a gap, this study uses information from a recently created dataset of Chinese archaeological sites to support the connection between trade and economic prosperity in pre-state civilization. Specifically, it provides novel empirical evidence supporting a causal association between trade potential and economic growth in the Neolithic era (5000 BP[1]) China. In addition, it also finds that such connections are not constant across a period ranging from the inception of the civilizations during the Neolithic era (7000 BP) to the Iron Age (2000 BP), during which China underwent a remarkable metamorphosis, evolving from diminutive Neolithic settlements into a unified empire (the Qin-Han empire).

The two principal variables of this study are trade potential and economic activity. To estimate a site's trade potential, this paper develops a Natural Road Score (NRS) Index that evaluates a location's inherent advantages in facilitating trade and exchange[2]. To measure the economic development level of a region, this research uses the presence of

[1] BP, an abbreviation for "Before Present", denotes a chronological scale predominantly employed in archaeology and geology, particularly in conjunction with radiocarbon dating techniques. Originating in the 1950s, this convention adopts 1 January 1950 as the baseline, rendering, for instance, the year 50 BCE equivalent to 2000 BP in this context.

[2] The concept of the Natural Road Score (NRS) was initially introduced in the study by Barjamovic et al. (2019). This study developed a topography-based index, known as the Natural Road Score, to elucidate the mechanism behind the phenomenon whereby locations with historically significant trade cities from the Bronze Age continue to exhibit higher levels of economic activity compared to other regions. A detail explanation of the construction of NRS index can be found in data part.

archaeological sites as a proxy. This approach is grounded in the hypothesis that a more significant number of human activity indicators suggest a higher degree of economic development (Berrey et al., 2015; Bakker et al., 2021). If trade plays an essential role in economic development, locations with a higher NRS are expected to exhibit more potential for economic development.

The NRS methodology adopted in this study has several obvious advantages. More prominently, it mitigates concerns of reverse causality and multiple confounders by leveraging a topography-based proxy for trade . Rather than directly examining trade, I estimate a reduced-form association that connects trade potential via natural roads index to economic development. However, this approach has also its limits. I face a challenge in effectively isolating the impact of exchange on goods since the availability of roads can also influence other phenomena like migration or the exchange of ideas. Therefore, within the scope of this study, the term "trade" is interpreted broadly, encompassing all these factors (Bakker et al., 2021).

In our analysis correlating trade potential with the levels of economic development, I have discerned several key findings. Our examination of cross-sectional data from 5000 BP reveals that a region's inherent geographical advantages for natural transportation routes significantly influenced the proliferation of archaeological sites during the Neolithic period. This relationship is robust to alternative specifications of the explanatory variable (NRS and market potential), several robustness calculations with different data sources and spatial scope, and alternative estimation methods, including the causality approach (2SLS).

An exploration of trade Coefficient over five millennia, from 7000 BP to 2000 BP, reveals that trade Coefficient has fluctuated considerably over time. Since humans settled in China around 7000 BP, economic activities (ancient settlements) generally concentrated in regions with accessible transportation routes. However, around 4500 BP, this relationship declined sharply and remained low for nearly a millennium, only rebounding with the emergence of the first "Empire." This turning point aligns with a significant global climatic event (Holocene Event 3), potentially indicating that a climate shock triggered a Malthusian trap, leading to prolonged conflicts that were eventually resolved by the formation of a unified state. In this way, the climate shock may have set in motion a process resembling the circumscription hypothesis (Carneiro, 1970).

Over time, the evolution of trade Coefficient reveals a similar trend. Following this climate shock, while trade Coefficient remained low, it gradually increased until the establishment of China's first large-scale state. Thereafter, as China entered the dynastic era, fluctuations in trade Coefficient closely matched the cyclical nature of dynasties. Specifically, in the early stages of each dynasty, trade Coefficient rises, peaking at mid-dynasty and declining significantly toward the dynasty's end. This pattern likely reflects the initial consolidation of new political orders, which gradually weakened over time, eventually leading to widespread conflict and the emergence of a new dynasty.

Finally, following the unification of China by Qin-Han Empire, a consolidated imperial structure led to the restructuring of urban hierarchy, ensuring centralized control over the vast territory. These patterns align closely with the findings in Chapter 3, where I analyze the relationship between city locations and natural endowments in the transportation network over the past 2000 years.

### 3.1.1 Contribution

This paper contributes to several fields. Firstly, it adds to the extensive literature on trade and growth[3]. Smith (1776) posited that trade plays a crucial role in promoting economic development. Contemporary studies have established causal relationships between trade and economic growth by examining exogenous events associated with changes in trade resulting from geographical discoveries, the establishment of new trade routes, and technological advancements (Acemoglu et al., 2005; Pascali, 2017; Donaldson, 2018; Donaldson and Hornbeck, 2016; Redding and Sturm, 2008a; Feyrer, 2021). Generally, these papers find that new trade opportunities produce economic growth. Most closely related to our study is a series of papers investigating the relationship between trade and economic growth during the early phases of human history (Barjamovic et al., 2019; Bakker et al., 2021). Our research aligns with their findings but encompasses an

[3]See, among others, the surveys of Findlay (1984); López (2005); Singh (2010).

even earlier and more extended period, covering the trajectory of societal development from Neolithic villages to a unified empire.

This research also connects to a subset of literature focusing on the location and dynamics of spatial distribution of economic activities. By examining the spatial distribution of economic activities throughout Japan's economic geography from the Neolithic period to the present, Davis and Weinstein (2002) observe a strong path dependency on population distribution in Japan and suggest that fundamental location factors establish the spatial pattern of economic activities. Subsequently, several studies have challenged this view by showing that path dependency on cities persists even when places lose their locational advantages (Bleakley and Lin, 2012; Nitsch, 2003). Additionally, temporary shocks may have long-term economic effects on the spatial distribution of economic activities (Hanlon, 2017; Redding et al., 2011). Our study contributes to this field by providing evidence from pre-historical China. I indicate that various factors, including climate, institutions, and social and political conflicts, can influence the spatial distribution of economic activities. I observe that (1) Short-term climatic shifts, leading to transitions in human production modes, can have enduring impacts on the spatial economic layout, and (2) alterations in the spatial economic configuration induced by institutional factors and conflicts tend to revert to their original state following the resolution of the institutional issues or the cessation of conflicts.

Outside the realm of economics, this paper is also relevant to the Formalist-Substantivism-Marxist debate that shapes the archaeological studies on trade. Formalists, like neoclassical economists, assert that economic principles such as supply, demand, and profit maximisation apply universally, even within prehistoric societies. They believe that pre-state trade was motivated by economic rationale, with individuals engaging in exchanges to acquire necessary or desired goods. As a result, trade is considered vital for economic growth (Schneider, 1968, 1974; Pospisil, 1963; Carrier and Carrier, 1989). From an alternative perspective, Substantivism emphasises the significance of trade in developing archaic states. It argues that exchange and trade were embedded within social and cultural structures, with market exchange not being the primary mode of economic organisation in pre-modern societies. Political and social elites primarily organised and controlled long-distance trade to establish and reinforce social and political relationships (Polanyi, 2002, 1965, 1975). In opposition to the previous two viewpoints that propose trade as essential to human development, Marxist approaches maintain that trade and exchange were influenced by the society's underlying social and economic structures, including class relations and modes of production. They attribute a minor role to trade in societal development, positing that control of production has always been the central strategy for elites to obtain and maintain power (Marcus, 1983; Price, 1978; Price et al., 1977). Our study contributes to this debate by offering direct evidence of trade's correlation to economic growth during the period of the inception of civilisation.

The subsequent sections of this paper are structured as follows. Section two outlines the study area, data construction process, and the sources utilised in this investigation. Section three explains the empirical strategies employed in this study. Section four delves into examining the coefficient of trade throughout the study period and explores the underlying mechanisms behind its fluctuations. Finally, section five presents the conclusions.

## 3.2 Settings and Data

### 3.2.1 Trade in pre-state communities

Trade, as defined by the Oxford Dictionary, encompasses the buying, selling, or exchanging of goods or services among individuals or nations. This study adopts a broad interpretation of trade, encompassing any exchange of goods, favors, or services for the benefit of individuals or groups, irrespective of the social framework (Oka and Kusimba, 2008). Under this definition, various evidence indicates the prevalence of trade among pre-state societies. In the Near East, geochemical analyses of obsidian from Melos in the Aegean suggest exchange networks during the Paleolithic and Neolithic periods in Southeast Europe and West Asia (Perlès et al., 2011). Similarly, oxygen isotope studies of Spondylus shells from Neolithic sites imply that ornaments found in the Balkans and Central Europe originated from the Aegean, indicating trade routes realignment during the Neolithic era (Shackleton and Renfrew, 1970). Hirth (1978) documented in Neolithic Mesoamerica how significant settlements developed along natural trade routes, crucial for managing commodity flow. Parallel findings have been observed in China. The Neolithic site of Shimao, a vast central settlement in the mixed farming-pastoral zone of Northern Shaanxi, revealed the presence of rice that is indigenous to Southern China. Archaeologists suggest this rare food, likely used for brewing, was acquired through exchanges with neighboring regions, further evidencing the extensive reach and significance of early trade networks (Yang et al., 2022).

### 3.2.2 China as a unique case

There are several distinct advantages of examining archaeological sites in China from 7000 BP to 2000 BP in considering the question posed in this paper. First, compared to Mesopotamia, Egypt, and the Mediterranean, China's enclosed topography led to a self-contained civilisation less susceptible to external invasions and influences. For example, evidence suggests that China's early agricultural and stock-raising systems developed independently from those of the Middle East (Harris, 1993; Bettinger et al., 2010). Second, the 5000-year timeframe spanning from 7000 BP to 2000 BP encompasses a period extending from the emergence of agricultural societies to the establishment of the first unified empire, thereby covering the entire progression of societal development. China's rapid archaeology development has made it one of the regions with the most systematic prehistoric archaeological data. Neolithic archaeological materials from the Near East are mostly from excavations carried out in the 1980s due to military conflicts over the past 40 years [4]. On the other hand, in China, many new archaeological materials have been excavated within the last few decades [5]. Owing to these factors, this case study presents a unique, data-rich, independent example of a civilisation's developmental

[4] Mesopotamia, located in the region of present-day Iraq, has experienced prolonged periods of conflict over the past 40 years, beginning with the Iran-Iraq War in 1980s. This turmoil has resulted in a stagnation of archaeological data, with most information remaining from the 1980s. For instance, the data used in Allen et al. (2023), is sourced from the "Akkad Survey" (Adams, 1965) and the "Sumer Survey" Adams and Nissen (1972); Adams (1981).

[5] In conjunction with the rapid economic expansion witnessed over the past few decades, the Chinese government's investment in archaeology has reached an unprecedented level. It could be posited that China is currently in the midst of an "archaeological golden age", characterized by the impressive application of new technologies, the availability of high-caliber talent and international collaborations, as well as some of the world's most generously funded archaeological projects (Jia, 2019).

trajectory, uninfluenced by external factors, spanning from agricultural settlements to creating a unified empire.

### 3.2.3 Study area and unit of observation

To explore the impact of trade on the advancement of civilisation, I created a new regular grid system with a resolution of ¼-by-¼ degree, spanning the geographical extent of China. The grid system consists of 16,121 cells, each serving as an individual observation for analysis. This research projected the dataset using the WGS 84 coordinate system to ensure compatibility with the vast size of China. It is worth noting that a quarter degree roughly corresponds to 28 kilometres at the equator.

This study distinguishes "China Proper" and "North China Proper" to account for historical variation in the territorial extent of Chinese civilisation compared to modern borders. "China Proper" includes all provinces in contemporary China, excluding the Northeast, Xinjiang, Inner Mongolia, Tibet, and Qinghai. It corresponds with the territorial expansion of China during the Qin and Han Dynasties Harding (1993). "North China Proper" is more restrictive, excluding the southern provinces and autonomous regions, such as Hong Kong, Macau, Hainan, Guangdong, Guangxi, Jiangxi, Hunan, Guizhou, Fujian, Taiwan, and Yunnan. This latter entity encapsulates an area covering the land in between and surrounding mid and lower regions of the Yangtze and the Yellow River, representing China's "Mesopotamia" . These regions have been traditionally regarded as the cradle and heartland of early Chinese civilisations Chang (1986); Su and Yin (1981). Figure 1 demonstrates the spatial boundaries of China, China Proper, and North China Proper. This study treats North China Proper as our main interest of study and the other two territorial extend of China as reference.

Our primary focus is on the period around 5000 BP, a juncture situated on the eve of the emergence of territorial state in China. During this era, Chinese civilization had already embraced agriculture, and large sedentary settlements began to emerge, yet complex societies had not fully developed. This temporal marker serves as an optimal time point for investigating pre-state communities.

For persistence, I observe each grid cell for every 500 years from 7000 BP to 3000 BP, and every 250 years from 3000 BP to 2000 BP. This approach arises from the decreasing temporal accuracy of archaeological data with increasing antiquity, attributed to larger confidence intervals in radiocarbon dating for earlier samples (Hajdas et al., 2021). In Chinese archaeological practice, age determination predominantly relies on stratigraphy, comparing newly excavated layers with radiocarbon-dated strata to infer ages. As a result, reports on sites earlier than 3000 BP often provide broad chronological terms like early or late Longshan period rather than absolute dates. Hence, I adopt a 500-year boundary for periods before 3000 BP. Beyond 3000 BP, the advent of historical records enhances the precision of dating, allowing for a 250-year boundary due to the potential for cross-verification between archaeological evidence and historical data.

### 3.2.4 Archaeological data

This study aims to measure the local economic development of China between 7000BP and 2000BP using the count of archaeological sites. I use two data sources for this project. The 'Atlas of Chinese Culture Relics' (ACCR) and the more recent 'China Archaeology Database Project'(CADB). The ACCR is a publication that documents the findings of the second campaign of a national systematic archaeological survey project. The Chinese National Cultural Heritage Administration launched this project in the 1980s. The CADB project is a project lead by Professor Chen Zhiwu at University of Hong Kong, seeking for digitizing all existing archaeological reports in China. This research primarily relies on CADB data, using the ACCR dataset as a reference for comparison.

There are some serious concerns about the archaeological sites listed in the ACCR. Firstly, the atlas intentionally alters the locations of these sites to protect them from looting, which leads to significant inaccuracies in the spatial data. In fact, some archaeologists conducting regional surveys based on this data found that it did not correspond at all with the actual site distributions, highlighting the challenges of using this dataset for precise spatial analysis. Secondly, the dating of these sites is often subjective because many have not been systematically excavated or surveyed, so local cultural workers estimate the age of the sites by their guess rather than evidence. Consequently, chronological information could contain inaccuracies. Lastly, some sites mentioned in the ACCR might not exist because the survey relied too heavily on local reports, often based on traditional heritage narratives (Jaffe et al., 2021; Jaffe and Hein, 2021; Flad et al., 2021).

The CADB mitigate the accuracy problems of the ACCR. This new dataset includes 10,044 archaeological sites across China from 7000 BP to 2000 BP. Each reported site has undergone excavation or systematic regional surveys and has published archaeological reports. This pretty much has covered all existing archaeological reports or regional surveys has been published in China before 2020, meaning this dataset has covered all archaeological sites that either has been excavated or surveyed as I have today in China. Consequently, it provides more precise locations and timeframes than the ACCR. Figure 2 illustrates the spatial distribution of archaeological sites in China around 5000 BP, based on the CADB data.

A natural question arises as to whether these datasets accurately reflect the spatial distribution of economic activities at the time, and whether their spatial coverage is biased by patterns of human activity. For the ACCR dataset, such concerns are indeed valid, as emphasized by Jaffe et al. (2021); Jaffe and Hein (2021); Flad et al. (2021). In contrast, for the CADB dataset these concerns can be minimized, and the data can be regarded as approximating a random sample. This is because most of the CADB materials are derived from archaeological work conducted over the past half century. Over the past forty years, China has experienced rapid economic development, and virtually all areas with evidence of human activity have undergone some form of land construction. During such construction, whenever archaeological remains are discovered, reporting to the local cultural heritage authorities is legally required, followed by official intervention, preliminary investigation, and the publication of excavation reports. As a result, nearly every piece of land in China suitable for human habitation has been subject to some form of archaeological survey, making the CADB dataset close to a random sample.

### 3.2.5 The Natural Road Score (NRS) Index

This study employs the Natural Route Score (NRS), proposed by Barjamovic et al. (2019), to measure the probability of a cell being located on a natural transportation route. The NRS represents a quantitative assessment of the likelihood that a given location, denoted as location $A$, lies along a potential traffic route. Specifically, it is defined as the frequency with which the optimal path between any two pairs of distinct locations $O$ and $D$ traverses $A$, given a predefined travel range.

To avoid a core–periphery bias—the tendency for central cells to accumulate higher route counts purely due to geography—I collect elevation data covering a wide region around China (70°E–140°E, 15°N–55°N; see Figure 3). The dataset has a spatial resolution of 1/12° (about 10 km at the equator) and is drawn from the FAO Global Agro-Ecological Zones (GAEZ) database (Fischer et al., 2008). Figure 5 illustrates the study area.

Travel times are calculated using the Langmuir (1984) equation for human walking on rugged terrain: 0.72 seconds per horizontal meter; an additional 6 seconds per vertical meter uphill; a reduction of 2 seconds per vertical meter downhill on slopes $\leq$21.25%; and an addition of 2 seconds per vertical meter downhill on slopes $>$21.25%.

The Dijkstra (1959) shortest-path algorithm is applied to compute optimal travel routes. For computational feasibility, I restrict origin–destination (O–D) pairs to those within 200 hours of walking distance. To construct the NRS, I then calculate each cell's betweenness centrality in the network of optimal routes among all O–D pairs located within 600 hours of distance. This two-stage procedure ensures that local routes are computed in a tractable manner while centrality captures the broader importance of each location in connecting the wider landscape. Because the resulting centrality scores are very small, values are rescaled by a factor of one billion. Our key variable, $r_i$, is defined as the maximum NRS within each cell, which serves as an indicator of its propensity to connect to the natural routes network. Importantly, this measure is exogenous, as it relies solely on topographical inputs. Figure 4 depicts the NRS across China proper.

Two exclusions are worth noting. First, maritime expeditions are omitted. Although textual sources suggest nascent seafaring during the Warring States period, empirically validated voyages appear only from the Han dynasty, with maritime commerce expanding substantially only during the Tang dynasty (Sun, 2011c,a,b). For most of the timeframe considered, oceanic travel was technologically limited and is excluded. Second, penalties for river crossings are omitted. Given the dramatic shifts of Chinese river systems across millennia, relying on modern river maps would introduce large inaccuracies. I instead assume river shifts to be random, which minimizes systematic bias in the NRS estimates.

### 3.2.6 Additional controls

In addition to trade and road networks, other factors may have influenced the location and development of early human civilisations. An obvious candidate is land suitability for agricultural production. This article utilises data on the maximum potential production capacity in tons per hectare of the three most diffused crops in China during the period considered to account for this (Lee et al., 2007). The data is sourced from the GAEZ database (Fischer et al., 2008) and scaled by historical calories per ton for each crop according to the FAO information (Chatfield, 1953b). The three crops considered here are wetland rice, foxtail millet, and wheat.

Wittfogel (1953) Hydraulic Theory posits that irrigation requirements might have been crucial to the emergence of civilisations and states. Thus, the estimations incorporate each cell irrigation suitability as a control variable. Bentzen et al. (2017) provides the underlining data. Additionally, I include elevation and terrain ruggedness as control variables in our regression analysis. The elevation data is retrieved from the Shuttle Radar Topography Mission (SRTM) dataset Farr and Kobrick (2000), while I compute terrain ruggedness using the Slope algorithm in ArcGIS. The dataset includes the mean elevation and terrain ruggedness for each cell.

Considering that the calculation process for the NRS does not account for maritime transportation, coastal regions inherently receive lower NRS than inland areas. To mitigate the impact of this discrepancy, I incorporate an additional variable, a 'coastal dummy', to control whether a cell is within 200 kilometres of the coastline.

Finally, I include longitude and latitude as control variables in our analysis. These variables control for the impact of temperature and climate change across study areas. Table 1 presents a summary of all variables in our dataset.

## 3.3 Specification and Results

The present study employs a series of econometric estimations to assess the relationship between economic activity and natural roads. Additionally, the research analyses the correlation between the same dependent variable and market potential. Finally, I estimate the same relationship but instrument it with NRS to obtain a causal effect.

To examine the relationship between economic activity and natural roads, I estimate regressions of the following form:

$$N_{it} = r_i \beta_t + X_i \theta + \lambda_i + \epsilon_{it}. \tag{3.1}$$

where $N_{it}$ denotes the intensity of economic activity in grid cell $i$ during period $t$. I use two alternative proxies for $N_{it}$, both measured as the number of archaeological sites recorded within each grid cell, but derived from distinct sources.

The first proxy is based on the China Archaeological Database (CADB), which compiles site-level records from published excavation reports and academic field surveys. This dataset offers high spatial precision and source traceability, making it a reliable representation of archaeological settlement patterns, especially in well-studied regions.

The second proxy is derived from the *Atlas of Chinese Cultural Relics* (ACCR), a national archaeological atlas produced under official direction in the 1980s. While ACCR provides extensive geographical coverage across provinces and offers a standardized representation of cultural relic distribution, it was compiled under significant institutional and technical constraints of its time. As such, it contains many omissions, inconsistencies, and classification errors when compared to more recent and rigorous datasets. Nevertheless, I include the ACCR-based proxy for robustness analysis and broader comparison, as it remains an important reference source in the study of China's archaeological landscape.

The variable $r_i$ is a time-invariant measure of natural road accessibility, constructed using least-cost path analysis based on terrain and hydrological conditions. The control vector $X_i$ includes time-invariant geographic covariates such as elevation, slope, and proximity to rivers or coastlines[6]. Province fixed effects $\lambda_i$ are included to absorb unobserved heterogeneity in archaeological efforts and institutional reporting practices. All data are ultimately derived from excavation reports and systematic surveys conducted under the supervision of provincial archaeological authorities.

As the analysis uses 1/4 degree cells and the NRS is at the 1/12 degree resolution, I use the highest NRS available in each cell as its measure for the natural road. Additionally, I use $N_{it}$ to measure the number of archaeological sites in each cell and year, which I consider a proxy for local economic activities (GDP).

Table 2 presents the results for the log NRS at a 200-hour distance and the log number of archaeological sites in 5000 BP, based on our two datasets (ACCR and CADB). Each column reports two rows of coefficients, corresponding to the ACCR proxy (top row) and the CADB proxy (bottom row). Column (1) displays the results with province fixed effects and additional controls for the North China Proper region; Column (2) restricts the sample to China Proper; and Column (3) extends the sample to the whole of China. Across both datasets, all columns indicate that cells with higher NRS had significantly more archaeological sites during 5000 BP, consistent with higher levels of economic activity.

[6]While elevation is input in the construction of the NRS, I also include ruggedness as a separate control. The rationale is that rugged terrain may affect human settlement patterns and agricultural productivity independently of its role in shaping natural transport routes. For instance, highly rugged areas can constrain cultivation and construction, thereby influencing site distribution even when transport accessibility is held constant. Importantly, the correlation between ruggedness and the NRS measure is moderate rather than extreme, and regression results remain robust when ruggedness is excluded. This suggests that including ruggedness helps to absorb potential confounding effects without generating severe collinearity.

Table 3 reports robustness checks on the NRS specification. In particular, I re-estimate the regressions after excluding short-distance trips (within 50 hours) from the NRS calculation. Each column reports results for both the ACCR proxy (top row) and the CADB proxy (bottom row). Column (1) restricts the sample to North China Proper, Column (2) to China Proper, and Column (3) to the whole of China. Across both datasets, the coefficients remain statistically significant, suggesting that the estimated relationship between NRS and economic activity is robust to alternative definitions of travel distance.

$$MP_{ot} = \sum_{d} \tau_{od}^{-\theta} N_{dt}. \tag{3.2}$$

Where $MP_{ot}$ is the market access for cell $o$ in time $t$, $\tau_{od}^{-\theta}$ is the great-circle distance from cell $o$ to cell $d$, $N_{dt}$ is the count of archaeological sites for cell $d$ in time $t$, and $\theta$ is the "trade Coefficient ", which is one here following You et al. (2022). It is important to note that any market access measure contains the dependent variable (the location of archaeological sites). To address this endogeneity issue, I use NRS as an instrumental variable for market potential (Bakker et al., 2021; Donaldson and Hornbeck, 2016). Table 4 presents the market access regressions, including the OLS and 2SLS results. The Kleibergen-Paap F-statistic in the table confirms that NRS is a reliable instrument for market access. The 2SLS effect is consistent across all specifications and is similar to the estimates obtained from the previous natural road analysis. For this reason, I have decided to use NRS as an explanatory variable in the subsequent regressions.

## 3.4 Persistence

In this section, I examine the evolving relationship between trade and economic development across different stages of civilization. To do this, I conduct a series of analyses using archaeological site data at 500-year intervals from 7000 BP to 3000 BP and 250-year intervals after 3000 BP. For each time interval, I perform regression analysis based on equation (1), reporting the coefficients of the log NRS with their standard errors.

It's worth noting that most Chinese archaeological sites rely on stratigraphic dating rather than radiocarbon dating, which may introduce discrepancies between actual and reported site ages. To mitigate the impact of these potential dating inconsistencies, I use broader intervals as our analytical units, as detailed in the data section.

Since the number of archaeological sites varies across time periods, I normalize the dependent variable by the average site count in each year, transforming our estimates into elasticities for more consistent temporal comparisons. Figure 6 and Table 6 present results derived from the CADB dataset using equation (1), covering the period from 7000 BP to 2000 BP, with log NRS set at 200 hours. These results primarily focus on North China Proper, the heartland of early Chinese civilization. Additionally, in Figure 3.9, I have overlaid historical periods and dynasties in the background for further context.

Figure 6 and Table 6 demonstrate that between 7000 BP and 2000 BP in North China Proper, a correlation existed between the availability of natural routes and economic development. However, this correlation was not consistent, showing several fluctuations over time. From 7000 BP to approximately 4750 BP, covering the early and middle Neolithic period, there was a consistently positive and significant relationship between natural routes and the number of archaeological sites. In other words, since humans first settled in this area, interaction and trade among settlements have already played a crucial role in determining settlement locations.

Significant fluctuations occur around 4500 BP. While the relationship remains positively correlated, it no longer reaches significance at even the 90% confidence level, with the coefficient dropping from around 0.2 to 0.135. This lower coefficient persists for nearly a millennium, until about 3500 BP, during which trade Coefficient remains non-significant within the 95% confidence interval.

Within this millennium, I observe that at 4250 BP, while the coefficient is not significant at the 95% level, it achieves significance at the 90% level, marking a slight increase from 4500 BP. By 4000 BP, the coefficient rises further and remains significant at the 90% confidence level. This period, from 4500 BP to 4050 BP, spans from the late Neolithic to the era of China's first state formation. This suggests that, on the eve of state formation, interactions and trade among settlements began to diminish, yet this association gradually recovered as states formed, though it did not return to pre-4500 BP levels.

After 4000 BP, China entered the era of statehood. As shown in Figure 3.9, fluctuations in the correlation coefficients correspond closely with dynastic changes and regime shifts. Broadly speaking, each new regime establishes a rise in the coefficient, which then gradually declines over time, often losing significance during periods of political transition.

Drawing on both archaeological and historical materials, I categorize these five millennia into three phases: Phase 1 (the Origin Era) from 7000 BP to 4500 BP, Phase 2 (the Dawn Era) from 4500 BP to 4000 BP, and Phase 3 (the State Era) from 4000 BP onward.

### 3.4.1 Phase 1, the Origin Era (7000 BP - 4500 BP): "Trade" after human settled down

In previous sections, I observed a significant positive relationship between the natural road score index and the presence of ancient settlements around 5000 BP. Further validation through 2SLS testing underscored this correlation, highlighting the strong link between market access and the spatial distribution of economic activities. This suggests that trade potential was a critical determinant in shaping economic landscapes during that period. In this section, by extending the analysis of $N_it$ to earlier periods, I find that this strong correlation has existed as far back as 7000 BP, persisting with relative stability until approximately 4500 BP.

Archaeological evidence reveals that as early as 8000 years ago, humans in China had already begun rice cultivation and even brewing (McGovern et al., 2004), signifying a transition to settled agricultural societies. By 7000 BP, during the Yangshao period —the temporal upper limit of this study—northern China had largely transitioned to agriculture-focused, semi-permanent settlements supplemented by foraging. Given the spatial alignment of ancient settlements with natural roads and trade potential, I propose the following hypothesis: from the moment human societies transitioned to settled agriculture, spatial interactions—driven by trade and cultural exchange—were already highly developed. This is especially evident in the tendency of settlements to locate near areas with better road access, where trade routes facilitated both material and cultural exchange across regions.

### 3.4.2 Phase 2, the Dawn Era (4500BP - 4000BP): The darkest hour before the dawn of the emergence of state

I observed a marked decline in trade Coefficient around 4500 BP (Event 1), signaling a significant shift. From this point, trade Coefficient remained at relatively low levels and lacked statistical significance at the 95% confidence interval, a trend that persisted over the following millennium (until 3500 BP).

During this low phase, I also found that, while coefficients were not significant at the 95% confidence interval, they did reach significance at the 90% level at 4250 BP and 4000 BP, with a gradual increase in coefficient values during this period. A notable change in significance emerged again around 3750 BP, with the coefficient eventually returning to pre-4500 BP levels by 3500 BP. For this period, I aim to answer two key questions: (1) What occurred around 4500 BP to trigger such a dramatic shift in the coefficient? (2) After the 4500 BP fluctuation, what factors contributed to the gradual recovery of the coefficient?

#### 3.4.2.1 The Holocene Event Three

Coincidentally, existing paleoclimatic studies indicate that a significant climate shock occurred in China around 4500 BP. As shown in Fig. 7, from approximately 7900 to 4500 BP, China experienced warmer and wetter conditions compared to other periods in the Holocene. However, beginning at 4500 BP, a notable cold and dry event occurred, characterized by weakened monsoon activity and significant drops in temperature and rainfall.

Following this period, there was a gradual shift toward warmer and more humid conditions that lasted until about 3500 BP (Xu et al., 2010; Wang et al., 2005). These climate fluctuations identified in Chinese paleoclimatology align well with widely accepted data from the North Atlantic. Bond et al. (1997) found evidence of periodic climate shifts during the Holocene through seabed core samples from the North Atlantic, identifying roughly eight major Holocene events over the past 11,000 years, with Holocene Event Three occurring around 4500 BP. Bond et al. (2001) suggested that these periodic shifts might be related to changes in the North Atlantic's thermohaline circulation, possibly driven by solar forcing. Despite the significant temperature drop around 4500 BP, long-term global temperatures remained higher than the 1950 average, as shown in Figure 8 (Marton et al. 2010), indicating that although 4500 BP saw a distinct climate event, the general global climate during that period was still relatively warm compared to the mid-20th century.

A series of studies have linked this climate shock—also known as the 4.2k event—to the end of the Neolithic period (Jaffe and Hein, 2021; Jaffe et al., 2021; Li et al., 2023; Zhang et al., 2023). They argue that this climate event contributed to the collapse of large settlements and the decline of Neolithic civilizations during the Longshan period. However, as shown in Table 5, the overall number of archaeological sites (according to CADB) did not experience a drastic decline before and after this climate event. This suggests that while large settlements may have been abandoned, it does not imply a total population loss. A more likely explanation is that people, for certain reasons, left their original settlements and relocated to other areas.

#### 3.4.2.2 Potential Explanations

Here, I propose two potential hypotheses: (1) a Hunter-Gatherer to Full Agrarian Transition Hypothesis and (2) a Climate-Malthusian-Conflict Hypothesis.

***The shift from hunter-gatherers to agrarian societies***

One possible explanation for the shift towards a less trade-intensive society is the transition from a hunter-gatherer to a primitive agrarian society. The hunter-gatherer lifestyle is contingent on the availability of animals and fruits (Binford, 1980; Kelly, 1995). A rapid decrease in temperature and precipitation could quickly disrupt the balance between animals/plants and humans, leading to an acute Malthusian crisis with insufficient resources for the population (Diamond, 2005; Fagan, 2000; Zhang et al., 2011). This crisis could have driven the shift towards agriculture, a response to climate change. Once the production method shifted to more advanced agriculture, even if the climate returned to its previous state, it is unlikely that society would revert to less advanced foraging agriculture, much like societies in the industrial age would not revert to agrarian practices.

Trade intensity was likely essentially different among hunter-gatherer and agricultural societies. In the hunter-gatherer era, food sources were unreliable. Additionally, hunting large wild animals resulted in the rapid spoilage of meat, offering incentives to trade the meat for plant-based products that would last longer. However, in an agrarian society, crops and domestic animals were produced simultaneously, which made these exchanges unnecessary. This transition reflects a shift towards a self-sufficient economy as described by Chaianov (1986) and the domestic mode of production discussed by Sahlins (1972). Both theories suggest that the primary goal of peasant households is to meet their family's consumption needs rather than maximising profits and, thereby, reducing the need for trade.

***A Climate-Malthusian-Conflict Hypothesis***

Existing studies in climate economics have found a strong link between climate variability and conflict/political stability (Dell et al., 2014; Bai and Kung, 2011). Given this established connection, it is plausible to anticipate that the sudden climate shock around 4500 BP could have led to large-scale conflicts or political instabilities. Conflicts or political instability undoubtedly could lead to a decrease in the importance of trade, which could explain the decline in trade Coefficient around 4500 BP.

While existing studies suggest that temporary shocks are unlikely to cause long-term impacts on economic structures or the spatial distribution of economic activities (Davis and Weinstein, 2002; Cavallo et al., 2013; Miguel and Roland, 2011), they also acknowledge that, in rare cases, short-term shocks can have lasting effects, especially when they lead to internal conflicts within the affected region. Thus, I propose a Climate Shock –Resource Scarcity –Conflict Hypothesis. I argue that the global climate event around 4500 BP likely caused a sharp decline in agricultural productivity and a scarcity of wild resources available for hunting and gathering in North China. This sudden resource scarcity triggered a Malthusian trap, transforming what had been a relatively resource-rich environment into one of extreme resource limitation.

In this context, survival pressures may have intensified conflicts between tribes over scarce resources, as suggested by Carneiro's circumscription hypothesis. Tribes began competing for limited resources, leading to conflicts that continued until a sufficiently powerful tribe unified the region and established a large-scale organization—the state. This period of conflict would also have altered settlement priorities: settlements, once positioned near roads to facilitate trade and interaction, may have shifted to more secluded areas to ensure geographical security. However, as tribes merged and an eventual dominant power emerged, I would expect trade Coefficient to gradually recover. This is because the dominant tribe would restructure the spatial urban hierarchy to maintain control over peripheral settlements. Once the first large-scale state emerged, encompassing extensive territories, I would expect trade Coefficient to regain significance, though likely at lower coefficient levels compared to pre-shock periods. Only with the emergence of even larger empires would trade Coefficient fully return to pre-shock levels.

The observed coefficient patterns align closely with the predictions of this hypothesis. In China, this conflict phase seems to have lasted for nearly a millennium. Following 4500 BP, trade Coefficient began to slowly increase, reaching significance at the 90% confidence level by around 4000 BP during the Xia (Erlitou) period, often considered China's first large-scale state. However, the coefficient only returned to a higher level by 3500 BP, during the early Shang (Erligang) period. Such pattern was likely due to the Xia's limited spatial influence over North China Proper. The true regional integration in China was achieved only with the advent of the Erligang culture, often referred to as "China's earliest empire" according to some archaeologists (Xu, 2023).

Compared to the previous hypothesis, this Climate Shock –Resource Scarcity –Conflict Hypothesis offers a more plausible explanation for why trade Coefficient experienced a millennium-long decline following 4500 BP, accompanied by a gradual recovery. Thus, I consider this hypothesis to be the more likely of the two.

### 3.4.3 Phase 3, the State Era (after 4000 BP): Dynastic Cycles and the Reshuffling of Urban Hierarchies

After 4000 BP, China entered the State Era, with historical records becoming increasingly detailed. As shown in Figure X, trade Coefficient fluctuations closely align with dynastic transitions. In each dynasty's early stage—whether Xia, Shang, or Zhou—trade Coefficient rises, peaking mid-dynasty and declining significantly toward the dynasty's end. This pattern reflects the initial establishment of new political orders, which gradually weakened over time, ultimately leading to widespread conflict and the rise of a new dynasty.

Broadly, I can categorize this era into three main phases: the Shang Dynasty (3500 BP - 3000 BP), the Zhou Dynasty (3000 BP - 2200 BP), which historians further divide into the Western Zhou, Eastern Zhou, Spring and Autumn, and Warring States periods; and finally, the Qin and Han Dynasties, beginning in 221 BCE (2171 BP). Each phase illustrates the dynamic interplay between political stability, trade, and urban hierarchy restructuring, as each dynasty reestablished control, fostering initial economic integration that declined as dynasties weakened.

#### 3.4.3.1 Shang: The rebound in 3500 BP and the crisis in 3000 BP

At around 3500 BP, there was a significant resurgence in trade Coefficient, indicating a positive recovery. A slight reduction at 3250 BP followed this initial recovery, but the trade Coefficient remained within the 95% confidence interval, indicating continued significance. These temporal changes align with the early Shang Dynasty (Erligang culture period). Conversely, at 3000 BP, I observed a pronounced decline in trade Coefficient, corresponding with the late Shang Dynasty (Yinxu culture). Interestingly, archaeological typology studies of bronze artefacts corroborated these fluctuations. During the early Shang, there was a remarkable uniformity in bronze artefacts across a vast region, encompassing Shandong, Shaanxi, Hubei, and the Taihang Mountains. This area closely covers the North China Proper region outlined in our study. However, during the late Shang Dynasty (Yinxu culture), this spatial consistency in bronze artefact styles diminished, with more regional variation in forms and styles (Xu, 2023).

The disparities between the Erligang and Yinxu cultures extend to the types of artefacts unearthed from these periods. The Yinxu culture introduced several novel features not observed during the Erligang period, including systematic writing (oracle bone inscriptions), chariots, large multi-chambered tombs indicative of severe social stratification, extensive human sacrifices, and divination practices, alongside a significant presence of Eurasian Steppe elements in the artefacts. Some scholars suggest that the differences between the Erligang and Yinxu cultures may indicate that they were two distinct dynasties, if not hindered by existing historical records (Olga, 2012). Xu (2023) further questions the reliability of historical accounts of the Shang Dynasty, suggesting potential discrepancies between recorded history and actual events.

Both archaeological evidence and our analysis led to a conclusion: the early Shang (Erligang culture) was likely a more open, communicative civilisation with significant spatial uniformity, possibly representing China's earliest form of empire. In stark contrast, influences from the steppe, a glorification of violence, and a rigid social stratification characterised the late Shang (Yinxu culture). These distinct societal structures could explain the observed variations in trade Coefficient.

#### 3.4.3.2 Zhou: Political order and trade

Following a decline around 3000 BP, a significant period of trade growth is observed until around 2500 BP, followed by stagnation near 2250 BP. This growth phase likely stems from important technological and institutional advancements. The advent of the Iron Age improved agricultural productivity, while the social hierarchy established under King Wu of Zhou facilitated regional interactions and reduced conflicts. This structured order was rigorously maintained through the Western and Eastern Zhou periods, including the Spring and Autumn period (2750 BP - 2500 BP), fostering a relatively stable and peaceful society. These conditions likely encouraged economic activities to concentrate in areas with well-developed transportation infrastructure (Qian, 1996; Xu, 2017b).

However, with the onset of the Warring States period around 2250 BP, the Zhou royal house's diminishing influence led to the erosion of traditional norms and the breakdown of this enforced social order, resulting in frequent large-scale conflicts (Qian, 1996; Xu, 2017b). Yet, despite these conflicts, trade and intellectual exchange continued to flourish. Historical records indicate an unprecedented era of ideological exchange, marked by the emergence of the Hundred Schools of Thought, drawing comparisons to the Axial Age in Greece. In terms of trade Coefficient, while coefficients did not further increase, they maintained previous levels and remained significant at the 90% confidence interval, reflecting sustained, albeit stabilized, trade activity amidst political upheaval.

#### 3.4.3.3 Qin-Han: Reshuffling urban hirearchy in unified empire

The political-motivated urban restructuration during the formation of the Qin and Han unified kingdom could explain the decline in the trade relationship between 2250 BP and 2000 BP. Existing empirical studies affirm the impact of political policies on spatial economic layouts (Chen et al., 2017; Bai and Jia, 2023; Hodler and Raschky, 2014). During this post-dynastic unification era in China, central authorities deserted numerous large Zhou dynasty cities, including feudal capitals, relocating and reconstructing them at nearby sites, albeit on a smaller scale (Xu, 2017b). This urban relocation phenomenon is evident in our analysis, as indicated by the significant drop in the correlation between the NRS and the count of archaeological sites.

## 3.5 Conclusion

This study employs a novel archaeological dataset to explore the relationship between trade routes and the early economic development of human civilisation. A topography-based NRS is a proxy for trade, and the number of archaeological sites represents local economic development. Our regression analysis reveals a significant positive correlation between these variables among Neolithic pre-state communities (5000 BP). Furthermore, a 2SLS analysis using the NRS as an instrumental variable for market potential confirms the existence of this trade nexus. Finally, our analysis of scaled coefficients from 7000

BP to 2000 BP reveals temporal fluctuations in this relationship, therefore indicating spatial distribution of economic activities changes throughout societal advancement.

An exploration of trade Coefficient from 7000 BP to 2000 BP shows that since the initial settlement of humans, economic activities clustered near accessible transport routes, but around 4500 BP, this relationship weakened dramatically for a millennium, likely due to a major climate event (Holocene Event 3) that triggered a Malthusian trap and subsequent conflicts, eventually leading to the establishment of a unified state. As China entered the dynastic era, trade Coefficient began to rise and fall in alignment with dynastic cycles —peaking during the consolidation phase of each dynasty and declining as political stability eroded. Finally, after the Qin and Han unification, a stable, centralized state restructured the urban hierarchy to maintain control over a vast empire.

## 3.6 Table

Table 3.1: *Summary Statistics for the Main Variables*

| | (1) Variables | (2) N | (3) mean | (4) sd | (5) Sources |
|---|---|---|---|---|---|
| Archeology data | ACCR 5000BP | 16,121 | 0.946 | 4.075 | 1 |
| | ACCR 7000BP-2000BP | 338,541 | 0.841 | 4.351 | 1 |
| | CADB 5000BP | 16,121 | 0.146 | 0.712 | 2 |
| | CADB 7000BP-2000BP | 338,541 | 0.105 | 0.639 | 2 |
| Natural Road | Natural Road Score | 16,121 | 2.776 | 1.219 | 3 |
| Controls | Terrain Ruggedness | 6,377 | 6.490 | 6.164 | 3 |
| | Elevation | 6,377 | 1658.447 | 1991.522 | 3 |
| | Agriculture suitability | 6,377 | 364.468 | 365.388 | 3 |
| | Irrigation suitability | 6,377 | 4.621 | 2.035 | 4 |
| | Longitude | 6,377 | 103.888 | 14.529 | 3 |
| | Latitude | 6,377 | 36.560 | 7.341 | 3 |

1: Atlas of Chinese Culture Relics
2: China Archeological database Project
3: GAEZ (Fischer et al. 2008)
4: Bentzen et al. (2016)

Table 3.2: *Basic Results for 5000 BP*

| Dependent Variable | (1) | (2) | (3) |
|---|---|---|---|
| ACCR 5000 BP | 0.170** | 0.119** | 0.0515** |
| | (0.0798) | (0.0575) | (0.0238) |
| CADB 5000 BP | 0.118*** | 0.0808*** | 0.0311*** |
| | (0.0341) | (0.0251) | (0.0102) |
| Observations | 3,944 | 6,274 | 16,104 |
| Prov FE | X | X | X |
| Controls | X | X | X |
| North China Proper | X | | |
| China Proper | | X | |
| Whole China | | | X |

Note: The dependent variable in this analysis is the log number of archaeological sites in the cell. Coefficients from regressions on log natural road score for 200 hours distance. Standard error clusters at the level of 2 degree cells, in parentheses.
$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 3.3: *Results for natural road score with distance from 50 to 200 hours*

| Dependent variable | (1) | (2) | (3) |
|---|---|---|---|
| ACCR 5000 BP | 0.169** | 0.126** | 0.0540** |
| | (0.0761) | (0.0551) | (0.0225) |
| CADB 5000 BP | 0.120*** | 0.0850*** | 0.0327*** |
| | (0.0328) | (0.0243) | (0.00962) |
| observations | 3944 | 6274 | 16104 |
| Prov FE | X | X | X |
| Controls | X | X | X |
| North China Proper | X | | |
| China Proper | | X | |
| Whole China | | | X |

Note: The dependent variable in this analysis is the log number of archaeological sites in the cell. Coefficients from regressions on log natural road score for 50 to 200 hours distance. Standard error clusters at the level of 2 degree cells, in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 3.4: *Market access regressions: 2SLS & OLS*

| | 2SLS | | OLS | |
|---|---|---|---|---|
| Dependent variable | (1) | (2) | (3) | (4) |
| ACCR 5000BP | 3.498*** | 2.527*** | 1.718*** | 1.638*** |
| | (1.290) | (0.926) | (0.170) | (0.142) |
| Kleibergen-Paap F-stat | 10.506 | 16.138 | | |
| CADB 5000BP | 2.697*** | 1.943*** | 0.873*** | 0.784*** |
| | (0.839) | (0.613) | (0.142) | (0.111) |
| Kleibergen-Paap F-stat | 13.437 | 19.577 | | |
| observations | 3,944 | 6,274 | 3,944 | 6,274 |
| Prov FE | X | X | X | X |
| Controls | X | X | X | X |
| North China Proper | X | | X | |
| China Proper | | X | | X |

Note: The dependent variable in this analysis is the log number of archaeological sites in the cell. Coefficients from regressions on log natural road score for 200 hours distance. Standard error clusters at the level of 2 degree cells, in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 3.5: *Number of sites in the different datasets*

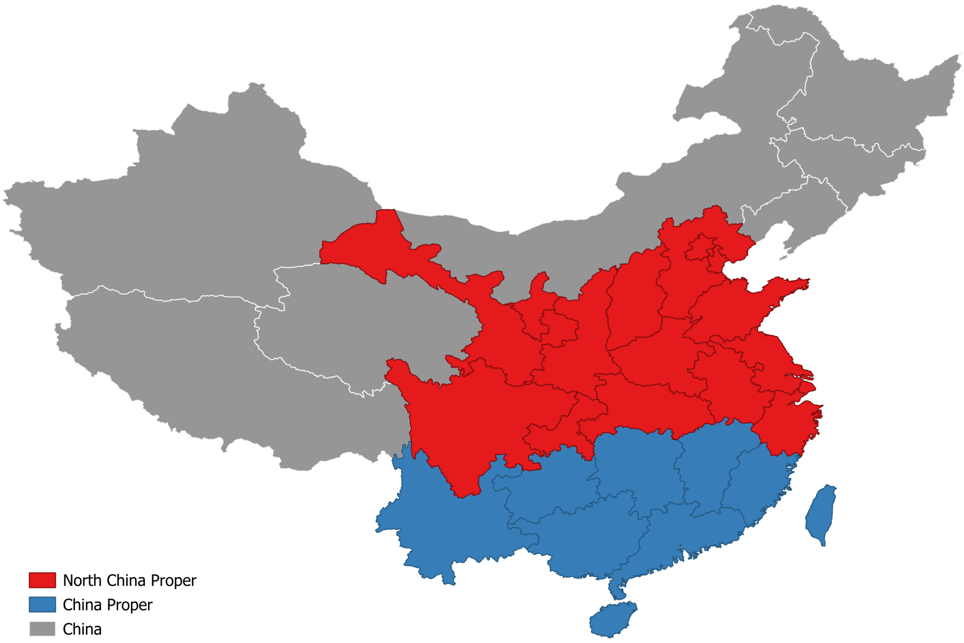
| Time Period (BP) | ACCR | CADB |
|---|---|---|
| 7000 | 10,216 | 1,561 |
| 6750 | 10,304 | 1,512 |
| 6500 | 11,472 | 1,644 |
| 6250 | 11,430 | 1,636 |
| 6000 | 12,331 | 1,893 |
| 5750 | 13,187 | 1,905 |
| 5500 | 12,777 | 1,955 |
| 5250 | 14,497 | 2,126 |
| 5000 | 15,250 | 2,350 |
| 4750 | 11,761 | 2,000 |
| 4500 | 15,629 | 2,487 |
| 4250 | 15,632 | 2,529 |
| 4000 | 28,317 | 2,956 |
| 3750 | 11,210 | 544 |
| 3500 | 15,507 | 1,195 |
| 3250 | 16,233 | 1,394 |
| 3000 | 4,624 | 667 |
| 2750 | 6,273 | 784 |
| 2500 | 6,125 | 777 |
| 2250 | 10,209 | 1,183 |
| 2000 | 31,743 | 2,590 |
| Total | 284,727 | 35,688 |

Table 3.6: *Scaled Coefficients and History*

| Year BP | Year BCE | NRS Coef | Std Err | Historical era | Historical Period | History |
|---|---|---|---|---|---|---|
| 7000 | 5050 | 0.207** | 0.099 | | | |
| 6750 | 4800 | 0.221** | 0.102 | | | |
| 6500 | 4550 | 0.229** | 0.096 | | | |
| 6250 | 4300 | 0.237** | 0.095 | Prehistory | Yangshao Period | The Yangshao period marks the start of Chinese civilization with millet cultivation, expanding settlements, and handicrafts such as painted pottery. Agriculture became dominant, replacing hunting by the period' s end. |
| 6000 | 4050 | 0.204** | 0.094 | | | |
| 5750 | 3800 | 0.207** | 0.094 | | | |
| 5500 | 3550 | 0.226** | 0.093 | | | |
| 5250 | 3300 | 0.193** | 0.087 | | | |
| 5000 | 3050 | 0.199** | 0.083 | | | |
| 4750 | 2800 | 0.223*** | 0.086 | | Longshan Period | The Longshan period saw early writing, copper and bronze use, wheat cultivation, and hierarchical urban settlements like Liangzhu. Cross-regional exchanges marked the rise of chieftain societies. |
| 4500 | 2550 | 0.135 | 0.089 | | | |
| 4250 | 2300 | 0.148* | 0.086 | Protohistory | | |
| 4000 | 2050 | 0.163* | 0.086 | | Xia | The Xia dynasty emerged as China' s first territorial state with centralized power, long-distance trade, and bronze artifacts symbolizing elite status. |
| 3750 | 1800 | 0.155 | 0.128 | | | |
| 3500 | 1550 | 0.222** | 0.088 | | | |
| 3250 | 1300 | 0.196* | 0.100 | | Shang | The Early Shang (Erligang) advanced bronze craftsmanship and social complexity, with some scholars viewing it as China' s first empire. The Late Shang (Yinxu) introduced early writing and chariots, alongside extensive human sacrifice. |
| 3000 | 1050 | 0.082 | 0.111 | | | |
| 2750 | 800 | 0.227* | 0.117 | History | | |
| 2500 | 550 | 0.288** | 0.140 | | Zhou | Established feudal system, initially brought peace, but wars between lords led to the rise of seven dominant states. |
| 2250 | 300 | 0.281* | 0.148 | | | |
| 2000 | 50 | 0.194 | 0.123 | | Qing-Han | The Qin unified China into its first centralized empire, continuing until the Qing's fall in the 20th century. |

## 3.7 Figure

Figure 3.1: *Study Area*




Note: Red parts stands for North China Proper. The union of blue and red parts are China Proper.

Figure 3.2: *Archaeological sites for 5000 BP from the CADB*

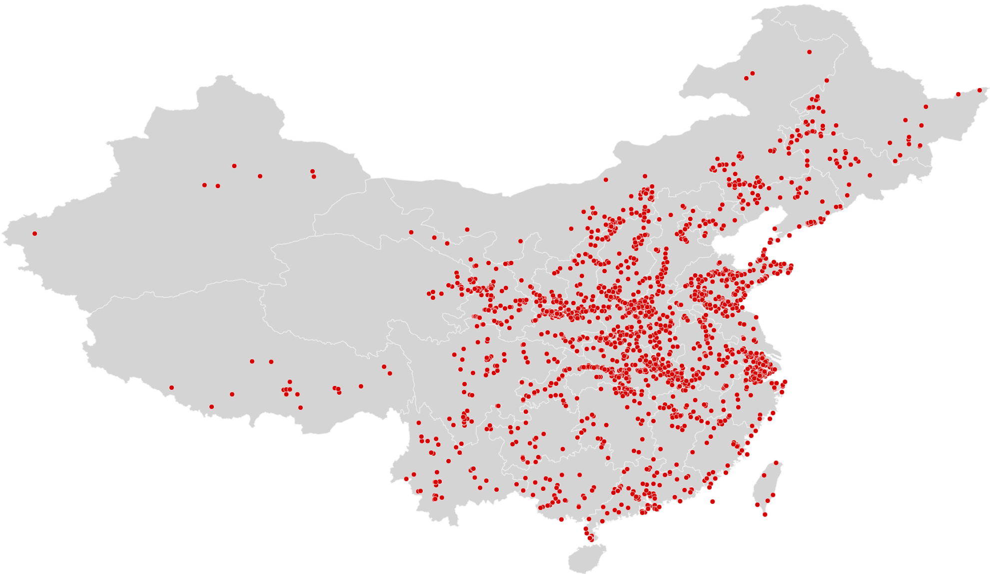


Figure 3.3: *Region for Natural Road Score Computation*

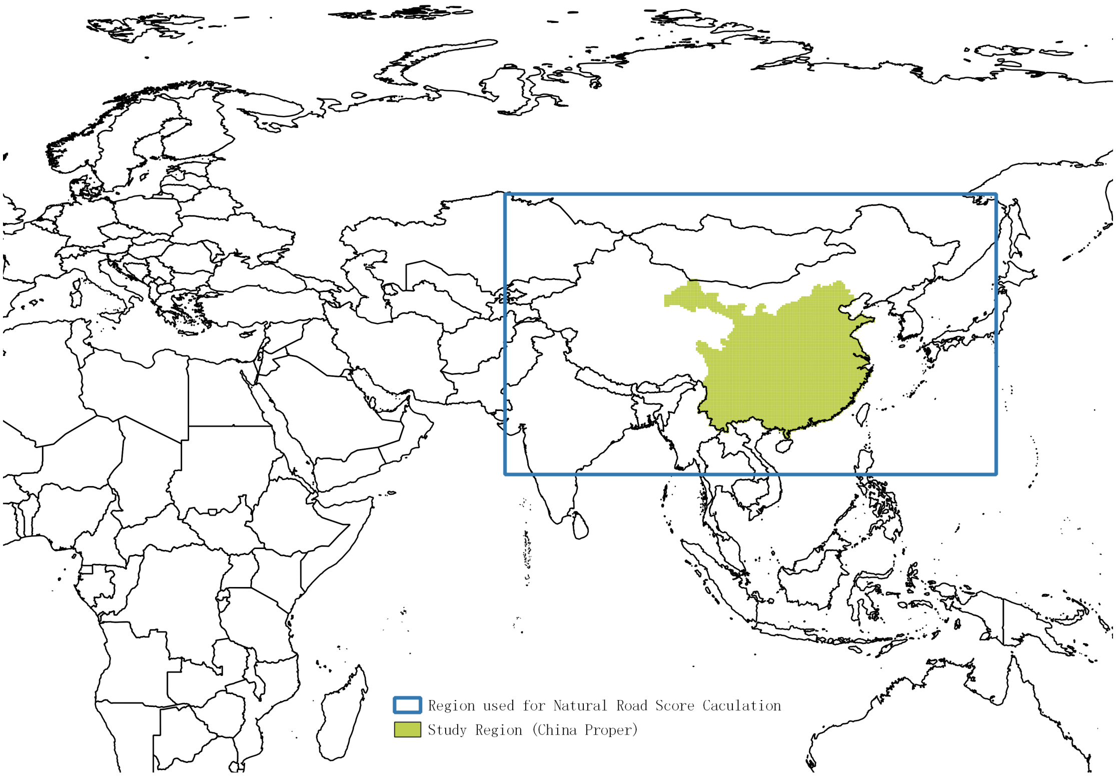


Figure 3.4: *Natural Road Score for cells in China*

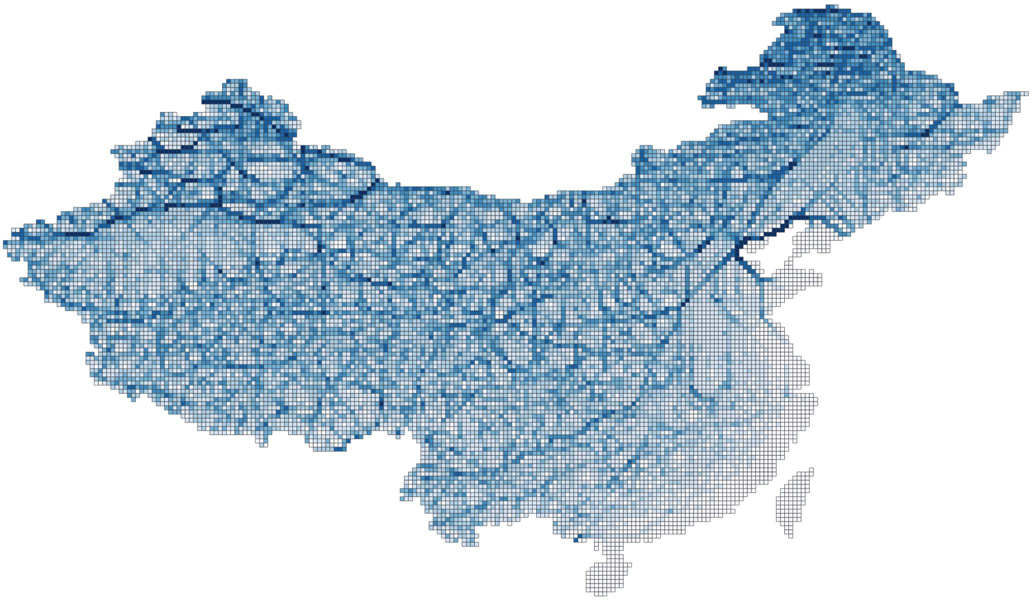


Figure 3.5: *Distribution of Natural Road Score*

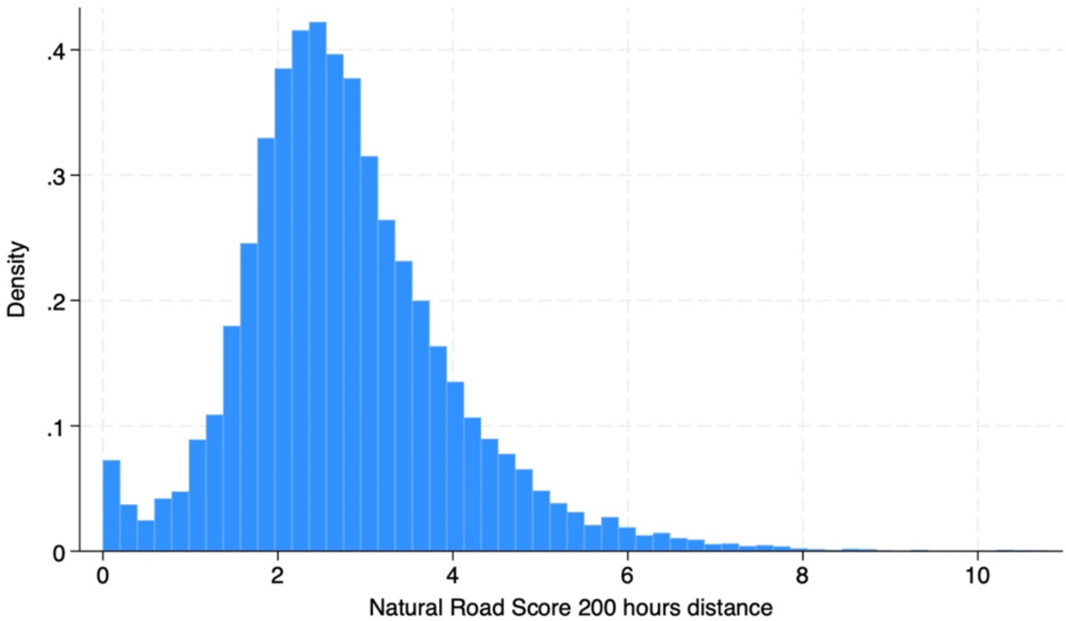


Figure 3.6: *Scaled coefficients for log CADB sites over time 7000BP to 2000BP in North China Proper, log Natural Road Score 200 hours*

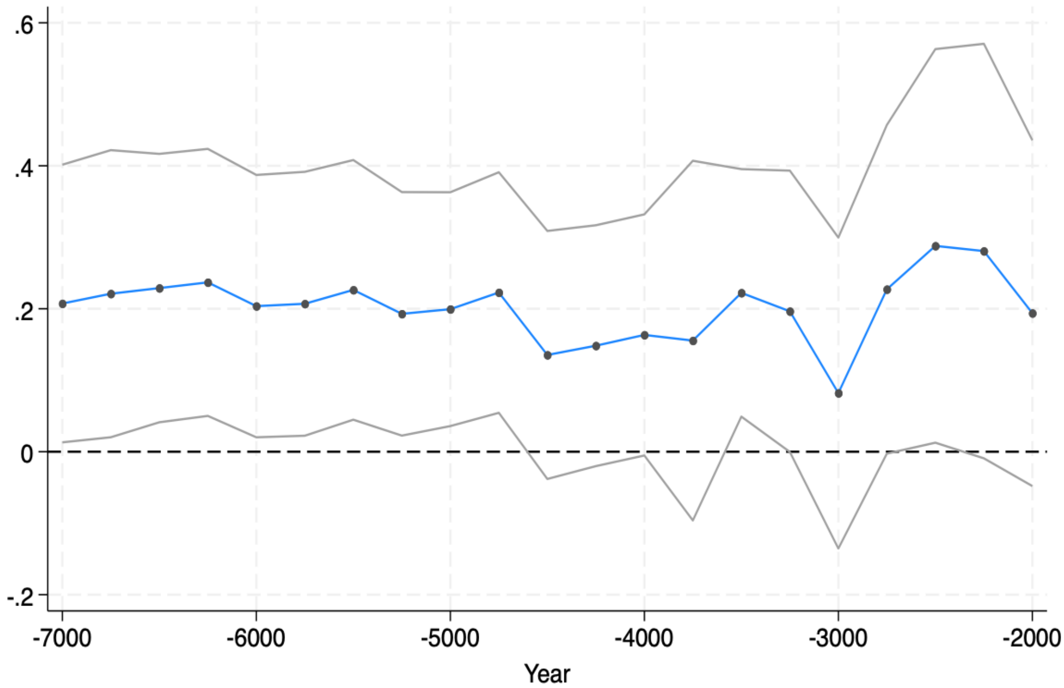
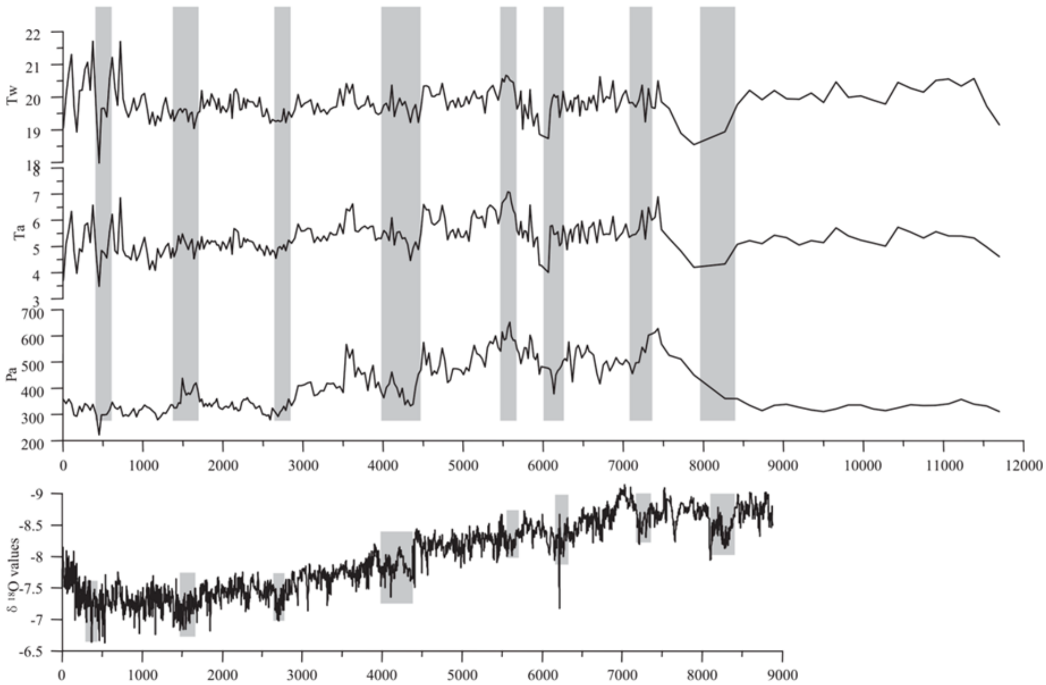
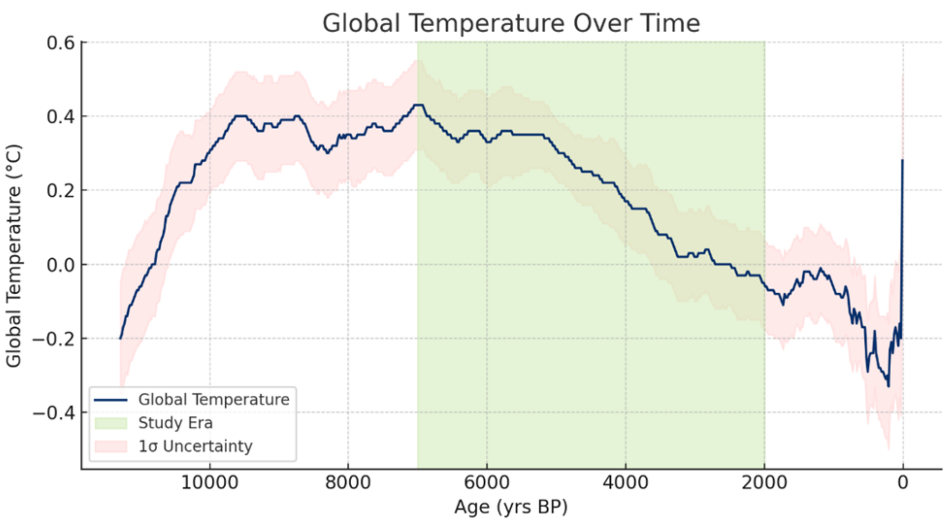


Figure 3.7: *Climate change in past 12000 year China*




Note: Sourced from Xu et al. (2010) , presents a detailed climatic reconstruction where 'Tw' represents the mean temperature of the warmest month, 'Ta' denotes the mean annual temperature, and 'Pa' signifies annual precipitation. The gray shading indicates Holocene events as identified by Bond et al. (1997). This climate data is reconstructed using pollen-based methodologies with samples taken from the Daihai Lake Area in Inner Mongolia, China. The gray bars in the figure highlight significant climatic episodes, notably observable from around 4500 BP, providing insights into historical climate patterns and their potential impacts on human activities during these periods.

Figure 3.8: *Global temperature in past 13000 years*




Note: Sourced from Marton et al. (2010)

FIGURE 3.9: *Scaled coefficients with dynasty colored in background*

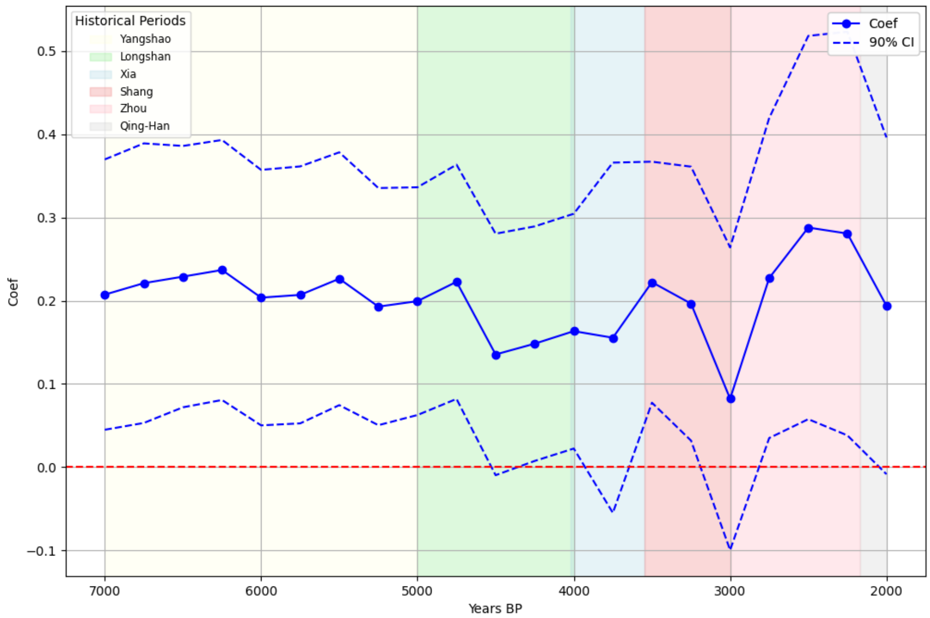
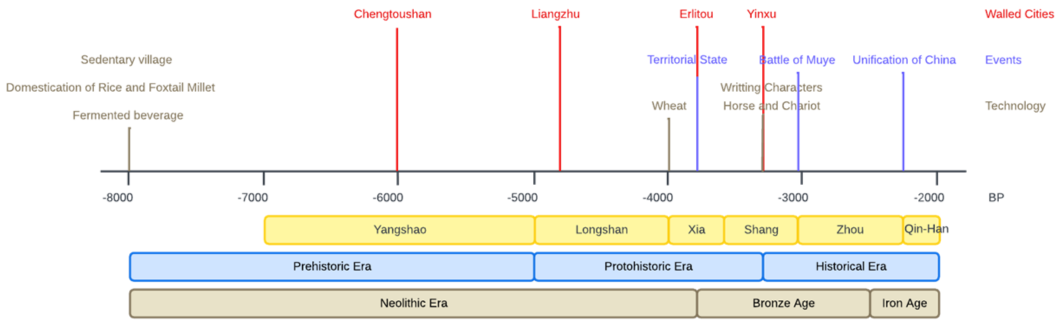



FIGURE 3.10: *Timeline*



## 3.8 Appendix: Historical Background

China's history from 7000 BP to 2000 BP can be divided into four stages based on its dynasties. These are the Prehistoric Neolithic Period (5000 BCE –2000 BCE), the Xia Period (2000 BCE –1600 BCE), the Shang Period (1600 BCE –1046 BCE), the Zhou Period (1046 BCE –221 BCE), and the Qin-Han period of unification (221 BCE –220 CE) (Chang, 1986; Loewe and Shaughnessy, 1999). Another way to categorise this period is based on historical records, which results in three stages: the Prehistoric Era (5000 BCE –3000 BCE), the Protohistoric Era (3000 BCE –1300 BCE), and the Historical Era (after 1300 BCE) (Xu, 2023). This period can also be classified using Thomsen's three-age system. According to this system, the period before 1800 BCE corresponds to the Stone Age, and the period after that is the Bronze Age (Zhang, 1983; Guo, 1963). It is important to note that the large-scale use of iron in China was already present in the historical era around the 5th century BCE (around the mid-Zhou dynasty). As such, China did not have a distinct Iron Age (Xu, 2009).

This section will explore the social and technological advancements during the various Chinese historical periods, categorised by the dynasty division method. Figure 6 will provide a timeline.

### 3.8.1 Pre-historical Neolithic era (5000 BCE –2000 BCE)

Literature indicates that the Neolithic Age in China started around 10,000 years ago, and lasted until about 6,000 years ago. Archaeological evidence indicates a notable surge in human activity within China by approximately 7,000 BP. This evidence suggests the presence of numerous large settlements, which could potentially signal the development of early complex societies in the region. Chinese archaeologists have identified two distinct periods in this era: the Yangshao period (7,000 to 5,000 BP) and the Longshan period (5,000 to 4,000 BP) (Liu, 2004; Underhill, 2013; Yuan et al., 2008).

The Yangshao period marks the start of Chinese civilisation. During this time, agricultural technology improved rapidly, and the cultivation of foxtail millet spread widely. Settlements grew in quantity and size, with some large settlements exceeding one million square meters and featuring surrounding trenches. Handicrafts, such as painted pottery, emerged and became widespread. Variations in mausoleum size and structure appeared. Central buildings for public gatherings, spanning up to 200 square meters, were located within settlements (Li, 2016; Zhang, 2021).

While rice and foxtail millet were domesticated in China 8,000 years ago (Doebley et al., 2006; Zhao, 2020), it was not until the late Yangshao period that a significant shift from hunter-gatherer to agricultural society occurred. During the early Yangshao period, agriculture had not completely replaced hunting and gathering. Wild plants remained an important food source. However, as agricultural technology advanced, reliance on wild plants decreased. By the late Yangshao period, agriculture had become the primary economic activity, marking the complete transition to an agrarian society (Zhao, 2017).

During the Longshan period, society progressed and evolved into a new phase (Wu and Ge, 2014). Key developments during this period included the potential emergence of a writing system (Chang, 1999), the application of red copper and bronze in small tools and ornaments (Linduff, 1998), and progress in agricultural technology, particularly as the introduction and cultivation of wheat in north China (Guo and Jin, 2019; Zhao, 2015). Additionally, there was an increase in the number and size of settlements featuring surrounding walls and distinct hierarchical structures (Liu, 2005; Xu, 2017b). The Liangzhu site in the Yangtze River basin, covering over 3 square kilometres, managed an extensive hydraulic system spanning more than 100 square kilometres. Its sophisticated urban structure comprised a palace city, inner city, and outer city, reflecting a state-level society. Tombs from this period revealed the existence of clear social classes. The specialisation of handmade craftsmanship, particularly in pottery production, experienced a notable enhancement and may have been confined to specific households (Liu, 2005; Underhill, 1996). Cross-regional exchanges of goods transpired, and regional cultures experienced rapid growth, along with an unprecedented frequency of interactions (Underhill, 1994). Considering the social evolution attributes of this stage, most scholars posit that during the Longshan period, the middle and lower Yellow River valley transitioned towards a chieftain society (Chang, 1999; Liu, 2005; Underhill, 1996).

### 3.8.2 Xia era (2000 BCE –1600 BCE)

The Xia Dynasty is considered the first hereditary monarchy in Chinese history, and it is believed to have been founded by Qi, the son of Yu, a distinguished hero in Chinese history known for his water management accomplishments (Chang, 1986; Loewe and Shaughnessy, 1999). According to the Xia-Shang-Zhou Chronology Project (The Xia-Shang-Zhou Chronology Project Expert Group, 2000, 2022), the Xia Dynasty spans from approximately 2070 BCE to 1600 BCE. However, Chinese archaeologists have not yet discovered direct evidence of the Xia Dynasty's existence, such as unearthed written records. Despite this, most scholars propose that the Erlitou culture signifies the cultural remnants of the Xia Dynasty, and they believe that the Erlitou site was the late Xia Dynasty's capital (Chang, 1986; Zhao, 1987; Liu and Chen, 2002; Zou, 1990). Two pieces of evidence support this conclusion. First, the Erlitou site, covering approximately 4 million square meters, is the largest and earliest site that emerged in China following the advent of the Bronze Age. Carbon-14 dating indicates that the site existed between roughly 1900 BCE and 1550 BCE, which matches the late Xia Dynasty (Kang, 1984).

Second, the Erlitou Culture, with its influence on the area and hierarchy of settlements, is widely considered the first territorial state in China (Liu and Chen, 2002). Compared to the Longshan period, the Erlitou culture demonstrates a marked enhancement in centralising political and economic control (Liu and Chen, 2002). The stratification among settlements becomes increasingly evident; while the quantity of sites diminishes significantly relative to the Longshan period, the scale of the settlements enlarges substantially (Chang, 1986). The political structure transforms an assembly of small, rival entities into a sizable central residence encompassing numerous smaller centres dispersed throughout a vast region. A reduction in pottery types signifies the standardisation of the pottery industry (Longacre, 1999; Rice et al., 1981; Rice, 1996). Bronze artefacts, specifically weapons and ritual vessels crafted from bronze, represented social status. The production of bronze artefacts was predominantly concentrated in the capital and is presumed to have evolved into an industry under state supervision (Liu, 1996, 2000). The long-distance exchange of luxury goods attained unprecedented levels, with elite tombs containing gold ring cowries that may have originated from the Indian Ocean

(Peng, 1999). Archaeologists have also unearthed artefacts and decorative elements embodying Central Asian styles at the Erlitou site (Fitzgerald-Huber, 1995).

### 3.8.3 Shang era (1600 BCE –1046 BCE)

As documented in surviving Chinese literature, the Shang Dynasty was founded around the 16th century BCE when its leader, Tang, overthrew the ruling Xia Dynasty (Loewe and Shaughnessy, 1999). In the early 20th century, the discovery of oracle bone inscriptions substantiated the existence of the Shang Dynasty, and the archaeological remnants of Yinxu were identified as the capital of the Shang Dynasty during the late Yin Shang period (Wang, 1959; Xu, 2023). Compared with the preceding and following periods, the Shang Dynasty underwent significant transformations as its political domain expanded and settlements grew. These changes manifested in several ways: the development of the first systematic Chinese writing system via oracle bone inscriptions; the introduction of domesticated horses and chariots (Olga, 2012); the construction of extensive mausoleum with multiple passages, disclosing further hierarchical differentiation (Xu, 2023); the occurrence of large-scale human sacrificial rituals that were extremely rare throughout Chinese history (The Institute of Archaeology, 1994; Huang, 2004); and a pronounced reverence for military prowess, evident in the quantity of unearthed bronze weapons surpassing ritual vessels, many of which exhibit steppe features (Han, 2008; He, 2020; Li, 2021). Consequently, some scholars contend that the Shang royal lineage originated from a nomadic tribe residing in the Eurasian steppe (Gorodetskaya, 2013).

The introduction of domestic horses and chariots was particularly notable among the earlier changes, as they substantially transformed transportation methods. In China, the widespread presence of chariots and domestic horses first emerged during the Yin Shang period (Olga, 2012). Recent genetic research indicates domesticated horses originated in the Western Eurasian steppes, particularly the lower Volga-Don region. Around 2000 BCE, these horses quickly spread across the entire Eurasian continent and replaced most other local horse populations, accompanied by the equestrian material culture, including Sintashta spoke-wheeled chariots (Librado et al., 2021). Both archaeological and genetic evidence reveal that Chinese domesticated horses did not come from native Przewalski's but, instead, from the Eurasian steppes (Cai et al., 2007; Liu, 2014). China's earliest chariots were discovered at the Yinxu, dating back to the late Shang Dynasty (1200 BCE). These chariots resemble Sintashta spoke-wheeled chariots found in the Near East. For this reason, some scholars propose Western Asian origins for Chinese chariots. Late 20th-century archaeological excavations in Central Asia further support the hypothesis that the chariot entered China from the northwest around 1200 BCE (Shaughnessy, 1988; Piggott, 1974, 1978).

### 3.8.4 Zhou Era (1046 BCE –221 BCE)

In 1046 BCE, King Wu of Zhou founded the Zhou dynasty after the defeat of the Shang dynasty (Loewe and Shaughnessy, 1999). Following its establishment, the Zhou dynasty instituted a feudal system upheld by an intricate set of rituals and a hierarchical structure to social class. In 771 BCE, the barbarian invasion destroyed the Zhou capital, Haojing (present-day Xi'an). The royal family reallocated to Luoyi (present-day Luoyang). This event marked the shift from the Western Zhou period to the Eastern Zhou period.

In this historical period, urban agglomerations emerged at an unprecedented scale, signifying a transformative era in the economic and spatial dynamics of the region. Two primary drivers can cause this urban expansion: military exigencies and economic shifts. From a military standpoint, the weakening institutional authority of the Zhou dynasty, particularly in its later phases, led to heightened inter-feudal conflicts. Consequently, there was an amplified demand for strategic fortresses to bolster territorial security and expansion. It was both an expansion and militarisation of pre-existing urban centres and the establishment of new fortified urban entities.

On the economic and technological fronts, the late Zhou era marked a pivotal transition with the extensive adoption of iron-based tools. This technological advancement played a crucial role in agricultural productivity, catalysing economic expansion and demographic growth . Concurrently, a burgeoning private sector signalled the rise of urban commerce and trade. As urban centres morphed into pivotal hubs for commercial activities, their economic significance was accentuated (Xu, 2017b).

### 3.8.5 Qin Han Era (221 BCE –220 CE)

In 221 BCE, the Qin Dynasty successfully vanquished all rival states and brought China under a unified rule, laying the foundation for the first expansive centralised empire in Chinese history. Its successor, the Han Dynasty, which lasted until 220 CE, upheld this unification. Following the rise of the Qin Dynasty, the traditional feudal system was supplanted by a vertical government system of prefectures and counties. This era saw the development of major infrastructural projects, including the construction of national-level expressways and canals and the standardisation of currency and measurement systems.

This era witnessed a notable shift in the urban landscape of China . The capital underwent significant expansion, serving as a testament to the nation's formidable power and the emperor's unparalleled authority . Concurrently, the newly established government system of prefectures and counties prompted a reshaping of urban centres outside the capital. Historical city sites, especially those of substantial scale like the former feudal capitals, were typically either downsized or relocated to new sites (Xu, 2017b).

## Chapter 4

# Route To Cities: Natural Endowments Under Varying Institutions

# Abstract

According to the economic geography literature, the location and size of cities are influenced by natural endowments (first nature) and human decisions (second nature). This study examines the role of natural endowments and their interaction with human decisions in the pre-industrial era. By examining the location of cities in China over the past 2000 years and linking natural endowments to historical transportation networks, my analysis reveals that natural endowments on routes generally had a positive and statistically significant influence on urban location. However, the magnitude of this effect was not constant over time but fluctuated across different dynastic cycles. This suggests that the value added to natural endowments shifted in response to changing institutional contexts. Mechanism tests indicate that governance strategies (direct vs delegated governance) and taxation structures (indirect vs direct taxation) were key institutional factors influencing the varying impact of natural endowments. Additionally, the arrival of Arab and European traders spurred the development of the maritime Silk Road and international trade, leading to a long-term, stable shift of cities towards coastal port areas.

## 4.1 Introduction

The literature on economic geography highlights that the location and size of cities are shaped by both natural endowments (first nature of geography) and human decisions (second nature of geography) (Krugman, 1993a; Redding and Sturm, 2008b; Bosker et al., 2013; Bosker and Buringh, 2017; Bleakley and Lin, 2012; Redding et al., 2011; Michaels and Rauch, 2018). This study examines how natural endowments interacted with human decisions in pre-industrialized societies by providing an new empirical case demonstrating that the value of natural endowments varied significantly depending on the prevailing institutional settings.

To gain such insights, I analyze the evolving relationship between the natural endowments of transportation networks—such as terrain suitability for roads, natural navigable rivers, and natural estuaries—and the location of cities in China over the past 2,000 years. This region, characterized by relatively stable territorial boundaries, has experienced significant variations in institutional frameworks across different dynastic periods. The findings reveal a statistically significant positive relationship between natural endowments of the transportation network and the presence of cities. However, this relationship is not static; it fluctuates over time in response to dynastic cycles. This highlights that the marginal effect attributed to natural features is shaped by the institutional context of each historical period.

Mechanism tests have demonstrated that the distinct patterns in the correlation between natural endowments of transportation routes and city locations can be attributed to variations in taxation systems and governance strategies. For instance, during the Song Dynasty[1] (10th to 13th centuries), an indirect tax system—where commercial taxes constituted a significant portion of total revenue—created strong governmental incentives to foster commercial prosperity. Governance strategies also influenced city placement relative to land routes. When the national capital was closer to the economic center[2], direct governance often favored cities near major roads. In contrast, greater

[1]The Song Dynasty stands out as the only period in Chinese history that predominantly relied on indirect taxation. The Song Dynasty experienced unprecedented economic prosperity, leading some scholars to suggest it marked the emergence of capitalist elements. (Deng, 1997, 2020; Liu, 2012)

[2]When national capital was located in central China, such as Xi'an (Tang Dynasty) and Kaifeng (Song Dynasty). More detail can be found at table 4.5.

distances[3] necessitated reliance on delegated governance, leading to cities farther from key routes.

These institutional factors largely explain observed trends in the correlations between transportation modes and city locations. For waterways, the correlation was notably high during the Song Dynasty, reflecting the era's emphasis on commercial activity, but it declined in other periods. For land routes, the correlation peaked during the Tang Dynasty (7th to 9th centuries), moderated during the Song Dynasty, and declined during the Ming and Qing Dynasties (14th to 20th centuries), consistent with shifts in governance strategies and the varying importance of road networks in urban development.

Regarding sea routes, the incoming of Arab and European merchants bolstered the development of the maritime Silk Road, leading to a sustained shift of cities towards coastal port areas. An exception to this trend was during the Ming Dynasty when the sea ban policy sharply curtailed the influence of international trade on city locations. This pattern aligns with the literature on market access and international trade.

These insights are gained upon the distinct roles of transportation routes during the pre-industrial era, transportation routes in China can be interpreted as representing three distinct forces: government force, domestic market force, and international market force. Waterways, with transportation costs significantly lower than those of land routes —often maintaining a cost ratio of 1:10 to 1:15—were the predominant mode for long-distance trade, symbolizing the domestic trade market force. Land routes, despite higher transportation costs, played a critical role in facilitating the rapid dissemination of official government information through China's courier system, with urgent messages traveling at speeds of up to 400 km per day, embodying governmental control. Meanwhile, sea routes, developed as part of the maritime Silk Road, represent the force of international trade.

To conduct this analysis, I developed new datasets that include the locations of cities and exogenous proxies for transport routes in historical China. Specifically, I utilized city location data from the China Historical Geographic Information System (CHGIS)

[3] When national capital was located in northern China, such as Beijing (Yuan, Ming and Qing Dynasty). More detail can be found at table 4.5.

project, which spans the past 2000 years. Given that existing historical sources only allow for a systematic analysis of transport networks during the Tang Dynasty and the Ming-Qing period, information on the national transport network is limited to other periods in Chinese history. To overcome these limitations and mitigate endogeneity issues in historical transportation network data, I constructed exogenous proxies that represent the natural endowments of the transportation network. These include a natural routes score index for land routes, natural navigable rivers for waterways, and natural estuaries for sea ports.

Selecting China as the focus of this study offers numerous benefits. Since its initial unification in 221 BCE, China has predominantly been under a unified and centralized governance structure, allowing me to significantly reduce the influence of omitted variables such as inter-state wars and conflicts. Additionally, the emergence and evolution of cities signifies the origins and development of civilization. Given its geographical and historical context, Chinese civilization has unique, indigenous traits and has been largely unaffected by external influences for most of its history. These aspects make the past two thousand years of China an unique case for analyzing how natural geographical endowments influence urban locations under varying institutional conditions.

### 4.1.1 Related Literature

This study engages with multiple strands of literature within the field of economic geography, which suggests that the location and size of cities are shaped by both natural endowments—referred to as the first nature of geography, encompassing location fundamentals—and human decisions, referred to as the second nature of geography, primarily driven by increasing returns effects. Initially, this study relates to the literature on location fundamentals and the long-term persistence of the spatial distribution of economic activities. This body of literature argues that spatial distribution of economic activities is persistent and resilient to temporary shocks, such as natural disasters or warfare (Davis and Weinstein, 2002; Miguel and Roland, 2011; Elliott et al., 2015; Cavallo et al., 2013; Kocornik-Mina et al., 2020), thus indicating that location fundamentals are crucial determinants of location and size of cities. However, opposing views challenge this perspective by demonstrating that: (1) persistence may still be evident even when locations lose their advantageous characteristics (Bleakley and Lin, 2012; Ellison and Glaeser, 1999; Kline and Moretti, 2014; Jedwab et al., 2017); (2) temporary shocks can indeed have lasting effects on the spatial distribution of economic activities (Redding et al., 2011; Hanlon, 2017); and (3) the same natural characteristics of a location may play different roles under varying circumstances (Michaels and Rauch, 2018). This study contributes to this debate by illustrating that the correlation between city locations and routes in Chinese history is not static but varies with changes in dynasties.

Second, this study contributes to the literature on increasing returns and market access. This strand of the literature suggests that urban growth is subject to increasing return effects, where locations with higher market access experience greater economic growth (Krugman, 1992; Donaldson and Hornbeck, 2016; Redding and Sturm, 2008b; Davis and Weinstein, 2003; Henderson et al., 2018; Jia, 2014; Bosker and Buringh, 2017). This research extends these findings by demonstrating that the presence and absence of international trade are closely correlated with the location of cities even in pre-industrialized society. This provides additional empirical evidence showing that increasing international market access can facilitate the agglomeration of economic activities.

Third, this study engages with the literature concerning the impact of institutions and political favoritism on urban development. Existing research indicates that institutions have played important roles in the location and size of cities (Henderson and Wang, 2007; Düben and Krause, 2023; Bai and Jia, 2023; Bosker et al., 2013; Cermeno and Enflo, 2019), and shows that locations benefiting from political favoritism experience enhanced urban economic growth (Chen et al., 2017; Hodler and Raschky, 2014; Ades and Glaeser, 1995). This study contributes to this body of literature by demonstrating that the relationship between city locations and natural endowments varies differently under different administrative levels. Specifically, at lower administrative levels, this connection shifts more dramatically and is closely tied to changes in dynasties. In contrast, at higher administrative levels, the connection remains more stable, exhibiting greater resilience. This phenomenon also aligns with findings in the economic geography literature. Several studies have observed that larger cities with higher administrative levels exhibit stronger resilience, while smaller cities are more susceptible to fluctuations. (Kocornik-Mina et al., 2020; Redding and Sturm, 2008b)

Finally, this study relates to the literature on historical economic geography. In recent years, there has been an increasing focus on the long run economic impact of historical roads for various regions and periods, including ancient nomadic migration corridors (Paik and Shahi, 2023), bronze age Assyrian (Barjamovic et al., 2019), iron age Mediterranean (Bakker et al., 2021), and Roman roads (Flückiger et al., 2022; Dalgaard et al., 2022). This study enriches this body of work by revealing the relationship between the locations of Chinese cities and their transportation routes over the past 2000 years.

The remainder of this paper is organized as follows: Section two provides historical background on transportation routes, their associated costs and interpretation to them in historical China. Section three introduces the data sources and main parameters utilized in this study. Section four presents the main results. Section five discusses potential mechanisms underlying the observed patterns. Finally, section six concludes the paper.

## 4.2 Transportation in Historical China

### 4.2.1 Historical Transport Routes

Studies on China’s historical transportation network have been relatively sparse. The most comprehensive restoration of China's historical road network is presented in Chapter 1 of this thesis, which reconstructs the Ming and Qing dynasties’ networks based on travel route books from those periods. For periods prior to the Ming and Qing dynasties, the most thorough study available is Yan (1985) about the Tang dynasty’s network. Unfortunately, Yan passed away before completing his series, which eventually only covered land routes in China’s northern and southwestern regions. Hence, our understanding of the southern land transportation network and the nationwide waterway network during that era remains significantly limited. Other works (Zeng, 1987; Lan, 1989), provide only scattered insights into a few regional transportation networks at certain times, offering limited help in comprehending China's historical nationwide network. It can be said that, apart from the Tang, Ming, and Qing dynasties, our knowledge of the national transportation network is considerably restricted.

Figure 4.2 displays the transportation network during the Ming and Qing periods constructed in Chapter 1 of this dissertation, while Figure 4.1 shows the (partial) network from the Tang dynasty researched by Yan (1985) and reconstructed into a GIS system by Zhu (2014). Comparing these two maps, I have two findings: (1) historical China possessed a rather comprehensive transportation network; (2) the main roads show strong historical path dependence, with most important routes during the Ming and Qing dynasties already existing in the Tang dynasty, and some even traceable back to the Spring and Autumn and Warring States periods.

Interestingly, the transportation network reconstructed in Chapter 1 from merchants' travel route books does not include maritime routes. The near absence of mention of sea trade, despite comprehensive records of the national commercial network, is particularly intriguing[4]. A rich number of literature and archaeological evidence indicates that by the 8th century, China's maritime trade was highly developed, with significant quantities of silk, handicrafts, porcelain, and tea being shipped overseas. (Wilson and Flecker, 2010; Chen, 2022; Yongjie, 2008; Deng, 1997, 1999)

Fortunately, a few historical maps provide direct evidence of ancient Chinese sea trade routes. The Selden Map, housed by Oxford University and speculated to have been produced in the early 17th century, records the Ming dynasty's sea routes.(Bodleian Libraries, University of Oxford, 2024) It details navigation paths from China's southeastern coastal regions to Ryukyu, Japan, the Philippine Islands, Vietnam, Java, and Malacca, among other Southeast Asian areas. Intriguingly, the routes documented only cover China's southeastern coastline, extending northward only as far as what is today the Lower Yangtze area near Shanghai, with no coverage of the northern regions. This study posits that this indicates maritime trade in the early 17th century was primarily

[4] The most plausible explanation for this phenomenon likely originates from the sea ban policy (*Haijin*) of the Ming dynasty. As such policy may have deterred authors and publishers from including any information about sea routes in travel route books.

concentrated in China's southeastern coastal areas, with the northern regions seeing scant maritime activity. This could be due to the northern coastline's unsuitability for navigation, described in Ming and Qing historical records as *"Wan Li Chang Sha"*, a long stretch of shallow, sandy shores predominated by mudflats, where large sea-going vessels could easily run aground. (Deng, 1997, 1999)

In summary, existing research reveals that: (1) historical China possessed a nationwide, comprehensive transportation network; (2) this network was broadly composed of three main components: land routes, waterways, and sea routes; (3) while primary transportation routes can be traced through historical records and demonstrate a significant degree of path dependency, studies on secondary routes remain scarce. As a result, detailed information is primarily available only for the nationwide transportation network in late imperial China.

### 4.2.2 Historical Transport Cost and Speed

Compared to the already limited research on historical transportation networks, studies focusing on historical transportation costs are almost nonexistent. Chapter 2 of this dissertation may be one of the few explorations into transportation costs throughout Chinese history. By synthesizing various materials, it was discovered that in the 7th century (Tang dynasty), the cost ratio between water and land transportation[5] ranged from 1:2 to 1:3. However, starting from the Song dynasty (12th century), this ratio dramatically decreased to 1:10, and this disparity then slightly increased and persisted at a ratio up to 1:15 until the late 19th century, only changing with the introduction of railways and steamships in China[6].

Looking at the absolute change from a cost perspective reveals an even more pronounced difference. A comparison based solely on nominal prices indicates that land transportation costs were similar in the 7th and 12th centuries. However, the cost of water transportation in the 12th century was only one-fifth of that in the 7th century. When

[5] Here, land routes are considered to be route with flat terrain, while water routes are typified by secondary rivers with stable currents, such as the Grand Canal and Fuchun River.

[6] More detail see Chapter 2

deflating costs using grain prices[7], the changes become even more stark. From the 7th to the 12th century, there was a significant reduction in transportation costs, with the cost of land transportation in the 12th century being only 5.6%[8] of that in the 7th century, and water transportation costs even lower at 1.7%[9]. Likewise, when deflating prices using grain prices, a comparison between the 12th century and subsequent periods shows that water transportation costs from the late 13th century were about twice those of the 12th century, while land transportation costs were three times higher. Considering the high grain prices in the 12th century due to warfare, it can be generally inferred that there was a significant reduction in transportation costs from the 7th to the mid-12th century, with the 12th century marking the period of lowest transportation costs in pre-industrial China. A slight increase (not much) occurred from the late 13th century, maintaining a relatively stable state thereafter. For detailed nominal costs and prices deflated using grain prices, refer to table 4.1 and figure 4.3.

In Chapter 1, the reconstruction of transportation speeds during the Ming and Qing dynasties is based on merchant travel route books[10]. For merchants transporting goods, the speed on primary rivers like the Yangtze River and its main tributaries was approximately 65 km per day. On secondary rivers, such as the Fuchun River and the Grand Canal (Jiangnan section), the speed was around 55 km per day. Overland, merchants primarily relied on pack horses or mules, moving at speeds close to human walking pace —about 43 km per day on flat terrain and 30 km per day on mountainous routes. Given the absence of revolutionary technological advancements in transportation technology (such as railways and steamships) until the late 19th century, it is reasonable to assume

[7]The necessity to deflate arises from the variations in currency used across different historical periods in China. During the Tang and Song dynasties, copper coins were the primary currency. By the Yuan dynasty, paper money had become the predominant medium of exchange, whereas the Ming and Qing dynasties primarily utilized silver as the main form of currency.(Peng, 1994)

[8]This change ratio is close to the transport cost reduction with railway revolution in 19th century England.

[9]The dramatic shift in the cost ratio between transportation modes from the 7th to the 12th century was determined by employing transportation cost data verified by Kiyokoba (1996) and grain price data authenticated by Peng (1994). The extent of price fluctuation observed is indeed remarkable, leading to potential explanations: (1) Kiyokoba's verification of transportation costs might be inaccurate. (2) During the 7th century, a period of peace resulted in exceptionally low grain prices, whereas the 12th century, marked by warfare, saw grain prices at significantly elevated levels, contributing to the pronounced discrepancy in the cost ratio.

[10]I rely on two sources, (1) Shi Wo Zhou Xing [Travelling Everywhere on my own], a merchant travel route book first written by anonymous and first published in 1694; (2) Yi Tong Lu Cheng Tu Ji [The comprehensive illustrated route book], a merchant travel route book written By Huang Bian (a Huizhou merchant) and first published in 1570.

that these transportation speeds remained relatively consistent from the 1st century through the end of the 19th century.

The speed of government information transmission through the postal station system was significantly faster than that of freight. China established a nationwide postal station system as early as the Han dynasty (2nd century BCE), which remained in use until the introduction of the telegraph. By the 15th century (Ming dynasty), China had over a thousand postal stations (see figure 4.4) and tens of thousands of employees along major roads, with a station every 60 to 80 *li* (approximately 30 to 40 km). Classified into land route stations, waterway stations, and amphibious stations, these stations were equipped with horses and boats according to their size[11], respectively. Functionally, waterway stations primarily handled official transportation[12], while land route stations mainly facilitated information transmission. Courier officers tasked with message delivery would change horses at each (or every few) station(s) to ensure the swift relay of information. Under normal conditions, a day's journey could cover 300 *li* (150 km), but in urgent cases, the speed could reach up to 800 *li* (or 400 km) per day, a scenario often referred to in Chinese as "emergency express of 800 *li* per day" ( *"Ba Bai Li Jia Ji"*. (Yang, 2006; Pan, 1959; Liu, 2017; Zhao, 1983)

The final aspect concerns the situation of maritime shipping. Compared to overland and river transport, historical records provide relatively scarce information on the costs and speeds of sea transport. Although it is difficult to make a detailed estimation of the costs associated with maritime shipping, existing research and literature indicate several key points: (1) Historical China possessed highly developed shipbuilding technology that supported long-distance voyages, with a plentiful supply of ships available for navigation in the market. (2) Despite the higher risks associated with sea transport, its cost-benefit ratio is incomparable to that of traditional inland river trade. (3) The cargo capacity of maritime vessels is significantly larger than that of river transport ships, which further reduces costs per unit. (4) The maritime routes to Southeast Asia rely on the monsoon

[11]The allocation of resources within the courier system varied according to the station's rank, with the number of horses prepared at each land route station ranging from as few as ten to as many as eighty or more. Similarly, waterway stations were equipped with varying numbers of boats, also dependent on their respective ranks.

[12]Including transporting grains and copper for coinage.

winds, typically allowing for only one round trip per year.(5) The maritime shipping market was highly developed, to the extent that financial markets and accompanying financial instruments emerged in major port cities.(Chen, 2022; Deng, 1999) These points illustrate that maritime shipping played a crucial role in international trade and was considerably prosperous.

### 4.2.3 Interpretation on mode of transportation

So far, I have examined the transportation networks and costs in historical China. Given that three primary modes of transportation—land routes, waterways, and sea routes—dominated the historical landscape, a pivotal question arises: how can the influence of these different transportation networks be interpreted? To address this, the article proposes three hypotheses to clarify these dynamics:

(1) **Land routes** are indicative of **governmental control** across regions

(2) **Waterways** represent the dynamics of **domestic trade**

(3) **Sea routes** reflect the mechanisms of **international trade**

These hypotheses are grounded in the distinct characteristics associated with each type of transportation route. As outlined in previous sections, for the majority of China's history, the cost ratio between land and water transportation remained in a range from 1:10 to 1:15, indicating that land transport was approximately ten to fifteen times more expensive than water transport, with maritime transport costs being even lower relative to inland waterways. On the other hand, land routes offered a significant advantage in terms of information transmission speed, facilitated by a nationwide courier system (figure 4.4), allowing official information to be disseminated at speeds up to 400 kilometers per day. Overall, the advantage of land routes in official information transmission implies that cities closer to land routes are more influenced by government control. Conversely, waterways and maritime routes have a notable advantage in transportation costs, suggesting that cities near these routes are more influenced by trade and market forces, with waterways representing domestic trade and sea routes international trade.

However, the trade advantages associated with proximity to waterways or sea routes are nonexistent or severely limited for inland cities far from navigable water. Such inland cities, which lack access to efficient and cost-effective trade networks, can only sustain themselves for reasons unrelated to trade, such as political considerations. Historical evidence suggests that many of these cities survived and thrived primarily because they served as administrative or military hubs. The location of these cities often reflected strategic priorities, such as proximity to land routes for rapid information dissemination or their role as seats of government power. As a result, inland cities highlight the significance of governmental control in shaping urban landscapes, contrasting sharply with the trade-driven growth of cities located near waterways or ports.

## 4.3 Study Area and Data

### 4.3.1 Using CHGIS data

Locating historical cities is challenging. The most detailed dataset for city locations in Chinese history comes from the China Historical Geographic Information System (CHGIS) project, a collaboration between Harvard University and Fudan University. It includes GIS data (point) for county and prefecture seat locations from 221 BCE to 1911 CE[13][14][15]. Due to the scarcity of administrative unit data during the Qin-Han period, this study utilizes CHGIS data from 1 CE (late Western Han dynasty) to 1911 CE (end

[13]This timeframe spans the entire historical period of the Chinese empire, specifically from the inception of China's first unified empire, the Qin dynasty, to the fall of its last empire, the Qing dynasty.

[14]The extensive historical records, city path dependency, and recent archaeological discoveries of ancient cities collectively ensure the high reliability of the historical urban location data within the CHGIS.

[15]The CHGIS also compiles data on the administrative spatial extents of prefectures and counties. However, two significant shortcomings necessitate caution in its use for this study. Firstly, the CHGIS exhibits a pronounced deficit in data regarding the administrative boundaries of prefectures and counties prior to the Ming dynasty. Secondly, even for the administrative units within the CHGIS that do include spatial boundary data, the reliability of this information remains questionable. This is attributed to the historical records, which, although often documenting the locations of prefectural and county seats, rarely specify the precise administrative extents of these jurisdictions. In fact, deducing historical administrative boundaries from these records is exceptionally challenging. The administrative spatial information in the CHGIS for prefectures and counties is derived from a retroactive reconstruction based on the administrative divisions as of 1911. This backward reconstruction is feasible for the Qing dynasty, supported by the abundant local gazetteer information ensuring relative accuracy. However, the number of surviving local gazetteers diminishes significantly with time, particularly starting from the Ming dynasty, making such reconstructions increasingly speculative. Indeed, the scarcity of administrative spatial data for periods preceding the Ming dynasty within the CHGIS is a direct consequence of the limitations imposed by the historical sources. Consequently, while the administrative spatial data in the CHGIS may serve as a reference, it is difficult to employ as material for objective, quantitative analysis.

of the Qing dynasty). Given China's changing borders over time, this research focuses on "China Proper" as its study area. Here, I define "China Proper" to all provinces within modern China's boundaries, excluding the Northeast, Xinjiang, Inner Mongolia, Tibet, and Qinghai. This area is chosen because it has historically been the heartland of Chinese dynastic governance, including under the Northern Song dynasty, which had the smallest territorial reach of all unified dynasties yet still governed this region effectively.

Utilizing data from the CHGIS, I have developed a two-tier dataset comprising "city" and "prefecture city" levels. The former represents a union of county-level units and prefecture-level units, while the latter exclusively encompasses prefecture-level units. It is critical to note that, in delineating prefecture-level units, I excluded all administrative units not classified as prefectures (while they are defined as "prefecture" level units in CHGIS). Due to the CHGIS data being processed by different historians across various periods and regions, inconsistencies arise in the dataset regarding the definition of prefecture-level units, even within the same historical period. This is attributed to the subjective interpretations of what constitutes a prefecture-level unit by different historians. For instance, during the Ming dynasty (as illustrated in figure 1), military garrisons (*wei* & *suo*) were classified as prefecture-level units in some regions but as county-level units in others[16]. To mitigate the potential ambiguities and inconsistencies arising from these differing classifications, this study reclassifies any prefecture-level unit that does not serve administrative purposes and falls under the central government's jurisdiction as a county-level unit, incorporating them into the city dataset[17].

In this study, *county seats*, *prefecture seats*, *chieftaincies* (*tu si*), and *military garrisons* (*wei* & *suo*) are all conceptualized as cities. Although the CHGIS primarily records

[16]During the Ming dynasty, garrisons (*wei* & *suo*) functioned as military rather than administrative units, lacking defined territorial jurisdictions and not governing any counties. The inhabitants of these garrisons were exclusively military personnel, not civilians. The author of this paper participated in the CHGIS project in 2020, undertaking a comprehensive restoration of the locations of all military garrisons from the Ming dynasty and creating a GIS dataset for these garrisons. It was discovered that the CHGIS had collected location information for only about one-third of the more than 400 garrisons identified. This dataset on Ming dynasty garrisons has now been made publicly available and can be found as part of the Digital China Project, which encompasses both the China Biographical Database (CBDB) and CHGIS.

[17]Taking the Ming dynasty as an example, exceptions to the typical prefecture-level units include garrisons (*wei* & *suo*) and chieftaincies (*tu si*) —hereditary tribal leadership roles acknowledged as imperial officials (refer to figure 4.8). Despite their unique administrative status, these entities unquestionably qualify as urban settlements. This is evidenced by the majority of them being fortified with walls and having populations exceeding a thousand.

these entities as administrative units, the focus of this research is on identifying urban settlements that meet both spatial and demographic criteria. Specifically, all these units—regardless of their formal administrative designation—are included in the city dataset based on the following characteristics:

1. They serve as local administrative or military centers, functioning as focal points of governance or strategic control within their respective regions;
2. They possess enclosure features, such as city walls or moats, which indicate spatially demarcated and fortified settlement structures;
3. They maintain a stable, resident population of sufficient size, rather than merely hosting transient or temporary populations.

Given the working definition adopted in this study—defining a city as an *enclosure settlement with a stable resident population exceeding a certain threshold*—these units consistently qualify as cities, even if their administrative titles vary across different historical contexts. This definition acknowledges the dual importance of both physical urban form (enclosure structures) and demographic substance (permanent population presence) in constituting an urban settlement.

Conversely, other settlements such as *market towns*, despite their possible economic prosperity, are excluded from the city dataset. This exclusion is based on three key considerations:

1. Market towns often lack defined enclosure structures that spatially delineate the settlement in a formal, defensive, or administrative sense;
2. Their population scale typically falls below the threshold expected of city-level settlements, and many such towns exhibit seasonal population fluctuations—with inhabitants congregating temporarily during market days but lacking a stable, sizeable resident population throughout the year;
3. They do not function as administrative centers, and therefore lack the political-institutional anchoring that underpinned the development and persistence of cities in historical China.

Figure 4.6 illustrates the variation in the total number of counties and prefectures recorded in the CHGIS from 1 CE to 1911 CE. Additionally, Figure 4.8 presents the specific data on counties and prefectures as documented by the CHGIS for the year 1500 during the Ming dynasty. Finally, Figure 4.5 illustrates the evolution of city distribution across the nation over the past 2000 years, segmented according to Skinner's macro-regional framework (Skinner, 1977).

### 4.3.2 Unit of Observation and Study Periods

To mitigate the risk of endogeneity and selection bias, this study adopts a grid cell methodology, as proposed in Allen et al. (2023) and Chen et al. (2024). The primary analytical unit is defined by a grid cell with a resolution of ¼ * ¼ degrees, approximately equating to 28 km by 28 km at the equator. These grids were generated using the WGS84 projection system, encompassing the entire region defined as "China Proper". Consequently, this dataset comprises 6,139 grid cells. This spatial extent, delineated by the grid cells, constitutes the sample area for my analysis. (figure 4.9)

The temporal scope of this study encompasses the past two millennia, during which I analyze each grid cell across 21 distinct time periods. The first 20 periods extend from 1 CE to 1900 CE, with each period representing a centennial snapshot. Given that the CHGIS provides data up to 1911, I supplemented this dataset with information on the locations of all county-level and prefecture-level administrative units in China for the year 2023, using data collected from Amap (also known as Gaode Map). Consequently, my analysis includes a final time period for the year 2023.

### 4.3.3 Proxies of historical routes

Direct analysis using historical transportation networks faces two main challenges: (1) the availability of data and (2) the inherent endogeneity of road networks. Regarding the first challenge, as outlined in the historical background section, the most systematic data on China's historical transportation networks available to us includes Yan's study ((Yan, 1985)) on the Tang dynasty's national transportation network (which is incomplete) (see figure 4.1), along with the reconstruction of the Ming and Qing dynasties' national transportation networks discussed in Chapter 1 (see figure 4.2). Our knowledge of the national road situations prior to the Tang dynasty and during the Song-Yuan periods is exceedingly limited, lacking systematic and reliable sources. As for the second challenge, the establishment of road networks is inherently endogenous. Directly analyzing these networks can lead to biased estimates of the results.

To address the aforementioned challenges, this paper leverages the natural endowments of the transportation network to conduct the analysis. Specifically, it employs three exogenous variables as proxies for the three main types of transportation networks. Specifically, I utilize a pure topography-based natural road score approach to proxy for land routes; navigable natural rivers to proxy for waterways; and the estuaries of rivers as proxies for harbors (sea routes). In the subsequent parts of this section, I will detail the methodology behind the construction of these three variables.

#### 4.3.3.1 *Natural Road Score*

As described in the historical background section, China's historical road networks exhibit a strong path dependency that persists to the present day. This path dependency stems, in part, from the backward and forward forces between cities and roads and, more significantly, from the influence of topography, where historical roads often represent the terrain's optimal solution. Given these characteristics, this study employs the Natural Road Score (NRS) approach, first proposed by Barjamovic et al. (2019), as a quantitative measure assessing the likelihood of a location, termed as location $A$, being situated on a potential transport route. The NRS for location A is calculated by determining how frequently the optimal path between any two distinct locations, origin ($O$) and destination ($D$), within a set range (e.g., 200 hours of travel distance) passes through location $A$.

To compute the NRS for China, elevation data encompassing a broad area around China are collected to mitigate core-periphery bias, which can lead to an overrepresentation of road crossings in centrally located areas. This study utilizes topographical data covering from 70 degrees east to 140 degrees east longitude and from 15 degrees north to 55 degrees north latitude, as shown in Figure 4.9. The topographical information, derived from the FAO's Global Agro-Ecological Zones (GAEZ) database (Fischer et al., 2008), includes elevation details with a resolution of 1/12 degree (approximately 10km at the equator).

Travel times for an individual walking across rugged terrain are estimated using Langmuir (1984) formula, which accounts for horizontal distance, elevation gain, and slope steepness. Dijkstra (1959) algorithm is applied to identify the optimal route between any two points, with calculations limited to origin-destination pairs within a 200-hour travel window due to computational constraints.

Each cell' s NRS (Natural Route Score) is defined based on betweenness centrality, a standard network metric that measures how often a node lies on the shortest paths between other nodes. In this context, betweenness is calculated for each node (1/12 degree grid cell) within a road network constructed from optimal natural routes between all pairs of points that are within a 400-hour walking distance. A higher betweenness value indicates that a cell acts as a more critical connector in the network of feasible natural paths. Given the large number of nodes, the raw betweenness centrality values are very small and are scaled by a factor of one billion for interpretability. Since the analysis is conducted at the 1/4 degree cell level, we select the maximum NRS value within each 1/4 degree cell to represent its overall accessibility to the natural route network. The NRS is considered exogenous, as it is derived solely from topographical inputs such as slope and elevation. Figure 4.11 displays the spatial distribution of NRS across China.

Figure 4.10 illustrates the distribution of the Natural Road Score (NRS) within a 400-hour range. As shown, the data exhibits a long tail. To address this issue in the analysis, the NRS underwent a log transformation. Additionally, since the other two transportation modes, waterways and sea routes, are represented as dummy variables (0 and 1), the NRS was further normalized to a range between 0 and 1. This ensures that the NRS values are comparable with the dummy variables for waterways and sea routes, facilitating consistent interpretation across all three transportation modes. The transformation was conducted using the following equation:

$$NRS' = \frac{ln(NRS) - \min(ln(NRS))}{\max(ln(NRS)) - \min(ln(NRS))}. \tag{4.1}$$

It is important to note that penalties for crossing rivers and undertaking sea trips have not been included in this study's calculations. The rationale for not incorporating a river-crossing penalty is threefold: (1) Over the past two millennia, the courses of rivers, notably the Yellow River, have frequently changed, with the river's basin exhibiting significant fluctuations that spanned the entire North China Plain(Wang and Su, 2011), as depicted in Figure 4.12. (2) The computation of the NRS is notably time-consuming; given the vast expanse of historical China, each calculation covering up to 600 hours of travel distance required approximately three months, even when utilizing an AMD CPU with 16 cores and 32 threads. This effectively precludes the possibility of conducting separate NRS calculations for each historical period. (3) Historical transportation networks from the Ming, Qing, and Tang dynasties suggest that the presence of rivers did not significantly alter the direction of land routes.

The exclusion of sea trips from the NRS calculation stems from the decision to use separate variables as proxies for sea routes. However, this approach introduces a potential issue, as it effectively positions coastal areas at the periphery of the NRS calculation zone, which could lead to a core-periphery bias. To mitigate this, an additional dummy variable has been introduced to account for cells located within 200km of the coastline, thereby compensating for the aforementioned bias.

#### 4.3.3.2 *Waterways*

To exogenously capture waterway routes, I have chosen to use only naturally formed major navigable rivers as proxies, due to the fact that a significant portion of natural rivers are not navigable. For example, the Yellow River and most of its tributaries lack navigability due to high silt content leading to riverbed sedimentation and frequent flooding. Historical records indicate that since the Tang dynasty, the Yellow River has had limited navigability, with Ming and Qing commercial route books omitting any mention of waterway information regarding the Yellow River[18]. Consequently, following Liu (2012), I define the Yangtze River and its major tributaries, the Pearl River and its major tributaries, along with crucial southeastern coastal rivers such as the Min River and Qiantang River and their major tributaries, as major navigable rivers. These rivers are entirely natural, historically stable, and have long been navigable in the past two millennium.

In practice, this article constructed a navigable river dummy variable. A cell is assigned a value of 1 if it intersects with any of the major navigable rivers as defined in this study; otherwise, the value is 0.

It is important to emphasize that canals, including the Grand Canal, are not included in my analysis due to their strong endogeneity and the potentially exaggerated role in commercial operations. The Grand Canal has been historically recognized as the world's longest artificial waterway and a major conduit for North-South traffic in China. However, research into Ming and Qing era merchant route books reveals that due to the perennial flooding of the Huai and Yellow Rivers, the canal was often silted and obstructed by numerous locks, leading to inefficient passage and the need for costly labor. In fact, route books from the Ming and Qing dynasties advised merchants wishing to travel from Yangzhou to Beijing to hire pack horses and opt for land routes over the Grand Canal, as this method was more time-efficient and the cost difference was negligible.

#### 4.3.3.3 *Sea Ports*

To identify the locations of sea route ports endogenously, I employ estuaries as an exogenous proxy for several reasons: (1) estuaries naturally possess advantageous characteristics for becoming harbors compared to other coastal areas[19], and (2) the location

[18] See chapter 2 of this dissertation.

[19] Historically, major ports are strategically situated at estuaries, notable examples being Quanzhou, Fuzhou, and Guangzhou in China; Liverpool and Hamburg in Europe; and New York in North America. Estuaries are preferred for port locations due to their three key geographical advantages. First, the continual scouring by river flows often creates natural deep-water channels, essential for accommodating large vessels. Second, estuaries offer natural shelter, protecting vessels from harsh weather conditions and providing a safe harbor. Lastly, they enable natural connectivity between the sea and inland areas through rivers, significantly enhancing trade and transportation networks. These advantages underscore the critical role estuaries have played in the development of major global ports throughout history.

of estuaries is determined solely by natural geography, making it entirely exogenous. Specifically, I utilize the CHGIS data on river networks from 1820, coupled with contemporary coastline information. Each cell is assigned two dummy variables: one indicating whether it is within 20km of the coastline and another indicating the presence of a river. A cell is considered an estuary cell if it satisfies both conditions of being within 20km of the coastline and containing a river.

Given China’ s geographical characteristics, I restrict the proxy to estuaries along the southeast coast. This choice reflects fundamental natural differences: the northern coastline is largely composed of tidal flats, while the southern coastline features deeper waters suitable for ocean-going vessels. To operationalize this distinction, I use the latitude of the Yangtze River estuary (32°N) as a natural boundary, classifying estuary cells south of this latitude as suitable for sea route ports. Importantly, this restriction is based on exogenous physical geography rather than observed port outcomes, ensuring the validity of the instrument.

### 4.3.4 Additional Controls

In addition to road networks, several other factors potentially influenced the location of cities in historical China. This article captures the role of agricultural periodicity in economic development by incorporating a parameter for agricultural suitability. Specifically, it utilizes data on the maximum potential production capacity in tons per hectare for two principal crops present during the study period, sourced from the Global Agro-Ecological Zones (GAEZ) database[20] (Fischer et al., 2008) This data is adjusted based on historical calorie content per ton for each crop, according to the Food and Agriculture Organization (FAO) (Chatfield, 1953a), with wetland rice and wheat being the crops under consideration[21].

Moreover, elevation and terrain ruggedness serve as control variables in the regression analysis conducted in this article. Elevation data is obtained from the NASA Shuttle Radar Topography Mission (SRTM) dataset (NASA Shuttle Radar Topography Mission

[20] It is a dataset has been widely used in economic studies. (Barjamovic et al., 2019)

[21] The unit used in this study is the potential calories that can be produced by agriculture production per square meter per year.

(SRTM), 2013), and terrain ruggedness is calculated using the Slope algorithm in ArcGIS, with the mean elevation and terrain ruggedness of each cell included in the dataset. Additionally, longitude and latitude information is incorporated to capture the temperature and climatic differences between the north-south and east-west axes of China. To further account for cultural and geographical variations across different regions of China, Skinner's (1997) macro regions are employed as dummy variables. Lastly, to address the issue of the Natural Road Score (NRS) disproportionately penalizing coastal areas, thus inadequately reflecting road conditions in these regions, a dummy variable indicating proximity within 200km of the coastline is included. Table 4.2 provides a detailed description of the data sources.

## 4.4 Empirical Strategy and Results

### 4.4.1 Empirical Set Up

This study begins by estimating the marginal effect of natural geographical endowments on the likelihood of city presence using a Linear Probability Model (LPM) specified as follows:

$$Y_{it} = \theta Geo_i + \lambda_i + \gamma_t + \epsilon_{it}. \tag{4.2}$$

where $Y_{it}$ is a binary variable indicating whether cell $i$ contains one or more cities at time $t$. $Geo_i$ includes cell-level, time-invariant control variables, as discussed earlier. These variables comprise the natural logarithm of agricultural suitability, slope, the natural logarithm of elevation, a dummy variable for proximity within 200 km of the coast, and the geographical coordinates of longitude and latitude.

To account for geographical variation across China, $\lambda_i$ represents Macro Region fixed effects, following the approach of Skinner (1977). To control for time trends, $\gamma_t$ represents year fixed effects. Standard errors are clustered at the level of 2-degree cells.

In the next step, to analyze the impact of natural endowments on transportation networks to the location of cities, this study employs a baseline estimation based on the following specification at the cell level:

$$Y_{it} = \beta Routes_i + \theta Geo_i + \lambda_i + \gamma_t + \epsilon_{it}. \tag{4.3}$$

Here, $Y_{it}$ remains a dummy variable indicating whether cell $i$ contains one or more cities at time $t$. $Routes_i$ represents the time-invariant measure of routes, which includes the Natural Road Scores (NRS) for land routes, the presence of a navigable river for waterways, and natural estuaries on the southeast coast for sea routes.

The study takes the natural logarithm of each cell's NRS and then normalizes it to a range of 0 to 1 (as in Equation 4.1) for analysis. A "navigable river" is defined as a dummy variable indicating the presence of a major natural navigable river flowing through the cell. "Natural estuaries" are identified by a binary variable meeting three simultaneous criteria: (1) within 20 km of the coastline, (2) overlapping with a river, and (3) located south of 32°N. This specification allows for an integrated analysis of how natural endowments and transportation networks influence urban development across time and space.

### 4.4.2 Main Results

#### 4.4.2.1 Geography Factors

Table 4.3 presents the results of Equation 4.2, highlighting the relationship between city presence and geographical factors. The analysis reveals that agricultural suitability and terrain slope are significantly associated with the presence of cities, while other variables exhibit no statistical relevance. Specifically, as shown in column (2), a 1 kcal increase in average agricultural productivity per square meter increases the probability of a city's presence by 11.2%, whereas a 1-degree increase in slope decreases it by 1.3%.

A similar pattern emerges for prefecture-level cities. Only agricultural suitability and terrain slope have significant effects: a 1 kcal increase in potential agricultural productivity raises the probability of a prefecture-level city's presence by 4.1%, while a 1-degree increase in slope reduces it by 0.3%.

#### 4.4.2.2 Routes

Table 4.4 presents the results from Equation 4.3, showing the correlation between three modes of transportation and the location of cities throughout Chinese history. Column 1 displays the coefficients linking the exogenous variables of the three transportation modes to whether a cell is occupied by a city. Column 2 includes geographical controls. Column 3 adds both temporal and spatial fixed effects, using years for temporal fixed effects and Skinner's macro-regions for spatial fixed effects.

As shown in Column 3, after incorporating location and time-fixed effects along with geographical controls, all three transportation modes are significantly positively correlated with city locations in the cities panel. For land routes, specifically the Natural Road Score (NRS) index, a 1% increase in the NRS (an exogenous proxy for road networks) corresponds to a 0.167% increase in the probability of a city's presence. Since the NRS has been log-transformed and normalized to a range between 0 and 1, this result can also be interpreted as follows: locations with very high NRS values are 16.7% more likely to host a city compared to those with very low NRS values. If a cell contains a major natural navigable river, the probability of city presence increases by 11.3%. Additionally, the presence of a natural estuary raises the probability by 9.3%.. For water routes, the presence of a natural navigable river in a cell leading to a increase on the likelihood of being occupied by a city by 10.3%. Finally, for sea routes, specifically estuaries in southeast China, a cell located on an estuary has a 9.3% higher chance of being occupied by a city. Notably, land routes only became significant after the addition of fixed effects, suggesting that the true effect of the NRS might have been obscured by region-specific factors.

In the panel for prefecture-level cities, after adding location and time-fixed effects and geographical controls, the three transportation modes also show a significant positive correlation with city locations, as seen in Column 3. For land routes, a 100% increase in the NRS index means a 1.8% higher probability of a cell being occupied by a prefecture seat. For water routes, a cell with a natural navigable river is 7.3% more likely to be occupied by a prefecture seat. For sea routes, a cell located on an estuary is 6.2% more likely to be occupied by a prefecture seat.

Given the vast scope of Skinner's macro-regions, for robustness, Column 4 uses a smaller-scale regional fixed effect. Since the three transportation mode proxies are time-invariant variables, instead of using cell-level fixed effects, I employed 1-degree level cell fixed effects. It can be observed that in both city and prefecture-level city panels, the three transportation variables remain statistically significant. Lastly, in Column 5, for robustness, a logit regression was conducted, and similarly, in both panels, the three transportation variables remained significantly positive within a 95% confidence interval.

### 4.4.3 Changing Importance of Geographic Advantages

To explore how these correlations change through Chinese history, I examine the time trend of these marginal effects. I begin by applying a cross-sectional regression for each time period using the following equation:

$$Y_{it} = \beta Routes_i + \theta Geo_i + \lambda_i + \epsilon_{it}. \tag{4.4}$$

The results are presented in Table 4.5 and 4.6. For clarity, I have extracted the coefficients and confidence intervals for the three modes of transportation across various periods and depicted these in a graph, as illustrated in Figure 4.13.

To facilitate the understanding of Chinese historical timelines, Figure 4.14 and 4.15 incorporates color coding to distinguish between dynasties. Now, reflecting on the characteristics of different route types, the results can be interpreted as follows:

#### 4.4.3.1 Cities

For land routes, indicative of governmental influence on city locations: (1) Prior to the Tang dynasty (pre 6th century), government influence on city locations was relatively stable. With the onset of the Tang dynasty (6th - 9th century), this influence surged and remained high. (2) The transition to the Song dynasty (10th century) marked a sharp decline in governmental influence, which stabilized throughout the Song and Yuan periods (10th - 14th century). (3) Beginning with the Ming dynasty (14th century), the influence of government further diminished, hitting a historical low in the 16th century, followed by a gradual ascent. (4) This upward trend persisted into the Qing dynasty (17th - early 20th century), where the coefficient reverted to Song-Yuan levels. (5) In the early 21st century, a steep decline was observed, bringing the coefficient back to levels seen during the Ming dynasty.

For waterways, representative of the market forces from domestic trade, the impact on city locations unfolds in four distinct phases: (1) During the Han dynasty, the coefficient remained low, reflecting minimal influence on city locations (3rd century BCE - 3rd century CE). (2) The Wei, Jin, Northern and Southern Dynasties through the Tang dynasty (3rd - 9th century) experienced a slight rise from the Han period, maintaining long-term stability. (3) The Song-Yuan period (10th - 14th century) witnessed a significant increase in the role of domestic trade in determining city locations, with a sharp rise observed from the 8th to 11th centuries and stabilization from the 11th to 13th centuries. (4) From the Ming and Qing dynasties to the modern era (14th century - present), the influence of domestic trade on city locations demonstrated a steady decline, approximating pre-Song levels.

Lastly, regarding sea routes, signifying the impact of international trade on city locations, I identify several stages: (1) An initial growth phase during the Wei, Jin, Northern and Southern Dynasties (3rd - 6th century). (2) A downturn in the early Sui and Tang periods (6th - early 8th century). (3) A prolonged period of growth from the late Tang through the Yuan dynasty (late 8th - 14th century). (4) A decline during the Ming dynasty (14th - 17th century). (5) A resurgence in the Qing dynasty (17th - early 20th century). (6) A period of stability in today and late Qing period, remaining essentially unchanged.

#### 4.4.3.2 Prefecture Level Cities

Within the CHGIS database, cities classified at the prefecture-level are predominantly identified as important urban centers compared to general cities. This significance is attributed primarily to two factors: (1) a higher administrative ranking within the administration system, and (2) the tendency to possess larger urban scales. Therefore, by analyzing prefecture-level cities, I ascertain the impact of different types of routes on major urban centers.

Changes in prefecture-level cities, which serve as significant urban centers, are more straightforward. For land routes, symbolizing governmental influence on city locations, there was a generally stable condition until the Song dynasty (13th century), followed by a decline during the Ming dynasty (14th - 17th century), and a subsequent rise in the Qing dynasty (17th - early 20th century). In the 21st century, there is a noticeable decline compared to the late Qing era.

As for waterways, which reflect the market forces of domestic trade, their impact on major cities was on a long-term ascent until the mid-Song dynasty (10th century), after which it remained stable until the late Qing (17th - early 20th century), with a significant downturn observed in the today (early 21st century) compared to the late Qing period.

Lastly, sea routes, representing the market forces of international trade, showed a steady, gradual increase throughout history, with a rapid escalation following the Opium Wars (mid-19th century), continuing to today.

### 4.4.4 Dynastic Cycles

As depicted in Figure 4.14 and Figure 4.15, the changes in the marginal effects of natural endowments on different modes of transportation networks appear to align with the cyclical patterns of dynastic transitions in Chinese history. To further investigate the variations across dynasties, I employ the following estimation model:

$$Y_{it} = \beta Routes_i + \gamma \left( Routes_i \times Dynasty_t \right) + \theta Geo_i + \lambda_i + \gamma_t + \epsilon_{it}. \tag{4.5}$$

This model allows for capturing the interaction effects between transportation modes and dynastic periods, providing insights into how the influence of natural endowments on transportation networks evolved by dynastic shifts.

The results are reported in Table 4.7 and illustrated in Figure 4.16. As shown, when using the Qing dynasty, China's last unified dynasty, as the baseline, the marginal effect of land routes differs significantly during the Sui and Tang dynasties. For waterways, significant differences are observed in the Song and Yuan periods compared to the Qing. Regarding sea routes, the Qing shows significant differences with the pre-5th century period, while no significant differences are found after the 5th century at the 90% confidence level. These findings suggest that the marginal effects of transportation networks vary across different dynasties.

## 4.5 Mechanism

So far, I have elucidated the observed changes in the correlation between city locations and types of transport routes throughout Chinese imperial history and discussed how to interpret the connection between types of transport and city locations over the past two millennia in China. In this section, I aim to explore the underlying mechanisms behind these changes.

### 4.5.1 Institution and Dynasty Change

This article first suggests that dynasty and institutional changes serve as a plausible mechanism influencing the observed shifts in coefficients. This hypothesis is proposed based on the high correlation between coefficient changes and the historical dynasties of

China[22][23], as depicted in figure 4.14, 4.15, 4.16 and table 4.7. The primary distinctions between dynasties in historical China stem from variations in territorial extent and the institutions they implemented. Given that this study is confined to China Proper, this geographical delimitation somewhat mitigates the impact of territorial changes. Hence, the differences attributed to dynasty changes observed in my analysis are more likely related to the distinct institutions enacted by each dynasty.

In considering the distinct forces represented by the three types of transportation routes, namely government force and market force from domestic or international trade, this paper posits the following two hypotheses:

*Hypothesis* 1. For **waterways**, which reflect the market force of domestic trade: If a dynasty relies more on **indirect taxes** (such as commercial taxes), then domestic market forces have a greater influence on city location during that period. Conversely, if reliance is placed more on direct taxes, such as land taxes, the influence of market forces is smaller.

*Hypothesis* 2. For **land routes**, primarily serving government information dissemination and interpreted as government force: If the **national capital** is located in a relatively remote part of the empire, there is a tendency to employ a proxy governance mechanism, hence, cities are more likely to be situated away from roads. Conversely, if the capital is at the empire's center, a direct governance system is preferred, making city locations more inclined to be near roads.

To examine these hypotheses, I have following estimation:

[22] Also utilizing data from the CHGIS, Düben and Krause (2023) observed a phenomenon akin to the one discussed in this paper, noting that the accuracy of their predictive models fluctuated with the succession of dynasties. Specifically, the impact of dynasty changes was more pronounced on administrative levels, with higher administrative echelons experiencing relatively less influence. This observation suggests that while administrative structures were subject to the dynamics of dynastic transitions, the core functions and influence of higher-tier administrative roles maintained a degree of continuity across different historical periods. This may probably due to higher-tier administrative cities are usually larger in size, and therefore have higher urban resilience.

[23] Another potential explanation for the observed phenomena could stem from the characteristics of the data source. The cities recorded in the CHGIS are those established by the government. Notably, after each dynastic transition, significant changes often attributed to the new regime's massive adjustments to the urban system can be detected. The tradition of reconstructing the urban structure following unification is a longstanding practice among unified dynasties in Chinese history, with its origins tracing back to the comprehensive reorganization of the urban hierarchy by the central government after the Qin-Han unification (Xu, 2017a). These adjustments are undoubtedly closely tied to the institutional frameworks of each dynasty.

$$Y_{it} = \beta_1 Routes_i + \beta_2 \left(Routes_i \times Institution_t\right) + \theta Geo_i + \lambda_i + dynasty_t + year_t + \epsilon_{it}. \quad (4.6)$$

Where $Y_{it}$ is a indicator on whether cell $i$ is occupied by one or more cities in time $t$. $Routes_i$ represents the time-invariant measure for routes, including Natural Road Scores (NRS) as land routes, the presence of a navigable river as waterways, and natural estuaries on the southeast coast as sea routes. $Institution_t$ represents the institutions discussed in this section. Under Hypothesis 1, it concerns whether the dynasty primarily relies on indirect taxes as its main source of taxation. Under Hypothesis 2, it relates to the distance between the national capital and the population centroid. The interaction term between $Instituion_t$ and $Routes_i$ captures whether the marginal effect of $Routes_i$ varies over time between different institutional settings. Additionally, $Geo_i$ are geographical controls, $\lambda_i$ represents a regional fixed effect at skinner macro region (Skinner, 1977), and $Dynasty_t$ is a dynasty fixed effect to account for dynasty-specific influences, while $Year_t$ captures linear trends over time, such as general socio-economic development, to prevent temporal trends from biasing the estimation results.

According to the two hypotheses, it is expected that $\beta_2$ will be positive for Hypothesis 1 and negative for Hypothesis 2. Furthermore, due to the differences in the administrative hierarchy and urban scale between cities and prefecture-level cities, the economic geography literature suggests that larger-size cities should exhibit stronger urban resilience compared to smaller-sized cities (Kocornik-Mina et al., 2020). This means prefecture-level cities should be less likely to be affected by changes in institutions.

#### 4.5.1.1 *Hypothesis one: Taxation structure and efficient market (Direct VS Indirect Taxation)*

Comparative research also shows that reliance on indirect taxation often promoted trade but limited the building of fiscal capacity, while direct taxation supported stronger states and long-run growth (North and Weingast, 1989; Besley and Persson, 2009; Sng, 2014). My hypothesis suggests that the extent to which a dynasty relies on indirect taxation, such as commercial taxes, amplifies the influence of domestic market forces on city locations during that era. Conversely, a greater reliance on direct taxes, including land taxes, results in a diminished impact of market forces.

Traditionally, Chinese historical tax systems predominantly comprised direct taxes, such as land and poll taxes. Over 80% of taxation during the Tang dynasty (7th –10th century) were derived from agricultural land taxes. During the Ming dynasty (14th – 17th century), land taxes accounted for over 70% of all fiscal revenues. A similar scenario was observed in the Qing dynasty (17th - 20th century), where, prior to 1850, land taxes constituted between 61% and 88% of total fiscal income. The late Qing period, post-1850, under the pressure of the Taiping Rebellion, saw an increase in indirect taxation through the opening of the *Lijin* tax, reducing the proportion of land tax to less than 50% of national fiscal revenue[24]. In stark contrast, the Song dynasty (10th –13th century) sourced approximately 40% of its tax revenue from commercial taxes, with the ratio of indirect taxes reaching an astonishing 84.7% (Qi, 2009). This shift towards indirect taxation may have prompted the Song empire to place greater emphasis on commercial activities for securing tax income, leading to a hypothesis that the Song dynasty's unique fiscal mechanism contributed to the flourishing of commerce, thereby elevating the role of market forces in determining city locations.

My analysis reveals a notable shift around the 10th century, where the influence of land routes on city locations began to decline, while the impact of waterways and sea transport started to ascend. Given the distinct characteristics of different types of routes, I interpret this phenomenon as a decrease in government influence on the locations of cities, with market forces driven by domestic and international trade becoming increasingly significant. This temporal juncture coincides with the onset of the Song dynasty (circa 960 AD), a period uniquely characterized within Chinese history. Specifically, the Song dynasty might represent the only era in pre-industrial China predominantly reliant on indirect taxes rather than direct taxes as the primary source of revenue, potentially marking it as the first sustainable tax state in global history(Liu, 2015).After the Song

[24]However, after 1850, railway is introduced into China, and therefore change the whole transport mode.

and Yuan dynasties, I observe a long-term decline in the coefficient for waterways, continuing to the present day. This trend corresponds with the government's return to relying on direct taxes, such as land taxes.

Columns (2) and (4) of Table 4.8 and figure 4.18 display the regression analysis results from Equation 4.6. Here, I use whether a dynasty depend on indirect tax as its main method of taxation as an institutional treatment. Specifically, if a dynasty primarily relied on indirect taxes as the main method of taxation, I labeled it as 1, otherwise as 0. It can be observed that, at both the city and prefecture levels, the interaction terms between waterways and the taxation method show statistically significant positive results. Additionally, at the city level, the interaction term between the sea route and taxation method is significant within the 90% confidence interval, while at the prefecture level, it is significant within the 95% confidence interval. Conversely, the interaction terms between the land route and taxation method do not show significance at either the city or prefecture level. These results are consistent with the predictions of Hypothesis 1. That is, in dynasties that primarily relied on indirect taxes as the main source of revenue, the government had an incentive to ensure an efficient market, which means that cities were more likely to be located near areas with higher market access, such as places near waterways and estuaries. However, this policy did not impact areas surrounding land routes, as they served more for government information transmission.

#### 4.5.1.2 *Hypothesis two: Location of national capital and governance strategy (Direct VS Delegated Governance)*

Sng and Moriguchi (2014) and Sng (2014) posits that agency problems in governance escalate with the increase in a state's geographical expanse. Specifically, their hypothesis concerning Imperial China suggests that the vastness of the empire, coupled with the costs associated with information dissemination, compelled the sovereign to delegate governance to agents due to monitoring challenges. These agents, motivated by self-interest, were likely to exploit taxpayers, particularly those with limited political clout. To mitigate the risk of exploitation-induced rebellion, the emperor was compelled to maintain low taxation and limit governmental expansion, resulting in a relatively weak state capacity. In contrast, the smaller geographical size of Tokugawa Japan afforded its government enhanced control over its territories, thereby facilitating a stronger state capacity.

Drawing inspiration from their analysis, I propose that the geographical size of an empire and the strategic positioning of its capital may offer a plausible explanation for this article's observations. Specifically, I argue that if a capital is situated in a location that allows for straightforward access to a substantial portion of the empire's economic activities, it is likely for governments to position cities closer to main land routes to enable better control through direct information flow. Conversely, a capital located far from economic hubs or near the empire's borders is more inclined to govern through local delegates, leading to cities being established away from main roads.

Figure 4.17 illustrates the locations of the capitals relative to the population centroids for the Tang, Song, Ming, and Qing dynasties. Notably, during the Tang and Song dynasties, the capitals were closely positioned to the population centroids. In contrast, the capitals of the Ming and Qing dynasties, both located in Beijing, were markedly distant from the population centroids. This geographical shift correlates with the higher Natural Road Score (NRS) coefficients during the Tang dynasty and lower ones during the Ming and Qing dynasties. Despite the Song dynasty's capital also being proximal to the population centroid, its reliance on indirect taxation and the presence of an efficient market meant that the city's location was influenced by both governmental and strong market forces, resulting in a comparatively lower NRS coefficient than during the Tang dynasty.

Columns 3 and 6 of table 4.8 and figure 4.18, presents the results of Equation 4.6, where the distance between the capital and the population centroid is utilized as an institutional treatment variable. A dynasty is assigned a '1' if the geographical distance from the capital to the population centroid is less than 500 km, otherwise, it is assigned a '0'. Due to the limited availability of reliable population data, centroids are calculated only for periods with documented population records: Tang (726 AD) (Dong, 2002), Song (976 AD, 1102 AD) (Wu, 2000), Ming (1393 AD, 1570 AD) (Cao, 2000), and Qing (1680 AD, 1820 AD, and 1910 AD) (Cao, 2001) dynasties. Therefore, the regression analysis focuses on the years 600, 700, 1000, 1100, 1400, 1500, 1600, 1700, 1800, and 1900. The distance between population centroids and national capital is reported in table 4.9.

Column 3 reveals that at the city level, only the interaction term for land routes shows significance, whereas waterways and sea routes do not, consistent with Hypothesis 2. Interestingly, column 6 indicates that at the prefecture level, no interaction terms are significant. This discrepancy between city and prefecture levels could be attributed to two factors: (1) Prefecture level cities have larger urban scales and exhibit greater urban resilience. Although affected by market forces, their robustness against governmental influence is enhanced. (2) The location of prefecture level cities is heavily influenced by their administrative status.(Düben and Krause, 2023) Being predominantly determined by governmental influence and institutional arrangements, their locations remain unaffected by changes in governance strategy across different periods.

### 4.5.2 Maritime silk road, the coming of Arabs and Europeans and Sea Ban Policy

China has records of large-scale ocean voyaging dating back to before the Common Era[25], but these activities were predominantly governmental. It was not until the 6th century CE that records began to frequently mention civilian maritime activities. These voyages, often directed towards Southeast Asia and as far as India, were primarily for religious and cultural exchanges, especially involving Buddhism. (Deng, 1999)

Maritime trade on a large scale in China began in the 8th century with the arrival of Arab merchants, who dominated the maritime commerce for the next six centuries, up to the end of the 14th century. Initially, these merchants maintained their commercial and familial connections through Islamic beliefs, legal norms, and cultural practices, such as dietary laws. However, over time, their ties to their homelands in West Asia weakened, and they gradually integrated into Chinese society.

[25] A typical example from Chinese history is the expedition led by Xu Fu during the Qin Dynasty. Xu Fu commanded a large fleet on a maritime quest to find the elixir of life for Emperor Qin Shi Huang.

Chaffee (2018) divides this historical narrative into three phases. The first phase occurred during the 8th and 9th centuries under the Tang Dynasty, when Muslim merchants dominates China's overseas trade. The second phase took place during the Southern Song Dynasty when, although foreign merchants were prohibited from entering city walls, Muslim traders established their own communities on the outskirts of cities like Quanzhou. The third phase saw an increase in the influence of Muslim merchants in China following the Yuan Dynasty's conquest of the Southern Song. However, with the advent of the Ming Dynasty and the strict maritime prohibitions imposed by Emperor Hongwu[26], these Muslim maritime trade communities rapidly declined.

Subsequently, since the 17th century, with the arrival of Europeans, maritime trade in Southeast Asia flourished anew. (Deng, 1997, 1999) Research indicates that since the 17th century, Southeast Asia's trade experienced unprecedented prosperity, with American silver flowing into China through European maritime trade, leading to the emergence of a vibrant financial market in Manila. (Rivas Moreno, 2022) The revival of international trade prompted urban migration towards locations with natural advantages as ports.

This historical context aligns with the observations made in Figure 4.19, where the coefficient between city locations and natural harbors has been rising historically until the Ming Dynasty implemented maritime restrictions, leading to a significant decline in this coefficient. From the 17th century onwards, an increase in the coefficient can again be observed. This observation is aligning with market access literature in economic geography, which stating the connection between market access and location of cities. (Redding and Sturm, 2008b; Donaldson and Hornbeck, 2016; Coşar and Fajgelbaum, 2016)

### 4.5.3 Division and Unification

It might be suggested that that during periods of unification and division in China, different types of governance (unified dynasties vs. regional regimes) might lead to varying marginal effects of natural endowments on city locations.

[26]The so called Sea Ban policy. (Kung and Ma, 2014)

Figures 4.20 and 4.21 build upon Figures 4.13 by incorporating color coding to indicate periods of unification and division in Chinese history, red for times of division and green for times of unification. I observe that the fluctuations in the marginal effects of natural endowments on the three modes of transportation do not display a consistent correlation with historical periods of unification and division at the city level.

To further investigate whether periods of division and unification in Chinese history influence the marginal effects of natural endowments on the transportation networks and the location of cities, I present the following estimates:

$$Y_{it} = \beta_1 Routes_i + \beta_2 \left( Routes_i \times Division_t \right) + \lambda_i + dynasty_t + year_t + \epsilon_{it}. \tag{4.7}$$

Here, $Division_t$ represents whether China Proper was in a divided state in $year_t$, meaning it was controlled by more than one de facto regime. The interaction term between $Division$ and $Routes_i$ captures whether the marginal effect of $Routes_i$ varies over time between periods of unification and division. The results from Equation 4.7 are reported in Figure 4.18 and Table 4.8, columns (5) and (6). As shown in column (5) and (6), both at the city level and prefecture level, there is no significant association between the state of unification or division and the marginal effect of natural endowments on three modes of transportation route.

### 4.5.4 Nomad invasions and three mass migrations in Chinese history

Historians have identified three major waves of mass migration in Chinese history, each triggered by significant nomadic invasions: the Yongjia Southward Migration in 307 CE, the An Lushan Rebellion in 755 CE, and the Jingkang Incident in 1126 CE. These pivotal events are believed to have reshaped the demographic and economic landscapes of China Proper by redistributing populations and economic activities across regions over time (Chen and Kung, 2022b). Evidence from molecular anthropology also supports these historical accounts, indicating substantial southward migrations from Northern to Southern China (Wen et al., 2004).

Historical and economic studies suggest that, despite their relatively small scale, these migrations shifted centers of population and economic growth. In particular, the migrations following the second (755) and third (1126) events initiated an "urban revolution" marked by increased long-distance trade, the rise of market towns, and rapid urbanization (Chen and Kung, 2022a; Elvin, 1973; Shiba, 1970).

This study examines the correlation between natural endowments along migration routes and city locations in the context of these migration events. Figures 4.20 and 4.21 provide a visual impression, with three red lines representing each migration event. To statistically test for changes before and after these events, I apply the following model:

$$Y_{it} = \beta Routes_i + \gamma \left( Routes_i \times Event_t \right) + \lambda_i + dynasty_t + \epsilon_{it}. \tag{4.8}$$

This equation will compare the marginal effects of natural endowments on the three modes of transportation in periods following each event to those preceding it. Using the period before each event as $T+0$ and the first period after as $T+1$, I present results at the city level in Table 4.10. For the first event, we observe a significant reduction in the influence of land routes at $T+1$ compared to $T+0$, while the marginal effect of sea routes shows a notable increase. This period coincides with a fragmentation of governance and increased invasions from northern nomads, leading to a decline in the impact of land routes. Concurrently, the significant rise in the effect of sea routes at $T+1$ and $T+2$ aligns with the long-term expansion of international trade.

For the second event, no significant changes are observed in $T+1$, $T+2$, or $T+3$. In contrast, the third event exhibits a noticeable shift in the marginal effect of land routes at $T+1$, albeit relatively small (0.009 compared to 0.174 in year 1100 CE). Additionally, a significant increase in the marginal effect of sea routes is observed at both $T+1$ and $T+2$, corresponding with the trend of burgeoning internal trade. By $T+3$, this statistical significance disappears, coinciding with the dynasty transition to the Ming and the imposition of maritime prohibitions. The coefficient for land routes also changes notably at $T+3$, likely due to this dynastic shift.

In summary, examining the marginal effects of natural endowments on transportation routes reveals differing impacts from the three waves of migration. While events 1 and 3 both had short-term effects on land and sea routes, their mechanisms of impact differed, and event 2 did not produce any significant changes. This suggests that other factors may have driven these shifts. Additionally, none of these impacts proved to be long-term, with effects generally dissipating by $T + 2$. Moreover, these findings suggest that at the city level, the three waves of southward migration may not have had as profound an impact on urban location as traditionally described by historians.

## 4.6 Conclusion

This study provides new empirical evidence demonstrating that the role of natural endowments in shaping cities is valued differently depending on prevailing institutional settings. Using data from the China Historical Geographic Information System (CHGIS) on historical cities and exogenous proxies for historical transportation networks, the study reveals that the correlation between natural endowments on transportation routes and city locations is not constant throughout Chinese history. Instead, these correlations exhibit significant shifts aligned with dynastic cycles. Mechanism tests highlight that governance strategies, such as capital location and modes of administration, and taxation structures—whether reliant on direct taxation like land taxes or indirect taxation like commercial taxes—were key institutional factors driving these changes.

Specifically, governance strategies influenced the spatial alignment of cities with land routes. Dynasties with capitals situated close to economic centers tended to employ direct governance strategies, leading to cities being concentrated near major land routes. In contrast, more distant capitals often necessitated proxy governance systems, resulting in cities being located further from these routes. Similarly, taxation structures played a pivotal role in shaping the influence of waterways and domestic trade networks on city development. Dynasties reliant on indirect taxes, such as the Song Dynasty, placed a higher emphasis on fostering efficient markets, which increased the significance of waterways in determining city locations. Conversely, dynasties primarily dependent on direct taxes saw a diminished role for such trade-driven factors.

For sea routes, the study reveals a complex dynamic shaped by both institutional policies and external trade forces. During the Tang and Song dynasties, the arrival of Arab merchants and later European traders played a crucial role in advancing China's maritime trade, fostering the growth of coastal port cities as key international trade hubs. This development was interrupted during the Ming Dynasty, when the implementation of the sea ban (Haijin policy) significantly restricted maritime trade, temporarily reducing the influence of sea routes on city locations. From the late Ming into the Qing Dynasty, the revival of international trade—driven by European maritime powers and the global flow of American silver—restored the significance of sea routes. Cities near natural estuaries along the southeastern coast experienced sustained growth, becoming vital centers for both international trade and emerging financial markets.

## 4.7 Tables

Table 4.1: *Transport cost and speed in historical China*

| Time | Travel Method | Nominal Price | Silver Grams | Grain Liter |
|---|---|---|---|---|
| | | *Copper Coin/100kg/100km* | | |
| Tang(738) | Land | 498.00 | 18.56 | 149.40 |
| | Waterway | 165.84 | 6.19 | 49.75 |
| Song(1202) | Land | 336.02 | 3.84 | 8.41 |
| | Waterway | 33.60 | 0.38 | 0.84 |
| | | *Zhongtong Chao/100kg/100km* | | |
| yuan(1288) | Land | 0.33 | 12.50 | 32.05 |
| | Waterway | 0.02 | 0.75 | 1.92 |
| | | *Silver Tales/100kg/100km* | | |
| Qing (1694) | Land | 0.21 | 7.95 | 25.72 |
| | Waterway | 0.02 | 0.60 | 1.93 |
| Qing (1890) | Land | 0.65 | 24.39 | 27.18 |
| | Waterway | 0.04 | 1.63 | 1.81 |

*Notes:* All data here are for Yangtze China. Tang and Song data are from Liu (2012), Yuan data from *Da De Dian Zhang* (大德典章), Qing (1694) data from my estimation in chapter 1, and Qing (1890) data from Fan (1992) and Kingsmill (1898). All grain price are sourced from Peng (1994).

Table 4.2: *Summary Statistics*

| Variable | Mean | SD | Min | Max | No. obs | Source |
|---|---|---|---|---|---|---|
| *Dependent Variable* | | | | | | |
| City | 0.188 | 0.391 | 0 | 1 | 128919 | (1) |
| Prefecture | 0.039 | 0.195 | 0 | 1 | 128919 | (1) |
| *Independent Variable* | | | | | | |
| Natural Road score | 0.476 | 0.140 | 0 | 1 | 6139 | (2) |
| Estuaries in Southeast China | 0.021 | 0.143 | 0 | 1 | 6139 | (1) |
| Natural Navigable Rivers | 0.076 | 0.265 | 0 | 1 | 6139 | (1) |
| *Geographical Controls* | | | | | | |
| Slope | 7.837 | 6.069 | 0.147 | 27.682 | 6139 | (3) |
| Elevation | 1045.589 | 1120.662 | 0 | 4796.556 | 6139 | (3) |
| Agriculture Suitability | 677.019 | 291.731 | 0 | 1083.040 | 6139 | (2) |
| 200 km Coastal Dummy | 0.234 | 0.423 | 0 | 1 | 6139 | (1) |
| Latitude | 31.208 | 5.453 | 18.293 | 42.793 | 6139 | |
| Longitude | 109.442 | 6.667 | 92.789 | 122.289 | 6139 | |

*Notes:* Data Sourced from (1) CHGIS, (2) GAEZ and (3) SRTM. "City" and "Prefecture" are variables indicating whether a cell is occupied by county-level or prefecture-level administrative units in a given year. "Estuaries in Southeast China" is a variable that shows whether a grid cell is located in a suitable area for seaports in Southeast Coastal China. "Natural Navigable Rivers" indicates whether a grid cell is situated in an area with major natural navigable rivers. "Elevation" is measured in meters and "Slope" in degrees; both represent the average values for the designated cell. "Agriculture suitability" measures the average potential agricultural production of a cell, expressed in calories per square meter per year. "Latitude" and "Longitude" are also provided in degrees. "City" and "Prefecture" are time-variant, all other variables are time-invariant.

Table 4.3: *Geographical Parameters Results*

| | OLS | | | Logit |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Panel A *Cities* | | | | |
| Agriculture Suitability | 0.112*** | 0.131*** | 0.074** | 2.098*** |
| | (0.037) | (0.035) | (0.032) | (0.332) |
| Terrain Slope | -0.012*** | -0.015*** | -0.022*** | -0.175*** |
| | (0.002) | (0.001) | (0.002) | (0.011) |
| Ln Elevation | -0.008 | 0.003 | 0.006 | 0.166*** |
| | (0.009) | (0.008) | (0.009) | (0.044) |
| Longitude | 0.004 | -0.000 | -0.004 | -0.010 |
| | (0.002) | (0.003) | (0.010) | (0.022) |
| Latitude | -0.001 | -0.008*** | -0.019* | 0.006 |
| | (0.002) | (0.003) | (0.011) | (0.025) |
| Coast 200km | -0.057** | -0.062* | -0.008 | -0.257 |
| | (0.028) | (0.031) | (0.023) | (0.168) |
| R-squared | 0.074 | 0.094 | 0.178 | 0.1231 |
| Panel B *Prefecture Seats* | | | | |
| Agriculture Suitability | 0.041*** | 0.034*** | 0.019 | 2.024*** |
| | (0.008) | (0.009) | (0.014) | (0.323) |
| Terrain Slope | -0.003*** | -0.004*** | -0.007*** | -0.175*** |
| | (0.000) | (0.000) | (0.001) | (0.016) |
| Ln Elevation | -0.000 | 0.001 | -0.000 | 0.137*** |
| | (0.002) | (0.002) | (0.003) | (0.046) |
| Longitude | -0.001** | -0.001* | -0.006 | -0.059*** |
| | (0.001) | (0.001) | (0.004) | (0.022) |
| Latitude | -0.001 | -0.001 | -0.006 | 0.034 |
| | (0.000) | (0.001) | (0.004) | (0.023) |
| Coast 200km | -0.003 | -0.004 | -0.002 | 0.011 |
| | (0.006) | (0.007) | (0.009) | (0.144) |
| R-squared | 0.012 | 0.019 | 0.053 | 0.0759 |
| Macro Region FE | | Yes | | Yes |
| 1 Degree Cell FE | | | Yes | |
| Year FE | | Yes | Yes | Yes |
| Observations | 128,919 | 128,919 | 128,919 | 128,919 |

*Notes:* Standard errors in parentheses. Standard error clusters at the level of 2-degree cells ($^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$). The dependent variable here is a dummy for whether a cell is occupied by cities or prefecture-level administrative units in the designated year.

Table 4.4: *Main Results*

| | OLS | | | | Logit |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Panel A *Cities* | | | | | |
| Land Route | 0.046 | 0.164*** | 0.167*** | 0.073** | 0.902*** |
| | (0.045) | (0.042) | (0.039) | (0.035) | (0.278) |
| Waterway | 0.168*** | 0.103*** | 0.113*** | 0.125*** | 0.511*** |
| | (0.025) | (0.024) | (0.020) | (0.018) | (0.097) |
| Sea Route | 0.130*** | 0.076* | 0.093** | 0.092** | 0.546*** |
| | (0.038) | (0.039) | (0.037) | (0.037) | (0.194) |
| R-squared | 0.015 | 0.086 | 0.105 | 0.184 | 0.135 |
| Panel B *Prefectures* | | | | | |
| Land Route | 0.053*** | 0.054*** | 0.055*** | 0.039*** | 1.225*** |
| | (0.012) | (0.012) | (0.012) | (0.013) | (0.331) |
| Waterway | 0.080*** | 0.071*** | 0.073*** | 0.081*** | 1.141*** |
| | (0.010) | (0.009) | (0.009) | (0.010) | (0.119) |
| Sea Route | 0.071*** | 0.060*** | 0.062*** | 0.059*** | 1.216*** |
| | (0.016) | (0.018) | (0.017) | (0.018) | (0.288) |
| R-squared | 0.015 | 0.025 | 0.032 | 0.064 | 0.103 |
| Geographical Controls | | Yes | Yes | Yes | Yes |
| Macro Region FE | | | Yes | | Yes |
| 1 Degree Cell FE | | | | Yes | |
| Year FE | | | Yes | Yes | Yes |
| Observations | 128,919 | 128,919 | 128,919 | 128,919 | 128,919 |

*Notes:* Standard error clusters at the level of 2-degree cells, in parentheses ($^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$).The dependent variable here is a dummy for whether a cell is occupied by cities or prefecture-level admiration units in the designated year. *Land Route* is normalized to a scale of 0 to 1 using the natural logarithm of the Natural Road Score, based on a 400-hour distance. *Sea Route* is a binary variable indicating whether a grid is physically suitable for seaports in Southeast Coastal China. *Waterway* is a binary variable indicating whether a grid is located near a major navigable river. Additional controls include the terrain's slope, the natural logarithm of elevation, a 200 km coast dummy, longitude, and latitude. Finally, to capture the spatial variance of China, I introduce spatial fixed effect at the level of China's macro-regions as proposed in Skinner (1977) and 1 degree cell.

Table 4.5: *Cross Sectional Results (cities) and brief dynastic history*

| Year | Land Route | Waterway | Sea Route | Dynasty | Capital | History |
|---|---|---|---|---|---|---|
| 1 | 0.189*** (0.049) | 0.073*** (0.019) | 0.027 (0.040) | Han | Xi'an / Luoyang | First long-lasting centralized unified empire |
| 100 | 0.163*** (0.048) | 0.074*** (0.020) | 0.035 (0.041) | | | |
| 200 | 0.153*** (0.048) | 0.078*** (0.021) | 0.032 (0.038) | | | |
| 300 | 0.199*** (0.054) | 0.110*** (0.023) | 0.059 (0.043) | Jin | Luoyang / Nanjing | Fragmentation and internal strife, marked by northern nomad invasions |
| 400 | 0.145*** (0.050) | 0.112*** (0.023) | 0.081* (0.042) | | | |
| 500 | 0.174*** (0.061) | 0.109*** (0.024) | 0.091** (0.039) | SND | Null | Southern and Northern dynasties, era of political division |
| 600 | 0.184*** (0.062) | 0.116*** (0.028) | 0.066 (0.041) | Sui | Xi'an | Reunification, built the grand canal |
| 700 | 0.238*** (0.054) | 0.109*** (0.029) | 0.059 (0.060) | Tang | Xi'an | A golden age of cosmopolitan culture and global trade (Silk Road), politically in-stabilized since Anshi Rebellion (755 CE) |
| 800 | 0.239*** (0.052) | 0.099*** (0.030) | 0.087 (0.068) | | | |
| 900 | 0.218*** (0.052) | 0.106*** (0.029) | 0.093 (0.066) | | | |
| 1000 | 0.156*** (0.050) | 0.138*** (0.028) | 0.100** (0.050) | Song | Kaifeng / Hangzhou | Peak in economic and cultural development, heavily rely on commercial taxes (both domestic and international trade), political fragmentation since nomad invasion in 1126 |
| 1100 | 0.174*** (0.050) | 0.152*** (0.028) | 0.109** (0.046) | | | |
| 1200 | 0.169*** (0.051) | 0.149*** (0.028) | 0.117** (0.048) | | | |
| 1300 | 0.157*** (0.047) | 0.160*** (0.028) | 0.149*** (0.048) | Yuan | Beijing | Mongol Empire, paper money, high inflation, sea trade with Arabs |
| 1400 | 0.120*** (0.046) | 0.140*** (0.028) | 0.131*** (0.045) | Ming | Nanjing / Beijing | Han Regime, sea ban policy, silver emerged as the primary currency |
| 1500 | 0.107** (0.051) | 0.118*** (0.028) | 0.111** (0.048) | | | |
| 1600 | 0.114** (0.051) | 0.122*** (0.026) | 0.102** (0.048) | | | |
| 1700 | 0.132*** (0.048) | 0.112*** (0.024) | 0.106** (0.047) | Qing | Beijing | China's last imperial dynasty, manchurian regime, restrictions on literati |
| 1800 | 0.161*** (0.048) | 0.100*** (0.024) | 0.125*** (0.049) | | | |
| 1900 | 0.181*** (0.049) | 0.103*** (0.024) | 0.149*** (0.045) | | | |
| 2023 | 0.142*** (0.044) | 0.094*** (0.024) | 0.130*** (0.037) | PRC | Beijing | Modern China under rapid development and globalization |

*Notes:* Standard error clusters at the level of 2-degree cells, in parentheses ($^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$).

Table 4.6: *Cross Sectional Results*

| | 1 CE | 200 CE | 400 CE | 600 CE | 800 CE | 1000 CE | 1200 CE | 1400 CE | 1600 CE | 1800 CE | 2023 CE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Panel A *Cities* | | | | | | | | | | | |
| Land Route | 0.189*** | 0.153*** | 0.145*** | 0.184*** | 0.238*** | 0.156*** | 0.169*** | 0.120** | 0.114** | 0.161*** | 0.141*** |
| | (0.0487) | (0.0479) | (0.0499) | (0.0618) | (0.0523) | (0.0502) | (0.0512) | (0.0464) | (0.0505) | (0.0482) | (0.0436) |
| Waterway | 0.0729*** | 0.0778*** | 0.112*** | 0.116*** | 0.0987*** | 0.138*** | 0.149*** | 0.140*** | 0.122*** | 0.100*** | 0.0935*** |
| | (0.0187) | (0.0210) | (0.0225) | (0.0283) | (0.0296) | (0.0284) | (0.0278) | (0.0282) | (0.0264) | (0.0239) | (0.0241) |
| Sea Route | 0.0266 | 0.0315 | 0.0810* | 0.0658 | 0.0870 | 0.100** | 0.117** | 0.131*** | 0.102** | 0.125** | 0.130*** |
| | (0.0404) | (0.0383) | (0.0416) | (0.0405) | (0.0675) | (0.0499) | (0.0479) | (0.0451) | (0.0481) | (0.0486) | (0.0366) |
| Adj R-squared | 0.195 | 0.161 | 0.0965 | 0.138 | 0.126 | 0.120 | 0.112 | 0.0890 | 0.0889 | 0.0953 | 0.0720 |
| Panel B *Prefectures* | | | | | | | | | | | |
| Land Route | 0.0284** | 0.0308** | 0.0730*** | 0.0351 | 0.0707*** | 0.0786*** | 0.0739*** | 0.0533** | 0.0596*** | 0.0711*** | 0.0576*** |
| | (0.0118) | (0.0142) | (0.0211) | (0.0219) | (0.0224) | (0.0274) | (0.0282) | (0.0206) | (0.0221) | (0.0223) | (0.0199) |
| Waterway | 0.0136** | 0.0252*** | 0.0558*** | 0.0514*** | 0.0912*** | 0.110*** | 0.108*** | 0.0974*** | 0.100*** | 0.0921*** | 0.0720*** |
| | (0.00618) | (0.00817) | (0.0140) | (0.0116) | (0.0187) | (0.0176) | (0.0159) | (0.0157) | (0.0167) | (0.0142) | (0.0140) |
| Sea Route | 0.00107 | 0.0170 | 0.0470** | 0.0347** | 0.0649* | 0.0604** | 0.0828*** | 0.0834*** | 0.0810*** | 0.0789*** | 0.128*** |
| | (0.00757) | (0.0156) | (0.0199) | (0.0155) | (0.0352) | (0.0300) | (0.0268) | (0.0268) | (0.0279) | (0.0256) | (0.0288) |
| Adj R-squared | 0.0136 | 0.0175 | 0.0196 | 0.0242 | 0.0376 | 0.0372 | 0.0356 | 0.0353 | 0.0338 | 0.0314 | 0.0372 |
| Geographical Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Macro Region Dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| No. obs. | 6139 | 6139 | 6139 | 6139 | 6139 | 6139 | 6139 | 6139 | 6139 | 6139 | 6139 |

*Notes:* The table reports the result for 4.3. The dependent variable here is a dummy for whether a cell is occupied by cities or prefecture-level admiration units in the designated year. Standard error clusters at the level of 2-degree cells, in parentheses ($^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$). *Land Route* is normalized to a scale of 0 to 1 using the natural logarithm of the Natural Road Score, based on a 400-hour distance. *Sea Route* is a dummy for whether a grid is located on a place good for seaports physically in Southeast Coastal China. *Waterway* is a dummy for whether a grid is located near one of the major navigable rivers. Additional controls includes slope, natural log of elevation, a 200 km coast dummy, longitude, and latitude. Finally, to capture the spatial variance of China, I introduce dummies for China's macro-regions as proposed in Skinner (1977).

Table 4.7: *Comparing Dynasty's marginal effect with Qing as baseline*

| | *Cities* | | | *Prefecture Seats* | | |
|---|---|---|---|---|---|---|
| | Land | Sea | Waterway | Land | Sea | Waterway |
| Han | 0.186*** | -0.174*** | -0.123*** | -0.020 | -0.088*** | -0.086*** |
| | (0.055) | (0.043) | (0.025) | (0.018) | (0.024) | (0.015) |
| Jin | 0.125** | -0.115** | -0.042* | 0.011 | -0.056** | -0.052*** |
| | (0.048) | (0.046) | (0.025) | (0.018) | (0.026) | (0.014) |
| SND | 0.113** | -0.067 | -0.026 | 0.029 | -0.036 | -0.056*** |
| | (0.052) | (0.045) | (0.024) | (0.021) | (0.031) | (0.016) |
| Sui | 0.211*** | -0.092 | -0.030 | 0.005 | -0.061*** | -0.042*** |
| | (0.057) | (0.062) | (0.029) | (0.021) | (0.023) | (0.014) |
| Tang | 0.149** | -0.023 | -0.003 | 0.001 | -0.010 | -0.002 |
| | (0.059) | (0.051) | (0.028) | (0.022) | (0.018) | (0.017) |
| Song | 0.101*** | -0.033 | 0.027* | 0.013 | -0.006 | 0.014 |
| | (0.038) | (0.036) | (0.016) | (0.018) | (0.014) | (0.011) |
| Yuan | 0.061** | 0.002 | 0.024* | -0.020 | 0.017 | 0.013 |
| | (0.029) | (0.031) | (0.014) | (0.016) | (0.012) | (0.011) |
| Ming | 0.010 | -0.030** | 0.006 | -0.005 | -0.008 | -0.001 |
| | (0.024) | (0.013) | (0.008) | (0.013) | (0.006) | (0.006) |
| PRC | 0.054 | -0.017 | -0.032 | -0.027 | 0.054* | -0.018 |
| | (0.036) | (0.041) | (0.022) | (0.022) | (0.031) | (0.013) |

*Notes:* The Qing Dynasty is used as the baseline, covering the years 1700, 1800, and 1900 CE. Among the compared dynasties, the Han includes 1, 100, and 200 CE; the Jin covers 300 and 400 CE; SND (Southern and Northern Dynasties) includes 500 CE; the Sui covers 600 CE; the Tang includes 700, 800, and 900 CE; the Song covers 1000, 1100, and 1200 CE; the Yuan includes 1300 CE; the Ming covers 1400, 1500, and 1600 CE; and PRC (People's Republic of China) includes 2023 CE.

Table 4.8: *Mechanism: Institutions and Natural Endowments on Routes*

| | Taxation | | Governance | | Division&Unification | |
|---|---|---|---|---|---|---|
| | City | Pref | City | Pref | City | Pref |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Land Route | -0.009 | 0.005 | -0.046*** | -0.004 | -0.003 | 0.000 |
| | (0.027) | (0.012) | (0.012) | (0.005) | (0.005) | (0.003) |
| Waterway | 0.057*** | 0.043*** | -0.006 | 0.001 | -0.008 | -0.010 |
| | (0.012) | (0.009) | (0.019) | (0.014) | (0.010) | (0.006) |
| Sea Route | 0.043* | 0.033** | 0.039 | 0.020 | -0.021 | -0.007 |
| | (0.026) | (0.013) | (0.040) | (0.016) | (0.017) | (0.009) |
| Observations | 122,780 | 122,780 | 61,390 | 61,390 | 122,780 | 122,780 |
| R-squared | 0.106 | 0.032 | 0.099 | 0.033 | 0.106 | 0.031 |

*Notes:* Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Taxation is a dummy variable indicating whether a specific year relied primarily on indirect taxation. Governance is a dummy variable indicating whether, in a given year, the distance between the national capital and the population centroid exceeded 500 km. Division & Unification is a dummy variable representing whether, during a particular time period, China proper was in a generally fragmented state.

Table 4.9: *Distance between population centroid and National Capital*

| Year | Dynasty | Distance (km) |
|---|---|---|
| 600 - 700 | Tang | 455 |
| 1000 - 1100 | Song | 352 |
| 1400 - 1600 | Ming | 989 |
| 1700 - 1900 | Qing | 970 |

*Notes:* Population centroids are calculated only for periods with documented population records: Tang (726 AD) (Dong, 2002), Song (976 AD, 1102 AD) (Wu, 2000), Ming (1393 AD, 1570 AD), and Qing (1680 AD, 1820 AD, and 1910 AD) (Cao, 2000).

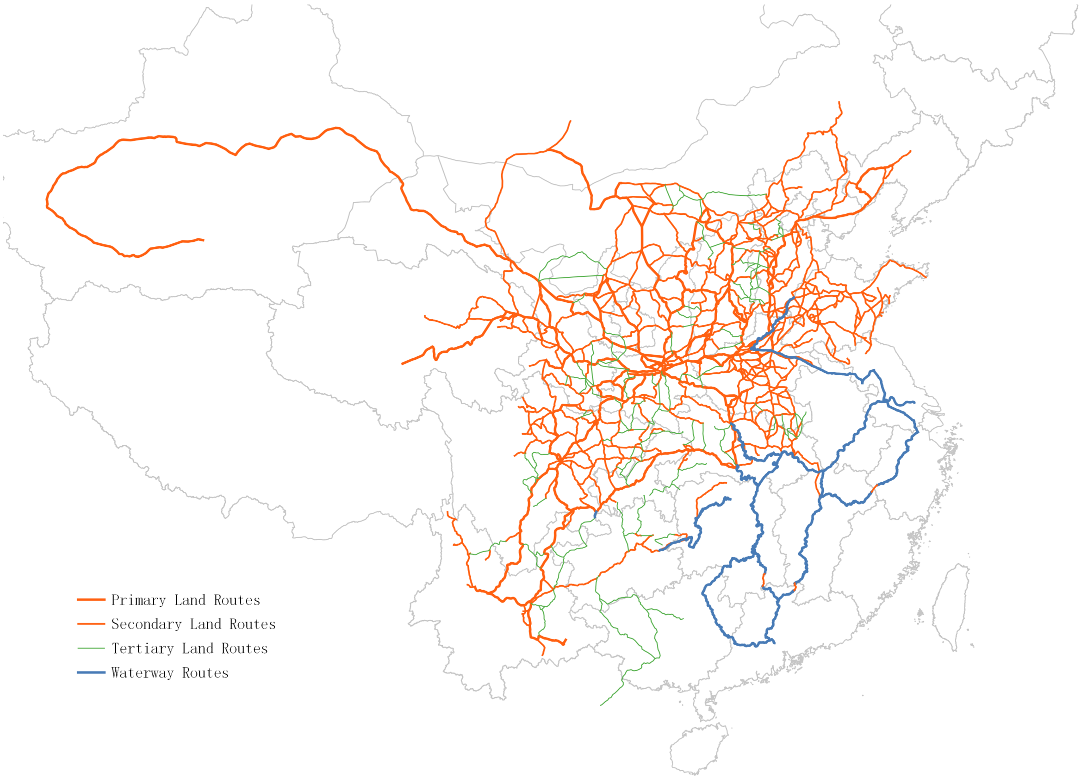
Table 4.10: *Nomad invasions and three mass migrations in Chinese history (cities)*

| | Event 1 (304 CE) | Event 2 (758 CE) | Event 3 (1126 CE) |
|---|---|---|---|
| *T+1* | *400 CE* | *800 CE* | *1200 CE* |
| Land Route | -0.029** | 0.002 | 0.009** |
| | (0.012) | (0.008) | (0.004) |
| Waterway | 0.015 | 0.005 | -0.000 |
| | (0.011) | (0.015) | (0.006) |
| Sea Route | 0.037** | 0.046 | 0.022* |
| | (0.016) | (0.030) | (0.011) |
| *T+2* | *500 CE* | *900 CE* | *1300 CE* |
| Land Route | -0.026 | 0.000 | -0.037 |
| | (0.031) | (0.008) | (0.025) |
| Waterway | 0.024 | 0.008 | -0.006 |
| | (0.017) | (0.013) | (0.012) |
| Sea Route | 0.066* | 0.046 | 0.042** |
| | (0.037) | (0.030) | (0.019) |
| *T+3* | *600 CE* | *1000 CE* | *1400 CE* |
| Land Route | 0.071 | -0.049 | -0.063** |
| | (0.046) | (0.041) | (0.029) |
| Waterway | 0.021 | 0.028 | -0.019 |
| | (0.028) | (0.024) | (0.014) |
| Sea Route | 0.041 | 0.016 | 0.020 |
| | (0.063) | (0.041) | (0.022) |

*Notes:* Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Result for cities from equation 4.8.

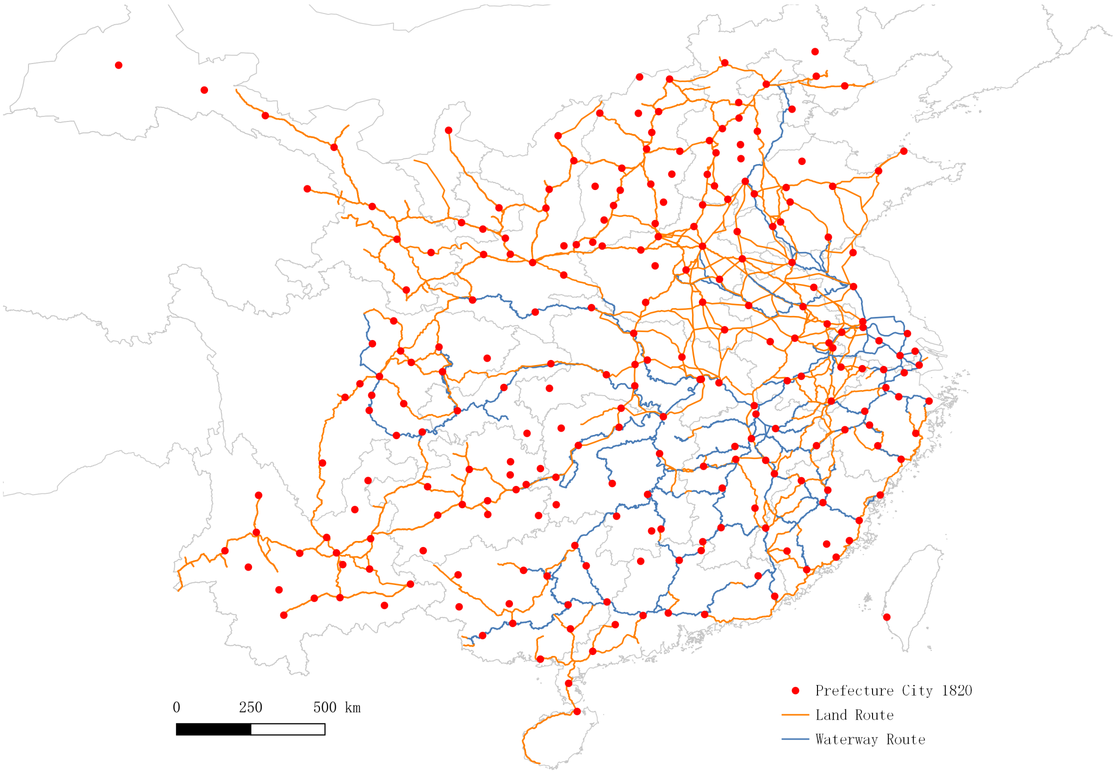
## 4.8 Figures

Figure 4.1: *Transportation Routes in Tang China*



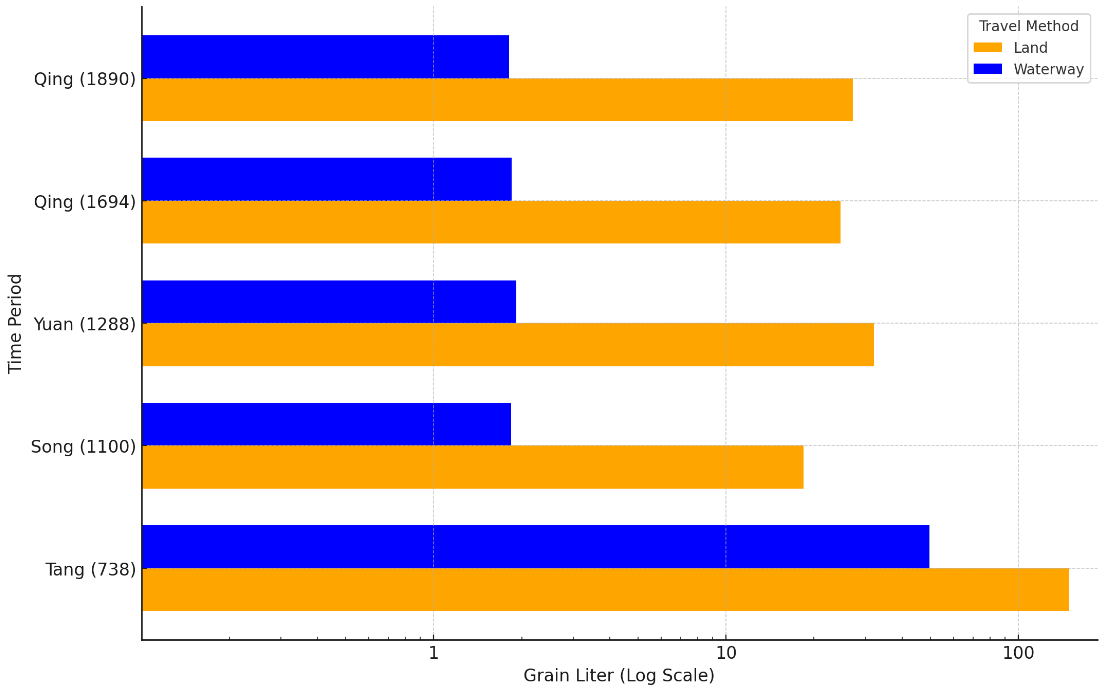

*Note:* Reconstructed with Yan (1985), Zeng (1987) and Zhu (2014). The national transportation network in Tang China (7th century) remains largely unknown, as Yan passed away before completing his study of the entire network.

Figure 4.2: *Transportation Routes in Ming-Qing China*



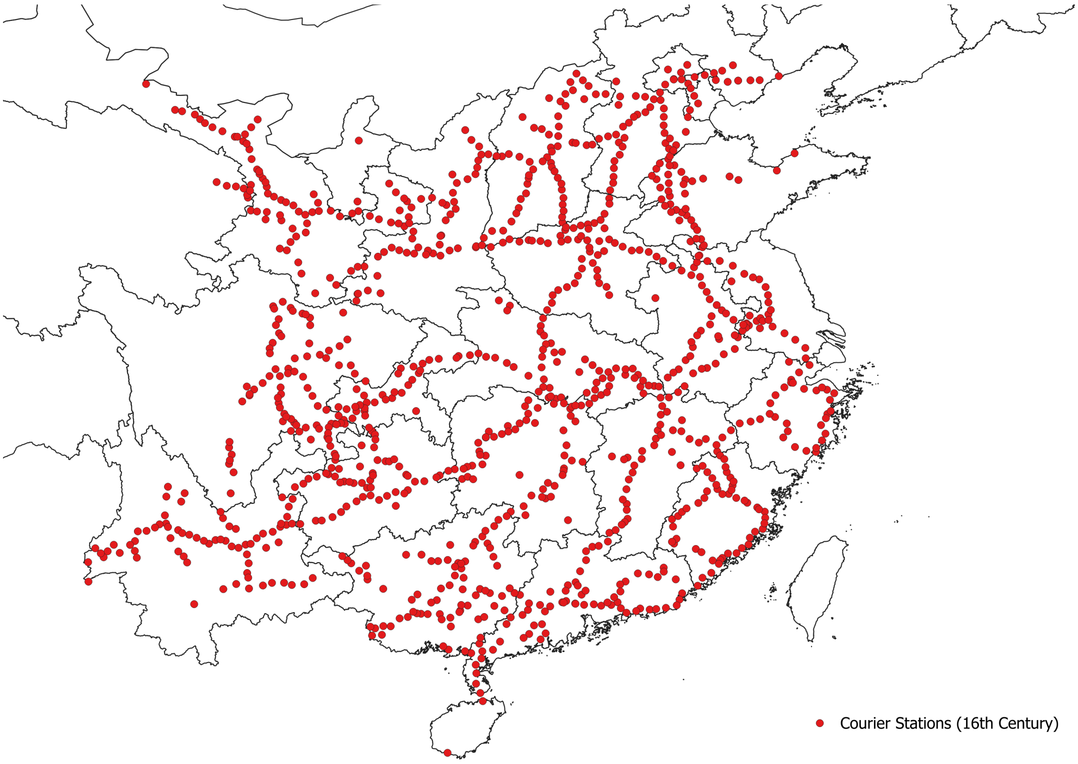

*Note: Reconstructed through historical route books in Ming China*

Figure 4.3: *Transport Costs over Different Dynasties in Historical China*




*Note:* Data source and notes see table 4.1

FIGURE 4.4: *Courier Stations in Late-Ming (16th Century) China*




*Note: Sourced from Yang (2006). I manually geo-referenced all 1029 courier stations recorded in Da Ming Hui Dian(大明会典) according to Yang (2006). More detial see chapter 1*

FIGURE 4.5: *City share in Skinner's Macro Regions across time*

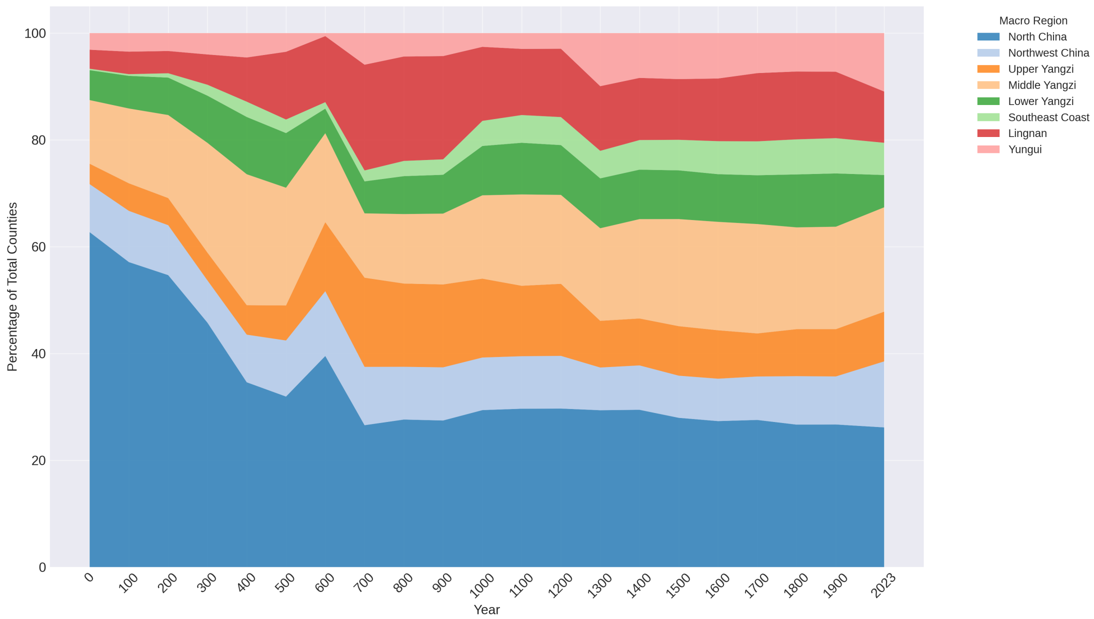


Figure 4.6: *Number of prefecture and county seats recorded in CHGIS*

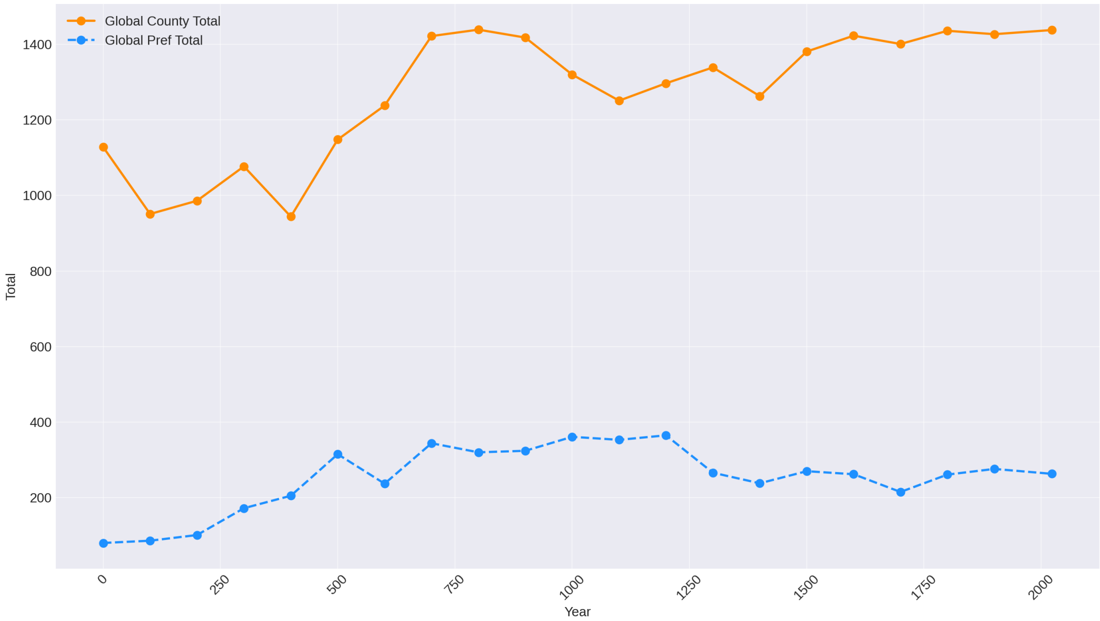
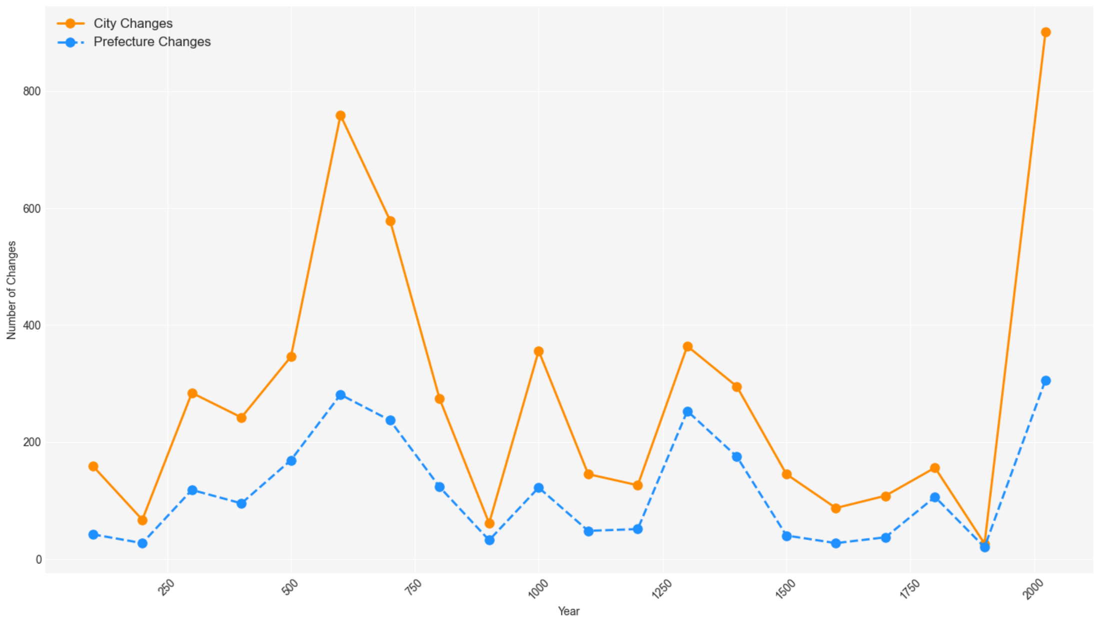
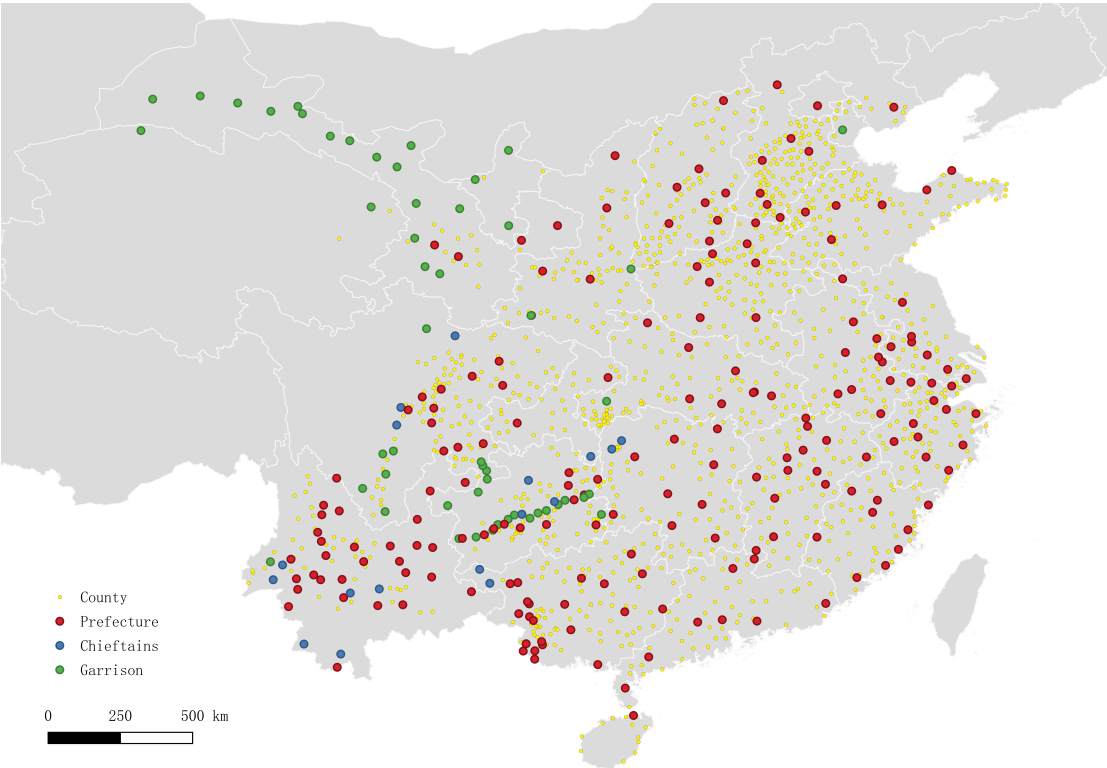



Figure 4.7: *Number of changes in prefecture and city dataset by century*




*Note:* This figure represents changes in cities and prefectures at the cellular level. Specifically, if a cell has a value of 1 at time $t$ and a value of 0 at time $t-1$ or counter-versa, it is counted as a change.

FIGURE 4.8: *CHGIS locations of prefectures and counties in 1500*




*Note:* This image depicts the locations of prefectures and counties in the year 1500 as collected by the China Historical Geographic Information System (CHGIS). Smaller yellow dots represent counties, while larger dots indicate prefectures. Among these, red dots denote prefectures under direct government administration, blue dots represent chieftaincies (*tu si*) —hereditary tribal leadership roles recognized as imperial officials, and green dots are military garrisons. It is observable that although government-administered prefecture seats constitute the majority of prefecture-level units in the CHGIS data for the year 1500, a portion of these units falls under the other administrative jurisdictions.

Figure 4.9: *Area used for NRS calculation and The Study area of this Research*

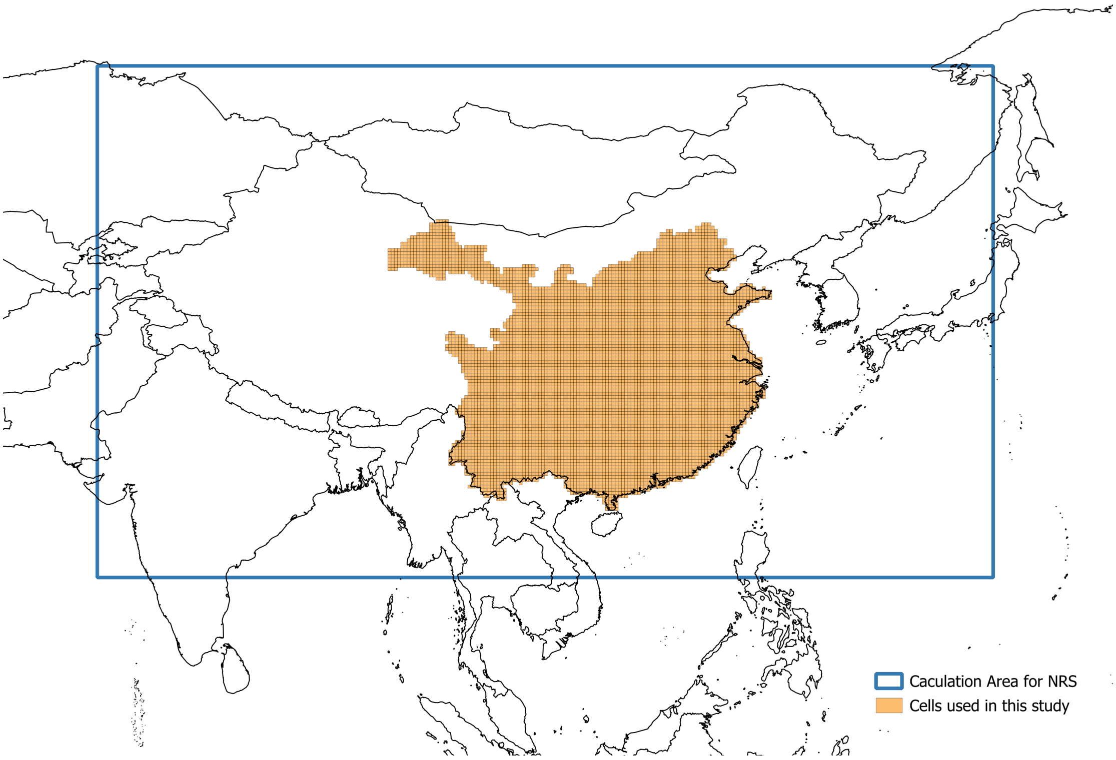



Figure 4.10: *Distribution of Natural Road Score (400h)*

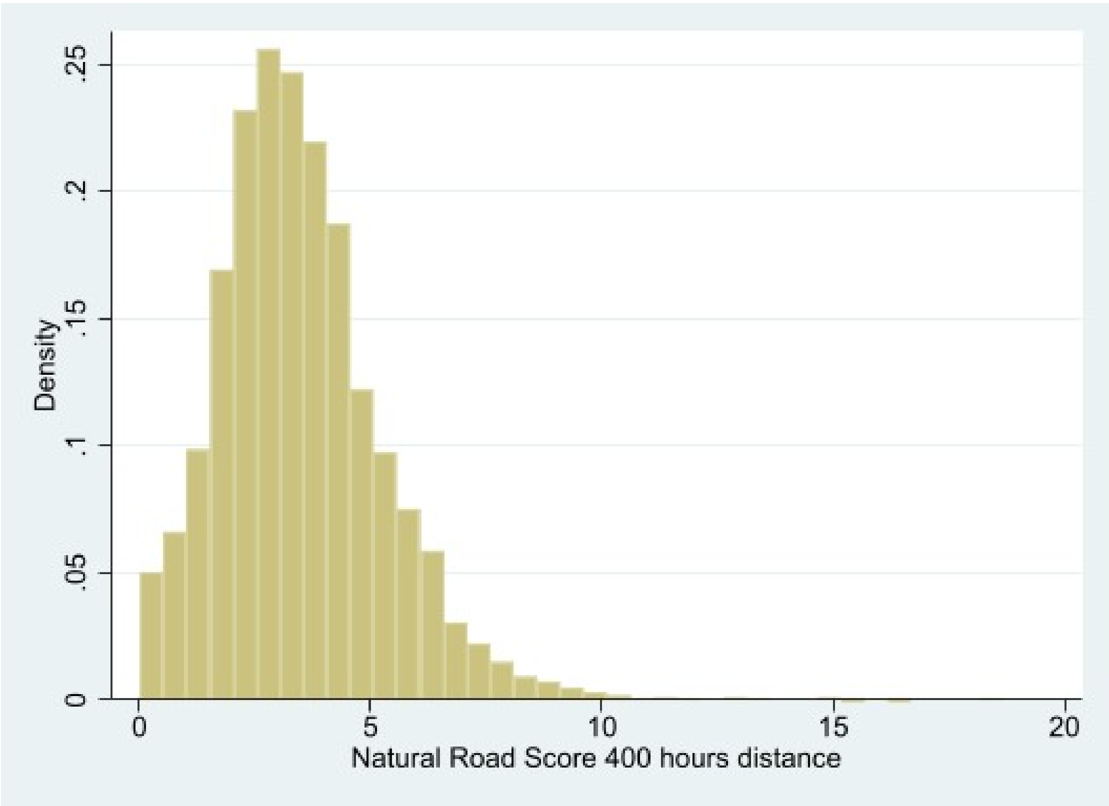


Figure 4.11: *Spatial Distribution of Natural Road Score*

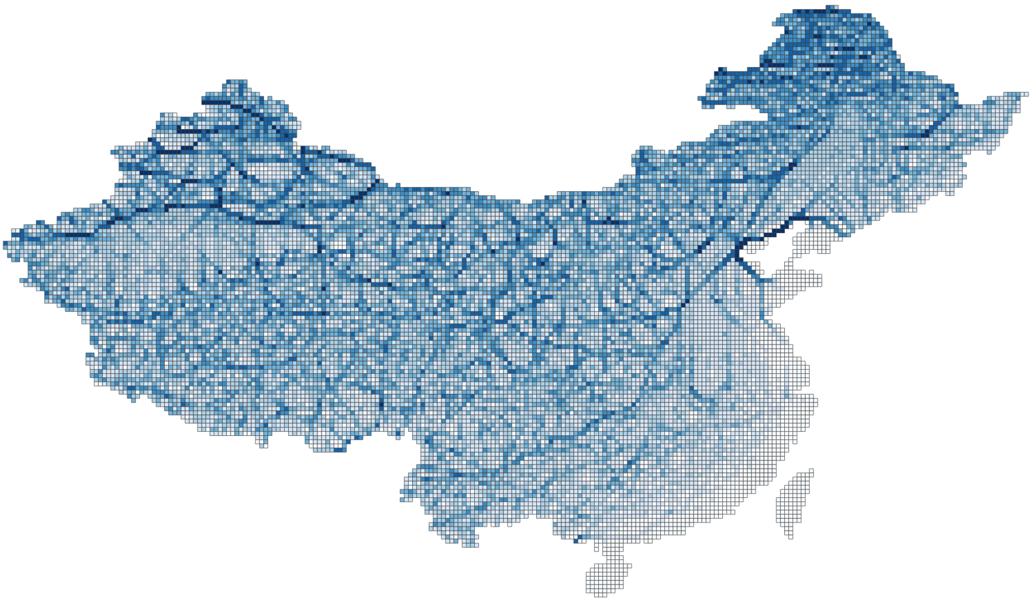
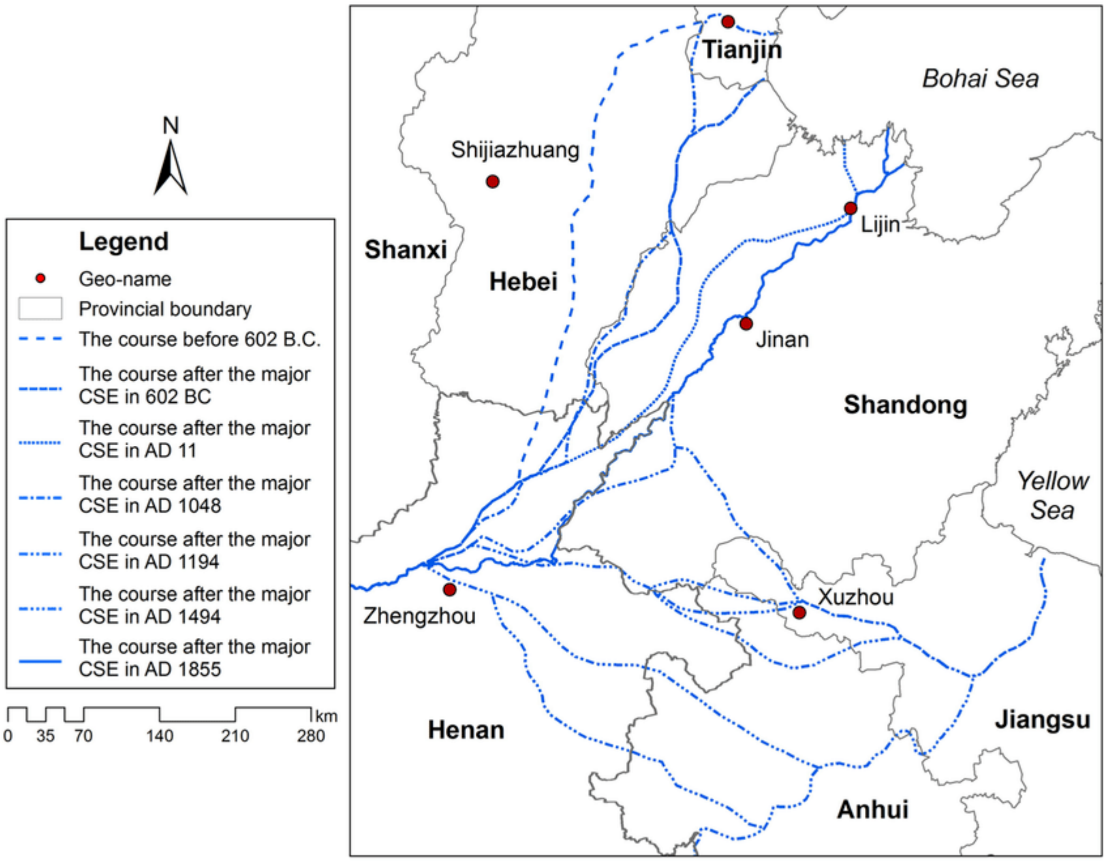


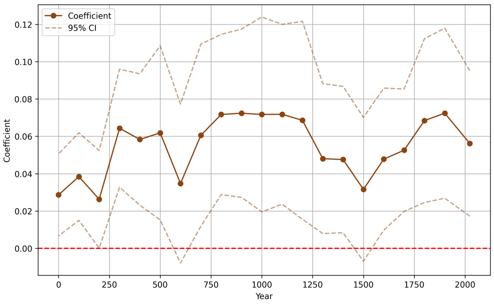
Figure 4.12: *Changes in the flow path of the Lower Yellow River in response to the six first-level course shifting events*



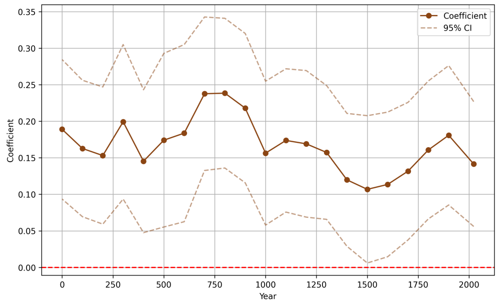

*Note: Sourced from* *Wang and Su (2011)*

FIGURE 4.13: *Persist*

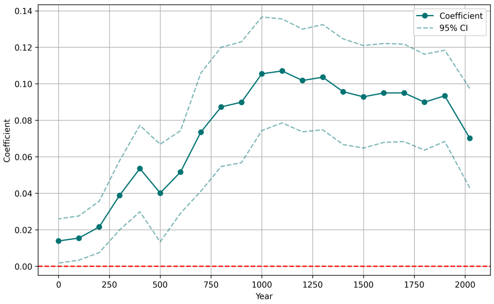
***Prefecture*** | ***City***



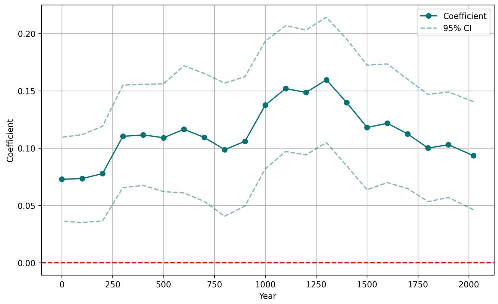

(a1) Natural Road Score



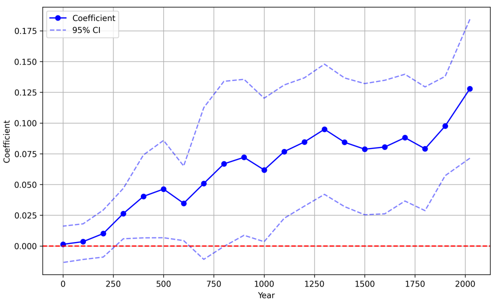

(a2) Natural Road Score



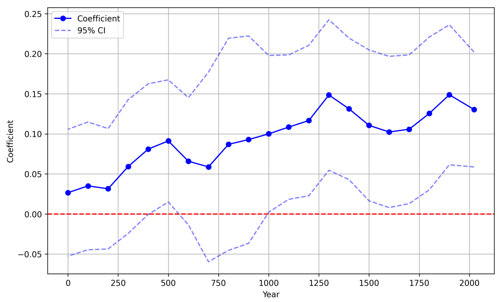

(b1) Navigable River




(b2) Navigable River



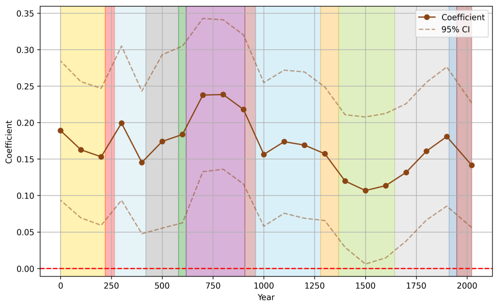

(c1) Estuary



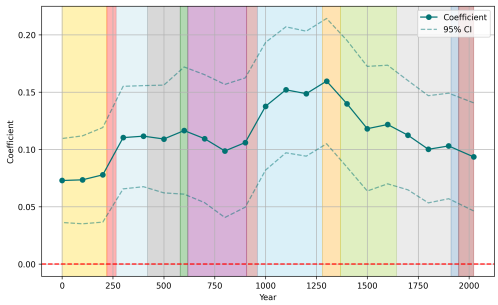

(c2) Estuary

*Note:* This figure uses a 95% confidence interval, with data sourced from Table 4.6.

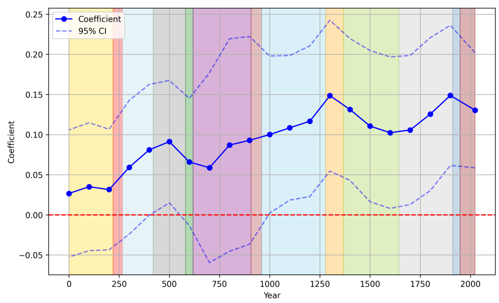
Figure 4.14: *City colored with Dynasties*




(a) Natural Road Score



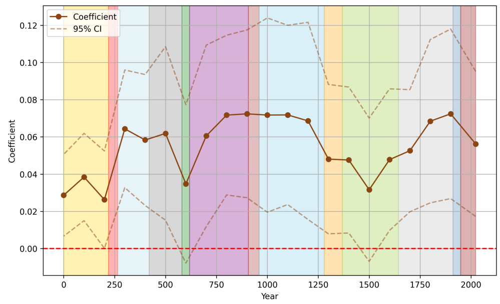

(b) Navigable River



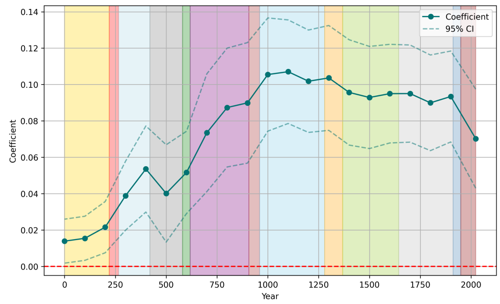

(c) Estuary

*Note:* Based on the results for cites in Table 4.6, the background is color-coded to represent the major dynasties and periods in Chinese history: Han Dynasty (206 BCE–220 CE), Three Kingdoms (220–266), Jin Dynasty (266–420), Southern and Northern Dynasties (420–581), Sui Dynasty (581–618), Tang Dynasty (618–907), Five Dynasties and Ten Kingdoms (907–960), Song Dynasty (960–1279), Yuan Dynasty (1279–1368), Ming Dynasty (1368–1644), Qing Dynasty (1644–1911), Republic of China (1912–1949), and People' s Republic of China (1949–present). Each dynasty and period is depicted with a distinct background color to contextualize the results within China's historical timeline.

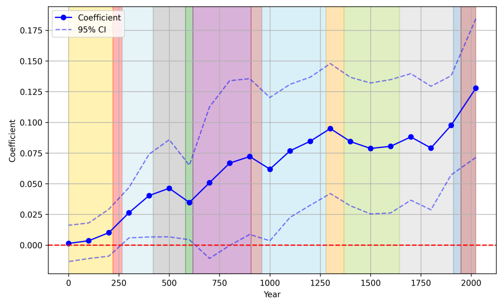
FIGURE 4.15: *Prefecture colored with Dynasties*




(a) Natural Road Score



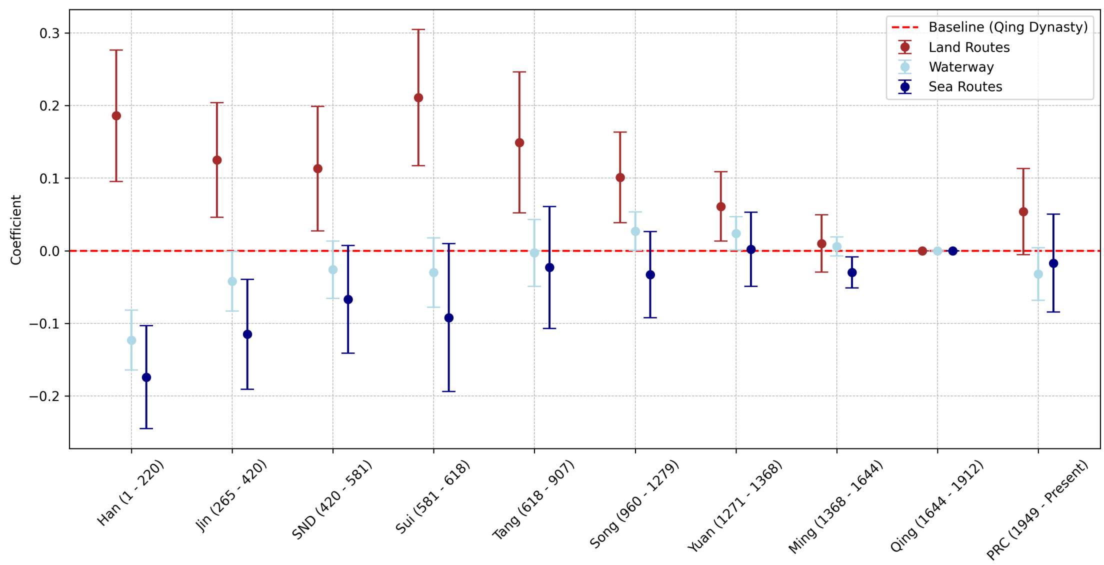

(b) Navigable River




(c) Estuary

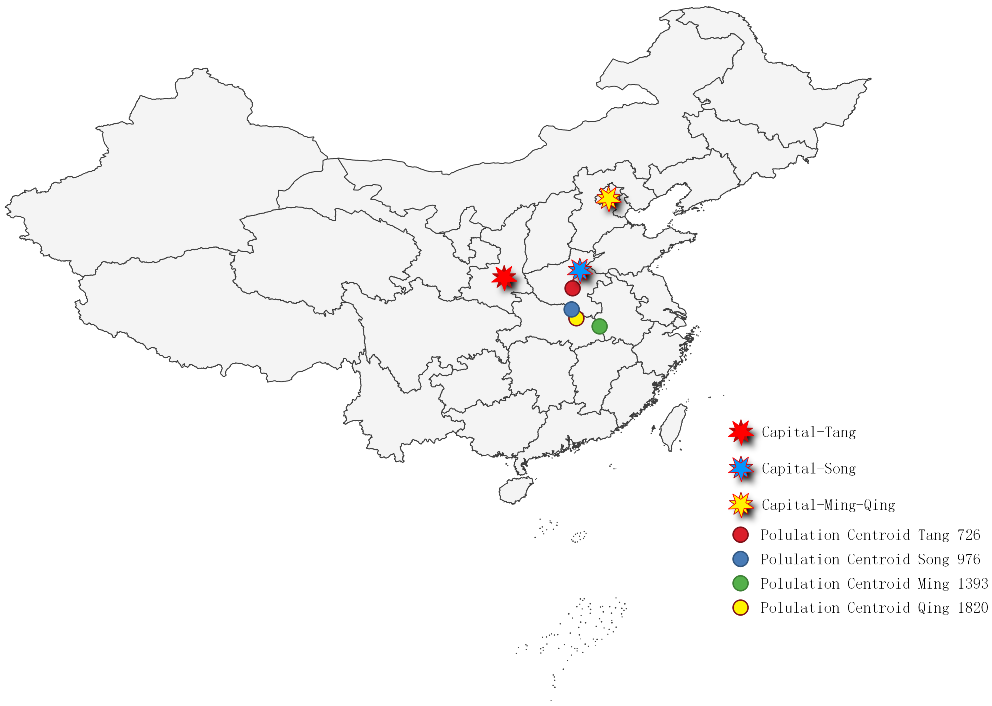
*Note:* Based on the results of prefecture level cities in Table 4.6, the background is color-coded to represent the major dynasties and periods in Chinese history: Han Dynasty (206 BCE–220 CE), Three Kingdoms (220–266), Jin Dynasty (266–420), Southern and Northern Dynasties (420–581), Sui Dynasty (581–618), Tang Dynasty (618–907), Five Dynasties and Ten Kingdoms (907–960), Song Dynasty (960–1279), Yuan Dynasty (1279–1368), Ming Dynasty (1368–1644), Qing Dynasty (1644–1911), Republic of China (1912–1949), and People' s Republic of China (1949–present). Each dynasty and period is depicted with a distinct background color to contextualize the results within China's historical timeline.

FIGURE 4.16: *Comparing Dynasty's marginal effect with Qing as baseline (Cities)*



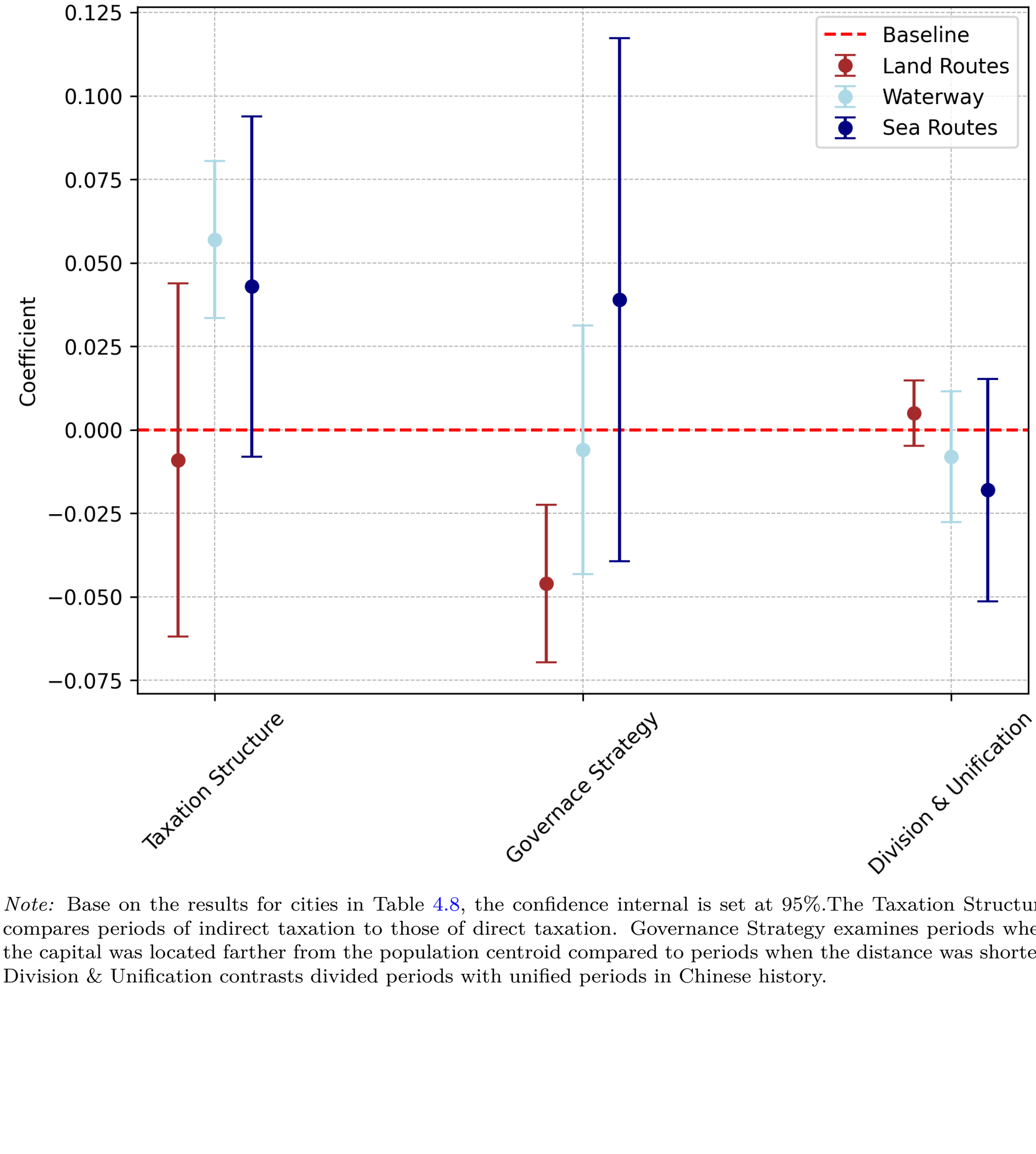

*Note:* Based on the results for cities in Table 4.7, the confidence interval is set at 90%. The Qing Empire, China's last unified dynasty, is used as the baseline.

FIGURE 4.17: *Capitals and Population Centroids in Historical China*



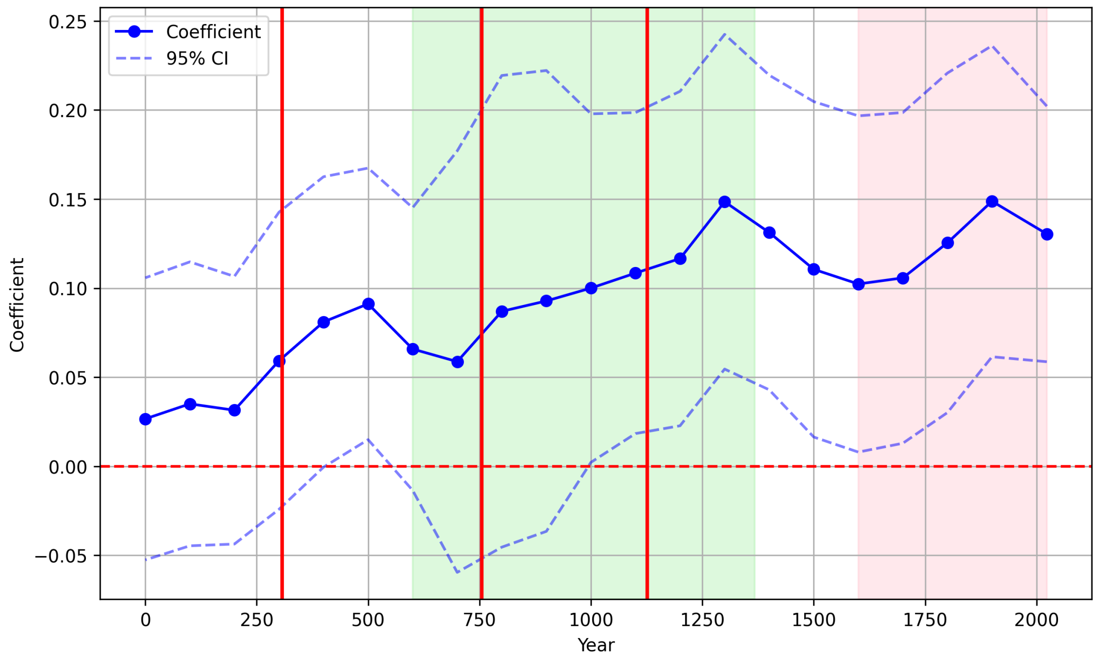

*Note:* This figure illustrates the locations of the national capital and the population centroid during periods with reliable population records. The distances between them are presented in Table 4.9.

FIGURE 4.18: *Mechanism: Institutions and Natural Endowments on Routes (cities)*



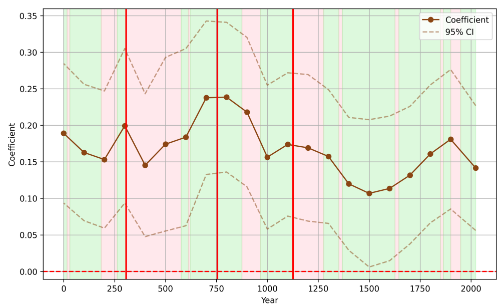

*Note:* Base on the results for cities in Table 4.8, the confidence internal is set at 95%.The Taxation Structure compares periods of indirect taxation to those of direct taxation. Governance Strategy examines periods when the capital was located farther from the population centroid compared to periods when the distance was shorter. Division & Unification contrasts divided periods with unified periods in Chinese history.

Figure 4.19: *The incoming of Arabs and Europeans, and Sea Ban Policy (cities)*

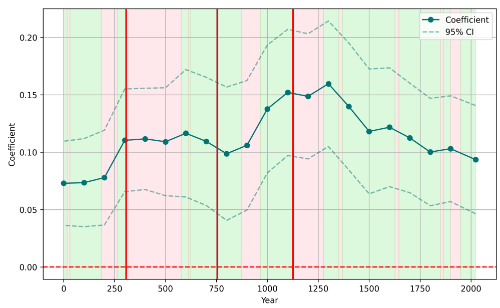



*Note:* This figure shows the marginal effect of sea routes on the location of cities. The background colors indicate different periods: green represents the era of Arab merchants, while red denotes the arrival of European merchants. It can be observed that during these two periods, the marginal effect of maritime trade on city locations shows an upward trend. Additionally, the three red lines mark the three major nomadic invasions that triggered large-scale migration events in Chinese history

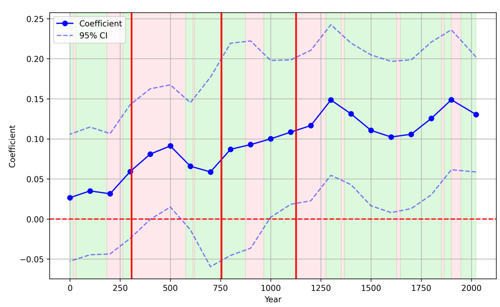
Figure 4.20: *City colored with Unification and Division*




(a) Natural Road Score



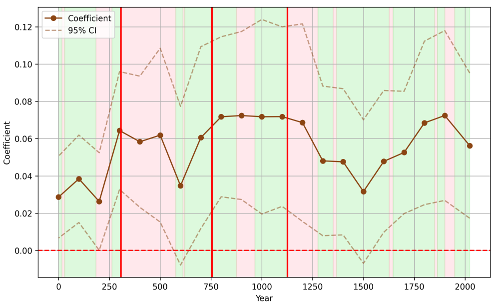

(b) Navigable River



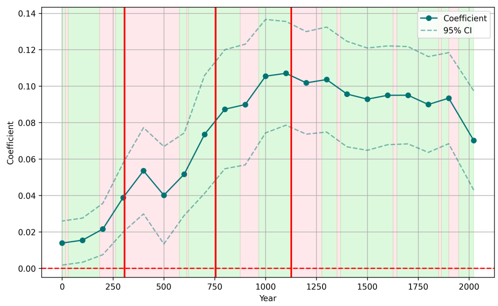

(c) Estuary

*Note:* Based on results of table 4.6. The background is color-coded to reflect periods of division (red) and unification (green) in Chinese history. A time period is classified as divided if multiple de facto regimes coexisted within China Proper; otherwise, it is considered unified. Additionally, the three red lines mark the three major nomadic invasions that triggered large-scale migration events in Chinese history.

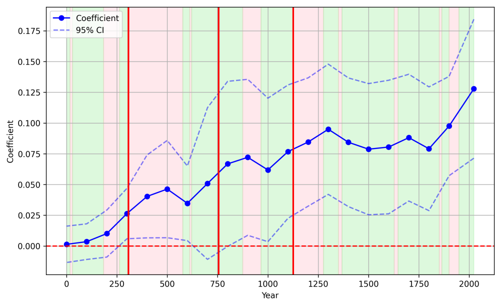
FIGURE 4.21: *Prefecture colored with Unification and Division*




(a) Natural Road Score




(b) Navigable River




(c) Estuary

*Note:* Based on results of table 4.6. The background is color-coded to reflect periods of division (red) and unification (green) in Chinese history. A time period is classified as divided if multiple de facto regimes coexisted within China Proper; otherwise, it is considered unified. Additionally, the three red lines mark the three major nomadic invasions that triggered large-scale migration events in Chinese history.

# Chapter 5

# Conclusion

This thesis represents an interdisciplinary exploration in historical economic geography, employing archaeological and historical data alongside analytical methods and theories from statistics, geography, and economics. By integrating these diverse approaches, the research has made significant contributions to three key areas: (1) the timing and potential causes of the Great Divergence, (2) the origins and evolution of civilizations, and (3) the characteristics of economic geography across different stages of human development.

Through this interdisciplinary methodology, the thesis has validated existing hypotheses while also uncovering novel and counterintuitive phenomena. For instance, it confirms prior conjectures on the timing of the Great Divergence by analyzing transportation networks, offering fresh material support to current theories. Simultaneously, it identifies previously unobserved patterns, such as a sudden and unexpected decline in spatial interaction during the Holocene Event 3. This finding contradicts traditional assumptions that increased social complexity during this period would lead to strengthened inter-settlement connections. Moreover, the research contributes to critical debates by demonstrating that the location of economic activities in ultra-long-term history is dynamic, contrary to Davis and Weinstein (2002), who concluded from Japan's 10,000-year economic landscape that the role of location fundamentals is immutable. Instead, this thesis provides evidence that institutional settings significantly influence the spatial distribution of cities over millennia.

Despite its achievements, this thesis acknowledges certain limitations. Firstly, the mechanism analysis in Chapter 3 is constrained by the scarcity of historical materials, leaving room for potential reverse causality. Secondly, the findings regarding prehistorical phenomena rely heavily on historical case studies and conjectures, offering statistical correlations but falling short of establishing robust economic causality.

Looking ahead, there are two main areas for further research. First, I aim to empirically establish the causal relationship between climate shocks and the origins of states using econometric methods. Currently, this thesis puts forward a hypothesis regarding the events of 4,500 years ago but lacks direct causal evidence. Preliminary observations suggest that Northern China, which faced more severe climate shocks, experienced a significantly faster progression in social complexity compared to Southern China, which endured milder shocks. Around 4,000 years ago, while Northern China had fully entered the Bronze Age, many tribes in Southern China (notably in the South China region) remained in the Neolithic Age. Future research will focus on determining the causality between these phenomena, potentially proposing new hypotheses about the origins of states.

This thesis lays the foundation for further exploration of these interdisciplinary questions, offering a road-map for future interdisciplinary studies to deepen our understanding of the origin and evolution of human civilization.

# Bibliography

Acemoglu, D., S. Johnson, and J. Robinson (2005). The Rise of Europe: Atlantic Trade, Institutional Change, and Economic Growth. *American Economic Review 95*(3), 34.

Acemoglu, D., S. Johnson, and J. A. Robinson (2001). The colonial origins of comparative development: An empirical investigation. *American Economic Review 91*(5), 1369–1401.

Adams, R. (1965). Land behind baghdad. a history of settlement on the diyala.

Adams, R. M. (1981). *Heartland of Cities*. Chicago: University of Chicago Press.

Adams, R. M. and H. J. Nissen (1972). *The Uruk Countryside: The Natural Setting of Urban Societies*. Chicago: University of Chicago Press.

Ades, A. F. and E. L. Glaeser (1995). Trade and circuses: explaining urban giants. *The Quarterly Journal of Economics 110*(1), 195–227.

Allen, R. C. (2001). The great divergence in european wages and prices from the middle ages to the first world war. *Explorations in Economic History 38*(4), 411–447.

Allen, R. C. (2009). *The British industrial revolution in global perspective*. Cambridge University Press.

Allen, R. C., J.-P. Bassino, D. Ma, C. Moll-Murata, and J. L. Van Zanden (2011). Wages, prices, and living standards in china, 1738–1925: in comparison with europe, japan, and india. *The Economic History Review 64*, 8–38.

Allen, R. C., M. C. Bertazzini, and L. Heldring (2023). The economic origins of government. *American Economic Review 113*(10), 2507–2545.

Allen, T. and D. Donaldson (2022, March). Persistence and path dependence: A primer. *Regional Science and Urban Economics 94*(C), 103724. Received 23 Nov 2020; revised 12 Aug 2021; accepted 19 Aug 2021.

Alvarez-Palau, E., D. Bogart, O. Dunn, M. Satchell, and L. Shaw-Taylor (2020). Transport and urban growth in the first industrial revolution.

Alvarez-Palau, E. J., D. Bogart, O. Dunn, M. Satchell, and L. Shaw-Taylor (2017). A gis approach to estimating multi-modal transport costs and productivity growth in england, 1680-1830.

Alvarez-Palau, E. J., D. Bogart, O. Dunn, M. Satchell, and L. S. Taylor (2017). Growth before steam: A gis approach to estimating multi-modal transport costs.

Antony, R. J. (2016). *Unruly People: Crime, Community, and State in Late Imperial South China.* Hong Kong University Press.

Arrow, K. J. (1962). The economic implications of learning by doing. *The review of economic studies 29*(3), 155–173.

Au, C.-C. and J. V. Henderson (2006). Are chinese cities too small? *The Review of Economic Studies 73*(3), 549–576.

Bai, Y. and R. Jia (2023). The economic consequences of political hierarchy: Evidence from regime changes in china, 1000–2000 ce. *Review of Economics and Statistics 105*(3), 626–645.

Bai, Y. and J. K.-s. Kung (2011). Climate shocks and sino-nomadic conflict. *Review of Economics and Statistics 93*(3), 970–981.

Bakker, J. D., S. Maurer, J.-S. Pischke, and F. Rauch (2021). Of mice and merchants: connectedness and the location of economic activity in the iron age. *Review of Economics and Statistics 103*(4), 652–665.

Banerjee, A., E. Duflo, and N. Qian (2020). On the road: Access to transportation infrastructure and economic growth in china. *Journal of Development Economics 145*, 102442.

Barjamovic, G., T. Chaney, K. Coşar, and A. Hortaçsu (2019). Trade, merchants, and the lost cities of the bronze age. *The Quarterly Journal of Economics 134*(3), 1455–1503. Publisher: Oxford University Press.

Bentzen, J. S., N. Kaarsen, and A. M. Wingender (2017). Irrigation and autocracy. *Journal of the European Economic Association 15*(1), 1–53. Publisher: Oxford University Press.

Berger, T. and K. Enflo (2017). Locomotives of local growth: The short-and long-term impact of railroads in sweden. *Journal of Urban Economics 98*, 124–138.

Berrey, C. A., R. D. Drennan, and C. E. Peterson (2015). *Regional settlement demography in archaeology.* ISD LLC.

Besley, T. and T. Persson (2009). The origins of state capacity: Property rights, taxation, and politics. *American Economic Review 99*(4), 1218–1244.

Bettinger, R. L., L. Barton, and C. Morgan (2010). The origins of food production in north China: A different kind of agricultural revolution. *Evolutionary Anthropology: Issues, News, and Reviews: Issues, News, and Reviews 19*(1), 9–21. Publisher: Wiley Online Library.

Binford, L. R. (1980). Willow smoke and dogs' tails: Hunter-gatherer settlement systems and archaeological site formation. *American Antiquity 45*(1), 4–20.

Bleakley, H. and J. Lin (2012). Portage and path dependence. *The quarterly journal of economics 127*(2), 587–644.

Bodleian Libraries, University of Oxford (2024). The selden map. https://seldenmap.bodleian.ox.ac.uk/. Accessed on 2024-04-15.

Bogart, D. (2005). Turnpike trusts and the transportation revolution in 18th century england. *Explorations in Economic History 42*(4), 479–508.

Bogart, D. (2013). The transportation revolution in industrializing britain: A survey. Working Paper 121306, University of California-Irvine, Department of Economics.

Bogart, D. (2019). Clio on speed. In *Handbook of Cliometrics*, pp. 1453–1478.

Bogart, D., S. Bottomley, M. Satchell, and L. S. Taylor (2017). Transport networks and the adoption of steam engines in england and wales, 1761-1800. Technical report, Working paper.

Bogart, D., A. Rosevear, and L. Shaw-Taylor (2023, 5). Did turnpikes make roads better? new evidence from 18th century travel diaries. https://sites.socsci.uci.edu/~dbogart/Using%20Diaries%20to%20assess%20road%20quality%20may%2016%202023%20all.pdf.

Bogart, D., X. You, E. J. Alvarez-Palau, M. Satchell, and L. Shaw-Taylor (2022). Railways, divergence, and structural change in 19th century england and wales. *Journal of Urban Economics 128*, 103390.

Bol, P. K. (2013). On the cyberinfrastructure for gis-enabled historiography: Space–time integration in geography and giscience. *Annals of the Association of American Geographers 103*(5), 1087–1092.

Bond, G., B. Kromer, J. Beer, R. Muscheler, M. N. Evans, W. Showers, S. Hoffmann, R. Lotti-Bond, I. Hajdas, and G. Bonani (2001). Persistent solar influence on North Atlantic climate during the Holocene. *Science 294*(5549), 2130–2136. Publisher: American Association for the Advancement of Science.

Bond, G., W. Showers, M. Cheseby, R. Lotti, P. Almasi, P. DeMenocal, P. Priore, H. Cullen, I. Hajdas, and G. Bonani (1997). A pervasive millennial-scale cycle in North Atlantic Holocene and glacial climates. *science 278*(5341), 1257–1266. Publisher: American Association for the Advancement of Science.

Bosker, M. and E. Buringh (2017). City seeds: Geography and the origins of the european city system. *Journal of Urban Economics 98*, 139–157.

Bosker, M., E. Buringh, and J. L. Van Zanden (2013). From baghdad to london: Unraveling urban development in europe, the middle east, and north africa, 800–1800. *Review of Economics and Statistics 95*(4), 1418–1437.

Brakman, S., H. Garretsen, and M. Schramm (2004). The spatial distribution of wages: estimating the helpman-hanson model for germany. *Journal of regional science 44*(3), 437–466.

Broadberry, S. (2013). Accounting for the great divergence.

Broadberry, S., H. Guan, and D. D. Li (2018). China, europe, and the great divergence: a study in historical national accounting, 980–1850. *The Journal of Economic History 78*(4), 955–1000.

Broadberry, S., H. Guan, and D. D. Li (2021). China, europe, and the great divergence: a restatement. *The Journal of Economic History 81*(3), 958–974.

Broadberry, S. and B. Gupta (2006). The early modern great divergence: Wages, prices and economic development in europe and asia, 1500–1800 1. *The Economic History Review 59*(1), 2–31.

Brook, T. (1981). Guides for vexed travelers: route books in the ming and qing. *Ch'ing-shih wen-t'i 4*(5), 32–76.

Brook, T. (2002). *Geographical Sources of Ming-Qing History* (2nd ed ed.). Center for Chinese Studies, University of Michigan.

Brook, T. (2017). Chinese charting of maritime asia. In *Oxford Research Encyclopedia of Asian History*.

Cai, D. ., L. . Han, C. . Xie, S. . Li, H. . Zhou, and H. . Zhu (2007). *内蒙古赤峰地区青铜时代古马线粒体 DNA 分析 Mitochondrial DNA Analysis of Ancient Horses from the Bronze Age in the Chifeng Region, Inner Mongolia*. Ph. D. thesis.

Cao, 曹树基, S. (2000, 9). *History of the Chinese Population, Volume 4: The Ming Dynasty 中国人口史（第四卷）明时期*. Fudan University Press 复旦大学出版社.

Cao, 曹树基, S. (2001, 5). *History of the Chinese Population, Volume 5: The Qing Dynasty 中国人口史（第五卷）清时期*. Fudan University Press 复旦大学出版社.

Carneiro, R. L. (1970). A theory of the origin of the state: Traditional theories of state origins are considered and rejected in favor of a new ecological hypothesis. *science 169*(3947), 733–738.

Carrier, J. G. and A. H. Carrier (1989). *Wage, trade, and exchange in Melanesia: a Manus society in the modern state*. University of California Press.

Cavallo, E., S. Galiani, I. Noy, and J. Pantano (2013). Catastrophic natural disasters and economic growth. *Review of Economics and Statistics 95*(5), 1549–1561.

Cermeno, A. L. and K. Enflo (2019). Can kings create towns that thrive? the long-term implications of new town foundations. *Journal of Urban Economics 112*, 50–69.

Chaffee, J. W. (2018). *The Muslim Merchants of Premodern China: The History of a Maritime Asian Trade Diaspora, 750–1400.* Cambridge University Press.

Chaianov, A. V. (1986). *The theory of peasant economy.* Manchester University Press.

Chang, K.-c. (1986). *The Archaeology of Ancient China* (4th ed.). New Haven: Yale University Press.

Chang, K.-c. (1999). China on the Eve of the Historical Period. *cambridge history of ancient china: from the origins of civilization to 221 bc*, 37–73. Publisher: Cambridge University Press.

Chatfield, C. (1953a). *Food Composition Tables for International Use.* FAO Nutritional Studies No. 3. Washington, DC: Nutrition Division, FAO UN.

Chatfield, C. (1953b). Food Composition Tables for International use FAO.

Chen, T. and J. K.-S. Kung (2022a). Commercial revolution in medieval china. *Available at SSRN 3960074.*

Chen, T. and J. K.-s. Kung (2022b). War shocks, migration, and historical spatial development in china. *Regional Science and Urban Economics 94*, 103718.

Chen, Y., J. V. Henderson, and W. Cai (2017). Political favoritism in China’s capital markets and its effect on city sizes. *Journal of Urban Economics 98*, 69–87. Publisher: Elsevier.

Chen, Z., W. Wang, and X. Zhang (2024). Origins of power actors in historical china: How war made some regions produce more political elites than others.

Chen, 陈志武, Z. (2022). *The Logic of Civilization* 文明的逻辑. CITIC Press Group 中信出版社.

CHGIS (2024). China historical gis. Version 6. Accessed July 31, 2024.

Childe, V. G. (1950). The urban revolution. *The town planning review 21*(1), 3–17.

Childe, V. G., A. Wolf, H. Pledge, G. Perazich, P. M. Field, and J. Bernal (1940). Man makes himself. *Science and Society 4*(4).

Ciolek, T. M. (2024). Old world trade routes project. Online resource. Available at http://www.ciolek.com/owtrad.html.

Coşar, A. K. and P. D. Fajgelbaum (2016). Internal geography, international trade, and regional specialization. *American Economic Journal: Microeconomics 8*(1), 24–56.

Dalgaard, C.-J., N. Kaarsen, O. Olsson, and P. Selaya (2022). Roman roads to prosperity: Persistence and non-persistence of public infrastructure. *Journal of Comparative Economics 50*(4), 896–916.

Davis, D. R. and D. E. Weinstein (2002). Bones, bombs, and break points: the geography of economic activity. *American Economic Review 92*(5), 1269–1289.

Davis, D. R. and D. E. Weinstein (2003). Market access, economic geography and comparative advantage: an empirical test. *Journal of International Economics 59*(1), 1–23.

Dell, M., B. F. Jones, and B. A. Olken (2014). What do we learn from the weather? The new climate-economy literature. *Journal of Economic literature 52*(3), 740–798. Publisher: American Economic Association 2014 Broadway, Suite 305, Nashville, TN 37203-2425.

Deng, K. (1997). *Chinese maritime activities and socioeconomic development.* Number 188. Greenwood Press (Westport, Conn.).

Deng, K. (1999). Maritime sector, institutions, and sea power of premodern china.

Deng, K. (2020). One-off capitalism in song china, 960–1279 ce. *Capitalisms. Towards a global history*, 227–250.

Deng, K. G. (2011). *China's political economy in modern times: changes and economic consequences, 1800-2000.* Routledge.

Diamond, J. (2005). *Collapse: How Societies Choose to Fail or Succeed.* New York: Penguin Books.

Dijkstra, E. W. (1959). A note on two problems in connexion with graphs. *Numerische Mathematik 1*, 269–271.

Ding, 文江, W., W. Weng, 文灏, and S. Zeng, 世英 (Eds.) (1934). *New Map of the Republic of China* 中华民国新地图. Shanghai 上海: Shanghai Shenbao Publishing House 上海申报馆.

Ding, Y. (1997). Naval maps collected in yale and study on naval routes in north china sea 耶鲁藏清代航海图北洋部分考释及其航线研究. *Zhongguoshi Dongtai Yanjiu* 中国史研究动态 (8).

Doebley, J. F., B. S. Gaut, and B. D. Smith (2006). The molecular genetics of crop domestication. *Cell 127*(7), 1309–1321. Publisher: Elsevier.

Donaldson, D. (2018). Railroads of the raj: Estimating the impact of transportation infrastructure. *American Economic Review 108*(4-5), 899–934.

Donaldson, D. and R. Hornbeck (2016). Railroads and american economic growth: A "market access" approach. *The Quarterly Journal of Economics 131*(2), 799–858.

Dong, 董国栋, G. (2002, 11). *History of the Chinese Population, Volume 2: The Sui, Tang, and Five Dynasties Period* 中国人口史（第二卷）隋唐五代时期. Fudan University Press 复旦大学出版社.

Düben, C. and M. Krause (2023). The emperor's geography—city locations, nature and institutional optimisation. *The Economic Journal 133*(651), 1067–1105.

Ejrnaes, M. and K. G. Persson (2000). Market integration and transport costs in france 1825–1903: a threshold error correction approach to the law of one price. *Explorations in Economic History 37*(2), 149–173.

Elliott, R. J., E. Strobl, and P. Sun (2015). The local impact of typhoons on economic activity in china: A view from outer space. *Journal of Urban Economics 88*, 50–66.

Ellison, G. and E. L. Glaeser (1999). The geographic concentration of industry: does natural advantage explain agglomeration? *American Economic Review 89*(2), 311–316.

Elvin, M. (1973). *The pattern of the Chinese past: A social and economic interpretation.* Stanford University Press.

Faber, B. (2014). Trade integration, market size, and industrialization: evidence from china's national trunk highway system. *Review of Economic Studies 81*(3), 1046–1070.

Fagan, B. (2000). *The Little Ice Age: How Climate Made History 1300-1850.* New York: Basic Books.

Fajgelbaum, P. and S. J. Redding (2022). Trade, structural transformation, and development: Evidence from argentina 1869–1914. *Journal of political economy 130*(5), 1249–1318.

Fan, I.-c. (1992). *Long-Distance Trade and Market Integration in the Ming-Ch'ing Period, 1400-1850.* Dissertation.

Farr, T. G. and M. Kobrick (2000). Shuttle Radar Topography Mission produces a wealth of data. *Eos, Transactions American Geophysical Union 81*(48), 583–585. Publisher: Wiley Online Library.

Feavearyear, A. (1932). *The Pound Sterling: A History of English Money.* Oxford: Clarendon Press.

Fenske, J., N. Kala, and J. Wei (2023). Railways and cities in india. *Journal of Development Economics 161*, 103038.

Feyrer, J. (2021). Distance, trade, and income—The 1967 to 1975 closing of the Suez Canal as a natural experiment. *Journal of Development Economics 153*, 102708. Publisher: Elsevier.

Findlay, R. (1984). Growth and development in trade models. *Handbook of international economics 1*, 185–236. Publisher: Elsevier.

Fischer, G., E. Teixeira, E. T. Hizsnyik, and H. Van Velthuizen (2008). Land use dynamics and sugarcane production. In *Sugarcane ethanol: contributions to climate change mitigation and the environment*, pp. 29–62. Wageningen Academic.

Fitzgerald-Huber, L. G. (1995). Qijia and Erlitou: The question of contacts with distant cultures. *Early China 20*, 17–67. Publisher: Cambridge University Press.

Flad, R., J. ZHOU, A. WOMACK, Y. JAFFE, J. KO, Y. WANG, X. SU, P. CHEN, L. HUNG, B. LIU, et al. (2021). Preliminary site prospection along the tao river 2011–2013: Testing the chinese register of archaeological sites. *Bulletin of the Museum of Far Eastern Antiquities 82*.

Flückiger, M., E. Hornung, M. Larch, M. Ludwig, and A. Mees (2022). Roman transport network connectivity and economic integration. *The Review of Economic Studies 89*(2), 774–810.

Frank, A. G. (1998). *ReOrient: Global economy in the Asian age.* Univ of California Press.

Fu, 傅林祥, L., J. Lin, 林涓, Y. Ren, 任玉雪, and W. Wang, 王卫东 (2013, 10). *History of the Chinese Administrative Divisions, Volume 12: The Qing Dynasty 中国行政区划通史（第十二卷）清代卷*. Fudan University Press 复旦大学出版社.

Fu, 傅林祥, L. and B. Zheng, 郑宝恒 (2007, 8). *History of the Chinese Administrative Divisions, Volume 13: The Republic of China Period 中国行政区划通史（第十三卷）中华民国卷*. Fudan University Press 复旦大学出版社.

Gerhold, D. (2014). The development of stage coaching and the impact of turnpike roads, 1653–1840. *The Economic History Review 67*(3), 818–845.

Glaeser, E. L., H. D. Kallal, J. A. Scheinkman, and A. Shleifer (1992). Growth in cities. *Journal of political economy 100*(6), 1126–1152.

González-Val, R., D. A. Tirado-Fabregat, and E. Viladecans-Marsal (2017). Market potential and city growth: Spain 1860–1960. *Cliometrica 11*, 31–61.

Gorodetskaya, O. (2013). 夏商周: 从神话到史实. *(No Title)*.

Guo, B. . (1963). 中国青铜器时代 *The Age of Chinese Bronze Ware*. 生活. 读书. 新知三联书店 Life, Reading, New Knowledge Sanlian Bookstore.

Guo, 郭红, H. and R. Jin, 靳润成 (2007, 8). *History of the Chinese Administrative Divisions, Volume 11: The Ming Dynasty* 中国行政区划通史（第十一卷）明代卷. Fudan University Press 复旦大学出版社.

Guo, R. . and G. . Jin (2019). 先秦时期海岱地区的麦作农业 wheat agriculture in the haidai region during the pre-qin period. *第四纪研究 Quaternary Research 39*(1), 144–160.

Guo, 郭声波, S. (2012, 5). *History of the Chinese Administrative Divisions, Volume 6: The Tang Dynasty* 中国行政区划通史（第六卷）唐代卷（两册）. Fudan University Press 复旦大学出版社.

Hajdas, I., P. Ascough, M. H. Garnett, S. J. Fallon, C. L. Pearson, G. Quarta, K. L. Spalding, H. Yamaguchi, and M. Yoneda (2021). Radiocarbon dating. *Nature Reviews Methods Primers 1*(1), 62. Publisher: Nature Publishing Group UK London.

Han, J. . (2008). 试论殷墟二期中型墓中的北方文化因素 a discussion on the northern cultural elements in the medium-sized tombs of the second phase of the yin ruins. *中原文物 Central Plains Cultural Relics* (6), 34–41.

Hanlon, W. W. (2017). Temporary shocks and persistent effects in urban economies: Evidence from british cities after the us civil war. *Review of Economics and Statistics 99*(1), 67–79.

Hanson, G. H. (1997). Increasing returns, trade and the regional structure of wages. *The economic journal 107*(440), 113–133.

Hanson, G. H. (2005). Market potential, increasing returns and geographic concentration. *Journal of international economics 67*(1), 1–24.

Harding, H. (1993, December). The Concept of “Greater China”: Themes, Variations and Reservations. *The China Quarterly 136*, 660–686.

Harris, M. (1993). Culture, people, nature: An introduction to general anthropology.

He, Y. . (2020). 殷墟“外来文化因素”研究 study on the ”foreign cultural elements” of the yin ruins. 中原文物 *Central Plains Cultural Relics* (2), 33–49.

Heblich, S. and W. Hanlon (2020). History and urban economics. *Regional Science and Urban Economics, forthcoming., Stephen J Redding, and Daniel M Sturm, “The making of the modern metropolis: Evidence from London,” The Quarterly Journal of Economics 135*(4), 2059–2133.

Helpman, E. (1998). The size of regions. In D. Pines, E. Sadka, and I. Zilcha (Eds.), *Topics in Public Economics*, pp. 33–54. Cambridge: Cambridge University Press.

Henderson, J. V. (1974). The sizes and types of cities. *The American Economic Review 64*(4), 640–656.

Henderson, J. V. (1996). Ways to think about urban concentration: neoclassical urban systems versus the new economic geography. *International Regional Science Review 19*(1-2), 31–36.

Henderson, J. V. (2003). Marshall's scale economies. *Journal of urban economics 53*(1), 1–28.

Henderson, J. V., T. Squires, A. Storeygard, and D. Weil (2018). The global distribution of economic activity: nature, history, and the role of trade. *The Quarterly Journal of Economics 133*(1), 357–406.

Henderson, J. V., A. Storeygard, and U. Deichmann (2017). Has climate change driven urbanization in africa? *Journal of development economics 124*, 60–82.

Henderson, J. V. and H. G. Wang (2007). Urbanization and city growth: The role of institutions. *Regional Science and Urban Economics 37*(3), 283–313.

Henderson, V., A. Kuncoro, and M. Turner (1995). Industrial development in cities. *Journal of political economy 103*(5), 1067–1090.

Hirth, K. G. (1978). Interregional trade and the formation of prehistoric gateway communities. *American Antiquity 43*(1), 35–45. Publisher: Cambridge University Press.

Hodler, R. and P. A. Raschky (2014). Regional favoritism. *The Quarterly Journal of Economics 129*(2), 995–1033. Publisher: MIT Press.

Hoshi, A. (1971). *A Study on the History of the Traffic System during the Ming and Ch'ing Periods.* Tokyo: Yamakawa Shuppansha. A book in Japanese.

Hu, 胡阿祥, A., X. Kong, 孔祥军, and C. Xu, 徐成 (2014, 12). *History of the Chinese Administrative Divisions, Volume 3: The Three Kingdoms, Western and Eastern Jin, and Southern Dynasties* 中国行政区划通史（第三卷）三国两晋南朝卷（两册）. Fudan University Press 复旦大学出版社.

Huang, P. C. (1990). *The peasant family and rural development in the Yangzi Delta, 1350-1988.* Stanford University Press.

Huang, Z. . (2004). 古代人牲人殉通论. a general discussion on human sacrifice and retainers in ancient times. *(No Title).*

Ioannides, Y. M. and J. Zhang (2017). Walled cities in late imperial china. *Journal of Urban Economics 97*, 71–88.

Jacob, M. C. (2014). *The first knowledge economy: Human capital and the European economy, 1750–1850.* Cambridge University Press.

Jaffe, Y. Y., L. Castellano, G. Shelach-Lavi, and R. B. Campbell (2021). Mismatches of scale in the application of paleoclimatic research to chinese archaeology. *Quaternary Research 99*, 14–33.

Jaffe, Y. Y. and A. Hein (2021). Considering change with archaeological data: Reevaluating local variation in the role of the~ 4.2 k bp event in northwest china. *The Holocene 31*(2), 169–182.

Jedwab, R., E. Kerby, and A. Moradi (2017). History, path dependence and development: Evidence from colonial railways, settlers and cities in kenya. *The Economic Journal 127*(603), 1467–1494.

Jedwab, R. and A. Moradi (2016). The permanent effects of transportation revolutions in poor countries: evidence from africa. *Review of economics and statistics 98*(2), 268–284.

Jia, H. (2019). Paleontology: advancing China's international leadership. *National Science Review 6*(1), 171–176. Publisher: Oxford University Press.

Jia, R. (2014). The legacies of forced freedom: China's treaty ports. *Review of Economics and Statistics 96*(4), 596–608.

Jian, J. ., C. . Tang, and Y. . Wang (2022, 5). A local study and gis presentation of two routes from fuzhou to hangzhou during the ming and qing dynasties 明清时期福州至杭州官私二路之现地研究与 gis 呈现. *Digital Humanities* 数字人文 *2021*(4), 115–180.

Kang, J. . (1984). 《中国考古学中碳十四年代数据集 (1965—1981)》carbon-14 dates in chinese archaeology (1965–1981). 考古 *Archaeology* (3), 286–287.

Kelly, R. L. (1995). *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways.* Washington, D.C.: Smithsonian Institution Press.

Kingsmill, T. W. (1898). Inland communication in china. *Journal of the China Branch of the Royal Asiatic Society, for the Year 1893-1894, New Series 28*, 1–213.

Kiyokoba, A. . (1991). On modern water and land transport - focusing on the leg method 近代の水陸運貨について -脚法を中心として. *Toyoshi Kenkyu* 東洋史研究 *50*(3), 58–74.

Kiyokoba, A. . (1996). *Study of Tang Dynasty Financial History: Transportation Volume* 唐代財政史研究. 運輸編. Fukuoka 福岡: Kyushu University Publishing House 九州大学出版会.

Kline, P. and E. Moretti (2014). Local economic development, agglomeration economies, and the big push: 100 years of evidence from the tennessee valley authority. *The Quarterly journal of economics 129*(1), 275–331.

Kocornik-Mina, A., T. K. McDermott, G. Michaels, and F. Rauch (2020). Flooded cities. *American Economic Journal: Applied Economics 12*(2), 35–66.

Krugman, P. (1991). Increasing returns and economic geography. *Journal of political economy 99*(3), 483–499. Publisher: The University of Chicago Press.

Krugman, P. (1992). *Geography and trade.* MIT press.

Krugman, P. (1993a). First nature, second nature, and metropolitan location. *Journal of regional science 33*(2), 129–144.

Krugman, P. (1993b). On the number and location of cities. *European economic review 37*(2-3), 293–298.

Krugman, P. (1999). The role of geography in development. *International regional science review 22*(2), 142–161.

Krugman, P., M. Fujita, and A. Venables (1999). The spatial economy. *Cambridge: MIT Press 1*, 999.

Kung, J. K.-s. and C. Ma (2014). Autarky and the rise and fall of piracy in ming china. *The Journal of Economic History 74*(2), 509–534.

Lan, 蓝勇, Y. (1989). *History of Ancient Transportation Routes in Sichuan* 四川古代交通路线史. Southwest Normal University Press 西南师范大学出版社.

Langmuir, E. (1984). Mountaincraft and leadership: a handbook for mountaineers and hillwalking leaders in the british isles.

Lee, G.-A., G. W. Crawford, L. Liu, and X. Chen (2007). Plants and people from the Early Neolithic to Shang periods in North China. *Proceedings of the National Academy of Sciences 104*(3), 1087–1092. Publisher: National Acad Sciences.

Lee, Y. S. (2018). International isolation and regional inequality: Evidence from sanctions on north korea. *Journal of Urban Economics 103*, 34–51.

Li, B. and J. L. Van Zanden (2012). Before the great divergence? comparing the yangzi delta and the netherlands at the beginning of the nineteenth century. *The Journal of Economic History 72*(4), 956–989.

Li, 李昌宪, C. (2007, 8). *History of the Chinese Administrative Divisions, Volume 8: The Song and Western Xia Dynasties* 中国行政区划通史（第八卷）宋西夏卷. Fudan University Press 复旦大学出版社.

Li, H., N. James, J. Chen, S. Zhang, L. Du, Y. Yang, G. Chen, M. Ma, and X. Jia (2023). Agricultural economic transformations and their impacting factors around 4000 bp in the hexi corridor, northwest china. *Land 12*(2), 425.

Li, L. M. (2000). Integration and disintegration in north china's grain markets, 1738–1911. *The Journal of Economic History 60*(3), 665–699.

Li, S. . (2021, February). *耀武扬威: 权杖源流考辨 Displaying Military Prowess: An Examination of the Origins of Scepters (Hardcover)*. 上海古籍出版社 Shanghai Ancient Books Publishing House.

Li, 文治, W. and T. Jiang, 太新 (2008). *Transport of Tribute Grain during the Qing Dynasty 清代漕运*. Beijing 北京: Social Sciences Academic Press 社会科学文献出版社.

Li, 李晓杰, X. (2014, 12). *History of the Chinese Administrative Divisions, Volume 7: The Five Dynasties and Ten Kingdoms 中国行政区划通史（第七卷）五代十国卷*. Fudan University Press 复旦大学出版社.

Li, X. . (2016). "最初的中国" 之考古学认定 the archaeological identification of "the earliest china". *考古 Archaeology 3*.

Li, 李治安, Z. and L. Xue, 薛磊 (2009, 4). *History of the Chinese Administrative Divisions, Volume 10: The Yuan Dynasty 中国行政区划通史（第十卷）元代卷*. Fudan University Press 复旦大学出版社.

Librado, P., N. Khan, A. Fages, M. A. Kusliy, T. Suchan, L. Tonasso-Calvière, S. Schiavinato, D. Alioglu, A. Fromentier, A. Perdereau, and others (2021). The origins and spread of domestic horses from the Western Eurasian steppes. *Nature 598*(7882), 634–640. Publisher: Nature Publishing Group UK London.

Lin, M.-h. (2006, 12). *China Upside Down: Currency, Society and Ideologies, 1808-1856*. Number 270. Harvard University Press.

Linduff, K. M. (1998). The emergence and demise of bronze-producing cultures outside the central plain of China. *The Bronze Age and early Iron Age peoples of eastern* *central Asia 2*, 619–644. Publisher: Institute for the Study of Man in collaboration with the University of ⋯.

Liu, G. W. (2012). Song china's water transport revisited: a study of the 1077 commercial tax data. *Pacific Economic Review 17*(1), 57–85.

Liu, L. (1996). Settlement patterns, chiefdom variability, and the development of early states in North China. *Journal of anthropological archaeology 15*(3), 237–288. Publisher: Elsevier.

Liu, L. (2000). The development and decline of social complexity in north China: some environmental and social factors. *Indo-Pacific Prehistory: The Melaka Papers 4*, 14–34.

Liu, L. (2004). *The Chinese Neolithic: Trajectories to Early States*. Cambridge: Cambridge University Press.

Liu, L. (2005). *The Chinese Neolithic: trajectories to early states*. Cambridge University Press.

Liu, L. . and X. . Chen (2002). 中国早期国家的形成——从二里头和二里岗时期的中心和边缘之间的关系谈起 the formation of early states in china: From the relationships between centers and peripheries during the erlitou and erligang periods. *古代文明 Ancient Civilization 1*.

Liu, 刘文鹏, W. (2017). *Study on Post Stations in the Qing Dynasty 清代驿站考*. People's Publishing House 人民出版社.

Liu, W. G. (2015). *The Chinese Market Economy, 1000 1500*. Suny Press.

Liu, Y. . (2014). 中国古代家马研究的回顾与展望 retrospect and prospect of the study on ancient domestic horses in china. *南方文物 Southern Cultural Relics* (1), 74–77.

Liu, Z. (2024). Wages, labour markets, and living standards in china, 1530–1840. *Explorations in Economic History 92*, 101569.

Loewe, M. and E. L. Shaughnessy (Eds.) (1999). *The Cambridge History of Ancient China: From the Origins of Civilization to 221 BC*. Cambridge: Cambridge University Press.

Longacre, W. A. (1999). Standardization and specialization: what' s the link. *Pottery and people: a dynamic interaction*, 44–58. Publisher: University of Utah Press Salt Lake City.

López, R. A. (2005). Trade and growth: Reconciling the macroeconomic and microeconomic evidence. *Journal of Economic surveys 19*(4), 623–648. Publisher: Wiley Online Library.

Marcus, J. (1983). Lowland Maya archaeology at the crossroads. *American Antiquity 48*(3), 454–488. Publisher: Cambridge University Press.

Marshall, A. (1890). The principles of economics. Technical report, McMaster University Archive for the History of Economic Thought.

McGovern, P. E., J. Zhang, J. Tang, Z. Zhang, G. R. Hall, R. A. Moreau, A. Nuñez, E. D. Butrym, M. P. Richards, C.-s. Wang, and others (2004). Fermented beverages of pre- and proto-historic China. *Proceedings of the National Academy of Sciences 101*(51), 17593–17598. Publisher: National Acad Sciences.

Michaels, G. and F. Rauch (2018). Resetting the urban network: 117–2012. *The Economic Journal 128*(608), 378–412.

Miguel, E. and G. Roland (2011). The long-run impact of bombing vietnam. *Journal of development Economics 96*(1), 1–15.

Mokyr, J. (2011). *The gifts of Athena: Historical origins of the knowledge economy.* princeton university press.

Mu, 牟发松, F., Y. Wu, 毋有江, and J. Wei, 魏俊杰 (2016, 12). *History of the Chinese Administrative Divisions, Volume 4: The Sixteen Kingdoms and Northern Dynasties* 中国行政区划通史（第四卷）十六国北朝卷. Fudan University Press 复旦大学出版社.

NASA Shuttle Radar Topography Mission (SRTM) (2013). Shuttle radar topography mission (srtm) global. Distributed by OpenTopography. Accessed: 2024-05-05.

Needham, J. (1974). *Science and civilisation in China*, Volume 5. Cambridge University Press.

Ni, Y. and M. Uebele (2019). Size and structure of disaster relief when state capacity is limited: China' s 1823 flood. *Australian Economic History Review 59*(1), 24–54.

Nitsch, V. (2003, July). Does history matter for urban primacy? The case of Vienna. *Regional Science and Urban Economics 33*(4), 401–418.

North, D. (1958). Ocean freight rates and economic development 1730-1913. *The Journal of Economic History 18*(4), 537–555.

North, D. C. (1990). Institutions, institutional change and economic performance. *Cambridge University.*

North, D. C. and B. R. Weingast (1989). Constitutions and commitment: the evolution of institutions governing public choice in seventeenth-century england. *The Journal of Economic History 49*(4), 803–832.

Oka, R. and C. M. Kusimba (2008, December). The Archaeology of Trading Systems, Part 1: Towards a New Trade Synthesis. *Journal of Archaeological Research 16*(4), 339–395.

Olga, G. . (2012). 古代亚洲的驯马, 乘马与游战族群 taming, riding, and nomadic warrior groups in ancient asia. 中国社会科学 *Chinese Social Sciences 6*.

Paik, C. and K. Shahi (2023). Ancient nomadic corridors and long-run development in the highlands of asia. *Explorations in Economic History 89*, 101482.

Pan, 潘念慈, N. (1959). On the courier system of the yuan dynasty 关于元代的驿. *Historical Research 历史研究*.

Parthasarathi, P. (1998). Rethinking wages and competitiveness in the eighteenth century: Britain and south india. *Past & Present* (158), 79–109.

Parthasarathi, P. (2001). *The transition to a colonial economy: weavers, merchants and kings in South India, 1720-1800.* Number 7. Cambridge University Press.

Parthasarathi, P. (2011). *Why Europe grew rich and Asia did not: Global economic divergence, 1600–1850.* Cambridge University Press.

Parthasarathi, P. and K. Pomeranz (2019). The great divergence debate. *Global economic history*, 19–37.

Pascali, L. (2017, September). The Wind of Change: Maritime Technology, Trade, and Economic Development. *American Economic Review 107*(9), 2821–2854.

Peng, K. . (2006, 5). *Grain Prices Since the Qing Dynasty* 清代以来的粮价. Shanghai People's Publishing House 上海人民出版社.

Peng, X. (1994). *A monetary history of China*, Volume 1. Western Washington.

Peng, X. . (1965). *History of Chinese Currency* 中国货币史. Shanghai People's Publishing House 上海人民出版社.

Peng, X. . (2020, 6). *History of Chinese Currency, Revised Edition* 中国货币史（校订版）. Shanghai People's Publishing House 上海人民出版社.

Peng, Ke 彭柯 and Zhu, Y. . (1999). 中国古代所用海贝来源新探 a new investigation into the sources of seashells used in ancient china. 收藏 *Collection* (0).

Perlès, C., T. Takaoğlu, and B. Gratuze (2011). Melian obsidian in NW Turkey: Evidence for early Neolithic trade. *Journal of Field Archaeology 36*(1), 42–49. Publisher: Taylor & Francis.

Piggott, S. (1974). Chariots in the Caucasus and in China. *Antiquity 48*(189), 16–24. Publisher: Cambridge University Press.

Piggott, S. (1978). Chinese chariotry: an outsider’s view. *Arts of the Eurasian Steppelands.–L.: Percival David Foundation of Chinese Art*, 32–51.

Plöchl, F. and E. Severnini (2022). Locational fundamentals, selection, and the persistence of spatial inequality. *Econometrica 90*(6), 2633–2671.

Polanyi, K. (1965). Trade and market in the early empires: Economies in history and theory. Publisher: Free Press.

Polanyi, K. (1975). Traders and Trade. In J. A. Sabloff and C. C. Lamberg-Karlovsky (Eds.), *Ancient Civilization and Trade*, pp. 133–154. Albuquerque: University of New Mexico Press.

Polanyi, K. (2002). The great transformation. *Readings in economic sociology*, 38–62. Publisher: Wiley Online Library.

Pomeranz, K. (2000). *The Great Divergence: China, Europe, and the Making of the Modern World Economy in the Asian Age*. Berkeley: University of California Press.

Pospisil, L. J. (1963). Kapauku Papuan Economy. Publisher: Dept. of Anthropology, Yale University.

Price, B. J. (1978). Commerce and cultural process in Mesoamerica. *Mesoamerican Communication Routes and Cultural Contacts, Papers* (40), 231–246.

Price, B. J., L. J. Bartolomé, G. Berthoud, R. L. Carneiro, A. K. Danda, S. Dasgupta, E. D. A. Carvalho, A. Y. Dessaint, R. Lawless, Z. Tagányi, and others (1977). Shifts in Production and Organization: A Cluster-Interaction Model [and Comments and Reply]. *Current Anthropology 18*(2), 209–233. Publisher: University of Chicago Press.

Qi, 漆侠, X. (2009). *Economic History of the Song Dynasty* 宋代经济史. Zhonghua Book Company 中华书局.

Qian, M. . (1996). 国史大纲 *Outline of National History*, Volume 6. 商务印书馆 The Commercial Press.

Redding, S. J. (2010). The empirics of new economic geography. *Journal of regional science 50*(1), 297–311.

Redding, S. J. and D. M. Sturm (2008a, November). The Costs of Remoteness: Evidence from German Division and Reunification. *American Economic Review 98*(5), 1766–1797.

Redding, S. J. and D. M. Sturm (2008b). The costs of remoteness: Evidence from german division and reunification. *American Economic Review 98*(5), 1766–1797.

Redding, S. J., D. M. Sturm, and N. Wolf (2011). History and industry location: evidence from german airports. *Review of Economics and Statistics 93*(3), 814–831.

Rice, P. M. (1996). Recent ceramic analysis: 2. Composition, production, and theory. *Journal of Archaeological Research 4*, 165–202. Publisher: Springer.

Rice, P. M., W. Y. Adams, J. W. Ball, W. M. Davis, T. Earle, R. E. Fry, I. Hodder, L. Joesink-Mandeville, C. C. Kolb, M. Nishimura, and others (1981). Evolution of specialized pottery production: a trial model [and comments and reply]. *Current Anthropology 22*(3), 219–240. Publisher: University of Chicago Press.

Rivas Moreno, J. J. (2022). *An alternative model for early modern long-distance trade finance: the capital markets of Manila, 1680-1838.* Ph. D. thesis, London School of Economics and Political Science.

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of political economy 94*(5), 1002–1037.

Rosés, J. R. (2003). Why isn't the whole of spain industrialized? new economic geography and early industrialization, 1797–1910. *The Journal of Economic History 63*(4), 995–1022.

Sahlins, M. (1972). *Stone Age Economics.* Chicago: Aldine-Atherton.

Schneider, H. K. (1968). Exchange of cattle in Africa. *American Anthropologist 70*(4), 757–758. Publisher: Wiley Online Library.

Schneider, H. K. (1974). *Economic man: The anthropology of economics.* Free Press New York.

Shackleton, N. and C. Renfrew (1970). Neolithic trade routes re-aligned by oxygen isotope analyses. *Nature 228*(5276), 1062–1065. Publisher: Nature Publishing Group UK London.

Shaughnessy, E. L. (1988). Historical Perspectives on the Introduction of the Chariot into China. *Harvard journal of Asiatic studies 48*(1), 189–237. Publisher: JSTOR.

Shi, 施和金, H. (2009, 8). *History of the Chinese Administrative Divisions, Volume 5: The Sui Dynasty 中国行政区划通史（第五卷）隋代卷.* Fudan University Press 复旦大学出版社.

Shiba, Y. (1970). *Commerce and Society in Sung China.* University of Michigan Press.

Shiue, C. H. (2002). Transport costs and the geography of arbitrage in eighteenth-century china. *American Economic Review 92*(5), 1406–1419.

Shiue, C. H. and W. Keller (2007). Markets in china and europe on the eve of the industrial revolution. *American Economic Review 97*(4), 1189–1216.

Singh, T. (2010). Does international trade cause economic growth? A survey. *The World Economy 33*(11), 1517–1564. Publisher: Wiley Online Library.

Skinner, G. W. (1977). Cities and the hierarchy of local systems. *The city in late imperial China 319*.

Smith, A. (1776). *The Wealth of Nations*. London: W. Strahan.

Sng, T.-H. (2014). Size and dynastic decline: The principal-agent problem in late imperial china, 1700–1850. *Explorations in Economic History 54*, 107–127.

Sng, T.-H. and C. Moriguchi (2014). Asia’s little divergence: State capacity in china and japan before 1850. *Journal of Economic Growth 19*, 439–470.

Su, B. . and W. . Yin (1981). 关于考古学文化的区系类型问题 on the problem of cultural regional types in archaeology. 文物 *Cultural Relics 5*, 10–17.

Sun, G. . (2011a). 中国航海历史的发展时期——秦汉 (公元前 221 年—220 年) the development period of chinese maritime history: Qin and han dynasties (221 bc–220 ad). 世界海运 *World Shipping 34*(4), 54–56.

Sun, G. . (2011b). 中国航海历史的形成时期——春秋战国 (公元前 770 年—前 221 年) the formative period of chinese maritime history: Spring and autumn to warring states period (770 bc–221 bc). 世界海运 *World Shipping 34*(3), 54–56.

Sun, G. . (2011c). 中国航海历史的繁荣时期——隋唐五代 (589-960 年) the prosperous period of chinese maritime history: Sui, tang, and five dynasties (589–960 ad). 世界海运 *World Shipping 34*(7), 53–55.

Tan, 谭其骧, Q. (Ed.) (1982). *The Historical Atlas of China* 中国历史地图集. Beijing 北京: Cartographic Publishing House 地图出版社.

The Institute of Archaeology, C. A. o. S. S. . (1994). 殷墟的发现与研究 *The Discovery and Study of the Yin Ruins*, Volume 23. 科学出版社 Science Press.

The Xia-Shang-Zhou Chronology Project Expert Group, . (2000). 夏商周断代工程 *1996–2000 年阶段成果报告: 简本 Xia-Shang-Zhou Chronology Project 1996–2000 Phase Results Report: Abridged Version.* 世界图书出版公司北京公司 World Book Publishing Company Beijing.

The Xia-Shang-Zhou Chronology Project Expert Group, . (2022, June). 夏商周断代工程报告 *Xia-Shang-Zhou Chronology Project Report.* 科学出版社 Science Press.

Underhill, A. (1996). Warfare and the Development of States in China. In M. Allen and E. Arkush (Eds.), *Archaeological Perspectives on the Transformation of War*, pp. 253–285. Gainesville: University Press of Florida.

Underhill, A. P. (1994). Variation in settlements during the Longshan period of northern China. *Asian Perspectives*, 197–228. Publisher: JSTOR.

Underhill, A. P. (Ed.) (2013). *A Companion to Chinese Archaeology.* Chichester, West Sussex: Wiley-Blackwell.

Van der Panne, G. (2004). Agglomeration externalities: Marshall versus jacobs. *Journal of evolutionary economics 14*, 593–604.

Von Glahn, R. (2016). *An economic history of China: From antiquity to the nineteenth century.* Cambridge University Press.

Wang, G. . (1959). 殷卜辞中所见先公先王考 an examination of the former lords and kings mentioned in the oracle bones of the yin dynasty. 观堂集林 · 卷九 *Guantang Jilin Volume 9*.

Wang, Y. (2018). A study of the 'complete map of rivers and coastline' and the routes of shippment by water in emperor daoguang's period 《江海全图》与道光朝海运航路研究. *Palace Museum Journal* 故宫博物院院刊 (5), 126–138.

Wang, Y., H. Cheng, R. L. Edwards, Y. He, X. Kong, Z. An, J. Wu, M. J. Kelly, C. A. Dykoski, and X. Li (2005). The Holocene Asian monsoon: links to solar changes and

North Atlantic climate. *Science 308*(5723), 854–857. Publisher: American Association for the Advancement of Science.

Wang, Y. and Y. Su (2011). The geo-pattern of course shifts of the Lower Yellow River. *Journal of Geographical Sciences 21*(6), 1019–1036. Publisher: Springer.

Wen, B., H. Li, D. Lu, X. Song, F. Zhang, Y. He, F. Li, Y. Gao, X. Mao, L. Zhang, et al. (2004). Genetic evidence supports demic diffusion of han culture. *Nature 431*(7006), 302–305.

Wilson, J. K. and M. Flecker (2010). Dating the belitung shipwreck. *Shipwrecked: Tang treasures and monsoon winds*, 35–37.

Wittfogel, K. A. (1953). Oriental despotism. *Sociologus*, 96–108. Publisher: JSTOR.

Wittfogel, K. A. (1957). *Oriental Despotism: A Comparative Study of Total Power.* United States: Yale University Press.

Worcester, G. R. G. (2020, 11). *The Junks and Sampans of Yangtze.* Naval Institution Press.

Wu, 吴松弟, S. (2000, 12). *History of the Chinese Population, Volume 3: The Liao, Song, Jin, and Yuan Periods 中国人口史（第三卷）辽宋金元时期*. Fudan University Press 复旦大学出版社.

Xu, 许宏, H. (2017a, 12). *Archaeological Study of Cities and Towns in the Pre-Qin Period 先秦城邑考古*. Jincheng Publishing House 金城出版社.

Xu, H. . (2009). 最早的中国 *The Earliest China.* 科学出版社 Ke xue chu ban she.

Xu, H. . (2017b). 先秦城邑考古 pre-qin city archaeology.

Xu, H. . (2023, July). *最早的帝国: 二里岗文明冲击波 The Earliest Empire: The Shockwave of the Erligang Civilization (Hardcover).* 大象出版社 Elephant Publishing House.

Xu, Q., J. Xiao, Y. Li, F. Tian, and T. Nakagawa (2010, June). Pollen-Based Quantitative Reconstruction of Holocene Climate Changes in the Daihai Lake Area, Inner

Mongolia, China. *Journal of Climate 23*(11), 2856–2868. Publisher: American Meteorological Society Section: Journal of Climate.

Yan, 严耕望, G. (1985). *Study on Tang Dynasty Transportation* 唐代交通图考. Institute of History and Philology, Academia Sinica 中央研究院历史语言研究所.

Yang, P. . (2001, 6). *History of Science and Technology in China: Volume on Metrology* 中国科学技术史：度量衡卷. Science Press 科学出版社.

Yang, R. ., N. . Di, X. . Jia, D. . Yin, S. . Gao, J. . Shao, Z. . Sun, S. . Hu, and Z. . Zhao (2022). 从石峁遗址出土植物遗存看夏时代早期榆林地区先民的生存策略选择 the choice of survival strategies by the early inhabitants of the yulin area during the xia dynasty as seen through plant remains unearthed at the shimao site. 第四纪研究 *Quaternary Research 42*(1), 101–118.

Yang, Z. . (2006, 11). *Study of Courier Stations in the Ming Dynasty* 明代驿站考. Shanghai Ancient Books Publishing House 上海古籍出版社.

Yang, Z. . (2019a, 8). *The comprehensive illustrated routebook* 一统路程图记. Nanjing Publishing House 南京出版社.

Yang, Z. . (2019b, 12). *Merchant's Handbook* 商贾便览. Nanjing Publishing House 南京出版社.

Yang, Z. . (2019c, 8). *The Thoroughfares of the World* 寰宇通衢. Nanjing Publishing House 南京出版社.

Yongjie, X. (2008). The dream and the glory: Integral salvage of the nanhai no. 1 shipwreck and its significance. *The Silk Road 5*(2), 16–19.

You, X., D. Bogart, E. Alvarez, M. Satchell, and L. Shaw-Taylor (2022). Transport development and urban population change in the age of steam: A market access approach.

Yu, 余蔚, W. (2012, 5). *History of the Chinese Administrative Divisions, Volume 9: The Liao and Jin Dynasties* 中国行政区划通史（第九卷）辽金卷. Fudan University Press 复旦大学出版社.

Yuan, J., R. Flad, and Y. Luo (2008). Pig domestication in ancient china. *Antiquity 82*(317), 373–388.

Zeng, 曾一民, Y. (1987). *Inland Transportation in Guangzhou during the Tang Dynasty 唐代广州之内陆交通*. Guozhang Publishing House 国彰出版社.

Zhang, D. D., H. F. Lee, C. Wang, B. Li, Q. Pei, J. Zhang, and Y. An (2011). The causality analysis of climate change and large-scale human crisis. *Proceedings of the National Academy of Sciences 108*(42), 17296–17301.

Zhang, G. . (1983). 中国青铜时代 the chinese bronze age.

Zhang, H. (2021, October). 仰韶文化与华夏文明——从农业起源到城市革命 the yangshao culture and the huaxia civilization: From the origins of agriculture to the urban revolution. *中国文物报 China Cultural Relics News*.

Zhang, Z., Z. Shen, S. Zhang, J. Chen, S. Chen, D. Li, S. Zhang, X. Liu, D. Wu, Y. Sheng, et al. (2023). Lake level evidence for a mid-holocene east asian summer monsoon maximum and the impact of an abrupt late-holocene drought event on prehistoric cultures in north-central china. *The Holocene 33*(4), 382–399.

Zhao, 趙效宣, X. (1983). *The Post Station System in the Song Dynasty 宋代驿站制度*. Lianjing Publishing Company 聯經出版事業公司.

Zhao, Z. . (1987). 论二里头遗址为夏代晚期都邑 on the erlitou site being a late xia dynasty capital. *华夏考古 Huaxia Archaeology* (2), 196–204.

Zhao, Z. . (2015). 小麦传入中国的研究——植物考古资料 the study of wheat introduction into china: Archaeobotanical data. *南方文物 Southern Cultural Relics* (3), 44–52.

Zhao, Z. . (2017). 仰韶文化时期农耕生产的发展和农业社会的建立——鱼化寨遗址浮选结果的分析 the development of agricultural production and the establishment of agricultural society during the yangshao culture period: An analysis of the flotation results from the yuhuazhai site. *江汉考古 Jianghan Archaeology 6*, 98–108.

Zhao, Z. . (2020). 新石器时代植物考古与农业起源研究 (续) neolithic plant archaeology and the study of the origins of agriculture (continued). 中国农史 *Chinese Agricultural History 39*(4), 3–9.

Zhou, 周振鹤, Z. and X. Li, 李晓杰 (2009, 1). *History of the Chinese Administrative Divisions, Volume 1: General Introduction and Pre-Qin Period* 中国行政区划通史（第一卷）总论、先秦卷. Fudan University Press 复旦大学出版社.

Zhou, 周振鹤, Z., X. Li, 李晓杰, and L. Zhang, 张莉 (2016, 11). *History of the Chinese Administrative Divisions, Volume 2: The Qin and Han Periods* 中国行政区划通史（第二卷）秦汉卷. Fudan University Press 复旦大学出版社.

Zhu, 朱開宇, K. (2014). Transportation maps of the tang dynasty and the spatial operation of the tang empire - frontier defense, military and administrative layout, and historical significance 唐代交通圖與唐帝國的空間運作——邊防, 軍政布局及歷史意義. *National Taiwan University Department of History Thesis* 國立臺灣大學歷史學系學位論文 *2014*, 1–208.

Zou, H. . (1990). 夏文化研讨的回顾与展望 review and prospects of xia culture research. 中原文物 *Central Plains Cultural Relics* (2), 3–14.