Route To Cities:
Natural Endowments Under Varying Institutions

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Abstract

According to 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.

Keywords: location fundamental, economic history, long-run development, transportation network, China

JEL Codes: N95, R12, O18

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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, 1993; Redding and Sturm, 2008; 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 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

[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 5.

[3]When national capital was located in northern China, such as Beijing (Yuan, Ming and Qing Dynasty). More detail can be found at table 5

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) 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 omit 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.

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, 2008; 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, 2008)

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.

2 Transportation in Historical China

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 2 displays the transportation network during the Ming and Qing periods constructed in Chapter 1 of this dissertation, while Figure 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 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.

In summary, existing research reveals that: (1) historical China possessed a nationwide, comprehensive transportation network; (2) this network was broadly composed of three

[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.

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.

2.2 Historical Transport Cost & Speed

Compared to the already limited research on historical transportation networks, studies focusing on historical transportation costs are almost nonexistent. Chapter 1 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.

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 deflating costs using grain prices[6], 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%[7] of that in the 7th century, and water transportation costs even lower at 1.7%[8]. 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

[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] 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)

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

[8] 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.

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 1 and figure 3.

In Chapter 1, the reconstruction of transportation speeds during the Ming and Qing dynasties is based on merchant travel route books[9]. 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 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) 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[10], respectively. Functionally, waterway stations primarily handled official transportation[11], 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, 1994; Pan, 1959; Liu, 2017; Zhao, 1983)

The final aspect concerns the situation of maritime shipping. Compared to overland

[9] 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

[10] 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.

[11] Including transporting grains and copper for coinage

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 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.

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), 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.

3 Study Area and Data

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 for county and prefecture seat locations from 221 BCE to 1911 CE[12][13][14]. Due to the

[12]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.

[13]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.

[14]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.

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 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[15]. 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[16].

It is essential to highlight that the issues encountered within the CHGIS prefecture dataset also manifest in the CHGIS county dataset. Specifically, many units classified at the county level do not represent counties but may correspond to other non-administrative entities, such as military garrisons (*wei* & *suo*) and chieftaincies (*tu si*) during the Ming

[15] 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.

[16] 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 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.

dynasty. This rationale underpins the decision to label the lower-tier dataset constructed in this study as "city" rather than "county". This choice is motivated by two main considerations: (1) a portion of the county-level units are not, in fact, counties and (2) the units included that are not counties often represent settlements with populations exceeding one thousand, some of which are even fortified with walls. Thus, these entities are conceptualized as cities within a broader definition, acknowledging their urban characteristics despite the variance from traditional administrative classifications.

Figure 6 illustrates the variation in the total number of counties and prefectures recorded in the CHGIS from 1 CE to 1911 CE. Additionally, Figure 8 presents the specific data on counties and prefectures as documented by the CHGIS for the year 1500 during the Ming dynasty. Finally, Figure 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).

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 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.

3.3 Proxy 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 1), along with the reconstruction of the Ming and Qing dynasties' national transportation networks discussed in Chapter 1 (see figure 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.

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 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 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 is defined based on the betweenness centrality within the road network constructed from optimal natural routes for all pairs within a 400-hour walking distance. Given the network's extensive size, the betweenness centrality values are small, necessitating multiplication by one billion for practicality. Considering the analysis operates with 1/4 degree cells and the NRS is at a 1/12 degree resolution, the highest NRS value within each cell is selected, indicating the cell's connectivity to the natural routes network. This metric is considered exogenous, relying solely on topographical inputs. Figure 11 illustrates the NRS for each cell within China.

Figure 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:

$$NRS' = \frac{ln(NRS) - \min(ln(NRS))}{\max(ln(NRS)) - \min(ln(NRS))} \tag{1}$$

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 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.

3.3.2 *Waterway*

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[17]. 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.

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

[17] See chapter 1 of this dissertation

becoming harbors compared to other coastal areas[18], and (2) the location of estuaries is determined 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.

As outlined in the historical background section, the majority of China's maritime trade routes are concentrated along the southeast coast. Consequently, I focus on estuary cells along the southeast coast as proxies for sea route ports. Specifically, I use the latitude of the Yangtze River estuary, 32 degrees North, as a boundary. If an estuary cell is located south of 32 degrees North, it is classified as a cell suitable for a sea route port.

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[19] (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, 1953), with wetland rice and wheat being the crops under consideration[20].

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 (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

[18]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.

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

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

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 2 provides a detailed description of the data sources.

4 Empirical Strategy and Results

4.1 Empirical Set Up

This study begins by estimating the marginal effect of natural geographical endowments on the location of cities using the following equation:

$$Y_{it} = \theta Geo_i + \lambda_i + \gamma_t + \epsilon_{it} \tag{2}$$

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, λ_i represents Macro Region fixed effects, following the approach of Skinner (1977). To control for time trends, γ_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:

$$Y_{it} = \beta Routes_i + \theta Geo_i + \lambda_i + \gamma_t + \epsilon_{it} \tag{3}$$

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 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.

4.2 Main Results

4.2.1 Geography Factors

Table 3 presents the results of Equation 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%.

4.2.2 Routes

Table 4 presents the results from Equation 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.

4.3 Persistence

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:

$$Y_{it} = \beta Routes_i + \theta Geo_i + \lambda_i + \epsilon_{it} \tag{4}$$

The results are presented in Table 5 and 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 13.

To facilitate the understanding of Chinese historical timelines, Figure 14 and 15 incorporates color coding to distinguish between dynasties. Now, reflecting on the characteristics of different route types, the results can be interpreted as follows:

4.3.1 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.

4.3.2 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 Dynastic Cycles

As depicted in Figure 14 and Figure 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:

$$Y_{it} = \beta Routes_i + \gamma \left(Routes_i \times Dynasty_t \right) + \theta Geo_i + \lambda_i + \gamma_t + \epsilon_{it} \tag{5}$$

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 7 and illustrated in Figure 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.

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.

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[21][22], as depicted in figure 14, 15, 16 and table 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.*

[21] 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

[22] 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, 2017). These adjustments are undoubtedly closely tied to the institutional frameworks of each dynasty.

To examine these hypotheses, I have following estimation:

$$Y_{it} = \beta_1 Routes_i + \beta_2 \left(Routes_i \times Institution_t \right) + \theta Geo_i + \lambda_i + dynasty_t + year_t + \epsilon_{it} \quad (6)$$

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, λ_i represents a regional fixed effect at skinner macro region, 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 β_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.

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

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[23]. 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 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 8 and figure 18 display the regression analysis results from Equation 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

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

not impact areas surrounding land routes, as they served more for government information transmission.

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 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 8 and figure 18, presents the results of Equation 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 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.

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[24], 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.

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

[24]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.

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[25], 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 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, 2008; Donaldson and Hornbeck, 2016; Coşar and Fajgelbaum, 2016)

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.

Figures 20 and 21 build upon Figures 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:

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

$$Y_{it} = \beta_1 Routes_i + \beta_2 \left(Routes_i \times Division_t\right) + \lambda_i + dynasty_t + year_t + \epsilon_{it} \tag{7}$$

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 7 are reported in Figure 18 and Table 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.

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 20 and 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:

$$Y_{it} = \beta Routes_i + \gamma \left(Routes_i \times Event_t\right) + \lambda_i + dynasty_t + \epsilon_{it} \tag{8}$$

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 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.

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.

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Tables

Table 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 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 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: *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 5: *Cross Sectional Results (cities) and brief dynastic history*

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

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

Table 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 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 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 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 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).

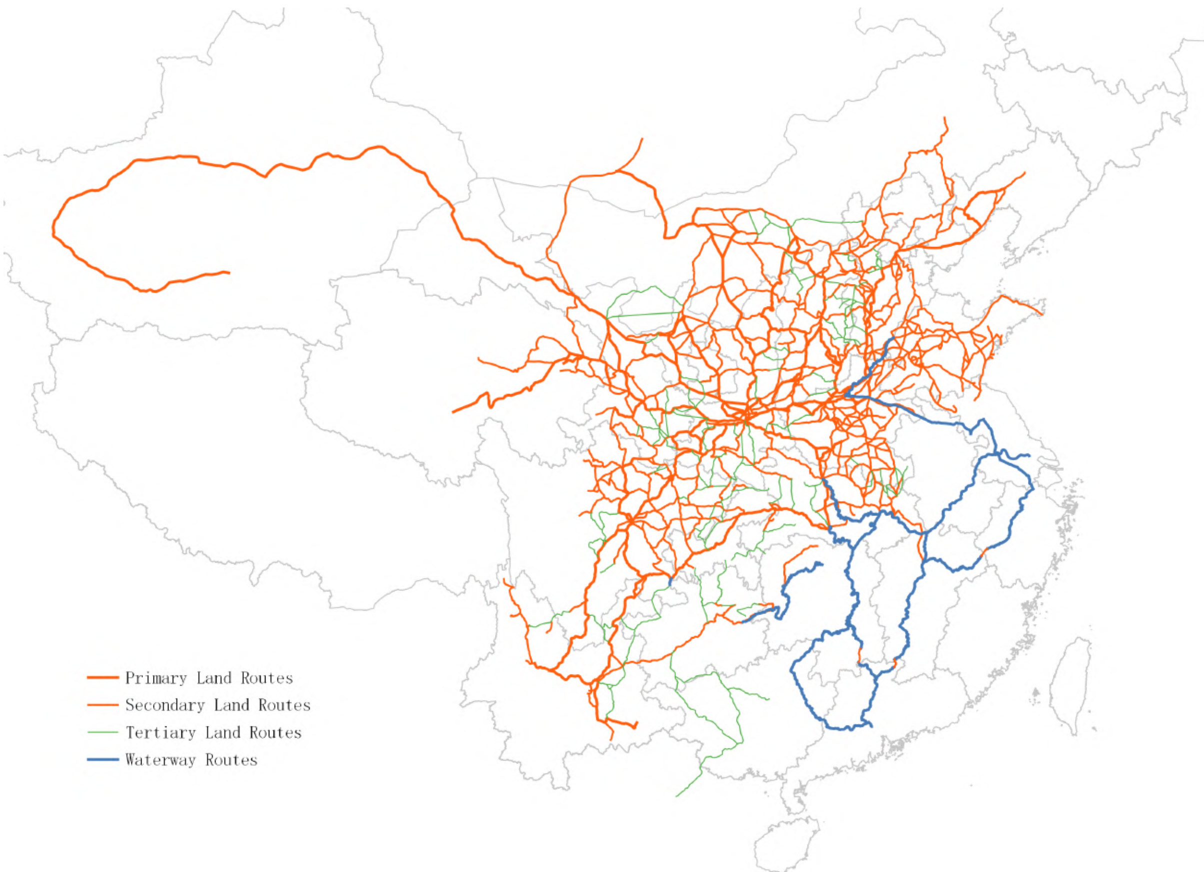
Table 10: *Nomad invasions and three mass migrations in Chinese history (cities)*

	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 8.

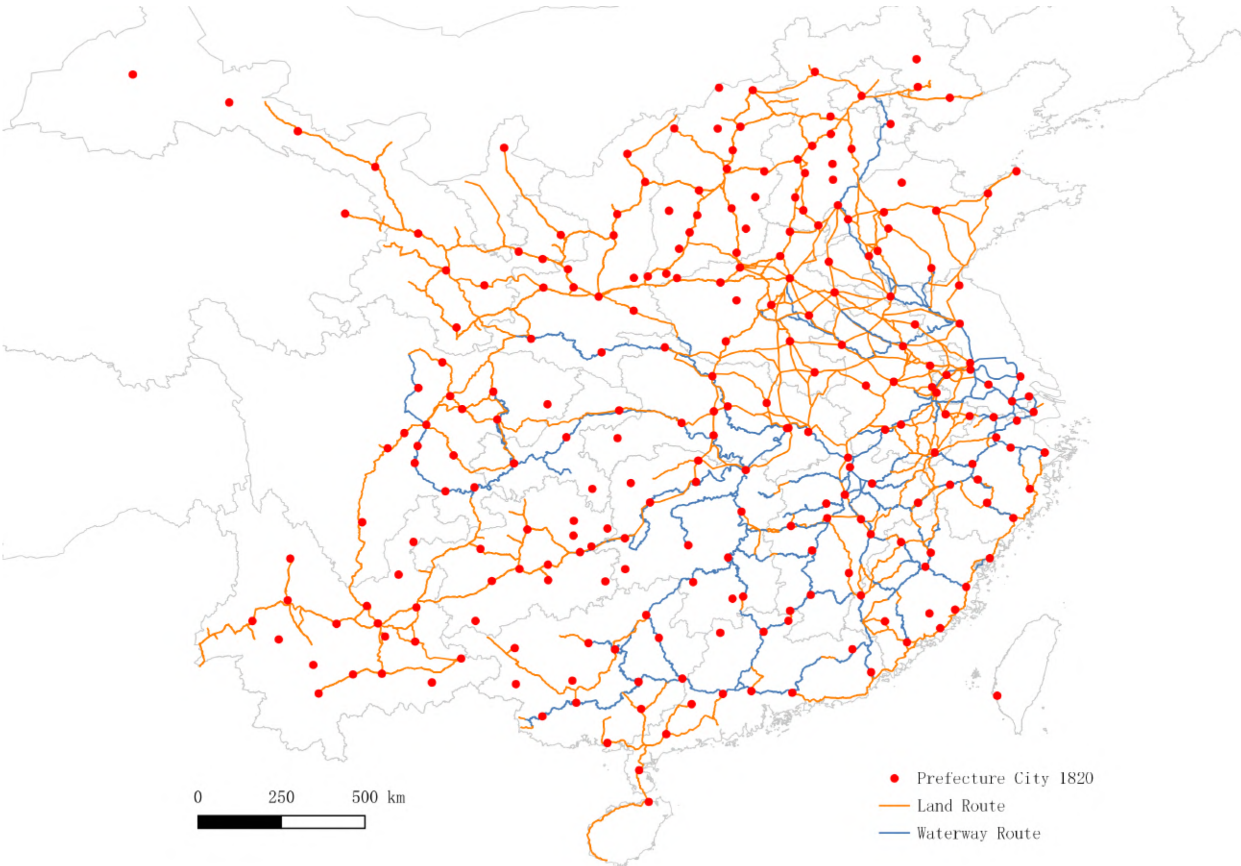
Figures

Figure 1: *Transportation Routes in Tang China*



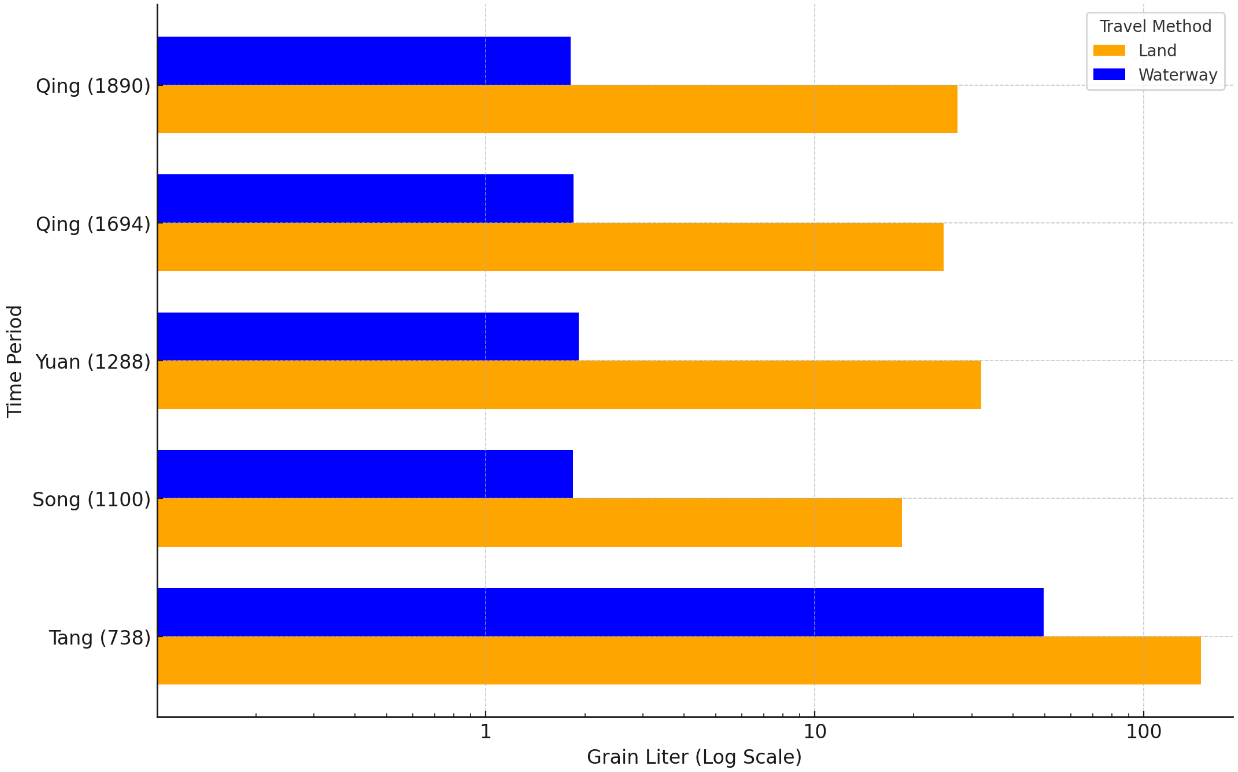
Note: Reconstructed with Yan (1985), Zeng (1987) and Zhu (2014). The national transportation network in Tang China (7th century) remains largely unknown, as Yan passed away before completing his study of the entire network.

Figure 2: *Transportation Routes in Ming-Qing China*



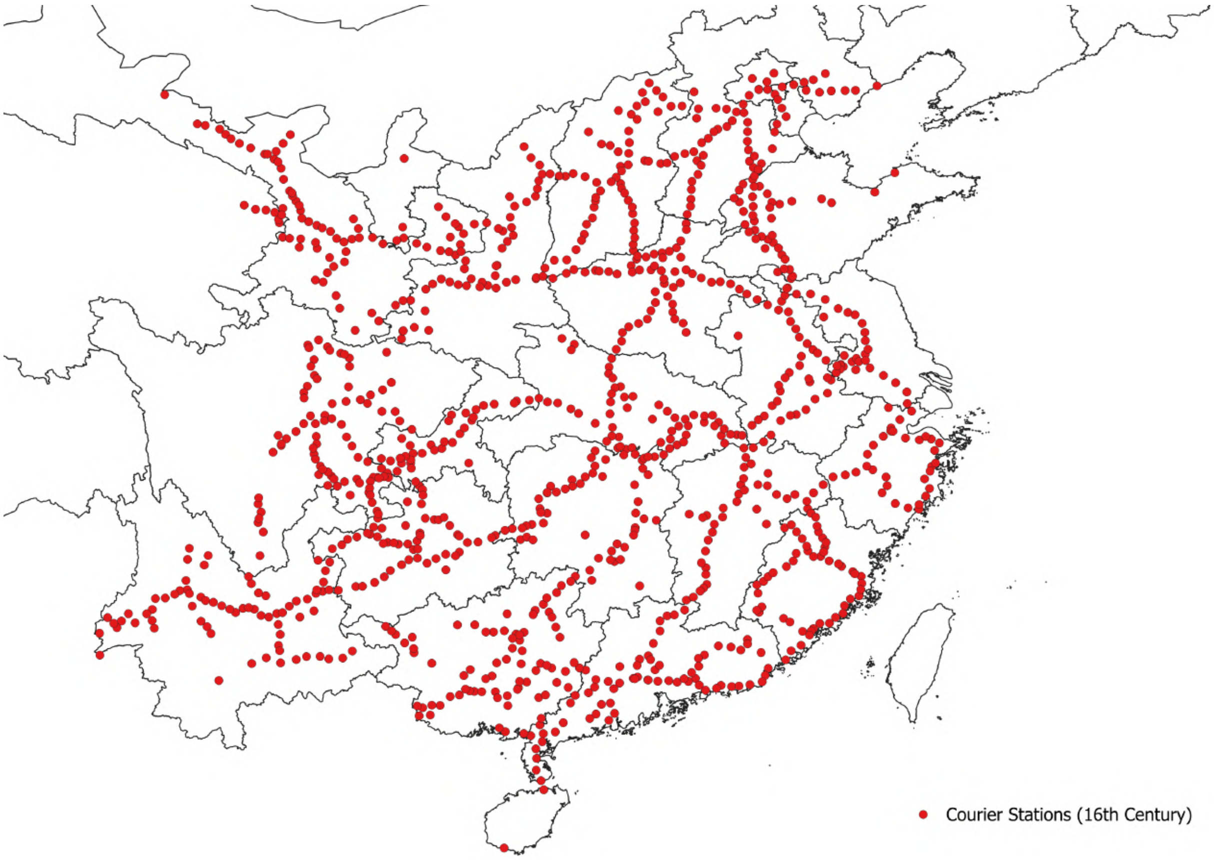
Note: Reconstructed through historical route books in Ming China

Figure 3: *Transport Costs over Different Dynasties in Historical China*



Note: Data source and notes see table 1

Figure 4: *Courier Station in Late-Ming (16th Century) China*



*Note: Sourced from Yang (1994). I manually geo-referenced all 1029 courier stations recorded in Da Ming Hui Dian(*大明会典*) according to Yang (1994). More detial see chapter 1*

Figure 5: *City share in Skinner's Macro Regions across time*

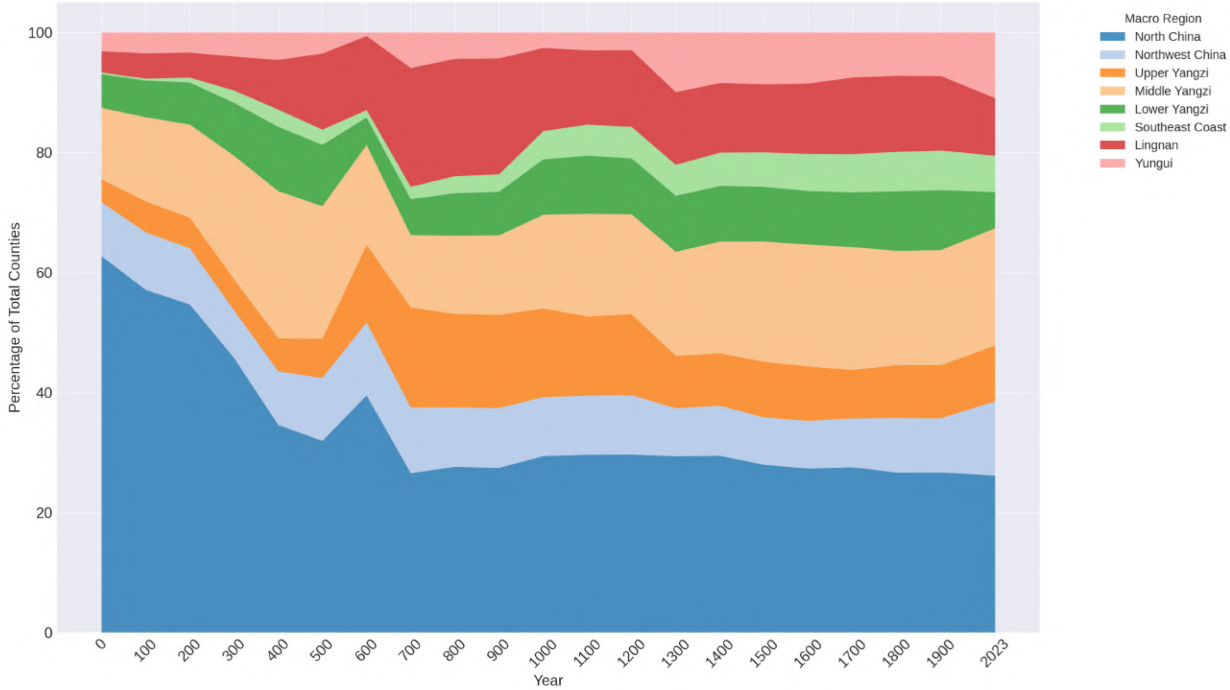


Figure 6: *Number of prefecture and county seats collected in CHGIS*

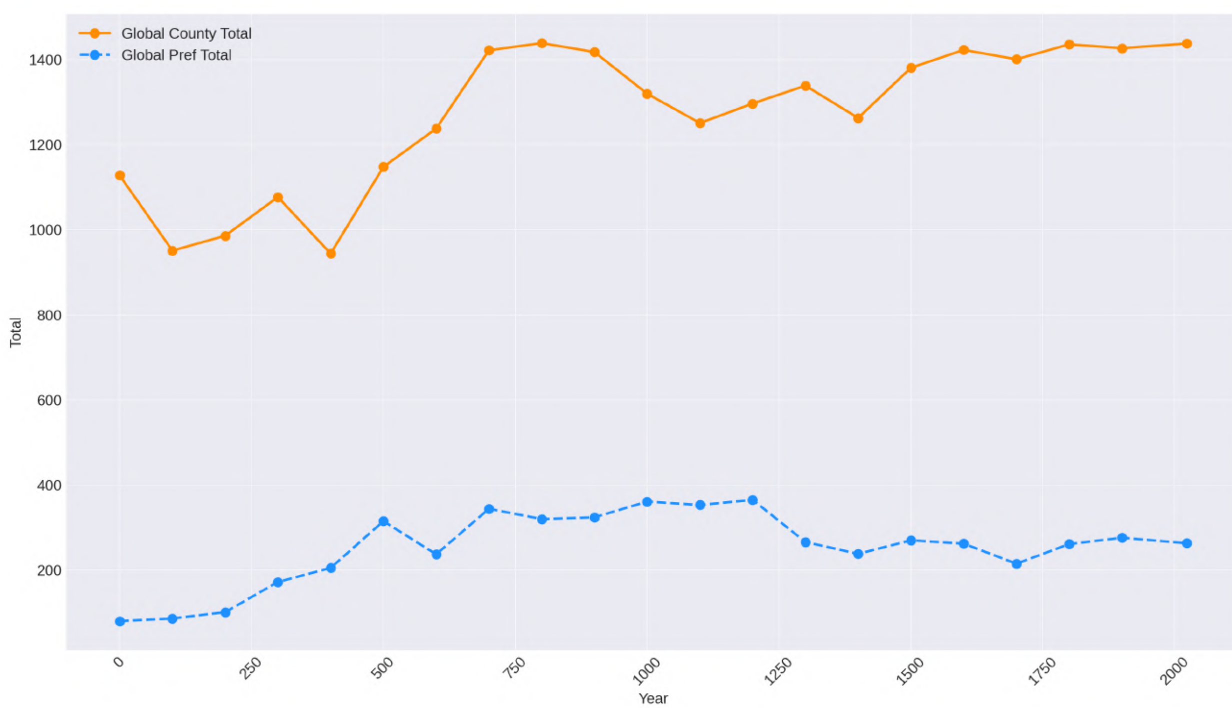
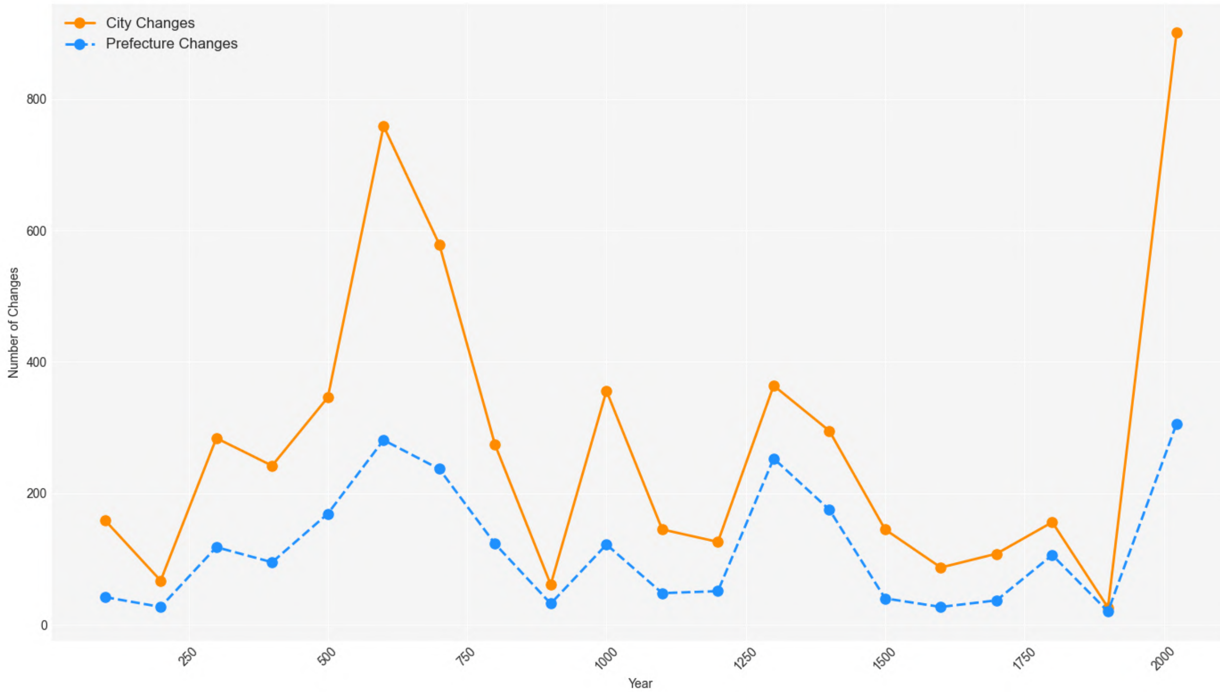
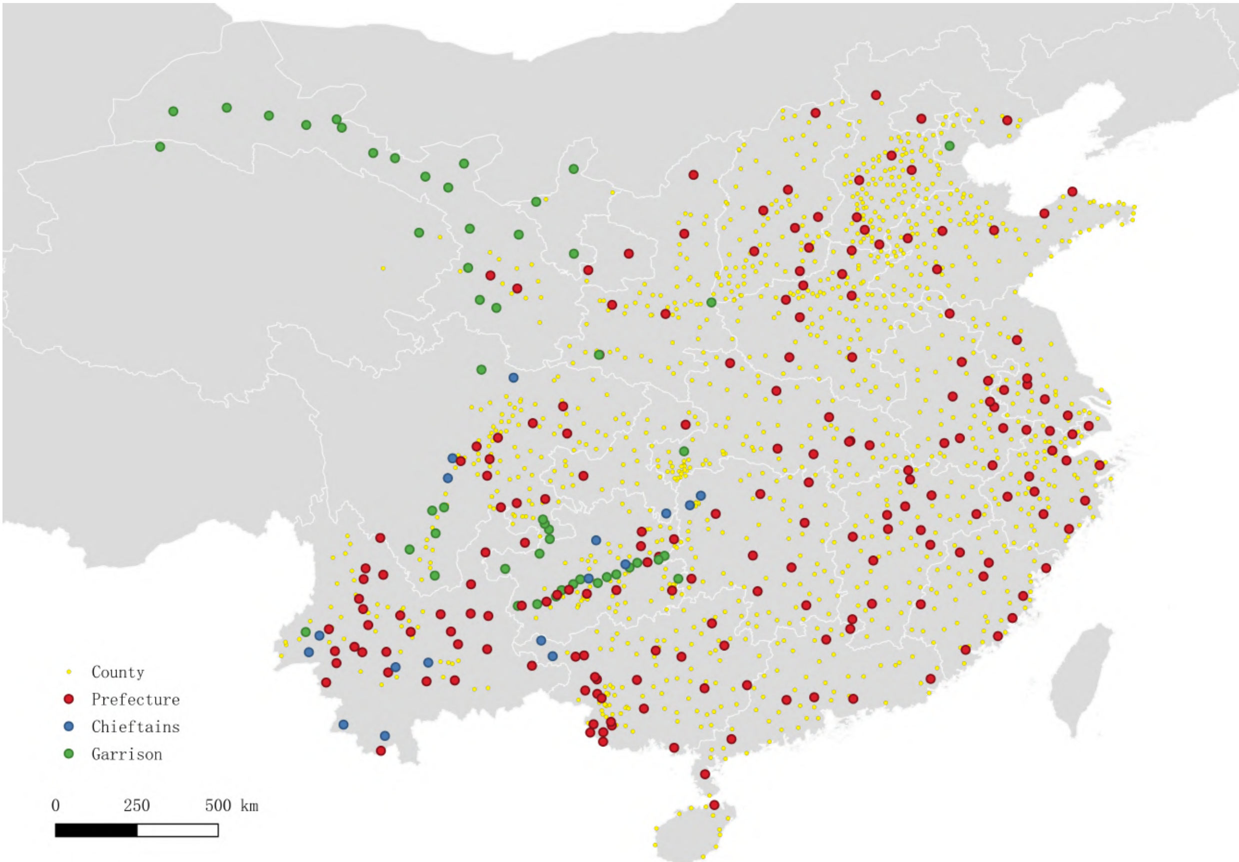


Figure 7: *Number of changes in prefecture and city dataset every century*



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

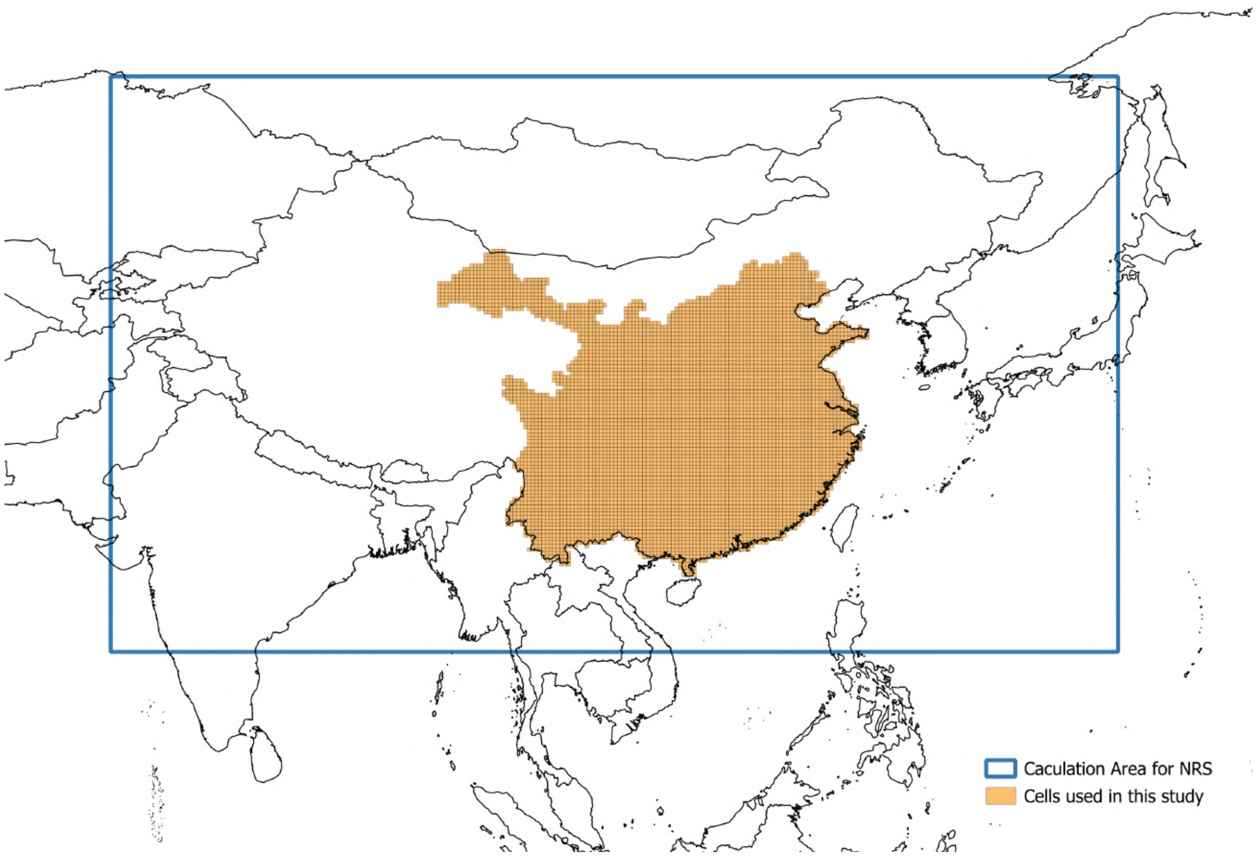


Figure 10: Distribution of Natural Road Score (400h)

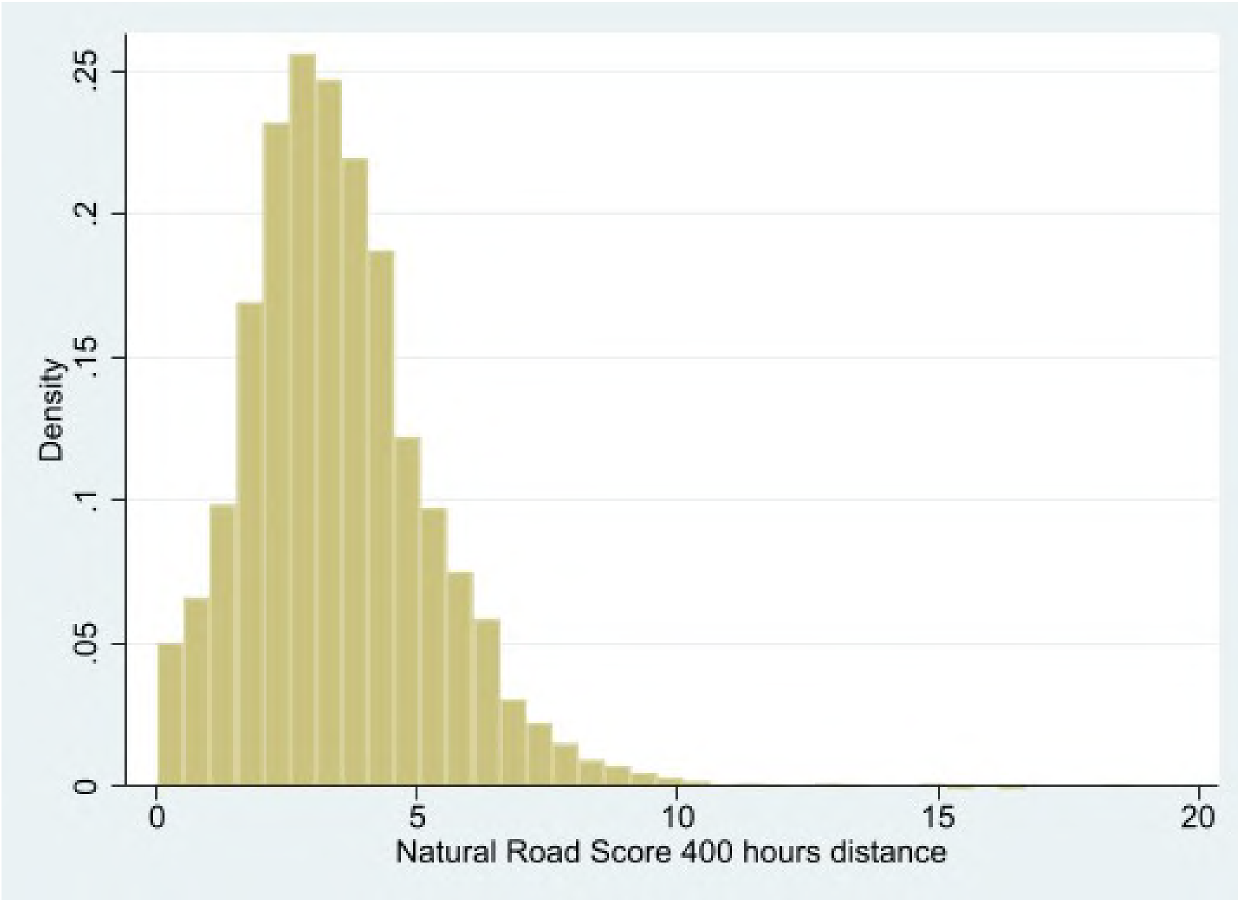


Figure 11: Spatial Distribution of Natural Road Score

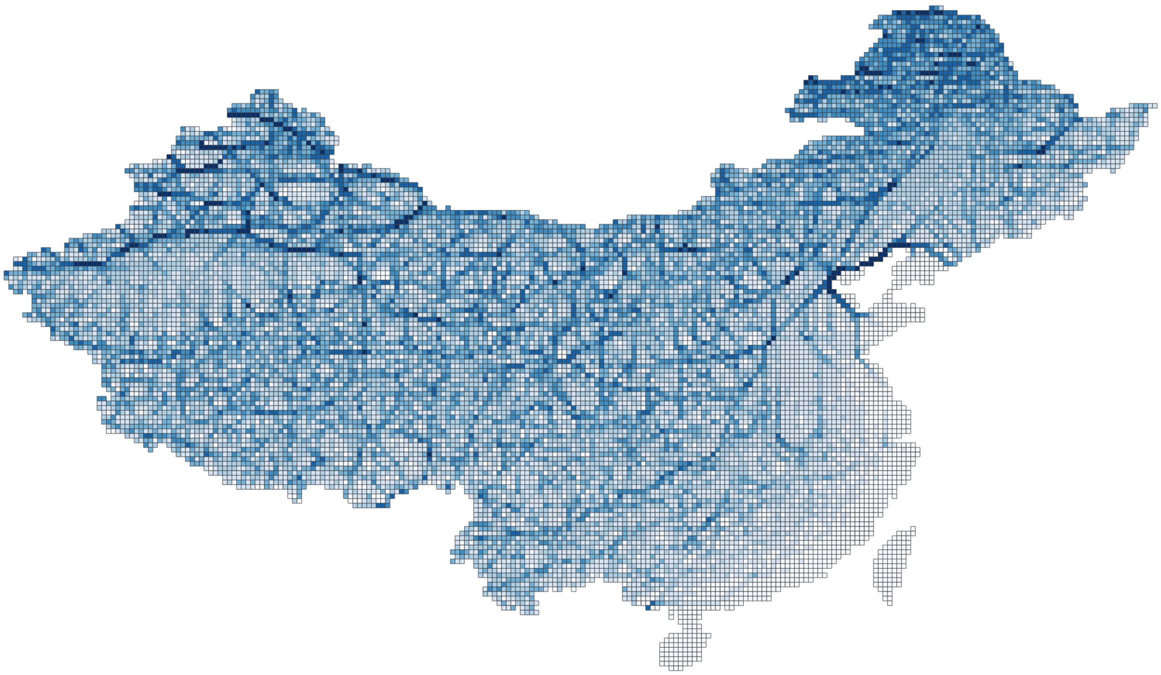
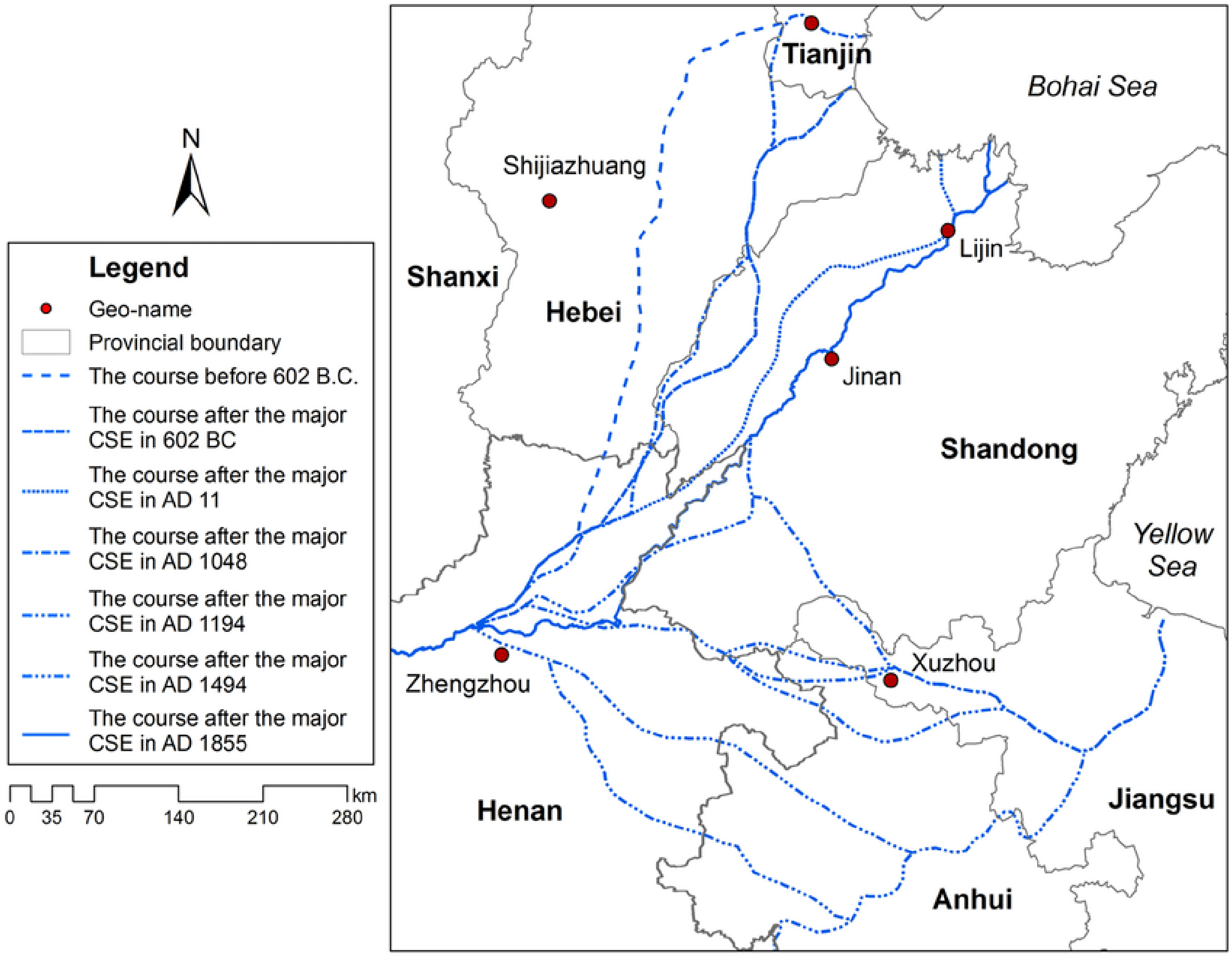


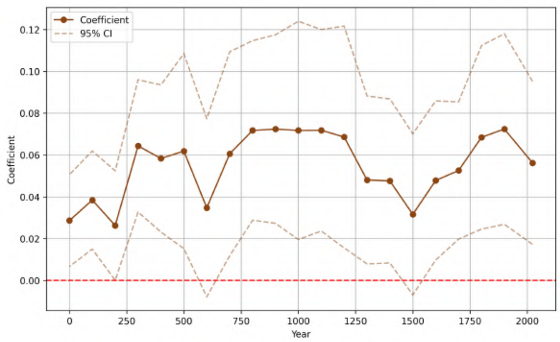
Figure 12: *Changes in the flow path of the Lower Yellow River in response to the six first-level course shifting events*



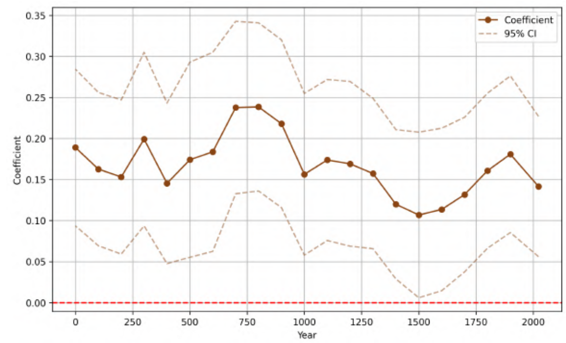
Note: Sourced from Wang and Su (2011)

Figure 13: Persist

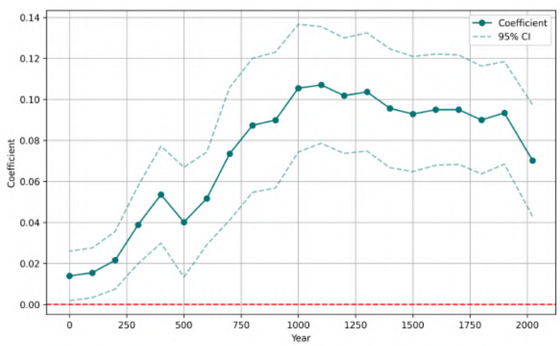
Prefecture ***City***



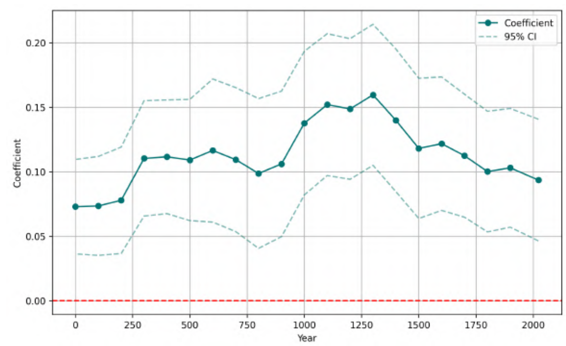
(a1) Natural Road Score



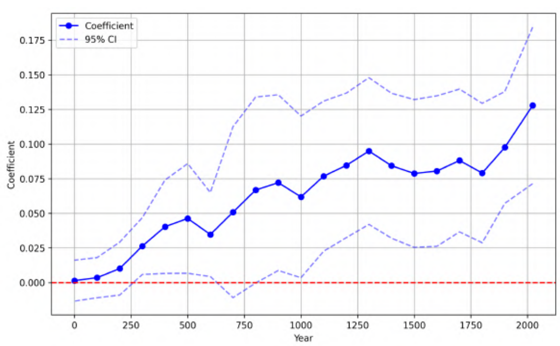
(a2) Natural Road Score



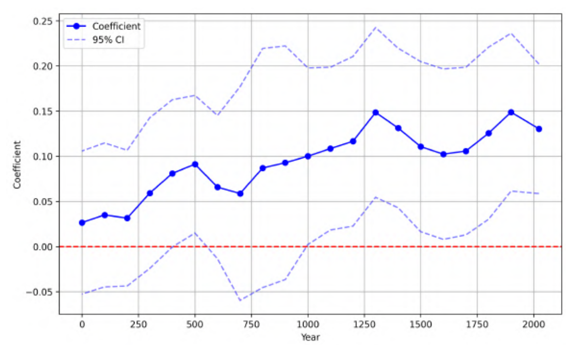
(b1) Navigable River



(b2) Navigable River



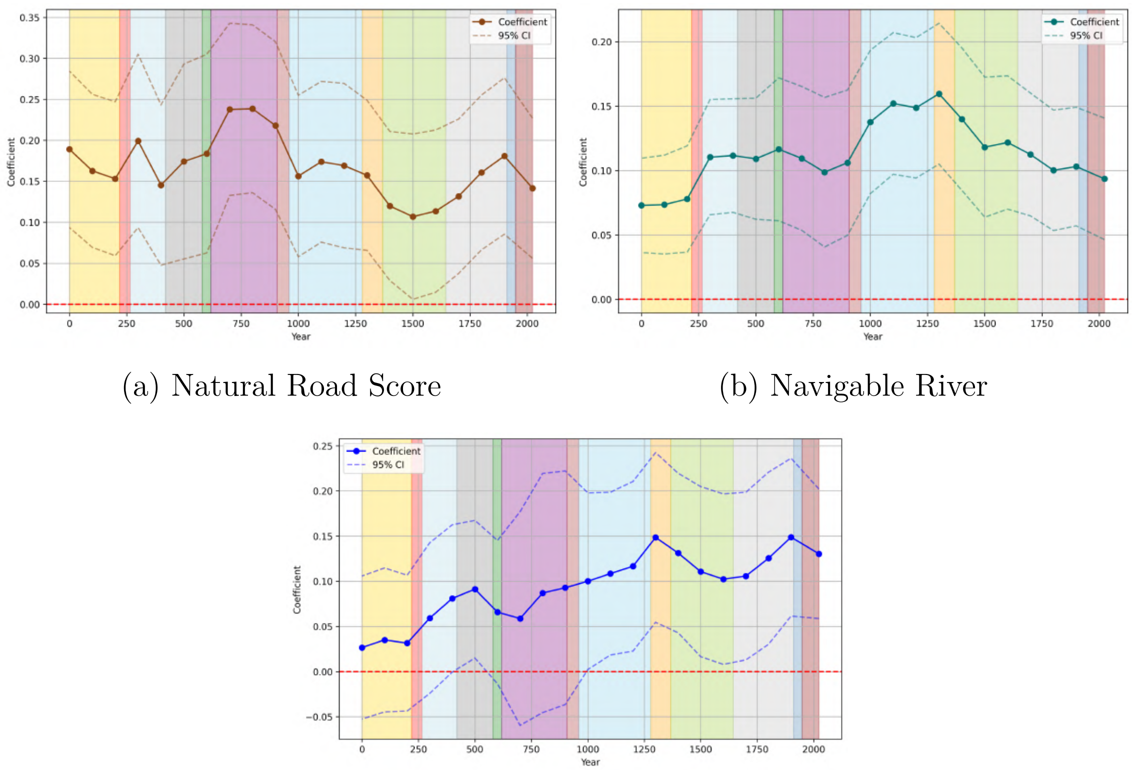
(c1) Estuary



(c2) Estuary

Note: This figure uses a 95% confidence interval, with data sourced from Table 6.

Figure 14: City colored with Dynasties



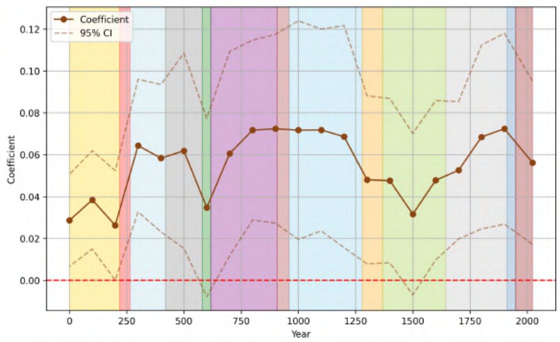
(a) Natural Road Score

(b) Navigable River

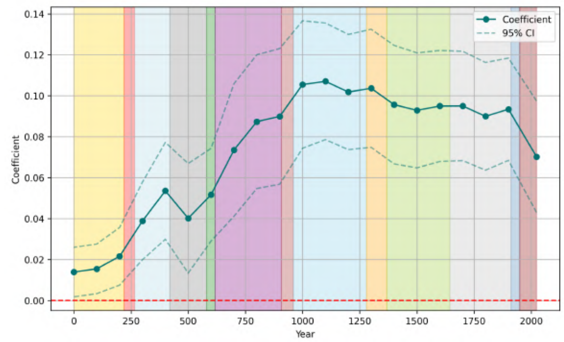
(c) Estuary

Note: Based on the results for cites in Table 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.

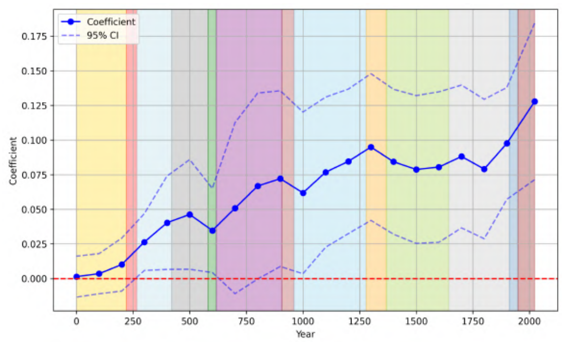
Figure 15: Prefecture colored with Dynasties



(a) Natural Road Score



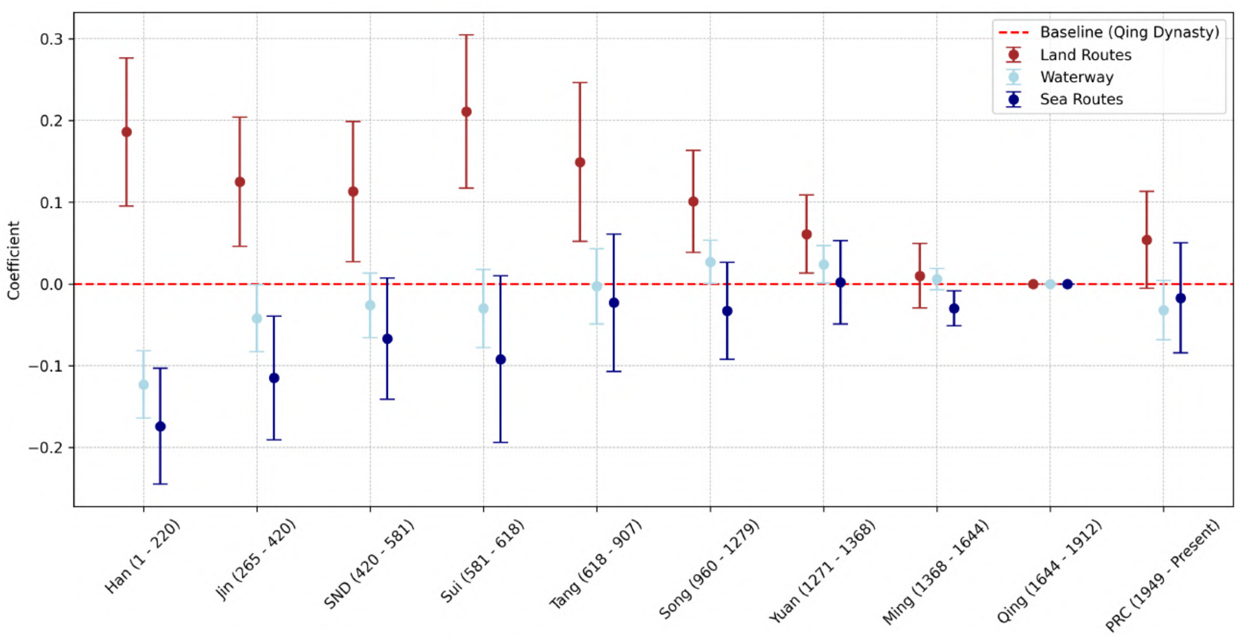
(b) Navigable River



(c) Estuary

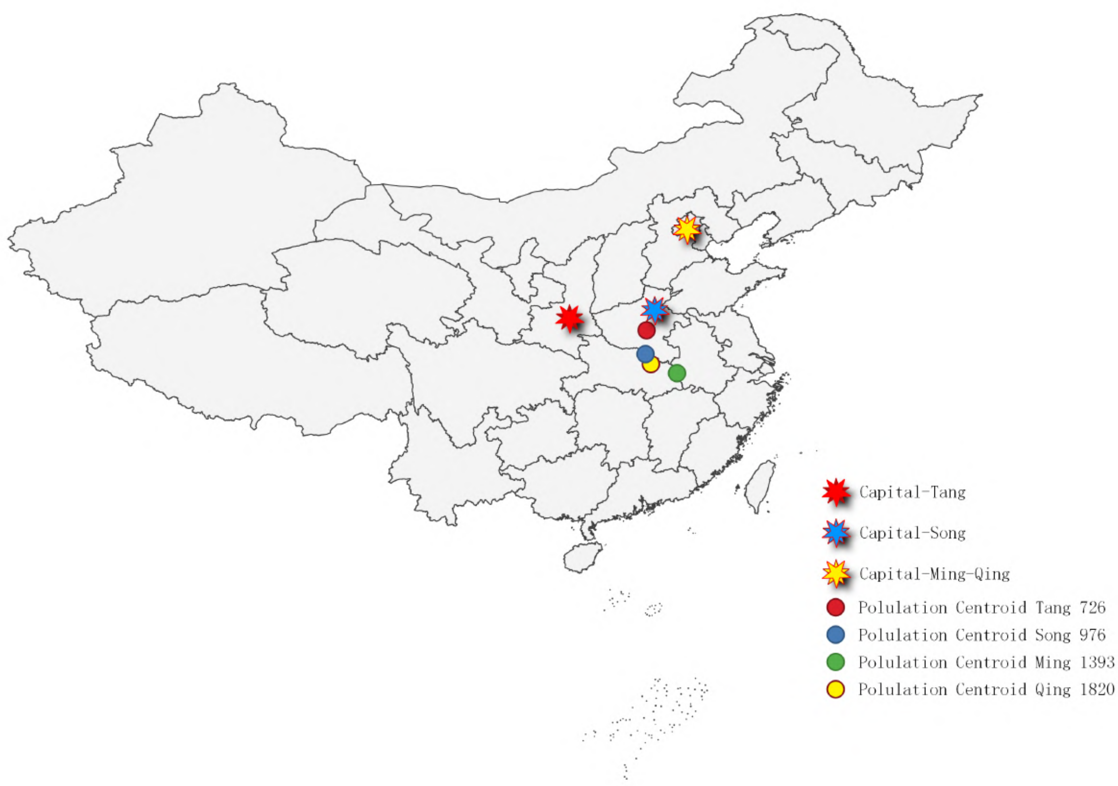
Note: Based on the results of prefecture level cities in Table 6, the background is color-coded to represent the major dynasties and periods in Chinese history: Han Dynasty (206 BCE–220 CE), Three Kingdoms (220–266), Jin Dynasty (266–420), Southern and Northern Dynasties (420–581), Sui Dynasty (581–618), 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 16: *Comparing Dynasty's marginal effect with Qing as baseline (Cities)*



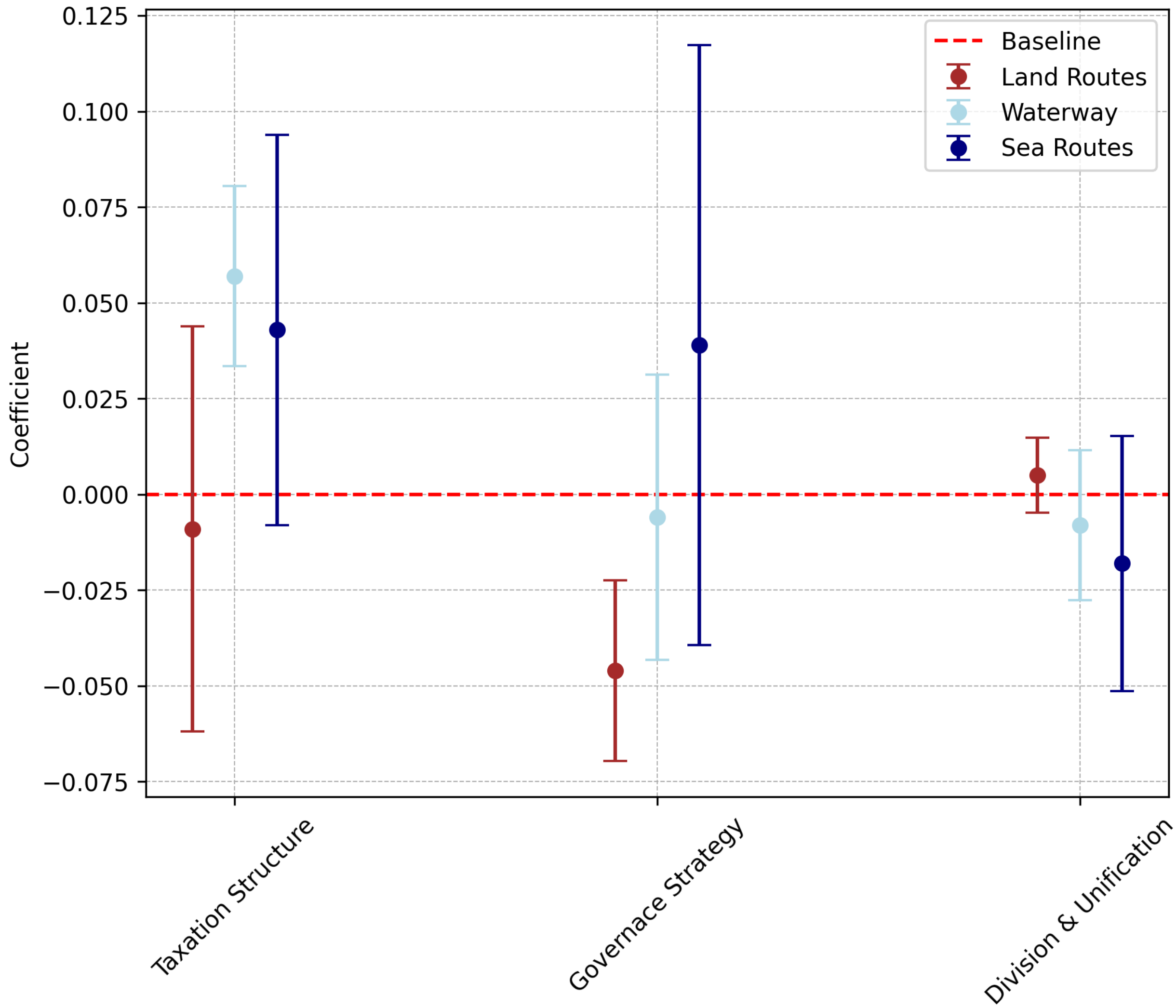
Note: Based on the results for cities in Table 7, the confidence interval is set at 90%. The Qing Empire, China's last unified dynasty, is used as the baseline.

Figure 17: *Capitals and Population Centroids in Historical China*



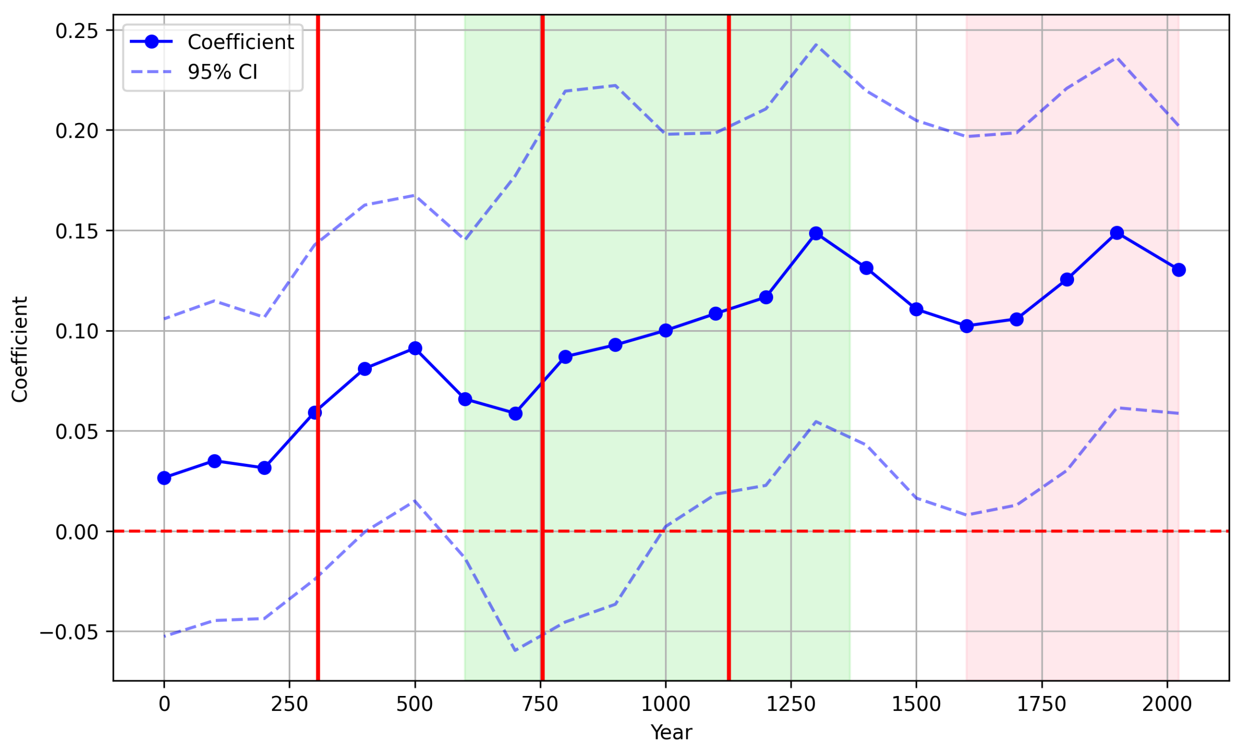
Note: This figure illustrates the locations of the national capital and the population centroid during periods with reliable population records. The distances between them are presented in Table 9.

Figure 18: *Mechanism: Institutions and Natural Endowments on Routes (cities)*



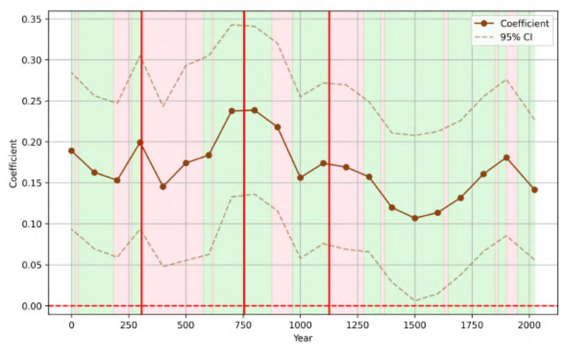
Note: Base on the results for cities in Table 8, the confidence internal is set at 95%.The Taxation Structure compares periods of indirect taxation to those of direct taxation. Governance Strategy examines periods when the capital was located farther from the population centroid compared to periods when the distance was shorter. Division & Unification contrasts divided periods with unified periods in Chinese history.

Figure 19: *The incoming of Arabs and Europeans, and Sea Ban Policy (cities)*

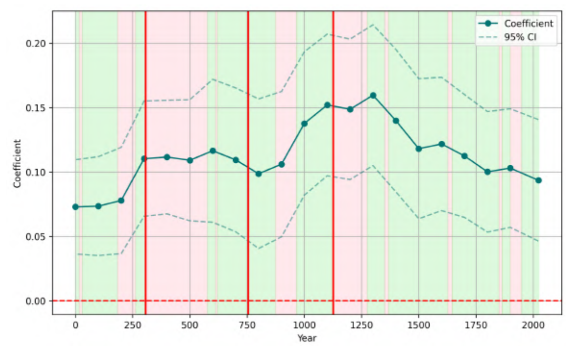


Note: This figure shows the marginal effect of sea routes on the location of cities. The background colors indicate different periods: green represents the era of Arab merchants, while red denotes the arrival of European merchants. It can be observed that during these two periods, the marginal effect 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

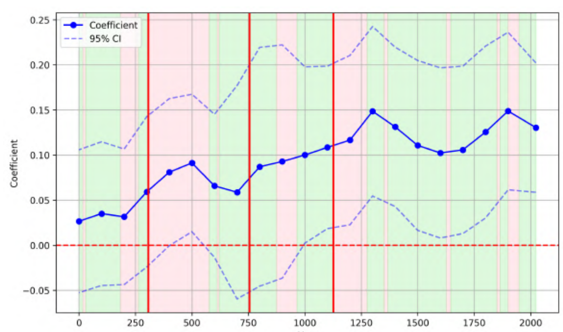
Figure 20: City colored with Unification and Division



(a) Natural Road Score



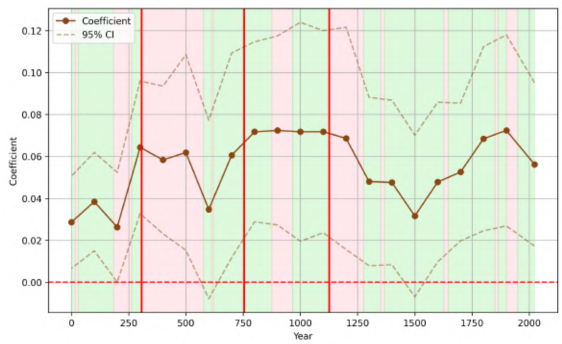
(b) Navigable River



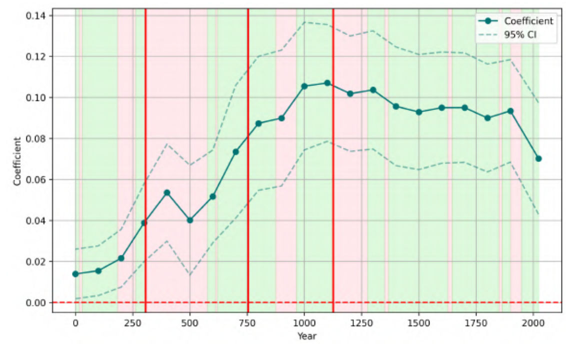
(c) Estuary

Note: Based on results of table 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.

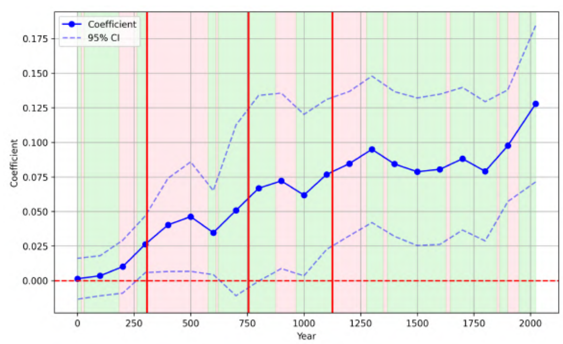
Figure 21: Prefecture colored with Unification and Division



(a) Natural Road Score



(b) Navigable River



(c) Estuary

Note: Based on results of table 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.