Can High-Speed Rail Improve Middle-aged and Elderly People's Mental Health? Evidence from China *

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Abstract

The paper studies the effect of the high-speed rail (HSR) service on the mental health of individuals aged 45 and older. I use historical documents and ArcGIS Pro to produce the railway map of the late Qing Dynasty (1911) and use it as an instrument for the modern HSR network in China. I find that the HSR service significantly improves the mental health of middle-aged and elderly people, and the causal impact is larger for urban than for rural residents. I also explore and find supporting evidence for three channels of influence: income, access to medical services and in-person interactions. The HSR increases employment opportunities and, hence, individual income, improves the accessibility of medical resources outside the local area, and increases the frequency of in-person visits by children who do not live in the same city as their parents.

Keywords: Mental Health, High-speed Rail, Historical Geographic Data, Population Aging

JEL Codes: I19, R40, H51, J14, N75

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1 Introduction

Mental health is the foundation for the well-being and effective functioning of individuals. The issue of mental health has attracted global attention. While it is not as pronounced in developed countries, it remains a significantly more serious concern in developing nations. Despite the rapid economic development in China in recent decades, mental health-related education and services have lagged behind. Based on the 2017 World Health Organization report, there are $23,000$ psychiatrists in China, or just 1.7 per $100,000$ people, compared with 12 per $100,000$ people in the United States. Fewer than half of these individuals undergo comprehensive psychiatric training; instead, they receive only brief, short-term psychiatric training before transitioning into psychiatric service roles or psychological counseling services (Fang et al., 2020). Most people with mental health problems do not have access to treatment (Phillips et al., 2009). Only a small number of economically well-developed areas in China have psychiatric experts serving mental health patients.

Since 2010, mental health has become an increasingly recognized issue in China. An increasing number of studies have conducted specific analyses and investigations into the current state of mental health issues in China. Among these, He et al. (2021) finds that the incidence of depression rises with age. The Chinese government released the first annual report on mental health in 2019.[1] The report highlights that the detection rate of depressive symptoms among urban elderly individuals exhibits a gradual upward trend over the 11-year span from 1998 to 2008. The specific scale-based detection rate of depression (CES-D[2]) experienced a notable increase of 21%. The report also summarizes that the empty nest elderly[3] group faces greater mental health risks than the younger population. Hence, it is crucial to prioritize the mental well-being of middle-aged and elderly individuals.

Simultaneously, according to the National Bureau of Statistics of China, the proportion of people aged 65 and over in China's total population reached 13.5% in 2020, and this figure is projected to rise to 28% by 2050. This demographic shift has significant implications for China's economy, social welfare, and healthcare systems. To address these challenges, the Chinese government has announced plans to gradually increase the retirement age in response to the challenges posed by the country's aging population. However, there are also

[1] The first annual report is titled " Report on National Mental Health Development in China (2017-2018)", which includes information on the prevalence of mental health issues, access to mental health services, and the government's efforts to promote mental health and prevent mental illness.

[2] The Center for Epidemiologic Studies Depression Scale (CES-D) is a brief self-report questionnaire developed in 1977 by Laurie Radloff to measure the severity of depressive symptoms in the general population.

[3] According to the data of the sixth national census, among the family households of the elderly aged 60 and over in the country, the number of empty-nest elderly households exceeds 32.6%, and the empty-nest rate is expected to reach 90% by 2030.

potential challenges associated with increasing the retirement age.[4] By keeping people in the workforce for longer, the Chinese government has made significant efforts to address the health needs of its aging population and improve elderly care services. Among the health needs addressed, improving people's mental health is often the most difficult and challenging.

On the other hand, the healthcare coverage for mental health services is not as comprehensive as the coverage for physical health services.[5] In comparison to young people, older individuals tend to rely more on seeking help from traditional healthcare providers, while young people have access to services through school-based counseling[6] or online therapy platforms. As a result, limitations in mental health healthcare coverage can hinder active help-seeking among the middle-aged and elderly populations with mental illness.

Another significant challenge is the pervasive stigma and lack of awareness surrounding mental health issues in China. Traditional Chinese culture places a historical emphasis on emotional control, resilience, and family reputation. Expressing vulnerability or seeking help for mental health issues can be perceived as a sign of weakness or a threat to family honor. Also, many people in China, especially older generations, have limited education about mental health conditions. As a result, many people, especially those who grew up in the last era, feel ashamed or embarrassed to seek help (Chung and Wong, 2004; Xu et al., 2018). The traditional Chinese cultural factors and lack of education that contribute to this stigma create barriers to effective health policy implementation. Therefore, implementing indirect policies and services to increase mental health support for the middle-aged and elderly population in China could be a strategic approach to overcome some of the challenges associated with stigma and cultural barriers.

Starting in the 21st century, China not only prioritizes public health but also actively invests in the development of diverse infrastructures. Infrastructure is an important pillar of support for economic, social and health development (Barro, 1990; Banerjee et al., 2012; Donaldson, 2018). The high-speed railway (HSR) is a newly emerging mode of transportation that has rapidly developed since 2008. Figure (1) describes the expansion of HSR over ten years. China's HSR network is one of the largest and most extensive in the world. Undoubtedly, the Chinese government has allocated substantial funds to the construction, expansion, and maintenance of this network because HSR cannot be operated directly on

[4]In 2018, the National People's Congress approved a plan to gradually increase the retirement age, starting with a two-year increase for some workers in 2021. Under the plan, the retirement age for men in urban areas will be gradually increased from 60 to 65, while the retirement age for women in urban areas will be gradually increased from 50 to 60.

[5]In China, public medical insurance does not cover psychological treatment and consultation fees. As a result, the cost of mental illness treatment is high.

[6]These services typically involve trained counselors or psychologists who work within educational institutions to provide emotional and psychological support to students.

existing railway tracks due to distinct technical requirements. HSR necessitates either technological upgrades to the existing railway lines to increase their speed or the construction of new tracks.

Assessing the impact of HSR on the socioeconomic landscape has always been a significant area of interest for policymakers and researchers. Due to the high and irreversible costs of building, maintaining, and operating HSR, it is essential to estimate whether HSR can bring sufficient economic benefits. Many scholars have done a lot of related research, which focuses on the economic impact of HSR on regional mobility, employment, and industrial development (Jiao et al., 2017; Liu and Zhang, 2018; Li et al., 2020; Shao et al., 2017; Wang et al., 2016). Economic prosperity, job opportunities, and enhanced transportation facilitated by HSR have influenced local healthcare, the local environment, and the daily lives of the people. These indirect benefits and developments constitute an essential aspect that researchers cannot overlook. Therefore, there is a growing body of research focused on estimating the unintended consequences stemming from HSR development, including its impact on residents' health levels and health infrastructure.

Specifically, several papers endeavor to identify and assess social externalities induced by the HSR system, such as its effect on public health. Chen et al. (2021) found that HSR accessibility improves the health of local residents, which would lead to around a 2.3% increase in the health index.[7] Other studies have suggested that transportation can effectively enhance the geographic accessibility of medical and healthcare infrastructure (Zimran, 2020; Choi et al., 2019). Nonetheless, previous studies have primarily concentrated on physical health or health infrastructure, with limited attention on the impact on mental health and the middle-aged and elderly population. As a result, this study addresses these limitations and examines the significant and positive causal impact of HSR's inauguration on the mental health of middle-aged and elderly individuals.

Ordinary least squares regressions, comparing cities with and without HSR, are unlikely to yield a consistent estimate of the causal impact of HSR improvements due to the non-random selection of locations into the treatment group. Thus, this analysis relies on a quasi-experimental design to solve the endogenous issue and estimate the causal impact of HSR projects on the target population's mental health outcome without random assignment. To obtain a consistent estimated effect of the HSR project, this paper contributes to finding an appropriate instrumental variable by using historical documents and geographical data.

[7] In this paper, the health index ranges from -9.290 to 3.656. Health changes caused by HSR accessibility account for 2.30% (0.298/12.946) of the total range. The health index is obtained by adding three standardized variables (objective incidence, self-health evaluation, and mental health). The larger the value, the higher the health level.

Chen et al. (2021) used the inconsequential units approach[8] in conjunction with difference-in-difference (DD), which excluded samples of who lived in provincial capitals and municipalities. However, it is difficult to assess the validity of the inconsequential unit approach. Although the government publishes the construction plan, it is difficult to prove that the relatively small cities lying between large cities are random. When using samples that only consist of individuals living in small cities, the sample size decreases significantly. As a result, the estimation results may only reflect the effects of respondents living in small cities, potentially overlooking the perspectives of those residing in larger cities or other areas. Furthermore, the DD approach only rules out the effects of omitted variables when their effects do not change before and after the event. The role of such omitted variables is likely to cause estimation bias. For this concern, I employ an instrument for the HSR service.

The study uses the distance to the railway at the end of the Qing dynasty (1911) as an instrument. If the distance to the historical railway is to serve as a valid instrument, it must be uncorrelated with the mental health of the middle-aged and elderly population, except through the HSR service. First, a portion of the HSR development involves enhancing pre-existing traditional railway infrastructure. Geographical conditions play a pivotal role in the construction of both traditional and HSR, with stringent criteria particularly applicable to HSR projects. Thus, conventional railway systems often serve as a valuable reference point when planning HSR construction. It is highly likely that cities that were located near the historical railway systems also received the construction of the HSR network.

Second, the unique history of China provides a basis for the instrument's exogeneity. Prior to the Revolution of 1911, China was ruled by the Qing dynasty and experienced a series of conflicts with foreign powers. During the late nineteenth century, countries such as Britain, France, Russia, and Japan invaded China multiple times and forced it to sign unequal treaties, granting them various benefits and rights on Chinese territory, including the construction of railways and the extraction of coal resources from surrounding areas. Thus, it is unlikely that closer proximity to the historical routes has an impact on middle-aged and elderly people's mental health other than through the modern HSR service. A crucial concern regarding the validity of the instrumental variable is the potential correlation between the historical railways and local development. The paper includes appropriate controls, such as highway length, population and GDP per capita. Furthermore, I conducted several robustness tests to address concerns regarding the satisfaction of the exclusion restriction.

The instrumental variable strategy in this paper is similar in spirit to the one used in previous works by Duranton and Turner (2012), Hsu and Zhang (2014),Garcia-López et al.

[8]The inconsequential units approach suggests that small cities located between large cities received HSR services 'accidentally' due to their geographic position rather than their economic potential.

(2015), Baum-Snow et al. (2017), and Volpe Martincus et al. (2017). In these studies, they develop historical transportation networks as a source of quasi-random variation in modern transportation networks. For example, Baum-Snow et al. (2017) use Chinese rail networks from 1962 as a source of quasi-random variation in road networks after 2000. Garcia-López et al. (2015) utilize Spain's historical roads, including the almost 2000-year-old Roman roads and the 1760 Bourbon roads, as instrumental variables to address the issue of endogeneity in highway provision.

In addition, this study also elucidates the underlying mechanisms from three perspectives: *income, family, and resources*. Figure (2) depicts the three mechanisms. Firstly, the findings on the *income effect* suggest that the HSR service has a positive impact on the employment of individuals aged 45 or above in the Chinese labor market. Additionally, the study reveals that the HSR service does not have a significant impact on individuals who are not in the labor force in the sample. The income effect is closely related to numerous studies which indicate that HSR accessibility promotes employment and increases income (Jia et al., 2017; Meng et al., 2018; Li et al., 2020; Yang et al., 2019). Secondly, the results regarding the *resource effect* indicate that HSR increases opportunities for people to travel and access better medical resources in different regions. This finding is consistent with the results of a previous study by Choi et al. (2019), which utilizes data from South Korea. The study reveals that HSR improves outpatient volume and medical care utilization among higher-income cancer patients while not significantly impacting inpatient visits. Chen et al. (2021) discusses the two channels, *the income effect* and *resources effect*, to analyze the impact of HSR on the health level in their study. They provide evidence supporting the notion that HSR can stimulate local employment and increase income in the regions where it operates. Additionally, Chen et al. (2021) indicates that the introduction of HSR has a positive impact on the medical resources accessible to individuals.

However, in previous studies, the researchers do not address the third channel, *the family effect*. Therefore, another significant contribution of this paper is identifying the third channel - *family effects*. Social isolation and loneliness are major risk factors for poor mental health outcomes, particularly in older adults. Regular social interactions with family members for older adults can help to combat feelings of loneliness and improve overall well-being. From the result, I find evidence that the HSR service leads to an increase in the frequency of meetings between respondents and their children who reside in a different city or province.

Lastly, this paper also includes an analysis of heterogeneity to address concerns regarding whether HSR projects may exacerbate health inequalities among different groups. I explore the differences in HSR accessibility across gender, income, employment status, marital status, urban/rural areas, number of children, and parents' background. More specifically, the mental health impacts of the HSR service are found to be more significant among residents of urban areas than those in rural areas. The effect of the HSR on mental health differs among various age groups, and its positive influence on mental health decreases with increasing age.

The remainder of the paper is organized as follows: Section (2) provides some background on mental health, the HSR system and the railway in the Qing dynasty; In Section (3), I link my analysis with previous literature. In Section (4), I turn to a description of the data, before reporting the estimates in Section (6). In Section (7), I examine specific mechanisms and explain how HSR service could affect the mental health of people aged above 45. Section (8) is a conclusion.

2 Background

2.1 *Mental Health*

In China, mental health has only recently gained significant attention from the public and academia, primarily over the past 20 years. Prior to the 21st century, mental health was largely overlooked in China, partly due to the prevailing cultural stigma associated with it (Xu et al., 2018). Traditional Chinese families tend to be more collectivist. Traditional Chinese cultural beliefs often emphasize the importance of maintaining harmony, saving face, and adhering to societal norms. Mental illness can be seen as a family "failure" and may be attributed to factors such as moral weakness, character flaws, or bad luck. These beliefs contribute to the stigmatization and marginalization of individuals with mental health conditions. It also leads to families concealing or denying the condition to protect their reputation. This prevents individuals from seeking help and support, exacerbating their condition and isolating them further (Chung and Wong, 2004; Chiu et al., 2015).

Prior to the 1980s, due to the impact of the Cultural Revolution, [9] the political climate was highly critical of psychology, resulting in limited progress within the discipline (Qian et al., 2001). Afterwards, China's education system was rebuilt, leading to steady development in psychology. Until the 21st century, the expansion of university enrollment has led to unprecedented growth and promotion of psychological research and psychological education in the past two decades. Furthermore, as China engaged in extensive collaborations and exchanges with the international community after the 21st century, the concept of stigma and its associated theories were gradually embraced and adopted by domestic academic circles.

[9]The Cultural Revolution in China, known as the Great Proletarian Cultural Revolution, was a tumultuous and highly significant socio-political movement that occurred from 1966 to 1976. It had profoundly detrimental effects on education, science, and culture, with far-reaching consequences.

This understanding of stigma eventually expanded to encompass research areas related to mental illness and the floating population.

Indeed, these historical factors have posed substantial challenges for the Chinese government in its efforts to enhance mental well-being. Especially elderly individuals have grown up in the last century when mental health was not widely understood or discussed. It leads to greater stigma and misconceptions surrounding mental illness among older generations.

2.2 *High-speed Rail Network*

The HSR system in China is an extensive network of fast and efficient trains that connect major cities across the country. It is favored by countries worldwide due to its advantages of large passenger capacity, fast operation speed, and shorter travel time. According to "The High-speed Railway Design Specifications" issued by the China National Railway Administration, HSR is defined as passenger-dedicated railways with a design speed ranging from 250 to 350 kilometers per hour. Conventional railways, on the other hand, typically operate at speeds ranging from 80 km/h to 160 km/h. In 2004, the executive meeting of the China State Council passed the "Medium and Long-term Railway Network Plan", which clarified the middle-term and long-term construction goals of China's railway network. The plan includes building new railway lines and upgrading existing ones to enhance connectivity and promote economic growth across China. The document clearly pointed out the planning requirements of the HSR network: *1. Linking major urban agglomerations. 2. Forming a high-speed railway network that connects provincial capitals and covers the surrounding area. 3. Try to link other medium-sized cities.* Another essential feature of this plan is establishing a national passenger HSR system with a total length of over 16,000 kilometers by 2020. Nowadays, the network is the largest in the world [10], spanning thousands of kilometers of track and offering modern amenities to passengers.

2.3 *Railway in Qing Dynasty*

In the late 19th century, the world witnessed a significant shift in the economic and political landscape, often referred to as the era of imperialism. During this period, the capitalist powers, particularly in Europe, underwent a transformation from a predominantly competitive capitalist system to a stage characterized by monopolies and capital export. The process of imperialism involved the expansion of the economic and political influence of

[10] The World Bank's report titled "China's High-Speed Rail Development", which was published in February 2014, examines the development of China's HSR network, which has become the largest in the world in terms of both length and operational capacity.

these capitalist powers beyond their national boundaries. These imperial powers, including countries like Great Britain, France, Germany, and others, sought to establish control over territories and regions across the globe to secure valuable resources, establish markets, and exploit cheap labor.

The Qing Dynasty was defeated by the Empire of Japan in the First Sino-Japanese War, which lasted from 1894 to 1895. The Qing government's loss in this conflict had significant consequences for China, both in terms of territorial concessions and the overall weakening of its national strength (Paine, 2003). Various imperialist countries saw an opportunity to exert influence and pressure on China. The weakened state of the Qing government and its loss of territories created openings for these powers to advance their own interests in China. Imperialist powers not only engaged in the economic exploitation of China through commodity dumping but also increasingly resorted to exporting capital and making investments in the country. They partitioned China into spheres of influence[11] and the construction of railway lines as part of their strategy to maximize their benefits from capital export and strengthen their control over China.

Imperialist powers during the era of imperialism in China employed various means to gain control over the railway system. These actions were part of their broader strategy to exploit China's resources, expand their economic influence, and exert control over key transportation routes. They either forcibly built or controlled by loans, more than 10,000 kilometres of road rights in China, which were divided up, forming the first climax of imperialist control of China's road rights. In some cases, they used force, seizing control over railroad networks through military ways(Wu, 2012).[12] In summary, the railways in China at the end of the Qing Dynasty were constructed for the benefit of foreign powers and were primarily meant to serve their economic interests, gain strategic advantages, and exploit resources, rather than connecting large cities within China.

But the situation changed in 1911, when Chinese nationalists and various social groups launched the road movement to advocate for the protection of China's railway rights. They called for the nationalization of railways and the removal of foreign control. The movement[13] gained momentum as a symbol of resistance against foreign domination and became a sig-

[11]The concept of "spheres of influence" referred to specific regions or areas within China where imperialist powers claimed exclusive economic and political privileges. These powers, including Britain, France, Germany, Russia, and Japan, carved out these spheres by imposing unequal treaties, economic dominance, and diplomatic pressure on the Qing government.

[12]More information about the historical railroad at the end of the Qing Dynasty can be found in Appendix C.

[13]The road movement, also known as the "Railway Protection Movement", emerged as a response to the perceived encroachment of foreign powers and their control over transportation infrastructure, specifically railways.

nificant catalyst for broader revolutionary sentiments in China. The road movement played a crucial role in the lead-up to the Xinhai Revolution of 1911, which led to the overthrow of the Qing Dynasty and the establishment of the Republic of China(Shilong, 2016).

3 Relevant Literature

This paper is closely connected to the growing body of literature concerning the transportation-health gradient. This paper conducts a comprehensive review of existing literature from three aspects. The initial perspective encompasses prior research focused on investigating the impact of transportation infrastructure on economic development. The economic evaluation of transportation infrastructure remains a prominent topic worldwide, generating considerable interest among researchers. They employ diverse methods and data to estimate the economic advantages resulting from the implementation of new transportation systems.

According to the findings of Chandra and Thompson (2000), there is a significant positive effect on earnings resulting from a highway connection. Specifically, they observe that the impact on earnings for non-metropolitan counties is approximately 7%, while untreated counties experience the opposite effect. Similarly, Michaels (2008) explores the economic impact of HSR on trucking and retail earnings and arrives at a result similar to that of Chandra and Thompson (2000).

In addition, research on transportation infrastructure's economic impact extends beyond developed countries and includes low-income countries as well. As demonstrated in Donaldson (2018), districts with access to railroads in India show approximately 17% higher real agricultural income per unit of district area compared to districts without such rail connections. Banerjee et al. (2012) creates a hypothetical network as an instrumental variable in China and observes that a 10% increase in distance to this hypothetical line leads to approximately a 6% decrease in county GDP. However, the hypothetical network they constructed predicts both railroads and highways in China. Consequently, their results cannot distinctly isolate the effects of roads and railroads on the variables. Farber (2014) finds that China's National Trunk Highway System has led to a reduction in GDP growth among non-connected peripheral counties. To address non-random route placements on the way between targeted city nodes, Farber (2014) proposes an instrumental variable strategy based on the construction of least cost path spanning tree networks.

With the rapid development of technology, HSR project is increasingly capturing a larger share of the transportation market. As a result, numerous researchers are focusing on analyzing the economic impact of HSR (Ke et al., 2017; Diao, 2018; Li et al., 2018). Specifically, Ke et al. (2017) identifies a positive effect of HSR on the economic growth of targeted city nodes in China. Diao (2018) finds that China's HSR increases local fixed asset investment, potentially stimulating local economic growth. According to the study by Jiao et al. (2017), the HSR network in China has a notable impact on the overall connectivity and nodal centrality of the city network. Additionally, the HSR network leads to a reduction in the average path length between cities. On the other side, several papers discuss the impact of HSR development on regional economic disparity (Liu et al., 2020; Chen and Haynes, 2017).

The second aspect of the literature focuses on health. Numerous previous studies have initiated extensive discussions regarding health in relation to various socioeconomic factors, such as income, education level, and occupation (Lleras-Muney and Cutler, 2006; Contoyannis and Forster, 1999; Ettner, 1996; Liu et al., 2008; Llena-Nozal et al., 2004). In particular, the study by Llena-Nozal et al. (2004) highlights the significant role of employment status in influencing people's mental health. This finding also emphasizes the *income effect* of HSR on mental health.

Furthermore, several papers discuss topics related to infrastructure and health utilization. For instance, in a study conducted by Aggarwal (2021), quasi-random variation in road-pavement intensity is utilized to examine the effects of improved access on the adoption of reproductive health services in India. The evidence gathered from this study indicates that beneficiaries tend to travel greater distances to access better health providers. Choi et al. (2019) conducts a study utilizing an interrupted time series model to investigate the correlation between the operation of HSR and healthcare utilization in South Korea. Their study reveals that the introduction of HSR has a positive influence on the volume of outpatient visits and medical care utilization, particularly among cancer patients. However, no significant impact of HSR on inpatient visits is observed.

The third aspect of the literature focuses on studying the relationship between HSR and health levels or inequality. The most recent literature related to this study examines the relationship between HSR accessibility and individual health levels using data from the China Health and Nutrition Survey (Chen et al., 2021). Chen et al. (2021) indicates that increased accessibility to HSR is associated with improved health among local residents. The coefficient of 0.298 suggests that HSR operation is associated with a 2.30% increase in health.[14] This suggests that the availability and accessibility of HSR services can have a positive impact on the overall health of individuals in the studied areas, highlighting the potential health benefits associated with HSR infrastructure development. Bu et al. (2022)

[14] Again, the health index in this paper ranges from -9.290 to 3.656. Health changes caused by HSR accessibility account for 2.30% (0.298/12.946) of the total range. The health index is obtained by adding three standardized variables (objective incidence, self-health evaluation, and mental health). The larger the value, the higher the health level.

points out that HSR exacerbates health inequalities more significantly among high-income groups in several ways, including high-quality healthcare services, socioeconomic status, and social capital.

The paper also relates to the existing research in the transportation field by exploring potential mechanisms linking HSR and mental health. One of the proposed mechanisms is the *income effect*. Previous studies have shown that HSR projects stimulate employment and enhance economic growth, leading to increased income (Dong, 2018; Li et al., 2018; Jia et al., 2017; Ke et al., 2017). This *income effect* is particularly pronounced in less developed regions (Liang et al., 2020). It is anticipated that the rise in income can positively impact health outcomes. The second mechanism is the *resource effect* because the distance factor plays a crucial role in determining how patients receive medical care. HSR enables patients residing in remote or rural areas to access medical treatments, as it enhances the accessibility and capacity of transportation networks (Wang et al., 2016; Choi et al., 2019; Chen et al., 2021). HSR projects are anticipated to reduce the time and economic expenses associated with healthcare services. Consequently, HSR is expected to enhance the overall health of residents.

This study provides new insight into the connection between HSR and mental health in the middle-aged and elderly population, specifically focusing on the *family effect*. To the best of my knowledge, no economic literature has explored this particular channel. However, a few studies conducted by psychologists have examined the role of loneliness as a significant factor affecting the mental health of older individuals (Bekhet and Zauszniewski, 2012; Domènech-Abella et al., 2017). According to Liu and Guo (2007), the empty nest group, when compared to the non-empty nest group, exhibited higher levels of loneliness and lower physical scores in rural areas of China. This paper examines and verifies the effect of HSR on increasing the frequency of meetings between parents and children who live in different cities or provinces. They suggest that HSR plays a role in improving connectivity and facilitating social relationships by making it easier for family members to meet and maintain closer ties despite living in different locations.

4 Data

4.1 *Data Resources*

The analysis relies on four data resources. The first data source consists of health and demographic characteristics data obtained from the China Health and Retirement Longitudinal Study (CHARLS). The second data source comprises information on the opening dates of each line of HSR service, which were sourced from the National Railway Administration website and CnOpenData. The third data source is the China City Statistical Yearbooks, which are obtained from the Department of Urban Socio-Economic Survey of the National Bureau of Statistics. The final data source pertains to historical railway data.

China Health and Retirement Longitudinal Study (CHARLS). – CHARLS is a comprehensive data collection initiative that gathers high-quality micro-data on families and individuals in China who are middle-aged and older adults, specifically those aged 45 and above. Its primary objective is to analyze the challenges posed by population aging in China and facilitate interdisciplinary research on cultural issues related to China's aging population. The CHARLS is a significant data collection project managed by the National School of Development at Peking University and executed by the China Social Science Survey Center, also affiliated with Peking University. The project initiated its first survey in 2011 and subsequently carried out the second, third, and fourth waves of data collection in 2013, 2015, and 2018 respectively. Apart from its suitability for the research question at hand, another crucial reason for selecting this data is the inclusion of relatively comprehensive health information in the survey. This aspect of the data proves to be highly valuable for the analysis conducted in the article.

China Health and Retirement Longitudinal Study (CHARLS) – Mental Health. – The CHARLS questionnaire incorporates the Center for Epidemiologic Studies Depression Scale (CES-D), which is a concise self-report questionnaire originally developed in 1977 by Laurie Radloff to assess the severity of depressive symptoms in the general population. The original version of CES-D consists of 20 questions (Radloff, 1977). However, CHARLS utilizes a modified version developed by Andresen et al. (1994) specifically for the elderly, which comprises 10 items and aids in screening for depression symptoms. Although CES-D scores were initially designed for use in general population surveys, they are also widely employed as an essential screening tool or mental health index in primary care clinics and psychological research. The data summary, including the means and standard deviations for the CES-D 10 items, is presented in Table (1). The cut-off scores of CES-D for depressive symptoms are ≥ 10 for the 10-item version.

The HSR Data. – The paper gathers information regarding the opening dates of HSR services in each city from two primary sources: the National Railway Administration website and CnOpenData. These sources provide reliable data on the commencement dates of high-speed rail services in various cities. The National Railway Administration website serves as a valuable source of HSR line data up until October 1, 2015. Consequently, the data collected prior to this date is obtained from the National Railway Administration website. Subsequently, for data beyond October 1, 2015, CnOpenData is utilized as the source for gathering the relevant information. By combining these two sources, a comprehensive dataset of HSR service opening dates is established for the analysis.

CnOpenData is a valuable open-source repository that encompasses a broad range of topics related to China, such as banking, entertainment, government, health, migration, minimum wage by region, and transportation. Within this repository, the data related to HSR projects is available at the city level. The original source of HSR data is obtained from CnOpenData, which collects information from the China State Railway Administration and the China Railway 12306 website. Specifically, the HSR data includes information on whether the HSR service has been opened in each city, along with the precise month when the HSR service was initially launched. This data recording provides a detailed timeline of the high-speed rail development across different cities in China.

China City Statistical Yearbooks. – The city-level control variables used in the study are obtained from the China City Statistical Yearbooks. These yearbooks serve as a primary source of statistical data and information on the social and economic development of cities at all administrative levels throughout China. Published annually by the National Bureau of Statistics (NBS) of China, the China City Statistical Yearbook is a comprehensive reference publication that offers a wealth of statistical indicators and data pertaining to various aspects of urban development, including population, employment, industry, infrastructure, education, and more. By utilizing the data from these yearbooks, the study incorporates relevant city-level variables to further analyze and understand the economic impact of high-speed rail on different cities in China.

Historical Railway Data. – To construct the railway map in 1911, the study relies on the work of Baum-Snow et al. (2017), who digitized large-scale national maps to create a railway map for the year 1962. The digital map from 1962 serves as the foundation for reconstructing the railway map in 1911. The study then utilizes multiple historical documents and sources[15] to restore and create a digital map of the railway network as it existed in 1911. This process involves the use of ArcGIS Pro, a geographic information system software, to accurately depict and represent the historical railway lines and their locations during that time period. By combining the digitized map from 1962 and the historical information, the study constructs a comprehensive railway map for the year 1911, allowing for a detailed analysis of the historical context and impact of the railway network

[15] The historical documents used by this paper include: *1. "History of Chinese Railways" by Kunhua Zeng 2. "The Historical Atlas of China" by Qixiang Tan*

in the study. Figure (7) represents the railway in 1911.

4.2 *Descriptive Statistics*

To identify the treatment exposure of cities in relation to the CHARLS survey, I adopt a criterion based on the opening year and month of the high-speed rail. Specifically, if the opening year and month of the HSR in a city occur before the year and month of the CHARLS survey interview, it is considered a treatment-exposed city. In order to standardize the survey month for all individuals in the CHARLS dataset, I set the survey month as August for all respondents.[16] Figures (3) to (6) display the survey areas, treatment group, and control group for each wave of data collection. Table (A.14) provides a statistical summary of the survey cities, treatment group, and control group for each wave of data collection. Furthermore, the particular waves of CHARLS utilized in this paper include waves 1 to 4, spanning the years 2011, 2013, 2015, and 2018.

The summary statistics for the sample are shown in Table (2). The individual-level controls encompass gender, education level, age, living location (rural/urban), public health insurance, marital status, and wealth level. Additionally, during the same period, the Chinese government focused not only on HSR construction but also on the highway system. With the advancement of China's economy, health infrastructure has significantly expanded in the past 20 years. Consequently, I also incorporate environmental-level (city-level) controls, including the number of hospitals, the length of highways, GDP per capita, and population.

Specifically, the average age of the respondents is 60 years old[17]. On average, the mental scores are relatively higher in the treated group. The mental score equals the reversed CES-D score.[18] The cut-off point of mental score for depressive symptoms is 20. Compared to the treated and not-yet-treated groups, the samples from the never-treated group are at a higher risk of exhibiting symptoms of mental health issues. Furthermore, on average, cities with HSR services also tend to have more hospitals and urban populations.

[16] Based on the data from CHARLS, more than 95% of respondents completed the survey before September of the survey year. Additionally, 94.26% of respondents participated in the survey during July and August.

[17] The sample is restricted to adults aged 45 or above.

[18] Reverse scoring means that the numerical scoring scale runs in the opposite direction. Mental score = 0: major depressive disorder

5 Empirical Approach

5.1 *OLS Estimates*

To start, I conduct an analysis to estimate the relationship between the availability of HSR service and the mental health scores of individuals aged 45 and above. The ordinary least squares (OLS) representation of this relationship is

$$Mental_{ict} = \beta hsr_c \times post_{ct} + \gamma X'_{ict} + \alpha Z'_{ct} + \delta_c + \theta_t + \epsilon_{ict}, \tag{1}$$

where $Mental_{ict}$ is the mental health score for individual i in city c at time t. The explanatory variable of primary focus is the interaction term, $hsr_c \times post_{ct}$. Specifically, hsr_c is a dummy variable indicating whether city c has HSR service. The variable $post_{ct}$ is a time indicator variable that takes the value of 1 for each city c in year t after the implementation of HSR intervention. The coefficient of $hsr_c \times post_{ct}$, denoted as β, is the main parameter of interest. It represents the effect of HSR service on the mental score of the population aged 45 or above. In the analysis, I also include a vector of individual-level demographic controls denoted as X'_{ict}. This vector encompasses various factors such as gender, education, age, urban or rural residence, marital status, public health insurance coverage, and wealth level[19]. The variable Z'_{ct} represents a vector of covariates that vary at the city and year level. These covariates capture additional factors that may influence the relationship between the HSR intervention and mental health outcomes. These environmental controls include the length of the highway and the number of hospitals in the local area. City and year fixed effects are denoted by δ_c and θ_t, and ϵ_{ict} is an error term.

A critical issue with OLS regressions is their inability to address selection bias in this context. There are two potential selection problems within this research question. First, individuals may choose to relocate to cities with HSR services. However, this concern is mitigated within China's economy due to factors such as the Hukou and public healthcare systems. The Hukou system, also known as the household registration system in China, historically restricted mobility by tying social benefits to specific local areas. Additionally, public health insurance is typically limited to use within the local area where it is obtained.[20]

According to the China Migrant Population Development Report 2016, China's migrant population accounted for 18% of the total population, with an average age of 29.3 years in

[19]The wealth level is calculated as the sum of four indices: 1. Total value of cash and deposits in financial institutions. 2. Total value of stocks and mutual funds. 3. Total value of government bonds. 4. Total value of all other savings.

[20]Medical expenses incurred in other regions are generally not reimbursed unless specific conditions.

2015.[21] The floating population primarily consisted of young individuals. According to the National Health and Family Planning Commission's 2015 survey on health services for the migrant elderly, the migrant elderly population constituted 7.2% of the overall migrant population (equivalent to 1.2% of the total population). Furthermore, based on the CHARLS Life History Survey in 2014 for the samples utilized in this paper, 541 out of 44,424 observations indicate that individuals stayed to another county for a duration exceeding six months during 2011 - 2014, accounting for 1.17% of all observations. Thus, the selection issue of middle-aged and elderly individuals staying in cities with HSR for the sake of improving their mental well-being is of minor concern in this study.

Another potential selection issue in this study is the non-random choice of locations with HSR services. To mitigate this concern, I have incorporated city-fixed effects into the regression model. Nevertheless, there remains a potential worry about unobserved time-varying differences across cities that are associated with both the presence of HSR services and the mental health of individuals. For instance, it's conceivable that locations with HSR are highly developed regions with extensive industrial parks and factories, which could lead to high levels of air pollution in the local area (Figure (10) shows the correlation between the city with HSR and PM2.5 index.), potentially harming people's mental health.(Chen et al., 2018) Furthermore, well-developed cities often contend with traffic issues, leading to both air pollution and traffic noise. Research by Sygna et al. (2014) examines the positive correlation between road traffic noise and psychological distress, particularly for individuals with sleep disorders. Additionally, sleep disturbance is common among older adults due to the increased prevalence of multimorbidity, polypharmacy, psychosocial factors affecting sleep, and specific primary sleep disorders. (Miner and Kryger, 2017) If this were the case, the estimated relationship of interest in an OLS model, even with fixed effects, would have a downward bias. To address this issue, I employ the instrumental variables (IV) approach to tackle this challenge.

The final concern is related to the endogeneity of the timing of the HSR service initiation, which might be correlated with the large cities. As per the "Medium and Long-term Railway Network Plan," the Chinese government had already established the route for the HSR network. Consequently, cities along the same route commenced construction simultaneously. However, variations in terrain and local environmental factors led to different construction periods in different cities. Notably, the opening of each line necessitated the completion of construction in all cities along the route. Given this situation, the endogeneity of $post_{ct}$ is of minimal concern. I have also conducted several robustness tests. Initially, based on

[21] It is published by Migrant Population Department of the National Health and Family Planning Commission

the policy where the primary aim of HSR is to connect provincial capitals or large cities, I examine the results by excluding the provincial capitals and solely focusing on small cities (see Table (7) and (8)). The findings remain robust. Second, I implemented event-study methods designed as the robustness test to examine whether the timing of the opening of HSR is not a concern (Details in Section (6.2)).

5.2 *IV Estimates*

5.2.1 *IV Estimation Equations*

The second-stage IV equation takes the following form:

$$Mental_{ict} = \beta \widehat{hsr_c \times post}_{ct} + \gamma X'_{ict} + \alpha Z'_{ct} + \delta_c + \theta_t + \epsilon_{ict}, \tag{2}$$

where $\widehat{hsr_c \times post}_{ct}$ is generated by the first stage regression in the IV framework.

$$hsr_c \times post_{ct} = \rho Dist1911_c \times post_{ct} + \pi X'_{ict} + \eta Z'_{ct} + \delta_c + \theta_t + \epsilon_{ict}, \tag{3}$$

where c indexes city, t indexes year, and i indexes individual.The variable $Dist1911$ represents the logarithm of the distance between the city and the railway in the year 1911, which is time-invariant. Its interaction with $post_{ct}$ is consistent with the interaction between hsr_c and the $post_{ct}$ indicator, creating an instrumental variable that takes on the value of zero before the HSR accessibility and the value of the logarithm of the distance after the opening of HSR service.

If there exists a relationship between historical railways and HSR, then it is expected that a reduced-form relationship between the distance to the railway in 1911 and the mental scores of middle-aged and elderly populations would emerge. The concept of the IV approach is apparent in the reduced-form specification:

$$Mental_{ict} = \zeta Dist1911_c \times post_{ct} + \tau X'_{ict} + \phi Z'_{ct} + \delta_c + \theta_t + \epsilon_{ict} \tag{4}$$

In this analysis, I use the distance to the railway at the end of the Qing dynasty(1911) as an instrumental variable (IV). The IV approach relies on the relevant conditions, $\rho \neq 0$. It requires that conditional on control variables, the instrument predicts the endogenous variable. The second condition the IV should satisfy is the exclusion restrictions. They require that the instrument(distance to the rail in 1911) affect the dependent variable(mental score of the middle-aged and elderly population) only through the causal variable of interest(dummy variable of adopting the HSR service, hsr_c)

5.2.2 *Validity of the Instrumental Variable*

China's HSR track construction can be broadly categorized into two types. The first type involves upgrading existing ordinary railway tracks to accommodate high-speed trains. This involves making necessary modifications and improvements to the existing infrastructure to meet the requirements of high-speed travel. Hence, some of the old railroad tracks become HSR tracks. The second type involves constructing entirely new high-speed tracks, designed specifically for high-speed train operations. Both old railways and HSR require surveying the terrain before construction begins. By optimizing the railroad network, minimizing land use, avoiding environmentally sensitive areas, and implementing cost-effective construction methods, the old railroads are an indicator of the difficulty of finding optimal routes through the local terrain. Therefore, it is reasonable to utilize the existing railroad network in 1911 as a basis for predicting the HSR network.

Figure (11) illustrates the railway network at the end of the Qing Dynasty and the HSR network in 2016. The connection between the modern HSR and the railway network from the late Qing Dynasty can indeed be observed in certain regions, particularly in central and northern parts of China. The specification of the instrumental variable in this paper is the distance to the railway in 1911. Figure (13) represents the distribution of the IV, log(distance to the railway in 1911), separately for the treatment and control groups. The distribution of height is skewed towards larger values for the cities without HSR than the cities with HSR, which means that most of the cities without HSR are located far away from the historical railway.

Figure (7) shows the map of the railroad lines at the end of the Qing dynasty.[22] As I mentioned in Section (2), the imperialist powers pursued the construction of railways in China at the end of the Qing dynasty with the aim of expanding their influence from the coastal regions to the interior. Following the Qing government's defeat in the Sino-Japanese War of 1894-1895, which resulted in territorial concessions and indemnity payments, China experienced a significant loss of national power. Exploiting this vulnerability, imperialist powers exerted pressure on the Qing government to secure railway rights and interests through various means, such as forced construction and loan control. Approximately 41% were directly constructed and operated by imperialist forces. Another 39% were controlled by imperialism through loans and financial arrangements. Among them, the railways constructed or controlled by foreign powers primarily considered the military situation and coal mine of the time. Figure (9) demonstrates the correlation between the distance to the railway in 1911 and the proximity of cities to coal-rich areas. Specifically, the negative slope value indicates

[22]The specific historical background and explanations of this figure is discussed in Section (2) and Appendix (8) in this paper

that cities near coal-rich regions were also near the railway in 1911.

The remaining 20% of railways in 1911 were constructed by the Qing government or financed by businessmen who aimed to contribute to the development of the country. To be more specific, the railways built by businessmen were mainly confined to local areas, with relatively shorter lengths and limited connections to other railway networks.(Zeng, 1969) The blue lines in Figure (7) represent the commercial railways, most of which are not connected to other rail lines. Therefore, the unique historical context of China's railroad development provides evidence to believe that the distance to the railroad in 1911 satisfies the exogeneity condition.

However, there is a concern about the potential correlation between the identification of historical railways and local development, which could potentially influence individual mental health levels. As previously mentioned, the historical railway is located in close proximity to coal-rich areas (Figure (9)). These coal resources might also positively impact the development of the surrounding areas. However, Figure (8) indicates that cities near the coal-rich regions are less developed. The evidence serves to diminish the potential correlation between the historical railway and the development observed 110 years later.

In addition, the span of over 100 years has witnessed significant historical events and political transformations that have considerably attenuated any potential link between them. Over this century-long period, China underwent two major population migrations and more than 30 years of wartime upheaval.[23] It is challenging to envision how a rail network established during the Qing dynasty by a foreign power can systematically relate to factors influencing city development in the 21st century. Second, The exclusion restriction requires the orthogonality of the dependent variable and the instrument conditional on control variables. In order to fully address this potential violation of the exclusive restriction, I include the GDP per capita and population as the control.

Furthermore, I conduct several tests to assess whether the instrumental variable might impact dimensions beyond the HSR. Initially, I examine whether the historical railway influenced local amenities. Columns (2) and (3) in Table (5) demonstrate that the instrument exhibits no correlation with local afforestation and park area. Additionally, the local amenities encompass various entertainment activities. Notably, I observe no significant correlation between the instrument and factors such as the volume of books in the local public library and the number of movie theaters (Column (4)-(5)).

[23]See Appendix C

6 Results

6.1 *Baseline Results*

The baseline results of my formal econometric analysis are presented in Table (3) - Panel A. Column (1) provides OLS estimates as described by equation (1). It reports the estimated HSR effect on the mental score of middle-aged and elderly individuals, equal to 0.448 and statistically significant at the 0.05 level. As mentioned previously, it is likely that OLS estimates are biased due to the endogeneity issue associated with HSR. To address this, I estimate an IV model. The first-stage regression results are reported in column (4), and the IV estimates are presented in column (2). The first-stage estimates, represented by equation (3), show a significant relationship between the historical railway and the modern HSR network. The coefficient of interest for the first stage, denoted as ρ, has a value of -0.194 and is statistically significant at the 0.01 level. The intuition behind this finding is that cities located farther away from the railway in 1911 have a lower probability of having HSR compared to cities located closer to the historical railway. The result also empirically supports the previous claim that HSR were more likely in places with existing railways.

Column (2) presents the regression results for the second stage of instrumental variable (IV) estimations, where the estimated coefficient, denoted as β, equals 1.491. This implies that the HSR service can increase respondents' mental scores by 1.491 points. The average mental score for the entire sample is 21.82, which is close to the mental score cutoff point of 20. The observed increase of 1.491 points represents a significant positive effect, reducing the risk of mental health issues among middle-aged and elderly individuals. In addition, the first-stage effective F-statistic, accounting for non-homoskedasticity, is 17.752, exceeding the conventional weak instrument threshold of 10. This indicates that our IV estimate is not subject to weak instrument bias, and the conventional t-test is sufficient for inference. Nevertheless, I also subject the estimate to the Anderson-Rubin weak IV robust test, assessing the null hypothesis of no effect of HSR on mental health. With a p-value of 0.0036, I reject the null hypothesis. This suggests that the main finding of this study remains robust even when considering the strength of the instrument.[24]

When comparing the OLS estimate with the IV estimate, it suggests that the OLS estimates are likely to be downwardly biased. The reason behind the downward bias in the OLS estimates could be attributed to unobserved time-varying differences among respondents during the survey period that are correlated with both the mental health scores of the respondents and the presence of HSR service. As we described earlier, if the presence of

[24] See Andrews et al. (2019)

omitted variables like pollution and surrounding environmental situations is the case, the estimated relationship of interest in an OLS model suffers from a downward bias.

Column (3) in Table (3) presents reduced form estimates as depicted by equation (4). The estimation results reveal a statistically significant negative relationship between the mental scores of the middle-aged and elderly population and the distance to the railway in 1911. The respondents who reside farther from the historical railway exhibit relatively lower mental scores than those who live near the historical railway, which provides consistent estimations supporting the hypothesis.

Panel (B) in Table (3) represents the estimation results while controlling for the linear city trends. This adjustment helps to account for the overall change or trend in the outcome variable over time within each city. The results remain robust. In addition, Panel (D) in Table (A.15) controlled for the age cohort. I divide the respondents into age cohorts such as 45-59, 60-64, 65-79, and so on. This division allows me to explore potential age-related effects within specific age ranges or cohorts. Respondents within the same cohort may share common experiences, such as educational policies during their childhood, and may have experienced similar political environments. The results are still consistent.

6.2 *Robustness to Violations of Perfect Exogeneity*

As I mentioned earlier, there is a concern about the potential correlation between the identification of historical railways and local development and amenities. To address this, I include the number of the population working in the culture and entertainment industry for the local area as an additional control, aiming to capture the richness of the entertainment activities provided by the local city. Column (2) in Table (4) displays the IV estimates, which amount to 1.492 and are significant at the 1% level. Furthermore, I also include the number of families receiving internet service within the city as another control to reflect local development, which could offer better online activities. The results in Panel (B) of Table (4) remain robust.

Based on the previous description, it is evident that a significant number of railways during the late Qing Dynasty were constructed by imperialist powers. The imperialists introduced new railway technology to China during their occupation. Consequently, not only the regions close to the historical railway lines that could be affected and involved in the construction of HSR but also those close to the concessions in China might experience an impact. This influence could be technical or ideological and potentially affect the future development of HSR. Panel (A) in Table (6) reports the estimation results obtained by using the logarithm of the nearest distance to rail or concession in 1911. The estimates obtained in the analysis show a high degree of similarity to the results obtained in the baseline estimates.

To assess the robustness of the estimation, an alternative IV specification is to redefine the instrument as a binary variable. In this case, the binary variable indicates whether the railway in 1911 passed through the city. Panel (B) in Table (6) represents the OLS and IV estimation. Under this specification, the interpretation of the first stage and reduced form change. Column (8) provides the first stage estimation, which equals 0.811. This indicates that if a city had a railway in 1911, there is a positive and statistically significant likelihood that it also includes the HSR services. Similar to the first stage results, the reduced form analysis also reveals a positive and statistically significant relationship between the indicator of historical railway service and mental scores.

As previously mentioned, a potential threat to the identification strategy is the influence of population migration and density, which could be affected by the historical railway and also correlated with HSR accessibility and mental health issues. I also have concerns about the timing of the initiation of HSR services in cities, which may also be endogenous and potentially correlated with development. I address this issue from two different aspects. First, as I discussed above, given the significant population changes resulting from years of war and political turmoil, it is less likely that this factor poses a significant threat to the identification strategy. Second, in accordance with Section (2), the HSR route design primarily focuses on connecting provincial capitals in China. As a robustness check, I performed regressions on different subsamples to account for this situation.

Table (7) displays the estimations excluding provincial capitals in China. This approach is frequently employed in research to address endogeneity concerns associated with transportation infrastructure[25]. Figure (12) illustrates the network of HSR in 2016 along with the locations of provincial capitals in China. It is evident that all the intersections of the HSR lines are concentrated in the red areas, which correspond to the provincial capitals. Panel (A) in Table (7) reports the OLS and IV estimates. The estimates demonstrate a nearly identical pattern to the baseline results reported in Table (3). Panel B in Table (7), which utilizes the administrative division in the late Qing Dynasty, corresponds to Figure (A.15) and provides robust results.

In Section (2), it is mentioned that another requirement of the HSR network is to connect medium-sized cities. To examine this aspect, Table (8) presents regression results for different subsamples categorized by population. Panel (A) in Table (8) includes only cities with a population below 10,000,000. Panel (B) focuses specifically on small cities with a

[25] Chandra and Thompson (2000) pioneers this approach by specifically limiting their sample to rural areas that received interstates "accidentally" due to their location between larger cities. Chen et al. (2021) also adopt this approach and complement it with a Difference-in-Differences (DID) design to mitigate bias.

population below 5,000,000. The samples taken from small cities face additional restrictions that support the assumption that they have received HSR services by virtue of lying between large cities. The estimation results presented in Table (8) demonstrate a consistently positive and significant causal impact of HSR on the mental health scores of the population aged above or equal to 45. Although the first-stage effective F-statistic decreases to below 10 in Table (8) for small cities with populations below 5,000,000, the Anderson-Rubin weak IV robust tests support the inference of a positive impact of HSR on mental health.

To further validate that the timing of cities receiving the HSR service is not a concern, I have reformulated Equation (4) using an event-study method for examination [26]. If the timing were a concern, it might suggest a spurious relationship before and after the treatment. The results are presented in Figure (14). During the period preceding the treatment, the coefficients are not statistically significant, with all joint coefficients hovering around zero. Subsequent to the HSR's introduction, there was a notable decrease, with three out of the four coefficients reaching statistical significance at the 10% level.

6.3 *Heterogeneity Effects*

Moving on from the main estimation, it is crucial to assess whether the impact varies across different groups. Evaluating the heterogeneous treatment effects of HSR construction is essential for understanding how it may affect health inequalities. Then, I evaluate the heterogeneous effects by estimating separate models by age, gender, urban/rural, and marital status.

In Table (9), I report the results for samples limited to four different age groups (45-54, 55-64, 65-74, and above 74). Regardless of whether considering the OLS or IV estimate, the results consistently indicate a positive and significant impact of the opening of HSR on the mental health of individuals in the 45-64 age group. For respondents aged between 45-54, the IV estimate is 1.980 (standard error = 0.933), while for those aged between 55-64, it is 1.882 (standard error = 0.444). The results demonstrate that the introduction of HSR has a substantial and beneficial effect on the mental well-being of the middle-aged population.

The impact of HSR on the elderly population, specifically those aged above 64, appears to be weakened. The IV estimation results are not significant for the samples aged 64 or above. This leads to the conclusion that the effect of high-speed rail on the mental well-being of individuals in the age group above 64 is not as significant as it is for the middle-aged population (ages between 45-64).

In the last panel of Table (9), which represents the age group above 75, the OLS results

[26] see Appendix B for details

indicate a negative and significant impact of the opening of HSR services on mental health. One possible reason for this outcome could be the limited number of observations for this group, which may introduce bias into the results. Furthermore, the IV estimation for this age group shows a positive effect, but it is not statistically significant. The decrease in the impact of HSR on mental health as age increases could also be attributed to cognitive decline in the elderly. As individuals age, cognitive abilities may decline, potentially reducing the extent to which they can fully benefit from the convenience and accessibility provided by HSR.

Additionally, the number of children for middle-aged individuals is lower compared to the elderly group due to the one-child policy in China. Consequently, the impact of HSR on middile-aged individuals's mental health is even more significant. HSR provides convenience and frequency for their child to visit their hometowns regularly, reducing loneliness and improving the happiness index. These channels will be discussed further in the next section.

Afterwards, I conduct estimations to assess the impact of HSR based on different gender groups. Panel A in Table (10) shows the estimation results for males and females. The disparity in estimation between the two genders is minimal. According to the IV results in Column (2) and Column (3), the difference in the impact of HSR on mental scores between females and males is 0.082.

Panel B in Table (10) reveals heterogeneity across marital status. While the IV coefficient estimates are higher for the unmarried group than the married group, there is no statistically significant evidence of the impact on the unmarried group. Contrasting the results in Column (2) and Column (3), it becomes apparent that the effects of the HSR project are considered beneficial for married individuals. This outcome also reflects the family effect, indicating that HSR enhances family connection, reduces loneliness among the elderly, and ultimately improves their mental health.

Panel C in Table (10) explores the heterogeneity of HSR effects across urban and rural areas. The IV coefficients and significance levels for respondents living in urban areas are notably higher compared to those for respondents residing in rural areas. This finding highlights that the urban population received a relatively higher impact on their mental health from HSR service than the rural population. It suggests that the HSR service may contribute to increased inequality of mental health between urban and rural areas. One potential explanation for this finding is that the ticket prices for HSR are higher compared to traditional railway services. Rural populations often face greater economic pressures, such as poverty and unemployment, which can make the cost of high-speed rail travel a potential barrier for low-income individuals and families.

Furthermore, I examine the heterogeneity effects of HSR projects based on parents' general health and education status. In Panel A of Table (A.17), I present the outcomes of regressions conducted on different subsamples categorized by the health status of respondents' parents. Specifically, it provides the results of both OLS and IV regressions for three groups: *1. Respondents whose parents have already passed away. 2. Respondents with one surviving parent. 3. Respondents with both parents still alive.* The results indicate that the impact of HSR is larger for respondents whose parents are both alive compared to the other two groups. This result could be attributed to two potential reasons. Firstly, the HSR have enhanced access to medical resources for individuals. Secondly, it could have facilitated increased communication between the respondents and their parents.

Panel B of Table (A.17) presents the estimation outcomes based on the education level of respondents' parents. The samples are divided into three distinct groups: *1. At least one parent possesses a college degree or higher. 2. At least one parent has a high school degree or higher. 3. Both parents have an education level below high school.* The findings indicate that the HSR has a comparatively more significant impact on the mental health of respondents whose parents possess a higher level of education. The observed variation in results might be attributed to the influence of parental education on the family's income level. Additionally, considering that HSR ticket prices are typically higher than regular tickets, the impact of HSR on relatively higher-income groups could potentially outweigh its effects on lower-income groups.

Finally, I also examine the heterogeneity effects based on the number of children respondents have. Table (A.18) presents the corresponding estimation outcomes. Columns (1) - (4) provide the OLS and IV estimations regarding the impact of HSR on the mental health of participants with only one child. The results indicate that if the respondent has only one child, the HSR increases the mental health score by 1.914, accounting for approximately 6.38% of the mental health score. Columns (5) - (8) showcase the results for families with two children. The IV estimation suggests that the HSR project contributes to a 4.95% enhancement in the mental health score for these samples. Columns (9) - (12) reveal that the HSR project has a positive influence on the mental health of respondents with three children or more. The IV estimation equals 1.344, which is relatively lower than the IV estimation for samples with only one child.

The observed disparity could potentially be attributed to the fact that in families with fewer children, parents are more prone to experiencing the challenge of their children not being physically close. The introduction of the HSR may have heightened the level of connectivity between parents and children in these situations. Consequently, for families with a limited number of children, the impact of the HSR on mental health is more significant and larger.

7 Testing for Channels of Causality

Up to this point, I have asked whether the HSR caused an increase in middle-aged and elderly mental health scores. In this section, I perform several empirical tests to prove the three channels of this causality, which are the *income effect, resource effect, and family effect.*

Income Effect – The first test focuses on the income effect. HSR has the potential to generate job opportunities and stimulate economic growth in the areas it serves (Jia et al., 2017; Meng et al., 2018; Liang et al., 2020). The construction and operation of the rail line can create jobs in various industries, including engineering, construction, and transportation. Furthermore, the improved mobility and connectivity facilitated by HSR can attract new businesses and industries to the area, resulting in additional job opportunities and potentially higher incomes for local residents.

In the survey, respondents are asked to report their wages from the past year. Column (1) of Table (11) - Panel A presents the OLS result, which reflects the effect of HSR on the logarithm of respondents' past year's wages for the full sample. The result indicates a positive relationship between HSR and wages, although the statistical significance level is relatively low. To further investigate this relationship, the sample is divided into two groups based on whether the respondents are in the labor force. Column (5) of the Table (11) presents the OLS regression results for respondents in the labor force (aged below 60). The OLS estimated coefficient for HSR is 0.489, which is higher than the OLS estimated coefficient of 0.173 for the entire sample. This suggests a stronger positive relationship between HSR and wages for individuals in the labor force. Furthermore, Panel A in Table (11) also presents the IV estimation of HSR's effect on annual wages. Despite the absence of statistical significance in the IV estimates, the findings still indicate that HSR positively impacts annual wages for the samples in the labor force (coefficient = 0.834).

Turning to the examination of whether HSR could improve employment, Panel B in Table (11) displays the estimated effects of HSR on employment status. Here, employment is represented as a binary variable, where 1 indicates being employed, and 0 indicates being unemployed. The results demonstrate that the introduction of HSR has a relatively strong positive effect on employment for the population in the labor force. The estimated coefficient (= 0.039) for this group is statistically significant at the 0.1 level, indicating a robust relationship between HSR and increased employment opportunities.

Columns (2) and (6) in Panel (B) of Table (11) display the IV estimation results, which do not exhibit statistical significance. This could be attributed to the diminished sample size, particularly for the subset of samples within the labor force. Despite the lack of statistical significance in the IV estimates, it is noteworthy that the estimated coefficients still exhibit comparable magnitudes and sizes.

Resource Effect – In my analysis, I also explore another potential mechanism: *resource effects*. HSR can positively impact local medical resources, which is influenced by factors such as reduced travel costs and the availability of medical facilities in the area. In China, there is an inequality in the distribution of medical resources between large and small cities. Typically, large cities have better access to healthcare facilities, medical equipment, and qualified medical professionals compared to small cities and rural areas. As a result, there is often a shortage of medical professionals in small cities and rural areas. HSR can play a role in addressing this disparity by providing faster and more convenient transportation options for both patients and medical professionals. It can make it easier for individuals to access medical facilities in other areas, including large cities which have better healthcare resources. The study conducted by Choi et al. (2019) reveals that HSR services provide convenience for regional communication, leading to an increase in outpatient volume and medical care utilization among high-income cancer patients in South Korea.

In the survey, the respondents were asked several questions regarding their hospitalizations in the past year. One question pertained to the location of the health or service facility. The respondents could choose from the following responses: (1) this province; (2) other provinces; (3) this county/city; (4) other counties/cities; (5) this township; (6) other townships; (7) this village; (8) other villages. Based on this question, I generated a binary variable, *otherhsp*, to indicate whether the respondent traveled to another city or province to seek better medical resources. If the respondent chose other provinces or other counties/cities, the binary variable is set to one; otherwise, it is set to zero.

Table (12) includes the OLS results of the *resource effect*. The dependent variable is the binary variable, *otherhsp*. Columns (1), (5), and (9) in Table (12) report the OLS estimation, which consistently shows positive and significant estimates. Columns (2), (6), and (10) in Table (12) present the IV estimations, in which the size of the coefficient is doubled compared with OLS result. Specifically, the IV estimations prove that HSR has a positive effect on enabling people to travel and access better medical resources. However, the IV result is not statistically significant. Therefore, if HSR is available, it becomes an attractive option for traveling to see a doctor in another city.

Family Effect – The last channel is the *family effect*. Compared with Western countries, family values in China is more important because of different cultural background. In China, the concept of filial piety, which means respect for one's parents and ancestors, is deeply ingrained in the culture. Chinese children are expected to take care of their parents when they get old and to support them financially. As a result, Chinese parents may rely more heavily on their children for emotional, financial, and practical support than parents in some other cultures. However, in recent years, there has been a trend of increased urbanization and migration within China, with many young people leaving their hometowns and moving to cities in search of better job opportunities and higher education. As a result, it's becoming increasingly common for Chinese children to live far away from their parents. Therefore, compared with other cultures, regular visits may have a high possibility of bringing happiness and contentment to Chinese parents. It can certainly have a positive impact on a parent's mental health, particularly if they are experiencing feelings of loneliness or isolation.

The survey includes a section to record the meeting frequency between respondents and their children. The respondents are asked the following question: How often do you see your *child's name*? Respondents chose from the following responses: (1) Almost every day - 1 point (2) 2-3 times a week - 2 points (3) Once a week - 3 points (4) Every two weeks - 4 points (5) Once a month - 5 points (6) Once every three months - 6 points (7) Once every six months - 7 points (8) Once a year - 8 points (9) Almost never - 9 points (10) Other - 10 points. On the other hand, the survey also provides where the *child's name* normally lives now. There are seven different answers, including living together, same or adjacent dwelling/courtyard, this village or neighbourhood, another village/neighbourhood in this city/county, another city/county, another province, and another country. Based on this information, I calculate the total points of the meeting frequency for the children who are not living in the same city or county as the household.

Table (13) presents the estimation results of the *family effect*. In Panel A of Table (13), I utilize a subsample consisting only of households where all their children live in another city, county, or province. To account for variations in family structures, the number of children living in another city is included as an additional control. The table provides both OLS and IV estimations, allowing for a comparison of the results. Column (1) in Panel A reports the OLS estimation, which indicates a positive impact of HSR on the meeting frequency between parents and children. Column (2) in Panel A presents the IV estimation, which is six times that of the OLS estimation and is significant at the 5% level. This provides significant evidence that HSR increases the frequency of meetings among family members and subsequently reduces loneliness. I also provide the first-stage effective F-statistic for weak IV tests and the Anderson-Rubin weak IV robust statistic for weak IV inference. Specifically, in Table (13), Panel A, the p-value of the Anderson-Rubin weak IV robust test equals 0.0086. Consequently, I can reject the null hypothesis that HSR has no effect on in-person meeting frequency.

During the survey period, it is crucial to acknowledge the significant rise in smartphone usage, which has considerably increased opportunities for contact between parents and children through social software. For example, platforms such as WeChat and features like video calling (e.g., Facetime) have emerged as prevalent means of communication. Given that HSR primarily reduces travel time and enhances in-person meeting frequency, it is expected that HSR would not have any influence on the frequency of communication through phone, email, or mail. To perform a more rigorous robustness test on this mechanism, I also explore the correlation between HSR and the frequency of communication via phone or mail. Hence, columns (5) to (8) in Panel A of Table (13) present the estimation outcomes of HSR's effect on the frequency of communication via phone, email, and mail. The results indicate that HSR does not exert a significant impact on the frequency of phone contact within the subset of samples where their children are all residing far away from them.

Afterwards, I conduct several robustness checks to further examine the validity of this channel. Firstly, if the primary effect of HSR is to increase the number of long-distance family meetings, it is expected that individuals whose children live nearby would not experience a significant impact. The samples in Panel B of Table (13) only include the respondents' children who live in the same city or abroad. Columns (1) and (2) in Panel B report the OLS and IV results, which indicate a negative relationship that is not statistically significant. Thus, no evidence supports the notion that HSR services lead to an increase in face-to-face interactions within this subset of samples. In addition, I present both the OLS and IV estimation outcomes concerning the relationship between HSR and the frequency of phone communication in columns (5) and (6). The results do not exhibit statistical significance. In summary, all the results suggest that HSR facilitates more frequent face-to-face interactions and strengthens family connections by reducing travel barriers and improving transportation convenience.

Finally, I employ the complete set of samples to assess the *family effect* channel. Table (A.19) shows the estimation results. The dependent variable for columns (1) to (4) in Panel A of Table (A.19) is the total meeting frequency of children residing in a different city or province.[27] However, only the OLS estimation result in Column (1) is positively signed and exhibits statistical significance at the 10% level. The IV estimation yields a positive coefficient but lacks statistical significance. This could be attributed to the potential issue of the sample set not being sufficiently refined. A considerable portion of respondents have some children living in another city or province, while others have children residing in the same city.

Furthermore, Columns (1) to (4) in Panel B of Table (A.19) present the OLS and IV estimation outcomes concerning the influence of HSR on the cumulative meeting frequency

[27] To be specific, if the respondent has three children and two of them are residing in another city, then the dependent variable is the cumulative meeting frequency of these two children.

of children living either in the same city or abroad. Notably, I also incorporate control for the number of children living in the same city or abroad. The results reveal positive coefficients but lack statistical significance. Subsequently, Columns (5) to (8) in Panel B of Table (A.19) illustrate the relationship between HSR and the frequency of communication through phone or mail. The estimated coefficients continue to be negative and statistically insignificant.

8 Conclusion

In recent years, there has been growing interest in exploring the indirect effects of high-speed rail, particularly in the context of health research. However, the understanding of whether high-speed rail can have an impact on mental health remains limited. On the other hand, it is also important given the increasing challenges posed by population aging in today's society, which necessitates policymakers to prioritize the health issues of middle-aged and elderly individuals. Mental health, in particular, is often overlooked, with long treatment cycles and significant stigma associated with mental illness in Chinese history and culture, presenting a substantial challenge in addressing the mental health needs of this population. This study aims to bridge this research gap by examining the potential impact of HSR on the mental health of middle-aged and elderly individuals.

Based on the analysis using data from CHARLS, I have found that HSR accessibility has a statistically significant effect on improving the mental health score of individuals aged above 45. To determine whether this relationship is causal, I employ an instrumental variable (IV) approach that utilizes the distance from the railway in 1911 as an instrument for HSR. The IV estimates reveal a positive effect of HSR on mental health. This finding remains robust when employing an alternative identification strategy and analyzing a different subsample. The estimated coefficient suggests that the introduction of HSR leads to an increase of 1.499 points in the mental health score of people aged 45 or above. Furthermore, the analysis indicates several potential channels through which HSR can contribute to mental health improvement, including increased employment opportunities, improved availability of medical resources, and especially, an increased frequency of meetings with children. Overall, these findings enhance our understanding of the complex relationship between HSR accessibility and mental health, highlighting the potential mechanisms through which HSR can positively impact the mental well-being of the targeted population.

In addition, I also examine the heterogeneity effects of HSR on the mental health of middle-aged and elderly individuals. I find that HSR service has similar effects on mental health scores for both females and males. However, I do find differences in the effects of HSR on mental health between urban and rural areas. The results indicate that HSR service has a relatively stronger positive effect on the mental health scores of individuals residing in urban areas compared to those in rural areas. The stronger impact observed in urban areas could potentially cause a gap in mental health outcomes between urban and rural populations. These findings emphasize the need for policymakers to consider the potential distributional impacts of HSR on mental health and take steps to address any disparities that may arise.

Finally, this study focuses on the impact of HSR on the mental health of middle-aged and elderly individuals in China. The findings and implications may have broader relevance beyond China's context. Exploring the experiences of other countries at different stages of economic development can provide valuable insights into the unintended benefits of HSR on mental health outcomes. Therefore, future research efforts that investigate the impact of HSR on mental health in various countries and contexts can contribute to the broader knowledge base and inform evidence-based policies in the transportation and public health sectors.

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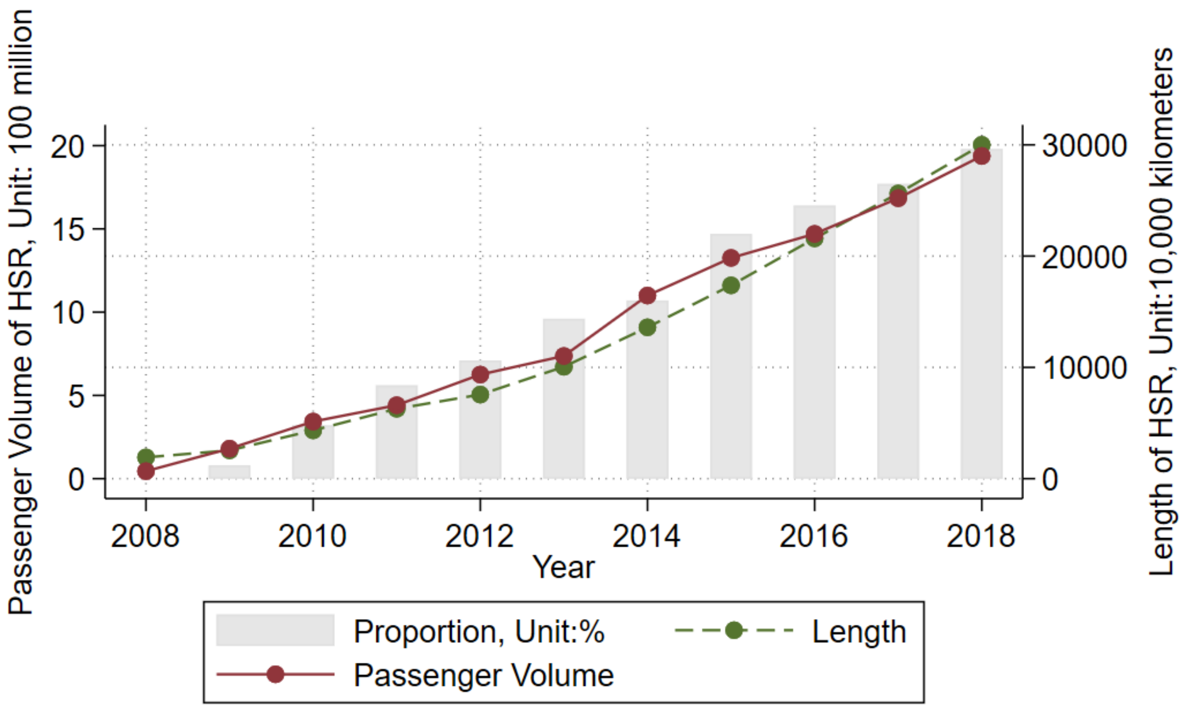
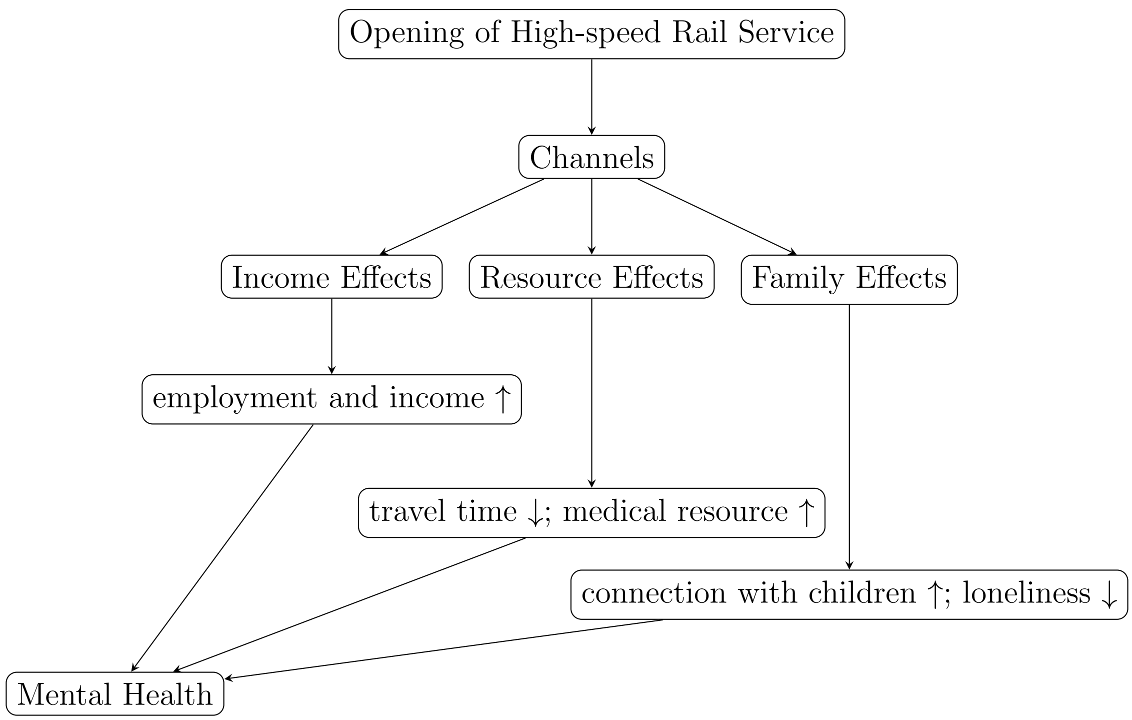
Figures and Tables

Figure 1 –Development of High-speed Rail in China



Note: The red solid line represents passenger traffic. The green dashed line describes the increasing trend of the operating mileage of the high-speed rail project. The gray bar shows the proportion of high-speed rail operating mileage to the total railway operating mileage. Data resource: Ministry of Transport of the People's Republic of China

Figure 2 –Channels of Causality: Effects of High-speed Rail on Middle-aged and Elderly People's Mental Health



Note: This figure describes three potential channels of influence. They are *income effect, resource effect and family effect.*

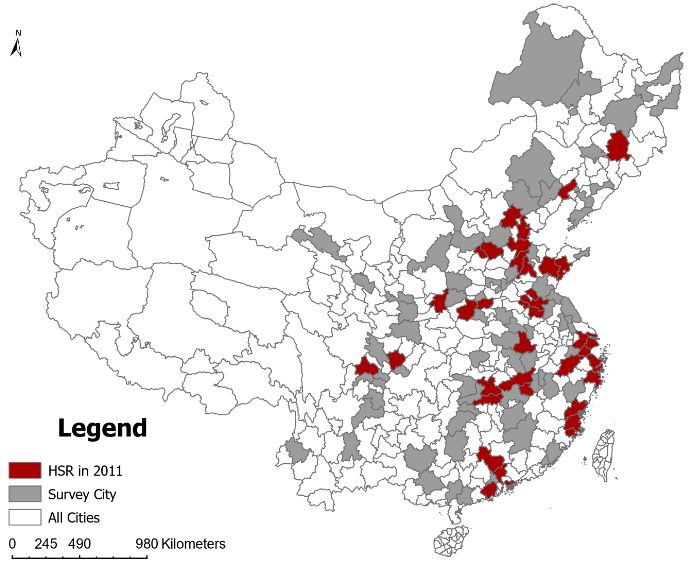


FIGURE 3 –HSR IN 2011

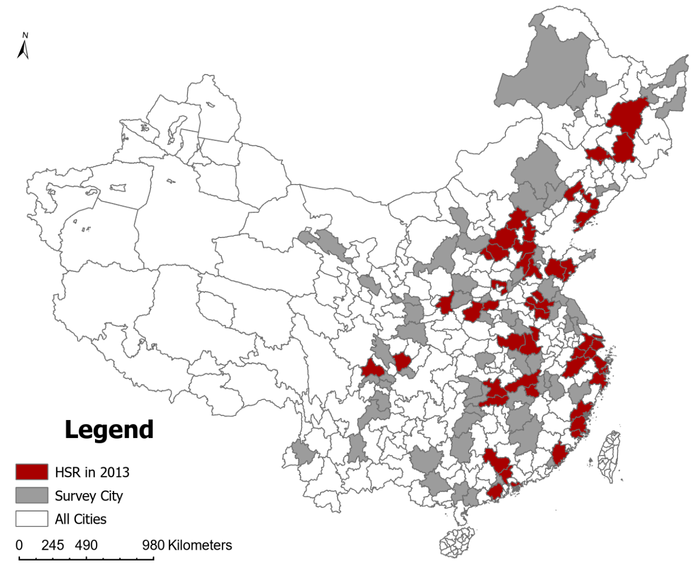


FIGURE 4 –HSR IN 2013

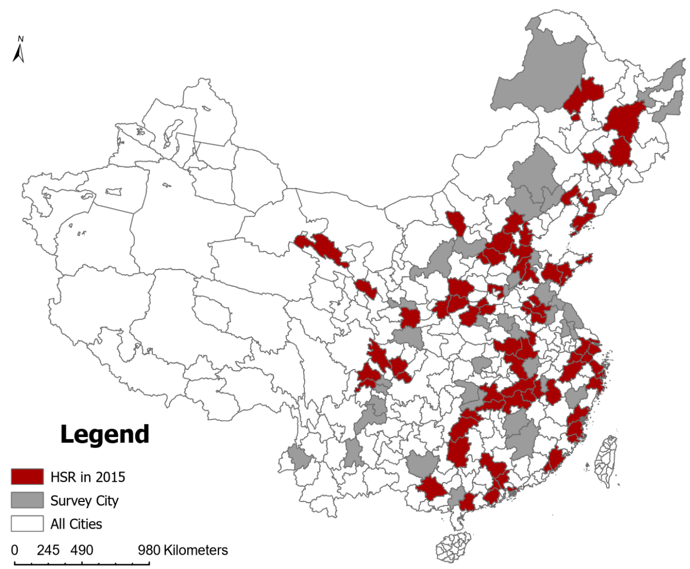


FIGURE 5 –HSR IN 2015

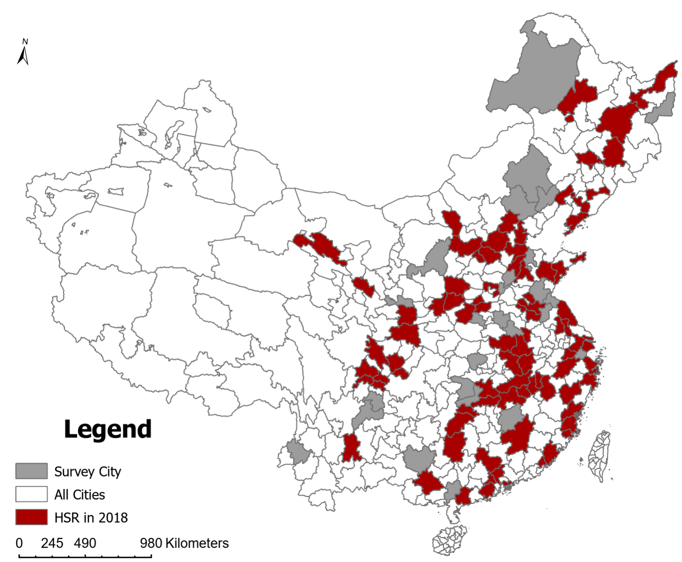
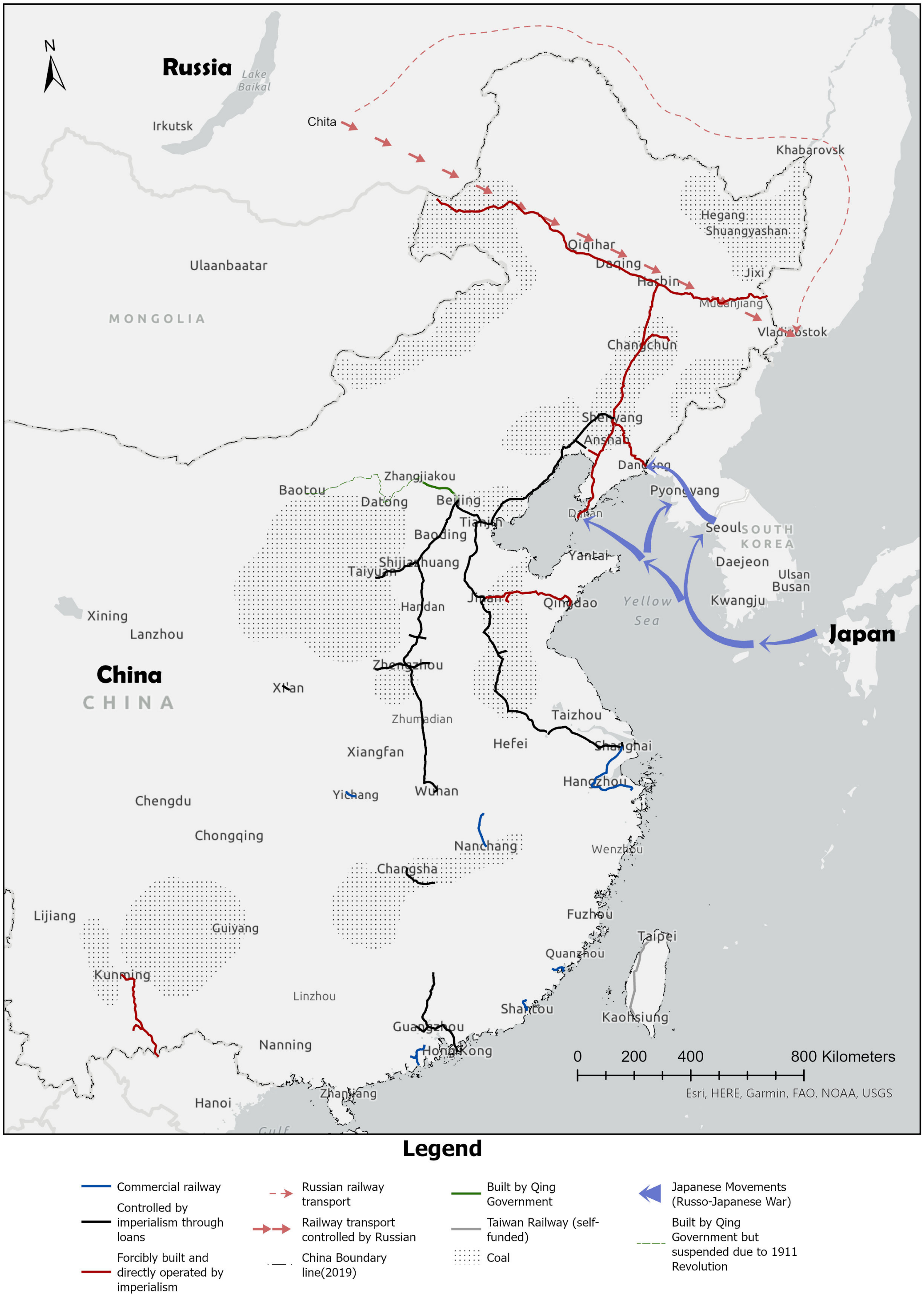


FIGURE 6 –HSR IN 2018

Notes: Figure (3) - (6) represent the treated group and untreated group in each surveyed year. The red area represents the cities with high-speed rail, while the grey area represents the cities without high-speed rail. The white area represents the unsurveyed areas. The city-level statistic summary refers to table (A.14).

Figure 7 –Railway in China at the end of Qing Dynasty



Note: This figure illustrates the railway system at the end of the Qing Dynasty. The red solid line represents the railway that was forcibly built and directly operated by imperialism. The black solid line represents the railway controlled by imperialism through loans. The solid green line represents the railway built by the Qing government, while the dashed green line represents the incomplete part of the railway. More information can be found in Appendix C.

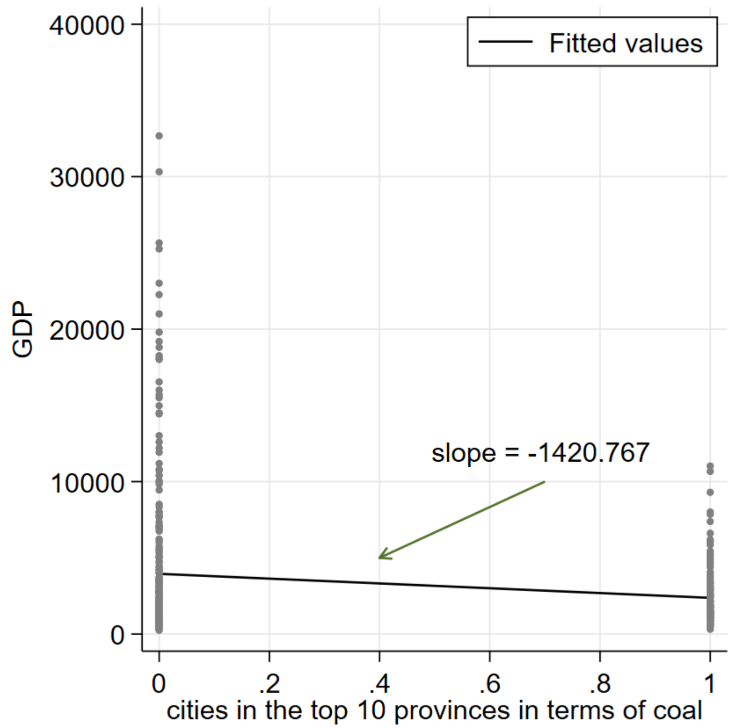


FIGURE 8 –GDP VS. COAL

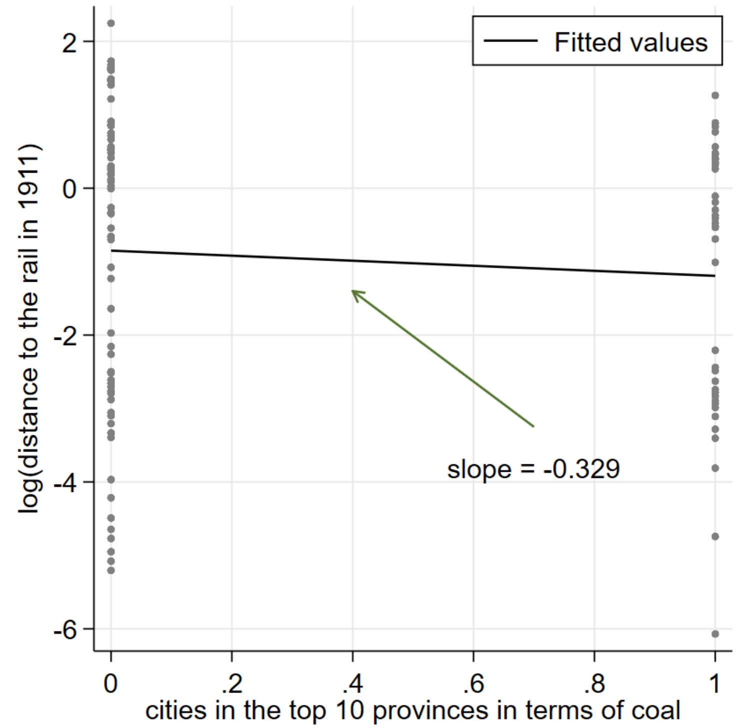


FIGURE 9 –LOG(DISTANCE TO THE RAIL IN 1911) VS. COAL

Note: the x-axis represents the binary variable, where it equals 1 if the city is in the top 10 provinces in terms of coal, for both Figure (8) and (9).

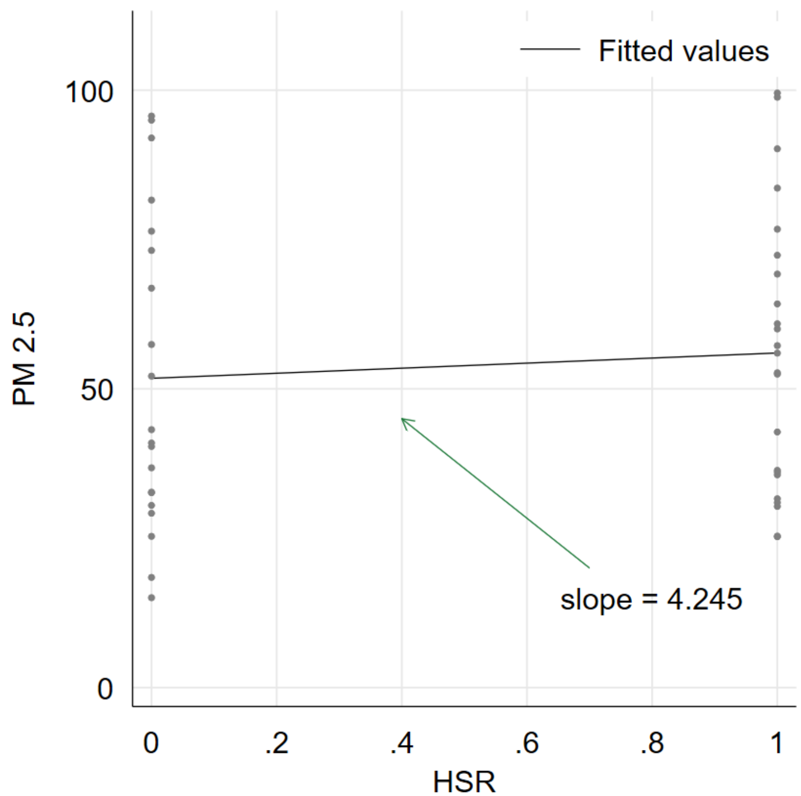


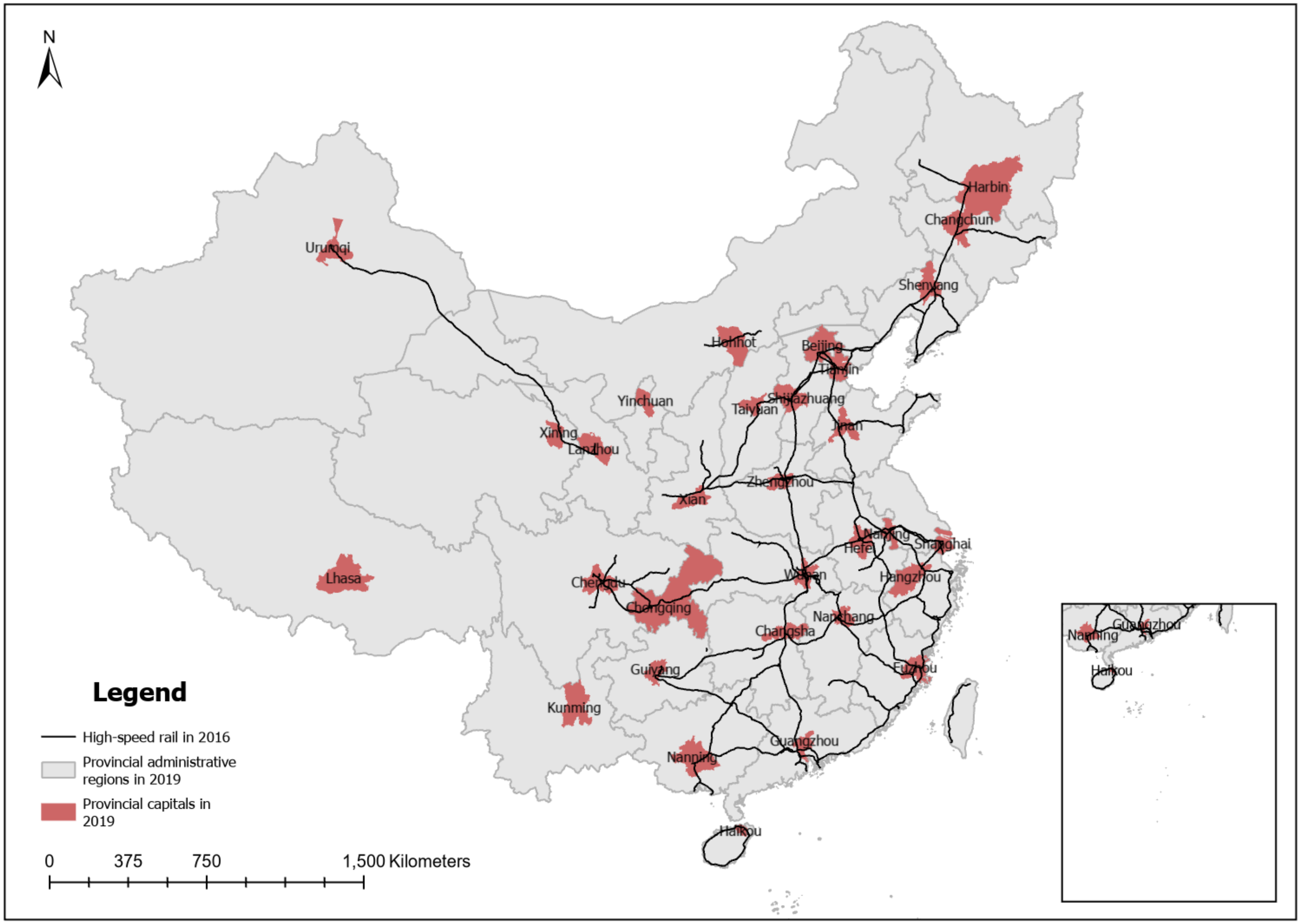
FIGURE **10** –PM2.5 VS. HSR

Note: This figure shows the relationship between PM2.5 and HSR. (HSR is a binary variable, =1 if the city has HSR service).

Figure 11 –High-speed Rail (2016) and Rail in 1911

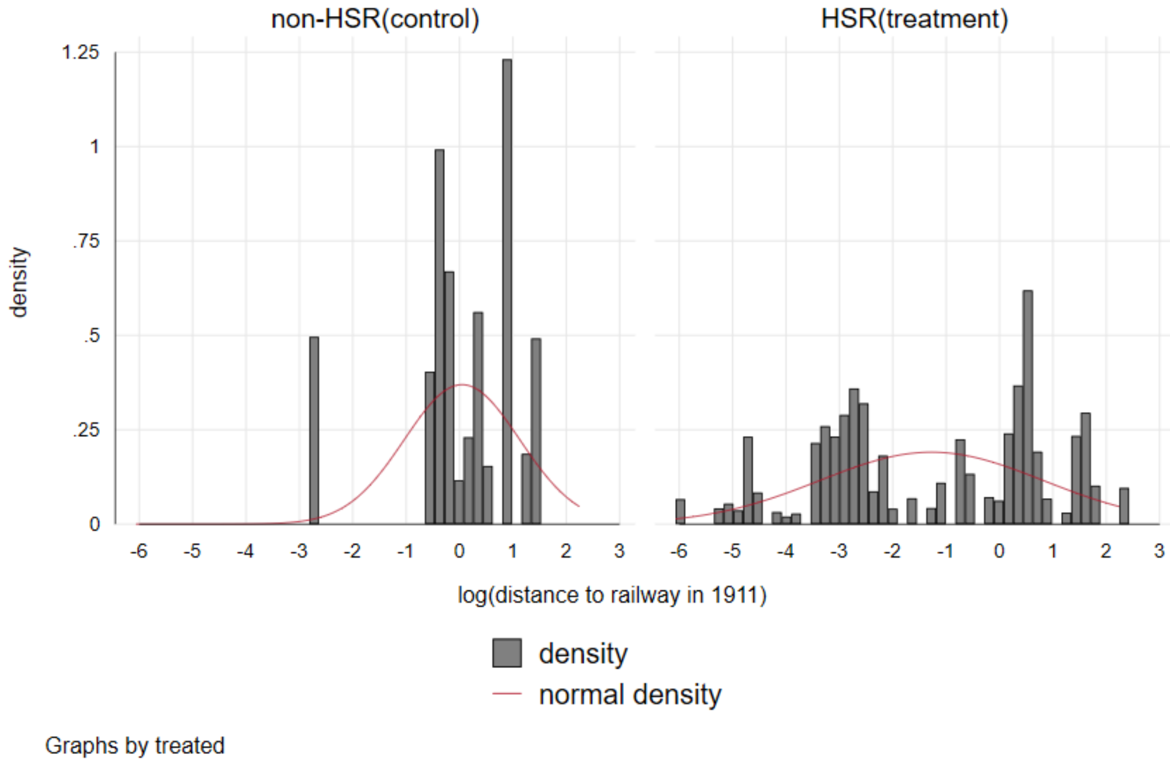
Note: The graph illustrates the HSR network in 2016 alongside the railway network from 1911. The solid black line represents the railway in 1911, while the red dashed line depicts the HSR network.

Figure 12 –High-speed Rail (2016) and Provincial Administrative Regions (2019)



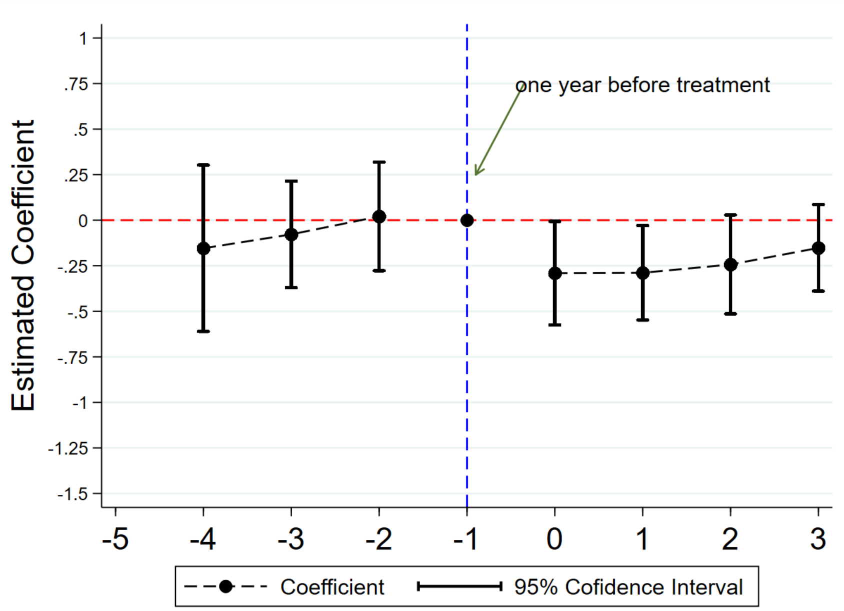
Note: The graph describes the provincial administrative regions in 2019. The red areas represent the provincial capitals. The black lines represent the railway in 2016. Data Resource: The China Historical Geographic Information System, CHGIS.

Figure 13 –log(distance to railway in 1911) by treatment



Note: This figure is a density histogram that represents the distribution of the dataset. It shows the distribution of the instrumental variable, log(distance to the railway in 1911), separately for treatment and control groups. The distribution of height is skewed towards taller values for the control group than the treatment group. The red curve is the normal density curve.

FIGURE 14 –REDUCED-FORM EVENT STUDY ESTIMATES OF THE IMPACT OF HSR



Note: Estimates reflect coefficients on the distance to the historical railways interacted with the year from the regression model.(Refers to the Equation (6))

Table 1 –Descriptive Statistics - Mental Score

	(N = 44,424)			
	Min.	Max	Mean	Std.Dev.
Questions				
I felt depressed.	0.00	3.00	0.88	1.07
I felt that everything I did was an effort.	0.00	3.00	0.91	1.14
My sleep was restless.	0.00	3.00	1.06	1.21
I was happy.	0.00	3.00	1.87	1.19
I felt lonely.	0.00	3.00	0.52	0.96
I was bothered by little things that usually don't bother me.	0.00	3.00	0.89	1.09
I could not get going	0.00	3.00	0.36	0.81
I had trouble keeping my mind on what I was doing.	0.00	3.00	0.85	1.08
I felt hopeful about the future.	0.00	3.00	1.62	1.28
I felt fearful.	0.00	3.00	0.33	0.78
Final Score				
CES-D score	0.00	30.00	8.18	6.28
mental score = 30 - (CES-D score)	0.00	30.00	21.82	6.28

Notes: CES-D score is the sum of these 10 items, after reverse coding question *I was happy* and *I felt hopeful about the future*. Additionally, the scales for each of the ten questions were adjusted so that the anchors were 0 to 3 rather than 1 to 4. I use the mental score to estimate the effect of the high-speed rail project. Mental score = 30 - (CES-D score). If the mental score equals 0, it means major depressive disorder.

For each question, the survey provides 4 different choices.
= **0**: Rarely or none of the time < 1 day
= **1**: Some or a little of the time 1-2 days
= **2**: Occasionally or a moderate amount of 3
= **3**: Most or all of the time 5-7 days

Table 2 –Descriptive Statistics - Variables

Descriptive Statistics	All (N=44,424)		Never Treated (N=12,271)		Not Yet Treated (N=18,070)		Treated (N=32,153)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Dependent variable								
mental score (0-30)	21.82	6.28	21.17	6.48	21.69	6.31	22.07	6.18
Major explanatory variable								
HSR	0.53	0.50	0.00	0.00	0.52	0.50	0.73	0.44
Individual-level controls								
gender (=1 woman, =0 man)	0.52	0.50	0.52	0.50	0.52	0.50	0.52	0.50
education category (1-10)	3.39	1.90	3.17	1.88	3.43	1.89	3.47	1.90
age in years	60.62	9.50	59.99	9.28	60.92	9.61	60.86	9.57
urban, (=1 urban, =0 rural)	0.38	0.49	0.26	0.44	0.37	0.48	0.43	0.49
public health insurance, (=1 have, =0 does not have)	0.94	0.24	0.94	0.23	0.94	0.24	0.94	0.24
marital status, (=1 married, =0 not married)	0.82	0.38	0.82	0.38	0.82	0.39	0.82	0.38
log(wealth)	7.37	3.24	6.97	3.13	7.43	3.19	7.53	3.27
Environmental controls								
log(length of road,km)	9.57	0.43	9.68	0.38	9.50	0.48	9.52	0.44
number of hospitals	239.12	186.34	215.12	193.14	233.55	187.24	248.28	182.85
GDP per capita(yuan)	46119.35	27628.73	34993.49	16873.93	41001.49	23124.83	50365.47	29677.42
population(10000)	589.71	275.02	557.70	279.73	544.93	262.83	601.92	272.21
Instrumental variable								
log(distance to railway in 1911)	-0.91	1.96	0.05	1.08	-0.85	2.14	-1.27	2.09

Notes: The sample is restricted to adults ages 45 or above. The wealth level is calculated as the sum of four indices: *1. Total value of cash and deposits in financial institutions. 2. Total value of stocks and mutual funds. 3. Total value of government bonds. 4. Total value of all other savings.* The distance to the railway in 1911 is the planar distance, which was collected by using ArcGIS Pro. This is the straight-line Euclidean distance calculated in a two-dimensional plane.

Table 3 –Baseline Results - The Impact of High-Speed Rail on Mental Health among Middle-aged and Elderly Individuals in China

	Panel A				*Panel B*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage
HSR	0.448**	1.491***			0.671**	2.194***		
	(0.197)	(0.506)			(0.298)	(0.502)		
log(distance to rail in 1911)×post			-0.194***	-0.130***			-0.419***	-0.191***
			(0.067)	(0.027)			(0.098)	(0.027)
City and year FE	✓	✓	✓	✓				
Linear city trends					✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓
Observations	44,424	44,424	44,424	44,424	44,424	44,424	44,424	44,424
R^2	0.130	0.063	0.131		0.136	0.135	0.137	
First-stage effective F-stat				17.752				35.802
Anderson-Rubin weak IV robust test(p-value)				0.0036				0.0000
(H_0: HSR has no effect on mental health)								

Notes: The table reports baseline estimates of the effect of the high-speed rail on individuals' ($age >= 45$) mental health. The unit of observation is an individual. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. The statistical significance stars for each result are based on the standard error reported in parentheses. All estimates were produced using survey weights. The individual controls are for age, education, a gender indicator variable, public health insurance, marital status, individual's wealth level, and an indicator for whether the respondent lives in an urban location. The city-level controls include the length of the highway and the number of hospitals within the city. Refer to Table (2) for variable definitions.

Table 4 –Baseline Result with additional controls

	Panel A				*Panel B*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage
HSR	0.448**	1.492***			0.456**	1.517***		
	(0.197)	(0.506)			(0.199)	(0.505)		
log(distance to rail in 1911)×post			-0.195***	-0.130***			-0.196***	-0.129***
			(0.067)	(0.027)			(0.067)	(0.028)
# of population working in culture and entertainment industry	0.018	0.006	0.027	0.014	0.014	-0.002	0.023	0.017
	(0.071)	(0.072)	(0.077)	(0.025)	(0.073)	(0.076)	(0.080)	(0.024)
# of families received wifi service					0.000	0.001	0.000	-0.000
					(0.001)	(0.001)	(0.001)	(0.000)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓
baseline controls	✓	✓	✓	✓	✓	✓	✓	✓
Observations	44,424	44,424	44,424	44,424	44,424	44,424	44,424	44,424
R^2	0.130	0.063	0.131		0.130	0.062	0.131	
First-stage effective F-stat				17.775				17.205
Anderson-Rubin weak IV robust test(p-value)				0.0036				0.0033

Notes: Panel A includes population as a control. The standard errors, reported in parentheses, are adjusted for clustering within cities. The unit of observation is an individual. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights.

Table 5 –Relevant Test

Relevence Test					
	HSR	*Environment*		*Entertainment*	
	(1)	(2) Green coverage ratio	(3) Park(area)	(4) Book collection	(5) # of movie theaters
log(distance to the rail in 1911)	-0.133***	-0.079	91.078	-1.146	5.377
	(0.029)	(0.348)	(150.386)	(0.881)	(239.622)
Province FE	✓	✓	✓	✓	✓
Baseline controls	✓	✓	✓	✓	✓
Observations	108	106	106	105	108
R^2	0.577	0.588	0.825	0.921	0.941

Notes: The standard errors, reported in parentheses, are adjusted for clustering within the province. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01.

Table 6 –Alternative IV Specifications - The Impact of High-Speed Rail on Mental Health among Middle-aged and Elderly Individuals in China

	Panel A				*Panel B*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage
HSR	0.448**	1.389***			0.448**	0.961**		
	(0.197)	(0.463)			(0.197)	(0.372)		
nearest distance to rail or concession in 1911 × post			-0.202***	-0.146***				
			(0.069)	(0.026)				
whether have rail in 1911 × post							0.779**	0.811***
							(0.307)	(0.038)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓
Observations	44,424	44,424	44,424	44,424	44,424	44,424	44,424	44,424
R^2	0.130	0.063	0.131		0.130	0.064	0.131	
First-stage effective F-statistic				26.471				534.517
Anderson-Rubin weak IV robust test(p-value)				0.0031				0.0107
(H_0: HSR has no effect on mental health)								

Notes: The table reports the estimations based on two alternative IV specifications. The standard errors, reported in parentheses, are adjusted for clustering within cities. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights.

Table 7 –Excluding Provincial Capitals - The Impact of High-Speed Rail on Mental Health among Middle-aged and Elderly Individuals in China

Excluding Provincial Capitals								
	Panel A (2019)				*Panel B (Qing Dynasty)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	IV	Reduced-form	First-stage	OLS	IV	Reduced-form	First-stage
HSR	0.361*	1.861***			0.376*	1.370**		
	(0.217)	(0.573)			(0.214)	(0.629)		
log(distance to rail in 1911) × post			-0.232***	-0.125***			-0.169**	-0.123***
			(0.069)	(0.030)			(0.079)	(0.031)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓
Observations	38,391	38,391	38,391	38,391	38,392	38,392	38,392	38,392
R^2	0.128	0.060	0.128		0.131	0.062	0.131	
First-stage effective F-statistic				13.123				11.700
Anderson-Rubin weak IV robust test(p-value)				0.0008				0.0322
(H_0: HSR has no effect on mental health)								

Notes: The table reports the estimations based on two sub-samples. Panel A shows the results without the provincial capitals according to the 2019 classification criteria (Figure (12)). Panel B shows the results without the provincial capitals based on the provincial administrative regions in 1820 (Figure (A.15)). The standard errors, reported in parentheses, are adjusted for clustering within cities. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights.

Table 8 –Population - The Impact of High-Speed Rail on Mental Health among Middle-aged and Elderly Individuals in China

Population								
	Panel A (< 10,000,000)				*Panel B* (< 5,000,000)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	IV	Reduced-form	First-stage	OLS	IV	Reduced-form	First-stage
HSR	0.370*	1.257**			0.445	1.786**		
	(0.200)	(0.602)			(0.268)	(0.723)		
log(distance to rail in 1911) × post			-0.151**	-0.120***			-0.205**	-0.115***
			(0.075)	(0.031)			(0.084)	(0.035)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓
Observations	39,149	39,149	39,149	39,149	17,835	17,835	17,835	17,835
R^2	0.130	0.063	0.130		0.150	0.076	0.151	
First-stage effective F-statistic				11.276				7.059
Anderson-Rubin weak IV robust test(p-value)				0.0441				0.0133
(H_0: HSR has no effect on mental health)								

Notes: The table reports the estimations based on two sub-samples. Panel A shows the results without the cities whose population is greater than 1,000,000, while Panel B shows the results without the cities whose population is greater than 500,000. The standard errors, reported in parentheses, are adjusted for clustering within cities. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights.

Table 9 –Heterogeneity Effect - Age

	Age between 45 - 54				*Age between 55 - 64*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	IV	Reduced-form	First-stage	OLS	IV	Reduced-form	First-stage
HSR	1.182***	1.980**			0.543**	1.882***		
	(0.383)	(0.933)			(0.227)	(0.444)		
log(distance to rail in 1911) × post			-0.275*	-0.139***			-0.258***	-0.137***
			(0.141)	(0.028)			(0.062)	(0.026)
First-stage effective F-statistic				18.140				21.067
Anderson-Rubin weak IV robust test(p-value)				0.0502				<0.0001
(H_0: HSR has no effect on mental health)								
Observations	13,480	13,480	13,480	13,480	16,454	16,454	16,454	16,454
R^2	0.157	0.074	0.156		0.149	0.069	0.149	
	Age between 65 - 74				*Age above 75*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	IV	Reduced-form	First-stage	OLS	IV	Reduced-form	First-stage
HSR	0.294	0.850			-1.036**	1.434		
	(0.273)	(0.942)			(0.463)	(1.987)		
log(distance to rail in 1911) × post			-0.100	-0.139***			-0.150	-0.118***
			(0.111)	(0.028)			(0.190)	(0.029)
First-stage effective F-statistic				12.679				8.899
Anderson-Rubin weak IV robust test(p-value)				0.3641				0.4251
(H_0: HSR has no effect on mental health)								
Observations	10,404	10,404	10,404	13,480	4,085	4,085	4,085	10,404
R^2	0.149	0.060	0.149		0.152	0.035	0.151	
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓

Notes: The table reports the estimations based on four sub-samples by age ($45-54, 55-64, 65-74, above75$). The standard errors, reported in parentheses, are adjusted for clustering within cities. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights. All estimates include city and year-fixed effects, individual controls and city-level controls.

Table 10 –Heterogeneity Effect - Gender, Marital Status, and Rural/Urban

Gender

	Male				*Female*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage
HSR	0.436**	1.447**			0.470*	1.529**		
	(0.190)	(0.585)			(0.269)	(0.668)		
log(distance to rail in 1911) × post			-0.189**	-0.130***			-0.198**	-0.130***
			(0.075)	(0.028)			(0.089)	(0.027)
Observations	21,382	21,382	21,382	21,382	23,042	23,042	23,042	23,042
R^2	0.107	0.037	0.107		0.119	0.036	0.119	
First-stage effective F-statistic				17.036				17.997
Anderson-Rubin weak IV robust test(p-value)				0.0112				0.0245
(H_0: HSR has no effect on mental health)								

Marital Status

	Not married				*Married*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage
HSR	0.100	1.618			0.520**	1.383**		
	(0.378)	(1.027)			(0.205)	(0.563)		
log(distance to rail in 1911) × post			-0.198	-0.133***			-0.183**	-0.122***
			(0.130)	(0.027)			(0.075)	(0.029)
Observations	7,924	7,924	7,924	36,500	36,500	36,500	36,500	7,924
R^2	0.126	0.047	0.127		0.129	0.058	0.129	
First-stage effective F-statistic				14.662				18.541
Anderson-Rubin weak IV robust test(p-value)				0.1267				0.0144
(H_0: HSR has no effect on mental health)								

Urban and Rural

	Rural				*Urban*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage
HSR	0.221	1.119*			0.695**	1.768**		
	(0.232)	(0.598)			(0.299)	(0.712)		
log(distance to rail in 1911) × post			-0.128*	-0.115***			-0.257**	-0.145***
			(0.075)	(0.041)			(0.110)	(0.027)
Observations	27,555	27,555	27,555	27,555	16,869	16,869	16,869	16,869
R^2	0.118	0.057	0.118		0.121	0.060	0.121	
First-stage effective F-statistic				14.662				27.198
Anderson-Rubin weak IV robust test(p-value)				0.0860				0.0185
(H_0: HSR has no effect on mental health)								
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓

Notes: The table reports the heterogeneous estimations based on three categories (gender, marital status, urban and rural). The standard errors, reported in parentheses, are adjusted for clustering within cities. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights. All panels include city and year-fixed effects, individual controls and city-level controls. The results exhibit a statistically significant difference within each group (See Table A.16).

Table 11 –Channels of Causality: Income Effect

Panel A: Dependent Variable: Earning(yearly)

	All samples				*Labor Force*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage
HSR	0.173	0.005			0.489	0.834		
	(0.132)	(0.428)			(0.313)	(0.833)		
log(distance to rail in 1911) × post			-0.001	-0.130***			-0.119	-0.143***
			(0.056)	(0.027)			(0.126)	(0.027)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓
Observations	44,324	44,324	44,324	44,324	21,482	21,482	21,482	21,482
R^2	0.207	0.159	0.207		0.208	0.124	0.208	
First-stage effective F-statistic				17.750				22.113
Anderson-Rubin weak IV robust test(p-value)				0.9902				0.3424
(H_0: HSR has no effect on earning)								

Panel B: Dependent Variable: Employment

	All samples				*Labor Force*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage
HSR	0.022	0.039			0.047*	0.114		
	(0.018)	(0.054)			(0.027)	(0.072)		
log(distance to rail in 1911) × post			-0.005	-0.130***			-0.016	-0.142***
			(0.007)	(0.027)			(0.011)	(0.027)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓
Observations	44,108	44,108	44,108	44,108	21,414	21,414	21,414	21,414
R^2	0.292	0.223	0.292		0.150	0.088	0.150	
First-stage effective F-statistic				17.562				22.012
Anderson-Rubin weak IV robust test(p-value)				0.4862				0.1329
(H_0: HSR has no effect on employment)								

Notes: The unit of observation is an individual. The dependent variable in Panel A is the yearly wage of each individual. The dependent variable in Panel B is a binary variable which indicates whether the individual has a job (=1, have a job). In China, the retirement age for male employees is currently 60, while female employees can retire at the age of 55. Thus, the respondents within the labor force are between the ages of 45 and 60. The standard errors, reported in parentheses, are adjusted for clustering within cities. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights.

Table 12 –Channels of Causality: Resource Effect

Dependent Variable: Inpatient care in another city												
	Panel A				*Panel B*				*Panel C*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	IV	Reduced-form	First-stage	OLS	IV	Reduced-form	First-stage	OLS	IV	Reduced-form	First-stage
HSR	0.053**	-0.040			0.040*	-0.064			0.057*	0.107		
	(0.026)	(0.044)			(0.022)	(0.080)			(0.031)	(0.096)		
log(distance to rail in 1911) × post			0.005	-0.128***			0.006	-0.096***			-0.013	-0.122***
			(0.006)	(0.020)			(0.007)	(0.022)			(0.011)	(0.036)
City and year FE									✓	✓	✓	✓
Individual controls					✓	✓	✓	✓	✓	✓	✓	✓
City-level controls					✓	✓	✓	✓	✓	✓	✓	✓
Observations	4,756	4,756	4,756	4,756	4,756	4,756	4,756	4,756	4,756	4,756	4,756	4,756
R^2	0.004	-0.009	0.001		0.044	0.030	0.043		0.138	0.064	0.137	
First-stage effective F-statistic				34.110				16.312				5.637
Anderson-Rubin weak IV robust test(p-value)				0.3687				0.3780				0.6646
(H_0: HSR has no effect on mental health)												

Notes: The unit of observation is an individual. The dependent variable is a binary variable (otherhsp: whether had inpatient care in another city during the past month). If the dependent variable equals one, the individual does have inpatient care in another city. The standard errors, reported in parentheses, are adjusted for clustering within cities. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights.

Table 13 –Channels of Causality: Family Effect

Panel A: Dependent Variable: Meeting frequency of children living in another city

	In-person				*By phone/mail*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage
HSR	0.393	2.425**			0.153	1.508		
	(0.301)	(1.160)			(0.303)	(1.165)		
log(distance to rail in 1911) × post			-0.286**	-0.118***			-0.175	-0.116***
			(0.110)	(0.038)			(0.129)	(0.038)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓
Observations	5,574	5,574	5,574	5,574	5,808	5,808	5,808	5,808
R^2	0.782	0.690	0.783		0.493	0.369	0.493	
First-stage effective F-statistic				8.160				7.694
Anderson-Rubin weak IV robust test(p-value)				0.0086				0.1717
(H_0: HSR has no effect on connection frequency)								

Panel B: Dependent Variable: Meeting frequency of children living in same city or abroad

	In-person				*By phone/mail*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage
HSR	-0.157	-0.145			0.154	-0.108		
	(0.395)	(0.750)			(0.616)	(1.546)		
log(distance to rail in 1911) × post			0.023	-0.161***			0.017	-0.153***
			(0.121)	(0.024)			(0.237)	(0.023)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓
Observations	5,357	5,357	5,357	5,357	7,294	7,294	7,294	7,294
R^2	0.586	0.492	0.586		0.606	0.407	0.606	
First-stage effective F-statistic				36.761				37.223
Anderson-Rubin weak IV robust test(p-value)				0.8455				0.9438
(H_0: HSR has no effect on connection frequency)								

Notes: The estimation of Panel A in this table only includes the individuals whose children are all living in another city. Columns (1)-(4) report the regression results of HSR on in-person meeting frequency while also controlling for the number of children living in another city. The dependent variable of columns (5)-(8) is the contact frequency by phone, email and mail. And columns (5)-(8) control the total number of children. Panel B presents the estimation results based on respondents whose children all live in the same city or abroad. The standard errors, reported in parentheses, are adjusted for clustering within cities. The unit of observation is an individual. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights. All estimates include city and year-fixed effects, individual controls and city-level controls.

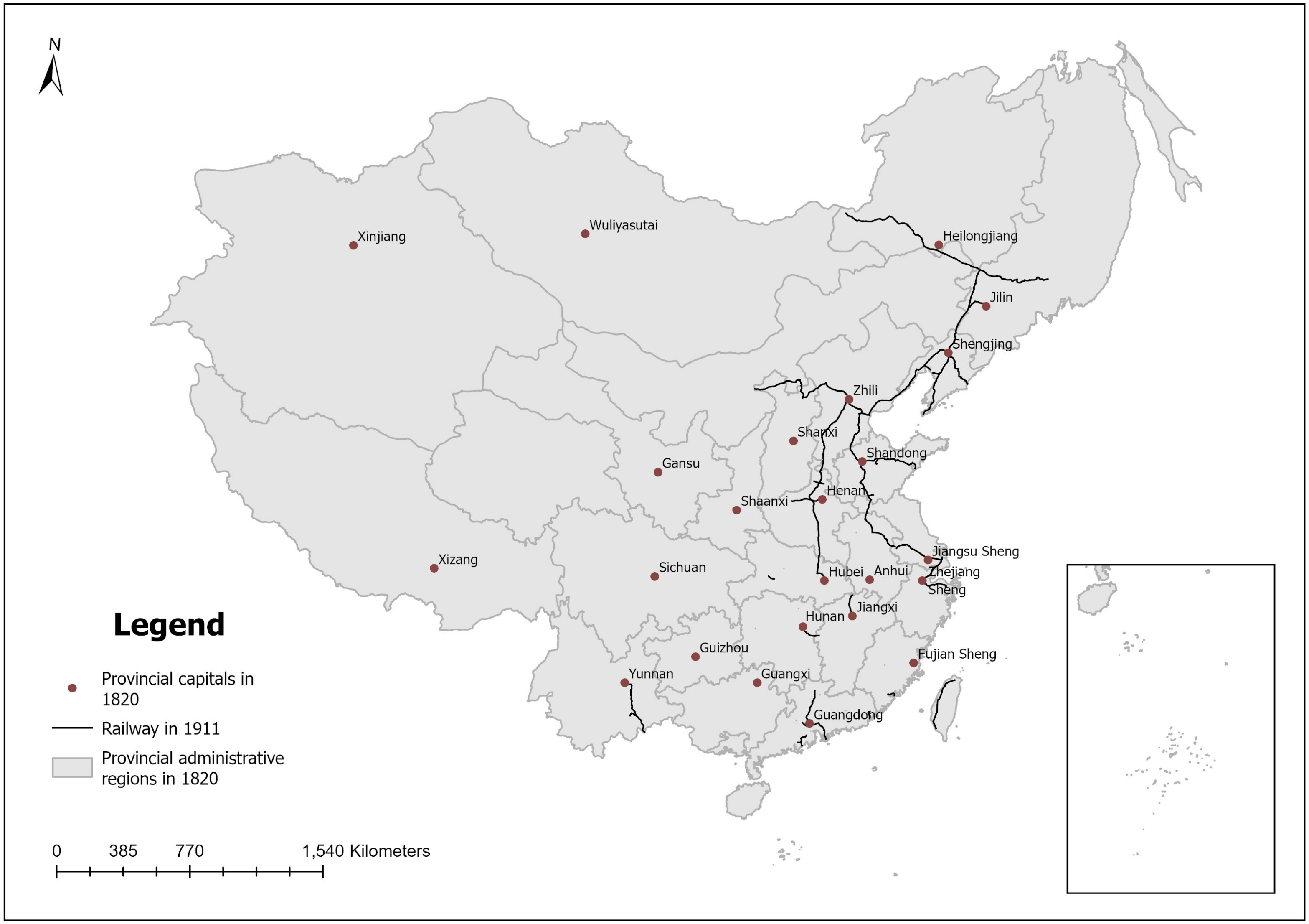
Appendix A. Figures and Tables

Table A.14 –Descriptive Statistics - Number of Cities

City Statistics			
	All Samples		
	All	***Not Treated***	***Treated***
Year			
2011	108	71	37
2013	108	60	48
2015	108	39	69
2018	108	26	82

Notes: The table reports the number of cities in the samples. It consistent with the Figure (3) - (6)

Figure **A.15** –Railway and Provincial Administrative Regions (Qing Dynasty)



Note: The graph describes the provincial administrative regions in 1820. The red points represent the provincial capitals in 1820. The black lines represent the railway in 1911 (end of the Qing Dynasty). Data Resource: The China Historical Geographic Information System, CHGIS.

Table A.15 –Baseline Result

	Panel A				*Panel B*				*Panel C*				*Panel D*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage	(9) OLS	(10) IV	(11) Reduced-form	(12) First-stage	(13) OLS	(14) IV	(15) Reduced-form	(16) First-stage
HSR	0.347*	1.536***			0.401**	1.610***			0.448**	1.491***			0.441**	1.503***		
	(0.207)	(0.453)			(0.202)	(0.489)			(0.197)	(0.506)			(0.198)	(0.509)		
log(distance to rail in 1911)×post			-0.190***	-0.124***			-0.199***	-0.124***			-0.194***	-0.130***			-0.196***	-0.130***
			(0.054)	(0.028)			(0.059)	(0.028)			(0.067)	(0.027)			(0.067)	(0.027)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls									✓	✓	✓	✓	✓	✓	✓	✓
age-cohort													✓	✓	✓	✓
Observations	44,424	44,424	44,424	44,424	44,424	44,424	44,424	44,424	44,424	44,424	44,424	44,424	44,424	44,424	44,424	44,424
R^2	0.071	-0.002	0.071		0.130	0.061	0.130		0.130	0.063	0.131		0.132	0.064	0.132	
First-stage effective F-statistic				15.508				15.517				16.668				17.762
Anderson-Rubin weak IV robust test(p-value)				0.0004				0.0006				0.0038				0.0034
(H_0: HSR has no effect on mental health)																

Notes: The standard errors, reported in parentheses, are adjusted for clustering within cities. The unit of observation is an individual. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights.

Table **A.16** –Heterogeneity Effect - Urban, Gender, and married

	urban	*gender*	*marital status*
	(1)	(2)	(3)
HSR × urban	1.768**		
	(0.707)		
HSR × gender		1.529**	
		(0.665)	
HSR × marital status			1.383**
			(0.560)
Observations	44,424	44,424	44,424
R^2	0.136	0.136	0.139

Notes: The standard errors, reported in parentheses, are adjusted for clustering within cities. The unit of observation is an individual. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights. All estimates include city and year-fixed effects, individual controls and city-level controls.

Table A.17 –Heterogeneity Effect - Parent's general health and education status

Panel A: Parent's General Health Status

	Parents have passed away.				*One of parents is still alive.*				*Parents are living.*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage	(9) OLS	(10) IV	(11) Reduced-form	(12) First-stage
HSR	0.359*	1.459***			0.674**	1.659*			0.693	2.137**		
	(0.196)	(0.543)			(0.338)	(0.891)			(0.436)	(1.063)		
log(distance to rail in 1911) $\times$ post			-0.181***	-0.124***			-0.231*	-0.139***			-0.291**	-0.136***
			(0.065)	(0.028)			(0.128)	(0.026)			(0.142)	(0.029)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	31,193	31,193	31,193	31,193	12,884	12,884	12,884	12,884	3,609	3,609	3,609	3,609
R^2	0.119	0.044	0.119		0.139	0.052	0.126		0.200	0.049	0.185	
First-stage effective F-statistic				14.854				22.647				15.256
Anderson-Rubin weak IV robust test(p-value)				0.0051				0.0701				0.0389
(H_0: HSR has no effect on mental health)												

Panel B: Parent's Education Level

	At least one parent holds a college degree or higher.				*At least one parent has a high school degree or above.*				*Both parents have an education level below high school.*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage	(9) OLS	(10) IV	(11) Reduced-form	(12) First-stage
HSR	0.410	1.973*			0.257	1.987**			0.474**	1.307**		
	(0.411)	(1.076)			(0.337)	(0.910)			(0.200)	(0.577)		
log(distance to rail in 1911) $\times$ post			-0.257*	-0.130***			-0.269**	-0.136***			-0.168**	-0.129***
			(0.152)	(0.027)			(0.130)	(0.027)			(0.074)	(0.028)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	8,740	8,851	8,851	8,851	10,068	10,068	10,068	10,068	34,356	34,356	34,356	34,356
R^2	0.148	0.053	0.149		0.157	0.053	0.152		0.131	0.042	0.113	
First-stage effective F-statistic				19.413				22.637				16.184
Anderson-Rubin weak IV robust test(p-value)				0.0894				0.0374				0.0227
(H_0: HSR has no effect on mental health)												

Notes: The standard errors, reported in parentheses, are adjusted for clustering within cities. The unit of observation is an individual. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights. All estimates include city and year-fixed effects, individual controls and city-level controls.

Table A.18 –Heterogeneity Effect - Number of Children

Number of Children												
	Number of Children = 1				*Number of Children = 2*				*Number of Children > 2*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage	(9) OLS	(10) IV	(11) Reduced-form	(12) First-stage
HSR	0.448	1.914*			0.525**	1.485**			0.262	1.344*		
	(0.331)	(0.970)			(0.260)	(0.589)			(0.262)	(0.777)		
log(distance to rail in 1911) × post			-0.267**	-0.139***			-0.197**	-0.133***			-0.164*	-0.122***
			(0.128)	(0.029)			(0.080)	(0.029)			(0.096)	(0.032)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	7,853	7,853	7,853	7,853	15,981	15,981	15,981	15,981	20,590	20,590	20,590	20,590
R^2	0.147	0.058	0.148		0.138	0.052	0.127		0.123	0.036	0.104	
First-stage effective F-statistic				20.979				15.605				11.782
Anderson-Rubin weak IV robust test(p-value)				0.0365				0.0126				0.0866
(H_0: HSR has no effect on mental health)												

Notes: The standard errors, reported in parentheses, are adjusted for clustering within cities. The unit of observation is an individual. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights. All estimates include city and year-fixed effects, individual controls and city-level controls.

Table A.19 –Channels of Causality: Family Effect

Panel A: Dependent Variable: Meeting frequency of children living in another city

	In-person				*By phone/mail*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage
HSR	0.283*	0.743			-0.018	1.132		
	(0.156)	(0.649)			(0.410)	(1.568)		
log(distance to rail in 1911) × post			-0.078	-0.105***			-0.117	-0.103***
			(0.065)	(0.036)			(0.157)	(0.036)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓
Observations	15,215	15,215	15,215	15,215	15,716	15,716	15,716	15,716
R^2	0.777	0.733	0.777		0.479	0.394	0.479	
First-stage effective F-statistic				6.342				6.037
Anderson-Rubin weak IV robust test(p-value)				0.2290				0.4561
(H_0: HSR has no effect on connection frequency)								

Panel B: Dependent Variable: Meeting frequency of children living in same city or abroad

	In-person				*By phone/mail*			
	(1) OLS	(2) IV	(3) Reduced-form	(4) First-stage	(5) OLS	(6) IV	(7) Reduced-form	(8) First-stage
HSR	-0.275	-0.749			0.002	-0.370		
	(0.319)	(0.776)			(0.491)	(1.431)		
log(distance to rail in 1911) × post			0.103	-0.137***			0.048	-0.131***
			(0.104)	(0.028)			(0.185)	(0.027)
City and year FE	✓	✓	✓	✓	✓	✓	✓	✓
Individual controls	✓	✓	✓	✓	✓	✓	✓	✓
City-level controls	✓	✓	✓	✓	✓	✓	✓	✓
Observations	12,522	12,522	12,522	12,522	17,178	17,178	17,178	17,178
R^2	0.528	0.446	0.528		0.547	0.440	0.547	
First-stage effective F-statistic				18.336				17.812
Anderson-Rubin weak IV robust test(p-value)				0.3216				0.7929
(H_0: HSR has no effect on connection frequency)								

Notes: Columns (1)-(4) report the regression results of HSR on in-person meeting frequency while also controlling for the number of children living in another city. The dependent variable of columns (5)-(8) is the contact frequency by phone, email and mail. And, columns (5)-(8) control the total number of children. The standard errors, reported in parentheses, are adjusted for clustering within cities. The unit of observation is an individual. Statistically significant estimates for two-tailed tests: * 0.10, ** 0.05, *** 0.01. All estimates were produced using survey weights. All estimates include city and year-fixed effects, individual controls and city-level controls.

Table A.20 –Railway in 1911

	Year	Controlled by
Forcibly built and directly operated by imperialism		
Chinese Eastern Railway	1903	Russian
Kunming-Haiphong Railway	1910	France
Shenyang-Dandong Railway	1905	Japan
Qingdao-Jinan Railway	1904	Germany
Controlled by imperialism through loans		
Shanghai-Nanjing Railway	1908	England
Kowloon-Canton Railway	1911	England
Yuehan Railway (Guangzhou-Sanshui)	1903	United States
Peking-Mukden Railway	1911	England, Russia
Shijiazhuang-Taiyuan Railway	1907	Russia
Beijing-Hankou Railway	1906	Belgium
Daokou-Qinghua Railway	1907	England, Italy
Longhai Railway (Luoyang-Kaifeng)	1909	England, Germany
Tianjin-Pukou Railway	1911	England, Germany
Patriotic Commercial Railway		
Jiujiang-Nanchang Railway	1911	Jiangxi Provincial Railway Corporation
Zhangzhou-Xiamen Railway	1911	Fujian Railway Company
Chaoshan Railway	1906	Chaoshan Railway Company
Shanghai-Ningbo Railway	1908	Zhejiang Quanzhou Railway Co., Ltd.
Chuanhan Railway (Yichang)	1911	Sichuan Railway Co., Ltd.
Built by Qing Government		
Beijing–Zhangjiakou Railway	1911	Qing Government

Notes: The table reports the railway completed at the end of the Qing dynasty (1911), and it also shows the control of each railway. These railways are also shown graphically(all solid lines) in the figure (7). The green dash lines in figure (7) are not listed in this table. These dash lines have not been fully completed or opened due to the revolution of 1911. The historical details refer to Appendix C.

Appendix B. Event-study Specification

The individuals entering the experimental group are constantly changing. The current way in which researchers evaluate the pre-treatment dynamics between treatment and control groups with different timing is to estimate a regression model that includes treatment leads and lags, which is also called the Event Study Approach. The event-study model is that:

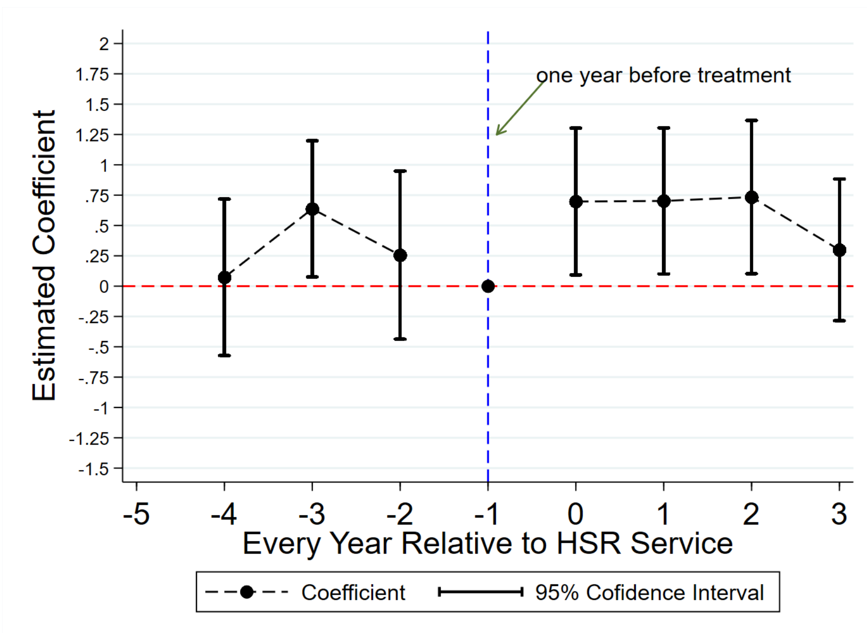
$$Mental_{ict} = \delta_c + \theta_t + hsr_c \times \sum_{\substack{y=-4 \\ y\neq -1}}^{3} \beta_y I(t - t_c^* = y) + \gamma X'_{ict} + \alpha Z'_{ct} + \epsilon_{ict} \tag{5}$$

The variable $treated_c$ equals 1 if individual i lived in a city that opened high-speed rail service between 2011 and 2018, and zero otherwise. Indicator variables $I(t - t_c^* = y)$ measure the time relative to the implementation year, t_c^*, of the opening in each city, and zero in all periods for non-opening states. The omitted category is $y = -1$, the year prior to the opening of high-speed rail. Therefore, each estimate of β_y provides the change in outcomes in opening cities relative to non-opening cities during year y, as measured from the year immediately prior to opening. If the mental score for opening and non-opening cities were trending similarly prior to the high-speed rail service, I expect that estimated coefficients associated with event times $y = -4$ to $y = -2$ will be small and not statistically significant.

In Figure (A.16), I plot the estimation result of Equation (5). Visual examination of the pre-period suggests a downward change in the estimated coefficient. The Figure shows a notable jump in the estimates during the first year of the HSR service. Although this change is not dramatically huge, this jump persists across post-periods. Figure (14) presents the estimation results in a reduced-form version of Equation (5) as follows:

$$Mental_{ict} = \delta_c + \theta_t + Dist1911_c \times \sum_{\substack{y=-4 \\ y\neq -1}}^{3} \beta_y I(t - t_c^* = y) + \gamma X'_{ict} + \alpha Z'_{ct} + \epsilon_{ict} \tag{6}$$

Figure **A.16** –OLS Event Study Estimates of The Impact of HSR



Note: Estimates reflect coefficients on HSR service interacted with year from the regression model.

Appendix C. History of the Railway during the Qing Dynasty

This section is divided into two subsections. The first part mainly serves as a supplementary introduction to the historical background of the railway at the end of the Qing dynasty (Section (2)) and the railway map in 1911 (Figure (7)). The second part lists the basic information about the railways in the late Qing Dynasty as a table.

Supplementary to the Historical Background and Map of Railway at the end of Qing Dynasty

TABLE **A.21** –TIMELINE

1876	First Railway: Woosung Railway.
1894	First Sino-Japanese War.
1904-1905	Russo-Japanese War.
1911	Railway Protection Movement, 1911 Revolution.
1912	Republic of China.
1949	People's Republic of China.
1978	Chinese economic reform.
2008	First High-speed Rail.

The pioneering period of China's railways was between 1876 and 1893. The Wusong Railway, which operated from Shanghai to Wusong Town, was the first railway in China, established in 1876. It also stands as China's earliest commercial railway. This railway was constructed without authorization by the British company. The Qing government subsequently reclaimed it for 285,000 taels of silver the following year, leading to its demolition in October 1877. During this period, the Qing government did not readily embrace the railway system introduced from the West. China's railway development progressed at a slow pace.

Before the Sino-Japanese War of 1894-1895, the completed Tianjin-Shanhaiguan Railway made significant contributions to military transportation during the conflict, highlighting its important role in national defence. After the Sino-Japanese War of 1894-1895, the Qing government found itself in a dire diplomatic and financial situation. At that time, Russia intervened and used a combination of threats and incentives to pressure the Qing government into signing the "Li-Lobanov Treaty." This treaty resulted in the eastern province losing its rights to construct and operate railways. In reality, this railway played a crucial role as a connecting line for the Russian Siberian Railway within Chinese territory. It was a strategic move carefully orchestrated by Russia, following an extended period of planning, with the ultimate goal of gaining control over China and establishing hegemony in Asia and the Pacific region. The construction and operation of this railway were part of a larger scheme by Russia to expand its influence and consolidate its power in the region. From Figure (7), the red arrow indicates the railway transport controlled by the Russians at the end of the Qing Dynasty. When comparing it with the Russian railway transport from Chita to Vladivostok(the red dashed line), we can observe that the distance between the two cities has been significantly reduced by the railway line across China.

On November 4, 1897, Germany dispatched its navy to occupy Jiaozhou Bay in Shandong province, China[28]. Following the German occupation of Jiaozhou Bay, Russia also took advantage of the situation and increased its influence in China. On December 14, 1897, the Russian fleet sailed into Dalian Bay and forcibly occupied the port cities of Lushun and Dalian. Consequently, under pressure from Germany, the Qing government was compelled to sign the "Convention between Germany and China relating to the Lease of the Jiaozhou Bay Territory" on March 6, 1898. As part of the lease agreement for Jiaozhou Bay, Germany also obtained control over the two railway lines in the region[29]. Germany secured a monopoly over the operation and management of these railway lines, along with the mining rights within a certain distance on both sides of the railways.

During the initial Russian-French loan negotiations in June 1895, subsequent to the Sino-Japanese War, France acquired the primary development rights for mines in the Yunnan border region, as well as in Yunnan, Guangxi, and Guangdong provinces. After the loan contract was signed, there was a request for the construction and operation of a railway from Tong Dang, Vietnam, to Longzhou, China. The project was undertaken by the Fives-Lille Company, a French industrial company specializing in engineering and construction. France coerced the Qing government into agreeing to build a railway from Vietnam to Kunming

[28]This act was carried out under the pretext of an incident known as the "Juye Incident" or the "Caozhou Incident".

[29]These railway lines were the Jiaozhou-Weixian-Jinan line and the Jiaozhou-Yizhou-Laiwu-Jinan line.

in 1898. This railway project, known as the Yunnan-Vietnam Railway or Yunnan-Kunming Railway, was an important transportation link that facilitated trade between the French colony of Indochina and southwest China.

In May 1898, Russia snatched the right to build the Shijiazhuang-Taiyuan Railway. There are abundant coal resources near this railway. On the same day that Russia was allowed to build the railway, Britain also infiltrated this region to compete for mining rights near the railway. In 1899, Russia obtained the priority for railway loan rights for the construction of a railway from Beijing to Zhangjiakou, north of the Great Wall. This railway project was known as the Beijing-Zhangjiakou Railway or the Jingzhang Railway.

In 1897, a concession for the construction of the Beijing-Hankou railway was awarded to a Belgian consortium backed by French financing. This concession aimed to establish a railway line connecting the Chinese capital of Beijing (then known as Peking) with the city of Hankou (now part of Wuhan) in central China.

At the time, the British were the dominant foreign power in China, and the awarding of the railway concession to the Belgian-French consortium prevented the route from falling into British hands. This decision was a strategic move to counterbalance British influence and ensure a more diverse range of foreign interests in Chinese railway development. Finally, Britain got control of Shanghai-Nanjing Railway and Kowloon-Canton Railway. In 1901, the British company opened the Jiaozuo Coal Mine in Henan, so in 1902, it obtained the right to build the Daokou-Qinghua Railway to facilitate the transportation of coal resources abroad.

To prevent the French from gaining complete control over the railway route between Beijing and Guangzhou (Canton), the Chinese government actively sought American involvement in the Guangzhou-Hankou railway project. This move aimed to maintain a balance of power among foreign interests. In 1898, a concession for the southern railway, specifically the Guangzhou-Hankou railway, was awarded to the American China Development Company.

The above summary encompasses all the railway lines controlled and built by imperialism. The red and black lines in Figure (7) correspond to the railways forcibly built by imperialists and the railways controlled by them through loans and other strategies, respectively. These railways were primarily constructed by imperialist powers with the intention of invading China to exploit its resources and wealth. During that period, the Russo-Japanese War also broke out. The Shenyang-Dandong Railway was a light railway forcibly constructed by Japan during the Russo-Japanese War under the pretext of the need for wartime military transportation. The blue arrows in Figure (7) indicate the route of the Japanese attack.

In the years following the Sino-Japanese War from 1895 to 1899, China experienced significant encroachment by foreign powers, resulting in the division of the country into spheres of influence. During this period, most of China's vast territory came under the control of imperialist countries, with the long coastline and major ports falling into foreign hands. Additionally, imperialist powers gained control over more than 10,000 kilometers of China's main railway lines, granting them significant influence over trade, transportation, and the exploitation of resources. This period marked a significant loss of sovereignty for China and sparked resistance movements against foreign dominance.

In 1911, the Railway Protection Movement occurred. It, also known as the "Railway Rights Protection Movement", was a political protest movement that erupted in 1911 late Qing China against the Qing government's plan to nationalize local railway development projects and transfer control to foreign banks. Then, the Revolution of Revolution broke out. Following the outbreak of the Revolution of 1911, the Qing Dynasty was swiftly overthrown, leading to the establishment of the Republic of China.

The Xinhai Revolution, which began on October 10, 1911, marked the end of the Qing Dynasty, which had ruled China for more than two centuries. The revolution led to the abdication of the last Emperor of China, Puyi, and the establishment of the Republic of China on January 1, 1912. The collapse of the Qing Dynasty and the subsequent establishment of the Republic of China represented a significant turning point in Chinese history, as it marked the end of the imperial system and the beginning of a new era of republican governance.