CHARLES UNIVERSITY
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What influences the impact of high-speed railway construction?

Bachelor's thesis

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Year of defense: 2024

Declaration of Authorship

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Prague, April 30, 2024

Dan Sedlacek

Abstract

This thesis investigates the impact of high-speed rail (HSR) construction on municipalities in its proximity, focusing on the heterogeneity of these impacts with respect to several municipality characteristics. It focuses on Japan's Shinkansen network lines constructed between 1983 and 2016, using municipality-level data from Statistics Japan and a novel methodology for causal estimation of Difference-in-Difference designs with staggered project launches. It compares municipalities close to Shinkansen stations (impacted by construction) to a control group consisting of municipalities located farther from these stations.

The study found significant positive effects of high-speed railway (HSR) construction on population size, economic output, and tax revenue in impacted municipalities. The heterogeneous effects were the most pronounced in the case of municipality size, with larger municipalities seeing substantial increases in per capita income and only marginal impact observed in smaller municipalities where the impact was marginal. Additionally, the impact on tax revenue was mainly driven by lower-income municipalities, while wealthier areas saw no significant change. No differences were noted between service-oriented and industry-oriented municipalities.

JEL Classification	F12, F21, F23, H25, H71, H87
Keywords	High Speed Railways, Shinkansen, Japan, Construction Impact, Callaway and SantAnna Staggered Difference-in-Difference, Exposure Effect
Title	What influences the impact of high-speed railway construction?

Abstrakt

Tato práce zkoumá dopad výstavby vysokorychlostních železnic (HSR) na obce v jejich blízkosti a zaměřuje se na heterogenitu těchto dopadů s ohledem na různé charakteristiky těchto dotčených obcí. Soustředí se na linky sítě Shinkansen v Japonsku, které byly postaveny mezi lety 1983 a 2016. Tato práce využívá data na úrovni obcí, získané ze Statistického úřadu Japonska a nově publikovanou metodologii pro kauzální odhad metodou rozdíly v rozdílech se stupňovitým spouštěním projektu. Porovnává obce ležící v blízkosti stanic Shinkansen (ovlivněné výstavbou) s kontrolní skupinou obcí ležících dále od těchto stanic.

Studie zjistila signifikantně pozitivní efekty výstavby vysokorychlostních železnic (HSR) na velikost populace, ekonomický výtlak a daňové příjmy v ovlivněných obcích. Bylo zjištěno, že rozdíly v míře dopadu výstavby je možné spojovat s počtem obyvatel ovlivněných obcí. Větší obce zaznamenaly výrazný nárůst průměrných příjmů, zatímco v menších obcích byl dopad výstavby signifikantně menší. Dále bylo zjištěno, že dopad na daňové příjmy byl tažen především chudšími obcemi, zatímco u bohatších obcí byl zaznamenán takřka nulový efekt výstavby. Mezi obcemi, jejichž ekonomika byla zaměřena na služby anebo průmysl, nebyly zaznamenány žádné rozdíly.

Klasifikace JEL F12, F21, F23, H25, H71, H87
Klíčová slova Vysokorychlostní železnice, Dopad výstavby, Callway a SantAnna rozdíly v rozdílech, Efekt výstavby
Název práce Na čem závisí dopady výstavby vysokorychlostních železnic?

Acknowledgments

The author is sincerely thankful to Matěj Bajgar, D.Phil., whose steadfast support and insightful advice were invaluable. Without his assistance, this thesis would not have reached its current form.

Gratitude is also extended to both the academic and non-academic staff at the Institute of Economic Studies of Charles University. The environment they created was of a high professional standard and will always be remembered.

Additionally, the author would like to express his gratitude to family and friends who provided the essential support necessary for studying such a demanding study programmme.

Typeset in LaTeXusing the IES Thesis Template.

Bibliographic Record

Sedlacek, Dan: *What influences the impact of high-speed railway construction?*. Bachelor's thesis. Charles University, Faculty of Social Sciences, Institute of Economic Studies, Prague. 2024, pages 97. Advisor: Matěj Bajgar, D.Phil.

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Acronyms

HSR High-Speed Railway

SBJ Statistics Bureau of Japan

ATT Average effect of Treatment on the Treated

TWFE Two-Way Fixed Effect

DiD Difference-in-Difference

CI Confidence Intervals

LE Logarithmic expression

JNR Japanese National Railway

TGV Train a Grande Vitesse

AVE Alta Velocidad Espanola

KTX Korea Train Express

CGE Computable General Equilibrium

TGV Train a Grande Vitesse

GMM Generalized Method of Moment

SDM Durbin mode

PSM Propensity Score Matching

VMGS Value of Manufactured Goods, Shipments, etc.

GEJE Great East Japan Earthquake

RTZ Relative Time Zero

OLS Ordinary Least Square

ATC Automatic Train Control

CI Confidence Intervals

JEM Japanese Economic Miracle

PSM Propensity Score Matching

SEM Structural Equation Modeling

Chapter 1

Introduction

The construction and expansion of high-speed rail (HSR) networks represent one of the most transformative infrastructural developments in modern history. Originating during the Industrial Revolution, railways have consistently played a pivotal role in economic and social development. They exemplify the profound influence of technological advancements on societal progress. The second half of the 20th century witnessed the rise of the automotive and aviation industries, which shifted public and political attention away from rail transport in most parts of the world, with Japan being a notable exception. Despite this, railways have continued to be a vital part of the infrastructure in developed countries around the world. In recent years, as the demand for sustainable and efficient transportation options has surged, the rail industry has undergone a significant renaissance. This has been particularly evident through the advent of HSR systems in other countries outside of Japan, which epitomize the evolution from steam propulsion to sophisticated, zero-emission transport solutions. HSR has not only resurge interest in railway development but has also raised crucial questions regarding its construction impacts, as another crucial person-oriented transportation option.

This thesis investigates the construction effects of Japan's Shinkansen, the world's first HSR network. Until recently, there was a commonly used Two-way Fixed Effect Difference-in-Differences (TWFE DiD) model for evaluating such cases. However, paper Sun & Abraham (2021) and Goodman-Bacon (2018) recently put light on drawbacks connected with usage of this model, such as problematic interpretations of negative weights in parameter estimates that could misrepresent treatment effects, with significant bias issues arising in cases with varying treatment effects across examined groups. Addressing these concerns, this thesis employs the Staggered Difference-in-Differences methodology, recently published by Callaway & Sant'Anna (2021), designed to robustly estimate effects over staggered implementations and also providing an insight into developmental impacts of HSR construction over relative time since treatment.

This innovative approach has not been previously applied to study the impacts of any major infrastructural projects, making this research pioneering in its application to HSR networks. Specifically, this research explore how municipalities impacted by the construction and ongoing operation of Shinkansen HSR networks experience changes in their economic output along with demographic and urban development. This study aims to dissect the effects of Shinkansen construction on these municipalities by analyzing variables including population size, economic output, and employment rates.

The hypothesis that municipalities connected to the HSR network experience significant growth compared to non-connected municipalities has been extensively tested in context of China by researchers like Wang *et al.* (2022) and Jin *et al.* (2020), and in Japan by Wetwitoo & Kato (2019) or Inoue *et al.* (2017). However, these studies present contrasts due to the divergent state governance models and developmental stages of each nation's economy. Specifically, Wetwitoo & Kato (2019)'s analysis is constrained by its limited observational period, range of variables examined and its focus either on the direct proximity to HSR stations or on a broader prefectural level, utilizing a simpler DiD methodology which, as previously noted, has been surpassed by more contemporary approaches.

This research aims to extend the analysis of HSR impacts beyond the immediate vicinity of stations, considering a broader infrastructural network and examining longer time periods to provide a more comprehensive view of the socio-economic changes across various prefectures in Japan. By employing the advanced Staggered Difference-in-Differences methodology, this study offers a refined analysis of the regional connectivity improvements and their broader economic effects, thereby expanding the scope of investigation to include a wider array of stations within the Shinkansen network. This approach allows for a comparative analysis with outcomes observed in China, Japan and other countries worldwide, providing a broader perspective than previous studies. The thesis builds mainly on the findings of Wetwitoo & Kato (2019) and Wang *et al.* (2022), yet diverges significantly in both methodology and analytical scope, aiming to fill gaps in the current understanding of HSR impacts.

The thesis finds that municipalities connected to HSR benefited significantly in terms of population size, economic output, and tax revenue. Intriguingly, the study also reveals that HSR construction can be associated with increase in unemployment and decrease in employment rates in affected municipalities. Furthermore, while the orientation of a municipality's economy prior to HSR connection was found to have no significant effect on the construction impact, it was found that the significant increase in the amount of taxes collected in the affected municipalities was driven only by municipalities with lower per capita incomes, while richer regions did not experience any impact of HSR construction on tax collection. The findings also confirm that the size of the municipality plays a crucial role in the magnitude of HSR impacts, with larger municipalities generally experiencing more pronounced benefits in per capita income than their smaller counterparts.

The thesis is structured as follows. Chapter 2 traces the evolution of high-speed rail technology and policy, providing context on how HSR has been integrated into broader transportation strategies both globally and within Japan. Chapter 3 reviews existing literature on the impacts of HSR, synthesizing previous research findings to highlight areas of consensus and divergence, and setting the stage for this study's contributions. Chapter 4 details the methodology, describing the data sources, econometric tools, and analytical techniques used to assess the impact of HSR on municipalities. This includes a breakdown of the models used for impact assessment and the rationale for their selection. Chapter 5 presents the core empirical analysis, offering a detailed account of the findings with respect to economic, demographic, and urban development indicators. This chapter discusses the implications of these findings in the context of existing HSR impact theories. Chapter 6 concludes with a comprehensive summary of the research findings, discussing their implications for policy and planning. This chapter also outlines recommendations for future HSR projects and identifies promising areas for subsequent research.

By providing valuable insights into the socio-economic transformations induced by HSR, this thesis aims to inform both current and future planning and policy-making, ensuring that these infrastructures maximize beneficial outcomes while mitigating adverse effects.

Chapter 2

Brief History of High-Speed Railway Development

This chapter provides an overview of the fundamental concepts connected to high-speed railways (HSR) development.

Initially, the chapter delves into the social, economic and political motivations behind the launch of the first HSR network (Japan's Shinkansen network).

Subsequently, attention shifts to the HSR lines relevant to this thesis, including the Japanese HSR and its global counterparts. Contextualizing Japan's HSR within the framework of international projects is crucial, given the commonalities among other HSR systems worldwide. Furthermore, much of the academic literature focuses on non-Japanese networks, making a broad understanding of global HSR developments essential for this analysis.

This discussion aims to highlight the challenges involved in these projects same as to place the effort connected with HSR construction in a wider context of overall infrastructure development.

2.1 Origins of the Shinkansen Network

In the aftermath of World War II, Japan was confronted with the formidable challenge of reconstructing its devastated economy and infrastructure. Emerging from the ruins of the conflict, Japan quickly undertook economic reforms, leading to a period known as the "Japanese Economic Miracle" (JEM). This era, extending from the 1950s through the early 1980s, was marked by unparalleled economic expansion, technological breakthroughs, and widespread industrialization, catapulting Japan to the status of the world's second-largest economy by the 1980s.

The groundwork for this extraordinary resurgence was established in the late 1940s and 1950s, underscored by substantial reforms and investments across industry, education, and technological sectors. Acknowledging the imperative of modernizing the economy and stimulating growth, the Japanese government enacted policies that favored industrial expansion, technological progress, and infrastructural development. These endeavors received a considerable boost from the United States through the Marshall Plan, which supplied financial assistance and contributed to economic stabilization. A pivotal element in Japan's post-war economic surge was its emphasis on high-tech industries (by the standards of the day), including electronics, automobile production, and steel manufacturing.

The rapid pace of industrialization and economic growth brought about significant demographic shifts within Japan. The nation witnessed a demographic transition characterized by declining mortality rates and a subsequent increase in population. Urbanization accelerated as individuals migrated from rural locales to cities in pursuit of employment opportunities and improved living standards.

However, this period of prosperity did not come without its set of challenges. The swift urbanization process led to all kinds of congestion, pollution problems and shortages of housing in major urban centers, alongside labor shortages throughout the country.

Japan's unique geographical composition, encompassing over 14,125 islands with its furthest points separated by 3,000 kilometers, further complicated domestic transport coordination. The narrow and elongated configuration of its main islands, especially Honshu and Shikoku, coupled with their predominantly mountainous terrain, presented substantial obstacles to efficient interstate transport (Shioshara, 2023).

In response, the Japanese government and the private sector made significant investments in urban development projects, environmental protection initiatives, and transportation systems. The conception of the Shinkansen (in Japanese: 'New Main Line'), envisioned by Hideo Shima, aimed to unify the country through an extensive network of high-speed rail lines. Shinji Sogo, the then-president of the Japanese National Railways (JNR), played an instrumental role in garnering governmental support and securing the necessary funding for the project (Salpukas, 1998).

The inauguration of the Tokaido Shinkansen line, linking Tokyo and Osaka (Japan's largest cities at the time) represented the biggest post-war investment in Japan. The Shinkansen project was conducted with great ambition, overcoming many technical and financial challenges. It entailed a comprehensive reevaluation of rail transport, from the engineering of the tracks to the aerodynamics of the trains. Coinciding with the Tokyo Olympics in 1964, the launch of the Shinkansen symbolized Japan's resurgence and technological dominance on the global stage.

The inaugural track system of the Shinkansen was meticulously engineered to support unprecedented speeds in rail travel, initially achieving velocities of up to 210 kilometers per hour. The construction of the pioneering Tokaido Shinkansen line involved laying approximately 515 kilometers of track, necessitating extensive tunneling and bridging to navigate Japan's challenging terrain. This massive undertaking resulted in the construction of 300 bridges and 67 tunnels, with the longest tunnel extending 7.8 kilometers.

The introduction of the Series 0 Shinkansen trains, known for their iconic streamlined, bullet-shaped noses (hence the English nickname 'bullet train') marked a new era in mass transportation, with each train capable of carrying up to 1,323 passengers.

Technological innovations and safety measures with the Tokaido line, the Automatic Train Control (ATC) system was launched, establishing a new standard in rail safety. This system enabled real-time speed monitoring and the automatic application of brakes to maintain safe distances between trains. Uniquely, it could automatically stop trains at the slightest indication of seismic activity, pioneering the world's first automatic rail safety system, now an integral part of all rail networks worldwide.

2.2 Further Development and Expansion of the Shinkansen Network

The successful launch of the Tokaido line catalyzed support for expanding the Shinkansen network. In addition to Sanyo line, an extension of the Tokaido line connecting Osaka to Fukuoka (regional centre of southern Japan), that was already implemented in the Tokaido project, the Japanese government aimed to get the funding for five additional Shinkansen lines: Tohoku, Joetsu, Hokuriku, Hokkaido, and Kyushu, which are central to this thesis.

Funding for the Tokaido Shinkansen included a World Bank loan, one of the first instances of international financial support for such a project, complemented by substantial domestic investment from the government, Japanese banks and the JNR. The network's expansion was financed through a blend of government grants, loans, and bonds, with the JNR's privatization into the JR Group introducing new financial dynamics.

The construction of the Joetsu and Tohoku lines in the 1970s, completed and operational by 1983 and 1986, respectively, extended the network northward. The Tohoku line became the longest Shinkansen line, connecting Tokyo to the northern regions of Honshu Island, while the Joetsu line linked Niigata City to Tokyo. Subsequent phases of construction aimed at further expanding the core network, with the Hokuriku line following the Joetsu line southwest to Nagano in time for the Nagano Olympics, and later extending westward by 2015. The Hokkaido line, extending the Tohoku line, reached the northern island of Hokkaido, fully opening in 2016. The Kyushu line, an extension of the Sanyo line, connected Kyushu Island to the main Shinkansen network in 2011 (Division, 2022).

The Seikan Tunnel, completed in 1988, is a hallmark of Japanese engineering, remaining the longest underwater tunnel in the world. It allows Shinkansen trains to travel at speeds of up to 250 kilometers per hour, 250 meters below sea level, connecting the islands of Honshu and Hokkaido.

The following figure serves as a visualisation of the distribution of the different lines of the Shinakansen network within Japan

Figure 2.1: Location of Shinkansen Lines within Japan

Note: years mentioned for each line are rather indicative. Source: Division (2022).

2.3 Other HSR Networks

The inauguration of the Shinkansen in Japan in 1964 not only announced the beginning of HSR but also established a global benchmark in rail transportation. Achieving speeds that were unthinkable at the time for mass ground travel, demonstrating HSR's capacity to revolutionize national economies, foster enhanced connectivity, and significantly curtail travel duration. The operational methodologies, technological breakthroughs, and safety measures pioneered by the Shinkansen served as a paradigm for ensuing HSR endeavors worldwide.

Motivated by the Shinkansen's accomplishments, European countries commenced the development of their HSR networks towards the latter part of the 20th century. France's TGV (Train a Grande Vitesse), launched in 1981 to link Paris with Lyon and subsequently extended across the nation and beyond, exemplifies such initiatives. A notable distinction between the TGV and Shinkansen lies in the TGV's capability to traverse both high-speed and conventional rail lines, using the so called 'tilting' technology.

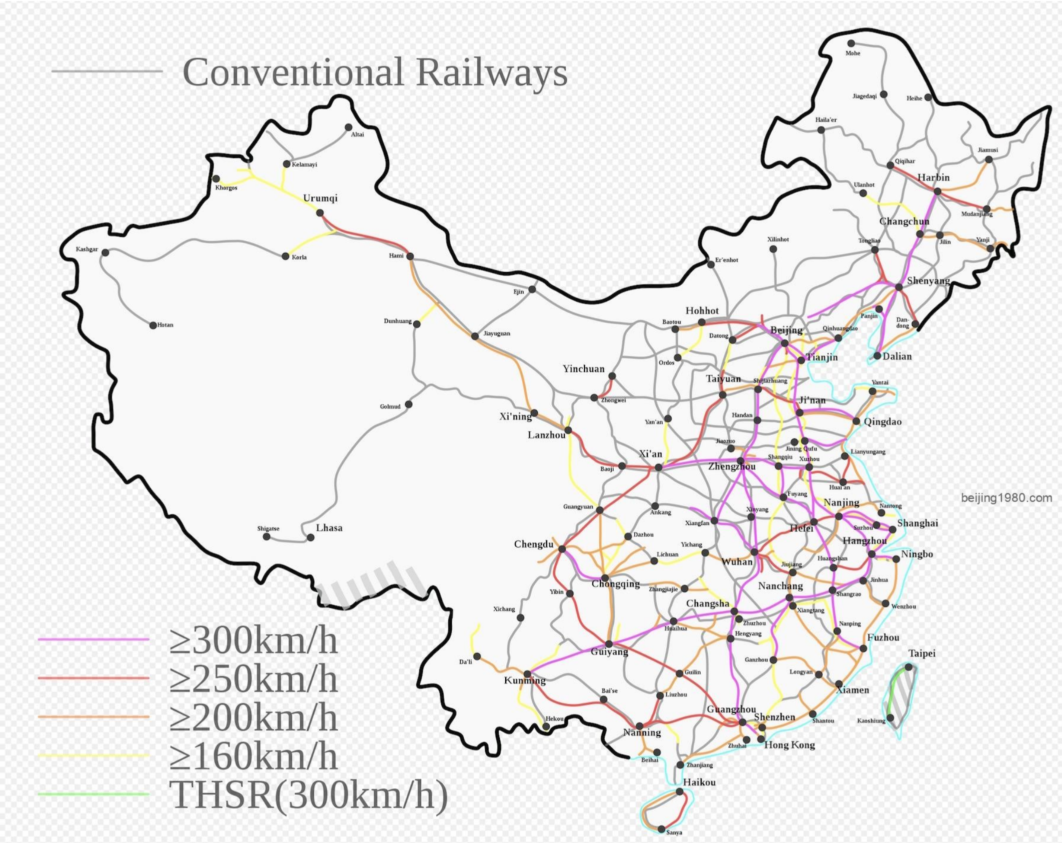
In areas where the demand does not justify the high cost of constructing new high-speed tracks, the introduction of tilting train offers a solution by enabling higher speeds on existing tracks with sharp curves, albeit at reduced velocities compared to non-tilting HSRs. The technology, which involves the train tilting into curves to counteract the effects of centrifugal force on passengers, allows the train's bogies to maintain their grip on the tracks while the carriage body tilts, thereby offsetting the centrifugal force. This innovative approach has been adopted by numerous countries seeking a cost-effective alternative to the conventional HSR models like the TGV. Other examples include Sweden's X-2000 and Italy's Pendolino (ETR-450), which achieve top speeds of 210 kph and 250 kph, respectively, on conventional rails. Furthermore, recent models of the TGV, such as the TGV Pendulaire, have incorporated tilting mechanisms as well to reach speeds up to 300 kph, and new Shinkansen models are also embracing this technology to enhance their operational flexibility and efficiency. This flexibility enables the TGV to access city centers via existing rail infrastructure, leading to substantial reductions in costs.

Italy's HSR, beginning with the Direttissima line connecting Rome and Florence, along with Spain's AVE (Alta Velocidad Espanola), both bear testament to the Shinkansen's influence on global HSR advancements. In a similar vein, South Korea's KTX (Korea Train Express) and Taiwan's HSR system have integrated pivotal insights from the Shinkansen, especially regarding Shinkansen's safety protocols and operational efficiency (Nunno, 2018).

While the previously mentioned HSR networks primarily seek to emulate the Shinkansen, they generally fall short of matching its performance in several aspects, including speed, efficiency, and reliability. However, the narrative diverges markedly when the China's high-speed rail came to the scene in the begging of the 21st century.

China's engagement with HSR was significantly shaped by the Shinkansen model. Prior to embarking on its ambitious endeavor to construct the globe's most extensive HSR network, the Chinese government undertook a comprehensive study of the Shinkansen system in Japan. High-ranked executives of the Chinese Ministry of Transport were sent to Japan to analyze in detail all the technical parameters of the Japanese network. The insights gleaned from this investigation have been adapted and augmented in the development of China's HSR, catalyzing innovations in train design and construction methodologies.

Figure 2.2: China High-speed Rail Network



Map showing the Chinese HSR network, based on lines in operation as of June 2021. Source: Van Kerckhove (2021).

Figure 2.2 shows the extent of today's Chinese HSR network together with the times it takes to travel the distances from Beijing across the Chinese mainland.

Presently, China's HSR constitutes two-thirds of the world's entire high-speed railway infrastructure, with its trains achieving maximum operational speeds of up to 380 km/h. The common elements originating from Japan in all other HSR systems clearly show the profound impact of the Shinkansen on global high-speed rail development all over the world(Jones, 2022).

Chapter 3

Literature Review

Infrastructure investments, such as HSR construction, yield multifaceted effects, each capable of being measured and examined in various ways. Central to this study is the exploration of the economic impact stemming from such a construction.

This chapter offers a comprehensive summary and critical analysis of the existing research literature relevant to the study of HSR development impacts. Understanding range and magnitude of changes brought by the construction of HSR networks is vital for grasping the full scope of its consequences on both local and broader scales.

The literature review is structured to methodically explore the effects of HSR construction, segmented according to the nature of impacts analyzed in the discussed thesis. The initial section delves into studies focused on the primary impacts of HSR construction, which encompass changes in passenger numbers traveling between areas affected by HSR development and shifts in transportation mode preferences among travelers. Subsequent analysis centers on the secondary impacts, i.e. examining literature specialising in certain part of economy impacted by alterations in transport choices caused by HSR development. Further, this review discuss papers that examine the impacts of HSR construction on the economy as a whole, i.e. how HSR construction affects the overall economic performance and macroeconomic indicators of the affected localities. The final fourth section then discusses how this work should contribute to the existing literature and our understanding of the impacts caused by HSR infrastructure construction.

3.1 HSR Construction Effect on Transportation Modes

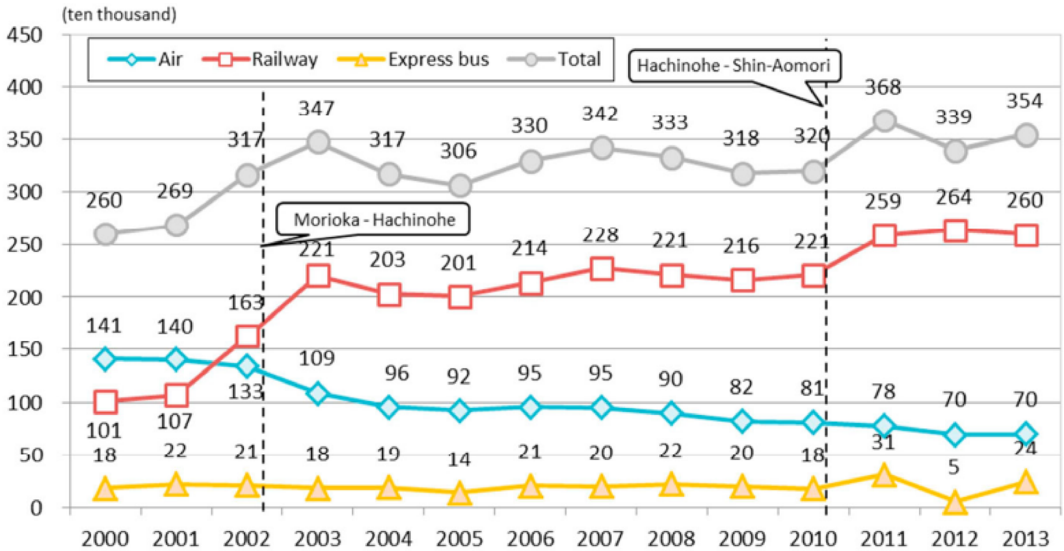
There are many factors changed by the construction of the HSR network, and each of these factors imprint to the national economy in its own way. This section is focused on the change in people's transportation choices and related behaviour caused by HSR construction

Such an impact can be seen in the the change of transportation opportunities, costs, amount of time required for such a transport and finally and the most importantly the change of people's behavior caused by certain HSR construction. A paramount benefit of HSR lies in its competitive edge over air travel, particularly regarding travel time and ticket pricing across medium to long distances. The principle of the HSR is defined by some as being "twice as fast as the car, half as expensive as air" (Sands, 1993) or "to provide the transport services to its passengers at the speed twice higher than a car and twice slower than the plane" (Commission, 1996).

Kojima *et al.* (2017) describing the impact of Kyushu and Tohoku lines extension of Shinkansen network, examining their role in supplanting air and other ground travel options. The study underscores the Shinkansen's supreme advantage in reducing travel times. It highlights the notable difference in the duration required to travel from Tokyo to Shin-Amori (in northern Japan) and from Osaka to Kagoshima (in southern Japan), before and after the introduction of the Shinkansen extensions that reach these cities. The travel time between Tokyo and Shin-Amori by highway was about 8 hours 30 minutes before the opening of the Tohoku line. This has been reduced to 2 hours 58 minutes after opening of the last Tohoku Shinkansen extension reaching up to Shin-Amori. Thanks to this extension, travel time on Shinkansen is about 20 minutes shorter than by airplane. The authors also state that the time needed for Osaka-Kagoshima connection was reduced from 5 hours to 3 hours and 45 minutes. Another aspect followed in this study is the travel fare. The ticket price of all Shinkansen connections remained clearly lower than the fares of air connections. According to Kojima *et al.* (2017), by creating new transport alternatives, these cities have become more attractive. This has led to a reduction in the proportion of people choosing air travel, while the amount of people traveling to this destinations increase in total numbers. In the following Figure 3.1 and Figure 3.2, compiled by previously mentioned Kojima *et al.* (2017), it can be seen how the connections of these cities to the Shinkansen network have had an impact on the choice of transport mode and the total amount of people transported.

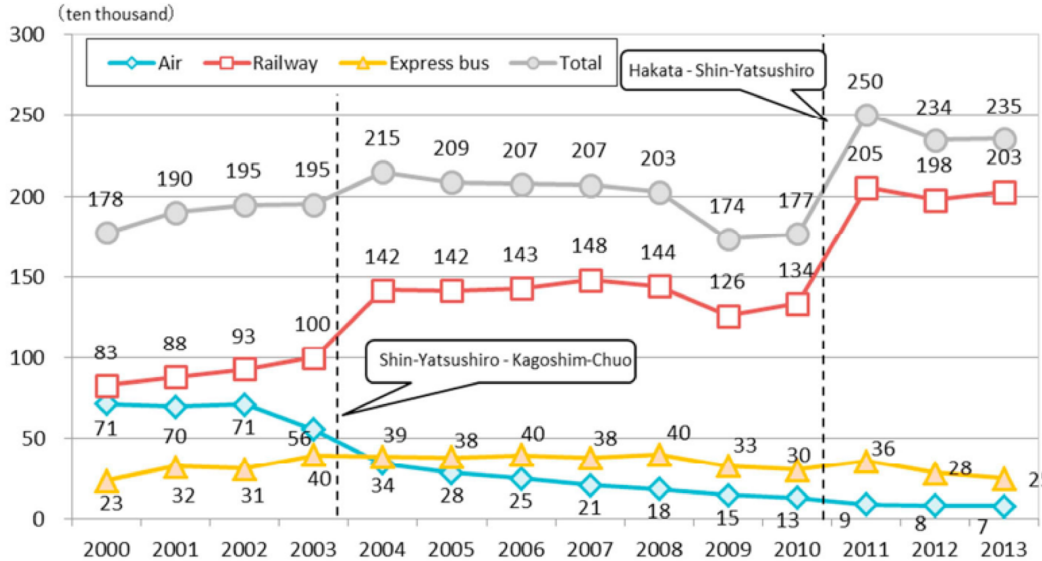
Notably, when the lines were extended to final destinations such as Shin-Amori and Kagoshima, there was a discernible surge in passenger numbers on these routes. This increase supports the hypothesis proposed by Kojima *et al.* (2017) that connecting cities to the HSR enhances their attractiveness, thereby attracting more visitors.

Figure 3.1: Development of the Passenger's Transportation Mode Choice on Tokyo Shin-Amori Route



Note: The vertical dashed lines on the graph mark the timelines when new extensions were commissioned and expand to the core Shinkansen network.
Source: Kojima *et al.* (2017).

Figure 3.2: Development of the Passenger's Transportation Mode Choice on Osaka Kagoshima Route



Note: The vertical dashed lines on the graph mark the timelines when new extensions were commissioned and expand to the core Shinkansen network.
Source: Kojima *et al.* (2017).

A similar work to Kojima *et al.* (2017) has also been carried out by Liu *et al.* (2019), who analyzes how the development of HSR networks in China and Japan has affected airport traffic volumes and the distribution of traffic in general. The dataset encompasses 46 airports in China and 21 airports in Japan, covering the period from 2007 to 2015. The airport traffic data for China were sourced from the Statistical Data on Civil Aviation of China, while for Japan, it was obtained from the Japanese Ministry of Land, Infrastructure, Transport, and Tourism. The authors used panel data regression analysis to evaluate the impact of HSR development on airport-level traffic. They employed fixed-effect models to account for unobservable, airport-specific characteristics that could influence the dependent variable, which in this case is airport traffic volume. The fixed-effect model choice is justified as the preferred approach over random effects models, based on the results of the Hausman test conducted during their analysis. The regression models incorporate a variety of independent variables, including centrality measures that reflect the position of the airport city within the HSR network (degree centrality and harmonic centrality), and a binary variable indicating the presence of air-HSR inter-modal connection. Control variables such as population size, real GDP per capita, low-cost carrier operations, fuel price, airport competition, and time-fixed effects for specific events like the

Beijing Olympic Games and the global financial crisis were also factored into the model. The study finds that increased HSR connectivity and accessibility is associated with a decrease in domestic and total airport traffic in China but has little impact on Japan. The research identifies a strong complementary effect of HSR in feeding international flights where air-HSR inter-modal linkage is present, potentially leading to an increase in total airport traffic. The study notes that hub airports in China tend to gain traffic regardless of the presence of air-HSR linkage, while airports without HSR connection in Japan tend to lose traffic, compared to HSR-connected airports.

The conclusions of the above-mentioned work are in line with the results of the meta-analysis constructed by Givoni (2007). The author discussing papers analyzing the case of France and Spain, which also saw a massive expansion of HSR networks at the beginning of the 21st century. In the case of France, the cities of Paris and Lyon were connected by the first line of the French TGV. Once this line was in operation, a very similar change in consumer behavior was observed, as in Japan. The number of passengers choosing air travel fell from 31 per cent to 7 per cent, while the number of passengers choosing rail travel rose from 40 per cent to 72 per cent. A similar pattern can be seen in the Madrid-Seville connection, where the amount of air passengers decreased by 27 percent, while the amount of railway passengers increased by 35 percent. Givoni (2007) claims that to enhance the advantages and minimize the drawbacks of the HSR, it is advisable for it to connect numerous cities through various stops, including cities where airports are located. Givoni (2007), however, mentions that adding more stops to an HSR line decreases its average speed, consequently diminishing the route's capacity and extending the duration of the journey, which undermines the HSR's advantages. This situation also highlights the excessive focus on the HSR's top speed, whereas the average speed should be the primary concern.

His statement can also be supported by Hall (1999), who claims that a HSR line is commercially viable if it is constructed between major urban agglomerations, with a population exceeding one million. Such agglomerations should be disposed along linear corridors, with cities spaced at approximately 125-mile (200-km) intervals. Hall's work was a follow-up to Vickerman (1997) paper where he adds the requirement for demand of between 12 million and 15 million railway passengers a year between two urban centers so that the HSR construction would have significant impact on total amount of passengers.

Chen & de Abreu E (2013) have also contributed to this topic with their work comparing different ways how to model the accessibility change of a location connected to a HSR network. They highlighted the importance of careful choice of control group used for evaluating the impacts and also a careful choice of an accessibility indicator, because the results could be strongly influenced by its definition and application. They claim that the Structural Equation Modeling SEM should be used for evaluating such cases. They demonstrate this approach in case study on Portuguese freeway construction in the 1990s where the data are obtained from 258 municipalities and the accessibility is calculated as:

$$A_i = \sum_j A_{ij} = \sum_j \text{Pop}_j \times \exp(-\beta \times t_{ij}) \quad (3.1)$$

where A_i is the accessibility of municipality i, Pop_j is the population of municipality j, t_{ij} is the travel time from municipality i to municipality j, β equal to 0.1 is the calibrated coefficient for the impedance function using SEM. Based on the results of this study, he claims that it is possible to see the significant increase in attractiveness of the cities connected into freeways resulting in significant increase in number of people choosing these cities as their destinations, at the expense of cities that were not included in this network. However, this increase is not even and these are other factors that can influence the gain the city can obtain from such a construction.

3.2 Secondary Effect Brought by HSR Construction

The previous section highlighted the significant role of HSR network construction in altering travel patterns and transportation choices among travelers. For this thesis, it's crucial to explore how these shifts in passenger volumes reflect on different economic sectors. Addressing the broad economic implications of HSR construction is complex; therefore, this chapter narrows its focus to reviewing literature discussing only the impacts of HSR construction to certain part of economy, i.e. to examine the impact on fields such as tourism, real estate prices, and business establishment rates.

Understanding HSR's economic effects requires a deep dive into its influence on these individual sectors. While HSR systems are credited with reducing travel costs and boosting attractiveness of tourism destinations, the literature presents mixed findings on their impact on tourism, suggesting that the benefits of HSR networks for the tourism sector are not universally positive.

The increases in competition among tourism destinations due to enhanced accessibility is suggest by the meta-analyse of Masson & Petiot (2009). Additionally, Pagliara (2015) states that HSR has been found to significantly boost the attractiveness of cities near Madrid for tourists, though not Madrid itself. This paper utilizes logistic regression models to predict the probability of a tourist revisiting Madrid and their decision to visit nearby cities using HSR. The models were developed using data from a Revealed Preference survey conducted in Madrid in June 2013, where more than five thousand tourists were interviewed at popular tourist sites. The logistic regression models depend on a set of explanatory variables derived from the survey, such as nationality, marital status, profession, motivations for visiting, transport costs, previous visits, stay duration, accommodation type, and whether the availability of HSR influenced their choices. These findings highlight a complex relationship between HSR and tourism, suggesting that the impact of HSR on tourism is ambiguous and may lead to unwanted disparities in inter-regional tourism, favouring localities with access to major HSR stations.

Hiramatsu (2016) published a study that explores the impact of HSR on tourism through the lens of Computable General Equilibrium (CGE) modeling, focusing on the regional economies and transportation networks. The study specifically examines the case of Kyushu, a region in Japan made up of several prefectures with varying levels of economic prosperity. The analysis results are estimated by using weights from the data obtained from Japan Ministry of Land Infrastructure, Transport and Tourism, on 38,000 households from 70 cities and 60 assemblies. Given that Kyushu includes prefectures that are either already served by HSR or are planned to be, the expectation was that these areas would experience increased tourism. The findings suggest that despite potential disparities affecting tourists, the economic benefits are distributed across all prefectures involved. This is attributed to the general equilibrium effect, where growth in one industry or prefecture leads to positive spillover effects on others, stimulating overall economic growth. Interestingly, while the demand for tourism goods might decrease in certain prefectures, the gross product of these areas, as well as for the entire regions of Japan and Kyushu, increases. This indicates that HSR not only boosts the tourism sector but also stimulates growth across various other industries. Additionally, incorporating business trips into the model is recommended to enhance its realism and thoroughness, with the appendix providing data to underscore the significance of business travel in this context. As also Hiramatsu (2016) suggested in his work, business travel plays an important part in the goal of understanding the impact of HSR construction on the economy. The amount of people traveling through the HSR network is highly connected to the outgoing business activities in the cities alongside the HSR stations.

Another paper discussing this topic and the case of Japan was publish by the Inoue *et al.* (2017), who examines how reducing travel costs influences innovative activities by facilitating knowledge diffusion. He specifically analyzes the impact of the Nagano (later renamed to Hokuriku) Shinkansen's launch in Japan in 1997, utilizing a Fixed Effect DiD approach to assess how this event affected the innovation of businesses near the railway. The findings reveal that the inauguration of the Nagano Shinkansen led to a significant increase in both the quantity and quality of innovative activities at establishments close to the rail stations. Additionally, there was a notable rise in collaborations between establishments along the Shinkansen line and in the citations of patents filed by businesses in Tokyo. These results suggest that the opening of the Nagano Shinkansen has enhanced the knowledge production.

Matas & Roig (2020) furthermore discuss this topic, evaluating the impact of HSR construction on company creation. The study uses data from the Central Business Register compiled by the National Institute of Statistics in Spain. It focuses on the number of newly registered companies categorized into four divisions: manufacturing, services (excluding public administration), tourism-related activities, and knowledge-intensive activities. The authors employ a fixed-effect model using panel data covering the period from 1995 to 2017. This model accounts for individual and temporal specific effects and allows for the examination of a dynamic structure within the data. The results reveal that, although HSR connectivity can enhance firm creation, the effects are not uniform across all sectors. It highlights that sector reliant on face-to-face interactions, such as services, tourism, and knowledge-intensive industries, experience more significant growth in firm creation due to HSR connectivity. The findings also discuss how HSR development influences the geographical distribution of economic activities. For service and knowledge-intensive sectors, HSR connectivity tends to increase the concentration of new firms in larger cities, thereby potentially reinforcing urban economic agglomerations. In contrast, the manufacturing sector does not exhibit a consistent pattern in relation to HSR connectivity. Moreover, the study suggests that improving short-distance

HSR connections may expand metropolitan areas by enhancing the benefits of agglomeration.

Wang *et al.* (2018) article discuss slightly different topic, however with consistent results. Author delves into the significant growth of real estate values in China, a phenomenon that has garnered widespread attention. His study aimed to explore the specific impact of HSR development on city-level housing prices in China. Employing a comprehensive dataset covering HSR and housing prices, alongside financial and population, across 285 Chinese municipalities and prefecture-level cities from 2009 to 2017, his study utilized the HSR's expansion as a natural experiment. By applying a TWFE model and Generalized Method of Moments (GMM) estimation for dynamic panel data models, with robustness checks, the research assessed city disparities and regional imbalances. It also examined economic effects such as the Siphon effect, Diffusion effect, and Synergistic effect using typical city pairs. The study arrived at three primary conclusions: First, the introduction of HSR is associated with a 13.9% increase in city-level housing prices, with the impact being more pronounced in large national central cities (31.7%) and regional central cities (19.6%). However, the increase in house prices was not associated with a decline in sales of real estate companies. This fact suggests that the increase in prices was correlated with an increase in attractiveness that HSR construction brought to these cities. Second, the development of HSR contributed to deepening regional imbalances, particularly benefiting large central cities and their agglomeration through housing price and associated construction and transactions growth. Third, different economic effects were observed between city pairs: the Siphon effects were notable in megacity-small city pairs, showing that mega-cities benefited from HSR more, while the synergistic effect was more common in megacity-megacity pairs, with these effects intensifying as the number of HSR lines increased and travel times decreased. However, his study also notes the unique political structure of China, which facilitates the efficient implementation of megaprojects like the HSR, through strong government control over land, public spending, and the ability to overlook potential negative impacts (e.g., noise and environment pollution) on residents.

3.3 Impact of HSR Construction on Overall Economy

In contrast to the previous section, this section focuses on the impact of HSR in a broader context and is interested in the literature looking at the impact of HSR construction on the overall economy and key macroeconomic indicators such as population, economic output, reported corporate results, collected taxes or household income.

As mentioned earlier, China's current HSR network is the largest in the world. It is also one of the reasons why most of the papers dealing with the impact of HSR are published by Chinese researchers or use data from China. The first and main part of this section is be devoted to 3 major studies that address the economic impacts of HSR construction in the China region. The conclusions of these studies is subsequently put into context with a Japanese study examining the relationship of economic activity with the proximity to Shinkansen network that is also the focus of this paper.

The previous chapter reported the findings of a study looking at the change in real estate prices associated with the construction of the HSR network. Following these findings, the paper published by Jin *et al.* (2020) measuring the correlation between HSR construction and economic growth and disparity in Chinese provinces. This article covers the period from 2002 to 2016 and the analysis is based on data from 285 municipalities in China, including various levels of cities (sub-provincial cities, and prefectural-level cities). Data were collected from the China City Statistical Yearbooks from 2003 to 2017, with adjustments for inflation to obtain real GDP figures. The study uses a spatial econometric model, incorporating a spatial Durbin model to detect local and spill-over effects of HSRs on economic growth. This approach allows for capturing both the impact of HSRs on the cities where they are located and their neighboring cities. The analysis includes control variables such as capital stock, labor input, industrial structure, public finance expenditure, and foreign direct investment to account for other factors influencing economic growth. HSRs are found to significantly contribute to local economic growth, with a notable but not statistically significant spill-over effect on neighboring regions. The study also reveals that HSRs tend to widen economic disparities between cities. While HSRs significantly promote economic growth in rich and developed cities, their effects are insignificant or even negative in less developed cities with lower income levels. This suggests that HSRs may contribute to increasing regional economic inequality and consequent disparities within a population.

A similar theme, but with different methods, and especially different results and conclusions, was also explored by Chen & Haynes (2017). To quantitatively assess the impact of HSR development on economic disparities, the research employs three indices: the weighted coefficient of variation, the Theil index, and the Gini index. These measures help in analyzing variations in economic disparity both at national and regional levels. The core of the empirical analysis is an endogenous growth model that incorporates panel data covering time period from 2000 to 2014. The model includes variables reflecting HSR's influence on regional economic growth, measured through indicators like rail network density and accessibility changes. These accessibility indicators include weighted average travel time, potential accessibility, and daily accessibility, aimed at capturing the qualitative improvements brought by HSR. The study finds a general decrease in regional economic disparities since the development of HSR, indicating a trend towards regional economic convergence. This conclusion is supported by the negative trend in the statistical measures of disparity over the study period. The regression analysis shows that improvements in HSR accessibility have a significant and positive impact on regional economic growth, particularly in less economically developed regions. The effects are more pronounced in the central, southwest, and south regions of China, suggesting that HSR has contributed to balancing regional economic disparities. The conclusions of this paper are therefore in direct contradiction (in the context of disparity level and economics growth allocation), with the conclusions of the above-mentioned Jin *et al.* (2020) and Wang *et al.* (2018).

Works of Jin *et al.* (2020) and Chen & Haynes (2017) were followed by Wang *et al.* (2022), in his work exploring the effects of the HSR on regional accessibility, urban development potential, and the economic and population changes of nine provinces along the Yellow River in China. The study utilizes data from 115 municipal administrative units across nine provinces along the Yellow River. This includes traffic network spatial data, the shortest travel time between urban stations, and demographic and economic indicators. The study periods are segmented into intervals from 2008 to 2020, considering the years before and after HSR operations began in these regions. In this work the gravity model is used to calculate the economic and population development potential between cities, reflecting the influence of HSR on urban spatial patterns. The study considers the shortest commuting times within and between cities, incorporating HSR travel times and frequencies. To explore the impact of HSR on regional and urban economy and population, the study also employs a TWFE DiD approach. This model helps isolate the effects of HSR from other factors influencing urban development, allowing for a clearer understanding of HSR's impact. Based on empirical results, the author claims that HSR encourages greater agglomeration rather than diffusion. Large cities economically benefit more from HSR, experiencing economic growth and population increase. However, HSR has led to population loss and economic downturn in small and medium-sized cities. The findings also highlight that while HSR can enhance regional accessibility and promote urban development in well-connected areas, it also exacerbates economic and demographic disparities between cities. Wang *et al.* (2022)'s work therefore supports the finding of Jin *et al.* (2020) and is also in contradiction to the finding of Chen & Haynes (2017).

The methodologies and findings of these studies lay a solid groundwork for future research on the impacts of HSR construction. It is crucial to note, however, that all three referenced authors highlight China's unique characteristics, distinct from other regions globally.

Wetwitoo & Kato (2019) delve into the economic repercussions of HSR's proximity on both regional and local scales within Japan, dissecting the effects on production and labor productivity. This research is meticulously organized by geographical specificity-analyzing prefecture and municipality levels over different periods. The analysis from 1981 to 2006 at the prefecture level centers on regional production, while the 2010 to 2015 municipality-level study zeroes on local tax revenues in light of new HSR expansions. Employing DiD and Propensity Score Matching (PSM) methods, the study navigates the complex dynamics of HSR's economic impact. The outcomes reveal a nuanced picture: at the prefecture level, there's a hint of positive influence on production, yet the broader DiD results suggest a lack of direct economic stimulation from the introduction of HSR stations. This trend continues at the municipality level, where initial positive impacts on tax revenue are later contradicted by in-depth analysis, indicating no definitive evidence that direct proximity (within 2 kilometers) to HSR stations directly boosts economic productivity or production.

Japan's demographic scenario, marked by a declining population over the past two decades, sets it apart from the countries previously discussed. This stark contrast, especially against regions experiencing population growth, necessitates a careful examination of Japan's unique context. Understanding Japan's demographic decline is essential for accurately interpreting the study's outcomes and integrating these findings into the broader discourse on HSR's economic impacts.

3.4 Contribution to Existing Literature

The construction of HSR systems has been extensively studied across various disciplines, reflecting a wide spectrum of impacts from focused examinations on singular aspects to comprehensive analyses encompassing the entire economic influence on a country. This thesis contributes to this body of literature by focusing on impact caused by construction of the Shinkansen HSR network, in Japan - a nation that is recognized as a pioneer in HSR development and renowned for its sophisticated infrastructure.

This work differs from all existing papers by using a completely new method. The sequential construction of HSR infrastructure across different regions is a prime example of Staggered Adoption. However, until recently, these stagger implementation "projects" were addressed using Two-Way Fixed Effects (TWFE) Difference-in-Difference (DiD). However, this method is imperfect in many ways, being sensitive to the size of each group, the timing of treatment and negative values in the estimated effect cause significant problems. The new method published by Callaway & Sant'Anna (2021) overcomes these shortcomings and opens the door to entirely new possibilities in terms of the accuracy of the estimates and the ability to track the development of these estimates over relative time from treatment.

It is the combination of this model, that has never been used to estimate the impact of any infrastructure project worldwide, and the case of Japan, which had much of its HSR infrastructure built until the end of 1980s, that gives us the unique opportunity to track the effects of construction over time horizons exceeding two decades.

Thus, this study builds largely on the findings obtained by Wang *et al.* (2022) based on the China case, extends the Wetwitoo & Kato (2019) study on the Japan case, and provides a completely new perspective on the impact that HSR construction has left in Japan. In addition, this paper uses the findings on the heterogeneity in effects, examined by Matas & Roig (2020), Wang *et al.* (2018) and Jin *et al.* (2020), caused by HSR construction and test whether it holds in the case of Japan.

This investigation seeks to illuminate the nuanced ways in which HSR contributes to urban development and economic dynamics, providing insights that are pivotal for policymakers, urban planners, and future research in transportation economics. By addressing these broader impacts, this thesis fills a gap in the literature, offering a unique perspective on the transformative effects of HSR in one of the world's most advanced rail network systems. The findings not only add depth to the comprehension of HSR's economic and social benefits but also underscore the importance of strategic infrastructure development in fostering sustainable urban growth.

Chapter 4

Data & Methodology

This chapter outlines the author's hypotheses, describes the data used in the analysis, explains the selected econometric method, and discusses the limitations encountered during the study.

4.1 Hypotheses

Building upon the historical context discussed in Chapter 2 and the effects of HSR construction explored in Chapter 3, this section formulates several hypotheses regarding the impact of the HSR construction in the case of Japan and its Shinkansen network.

The existing literature, such as the studies by Chen & de Abreu E (2013) and Jin *et al.* (2020), documents the positive impacts of HSR construction on the economies of affected regions and highlights increased accessibility that boosts the attractiveness of municipalities within the HSR network. This attractiveness presumably leads to population growth and enhanced economic activity. Given these findings, this thesis examine whether similar effects are evident in Japan.

Further, research noted in Chapter 3, such as that by Matas & Roig (2020), indicates that HSR impacts are particularly pronounced in the service sector and industries reliant on human capital, as HSR primarily intended for transport of people, not goods or materials. Therefore, this thesis investigate if this phenomenon has also similarly occurred in Japanese municipalities.

In studies focusing on China, such as those by Jin *et al.* (2020), Chen & de Abreu E (2013) or Wang *et al.* (2022), it was argued if HSR construction has exacerbated disparities or not. The results of the studies by these authors differ considerably. While there are views that HSR operation contributes to the levelling of inequalities across the state and society, there are also findings that speak of deepening these disparities. The Siphon effect was presented in combination with the Agglomeration effect, and thus that large and wealthy municipalities are pulling in the population and economic activities of smaller and poorer municipalities; other studies, on the other hand, talk about the Diffusion effect and the spreading of wealth and population outside the mega-cities and agglomerations. Thus, this paper also tests in which way HSR construction has affected municipalities in case of Japan. Based on the findings discussed above, this author of this thesis identify hypotheses for further testing as follows:

- **Hypothesis 1:** The construction of the HSR network positively impacted the population size and economy of municipalities lying within its proximity.
- **Hypothesis 2:** The impact of HSR construction was more pronounced in municipalities with a higher proportion of services in their total taxable income.
- **Hypothesis 3:** The influence of HSR construction was more significant in richer municipalities, i.e. those with higher per capita income.
- **Hypothesis 4:** Municipalities with larger population experienced greater benefits from HSR development, as major economic activities tended to shift towards regional centers.

4.2 Data

This thesis utilizes panel data on Japanese municipalities, sourced from the Statistics Bureau of Japan (SBJ) via their e-Stats portal. This section outlines how this data is structured, how municipalities are classified into treated and control groups, and the rationale behind these classification.

4.2.1 Group Categorization and Data Collection Methodology

Japan is structured into five main regions, which are further divided into 47 prefectures. These prefectures are then structured into municipalities and there are 1741 municipalities in total (according to the latest 2022 update). Each municipality then contains a central city/ village, which is also a subject to categorisation into 3 types. These central cities/ villages in the Japanese language get the ending -shi, -mochi, -ho based on their population and the fulfilment of certain criteria such as the presence of hospitals, schools and other public institutions (English equivalents to Japanese endings are City, Town, Village). The vast majority of the population of a given municipality generally resides in these central city/ village and municipality as a whole can still include a large area of natural character (which is no longer part of this central city/ village). Thus, the entire territory of Japan can be divided among the individual municipalities.

The SBJ provides complete data at this municipality level from 1980 to 2021. Although some of the variables examined in this paper are published on an annual basis, some variables are only published on a five-year basis (for the municipal level). Therefore, this thesis only uses data from the years for which records are available for all variables examined, i.e., on a five-year basis from 1980 to 2020. This paper therefore focuses on examining data in this time horizon and therefore, the analysis specifically targets municipalities affected by the construction of key Shinkansen lines: Hokkaido, Tohoku, Joetsu, Hokuriku, and Kyushu. These lines were selected due to their commissioning within the study's time-frame and because their belonging to the main core of the Shinkansen network.

The municipalities are segmented into 'Treated' and 'Control' groups based on their proximity to the nearest Shinkansen station. The Treated group includes municipalities that have their central city/ village located within 15 kilometers to a nearest station of one of the mentioned Shinkansen lines and it is therefore assumed that there should be seen the strongest social-economic impacts from the HSR construction. Conversely, the Control group consists of municipalities from the same or neighboring prefectures but situated at least 30 kilometers away from any station, used as a baseline to assess the HSR's impact. This distribution is based on the work of Wetwitoo & Kato (2019), who applied a similar approach and set the 30 kilometres radius from the nearest station to ensure that there is no potential construction effect on the Control group.

Manual Selection and Group Assignment

Given the lack of an automated method to classify these municipalities, a manual selection process had to be done. In order to get the data, it was needed to manually measure the distance between each central city/village and the nearest Shinkansen station. Subsequently, out of the 21 prefectures of concern, roughly 800 central cities/ villages were localized. Afterwards the distance to the nearest Shinkansen station was measured one by one. Based on the distance measured, it was decided which group the certain municipality should belong to - Treated or Control. Those municipalities which have their central city/village localized in ambiguous position between the 15 to 30 kilometres from the nearest Shinkansen station were excluded for further measurement. Some other municipalities were also excluded because of missing some of the data [1]. Further, the procedure proposed by Chen & de Abreu E (2013) was applied. To maintain rigorous standards, any municipality smaller (in the matter of population size) than the smallest in the Treated group was excluded, ensuring that the remaining sample was representative and comparable in size and demographic characteristics. This meticulous approach helps in minimizing variability that could skew the analysis of HSR's impact.

The final dataset comprises 624 municipalities, with 162 in the Treated group and 462 in the Control group. This dataset was used to assess the Average Treatment Effect on the Treated (ATT) by comparing changes over time in both groups. This sapproach to data collection and analysis should lead to a more robust framework for evaluating the socio-economic impacts of HSR construction on Japanese municipalities, providing a solid foundation for the subsequent hypothesis testing and discussions.

In the following Table 4.1 to 4.5, the summary statistics of the main socio-economic indicators, Total Population and Taxable Income, from the selected samples can be seen. The tables have been compiled in such a way that it is possible to compare the 25th percentile, 50th percentile (mean value) and 75th percentile of these variables for municipalities included in the Treatment and Control groups, depending on which of the lines they belong to.

[1]Municipalities with missing data were predominantly those affected by GEJE.

Table 4.1: Hokkaido Line

Treated Group - 32 municipalities

	25%	50%	75%
Total population	17,433	24,610	69,106
Taxable income	12,982,982	21,514,922	64,632,233

Control Group - 63 municipalities

	25%	50%	75%
Total population	15,088	25,268	42,740
Taxable income	10,742,048	21,859,411	41,022,860

Table 4.2: Joetsu Line

Treated Group - 35 municipalities

	25%	50%	75%
Total population	43,504	70,323	109,468
Taxable income	41,666,376	70,949,618	131,987,250

Control Group - 39 municipalities

	25%	50%	75%
Total population	28,946	64,917	90,662
Taxable income	28,329,182	65,636,113	111,715,787

Table 4.3: Hokuriku Line

Treated Group - 36 municipalities

	25%	50%	75%
Total population	26,774	41,778	93,524
Taxable income	28,483,189	47,791,060	102,081,455

Control Group - 80 municipalities

	25%	50%	75%
Total population	11,331	32,441	71,932
Taxable income	11,750,696	36,319,014	78,055,744

Table 4.4: Kyushu Line

Treated Group - 49 municipalities

	25%	50%	75%
Total population	24,269	43,811	67,777
Taxable income	19,926,481	40,789,303	72,292,585

Control Group - 184 municipalities

	25%	50%	75%
Total population	15,064	30,090	57,728
Taxable income	11,391,836	25,159,044	49,640,056

Table 4.5: Tohoku Line

Treated Group - 44 municipalities

	25%	50%	75%
Total population	26,449	61,869	105,940
Taxable income	26,159,048	58,685,557	111,487,522

Control Group - 92 municipalities

	25%	50%	75%
Total population	20,616	59,890	83,280
Taxable income	19,056,702	50,544,912	88,716,036

From the data that can be observed in these tables, it can be seen that by applying the methods proposed by Wetwitoo & Kato (2019) and Chen & de Abreu E (2013), construction of the very comparable Treated and Control groups was achieved. The fact that these groups show very comparable values was further crucial for fulfilling the assumptions needed for the follow-up testing of the proposed hypotheses.

It is also possible to see that different regions of Japan are very different from each other. While in the northernmost and southernmost parts of the main Japanese archipelago, through which the Kyushu and Hokkaido lines run, the population is concentrated in small, evenly distributed municipalities, the central part of the island of Honsu, through which the Joetsu and Tohoku lines run, the population is mostly concentrated in larger agglomerations.

4.2.2 Description of the Obtained Variables

Six variables related to selected municipalities were directly obtained from the e-Stats portal site, as they were collected with the highest quality and are best suited to serve the purpose of this paper.

- **Total Population:** According to the Japan Statistics Bureau, "Total Population" refers to the count of permanent residents in a specific municipality district. A "permanent resident" is defined as someone who has been living in a dwelling for over three months or is expected to live there for such a duration. Furthermore, for certain individuals, their permanent residency is based on the location where the survey is conducted. This variable is recorded every five years.
- **Taxable Income:** The term "Taxable Income" refers to the total income amount in thousands of Japanese Yen generated within municipality, that is subject to taxation, including both municipal and prefectural taxes, but excluding retirement income that is subject to separate taxation. This definition considers income before any deductions, such as miscellaneous loss deductions.
- **Local Taxes:** Local taxes are defined as taxes contributed by residents of a specific area, serving as a major source of revenue for local governments. These taxes are crucial for financing local government expenses and can be freely used by the local entities according to their discretion. They are measured in thousands of Japanese Yen.
- **Number of Employed Persons:** This term refers to individuals classified as "employed" in the national census, who engaged in any income-generating work during the survey week. This includes wages, salaries, allowances, business revenue, commissions, and income from home-based work (including payment in kind).
- **Number of Unemployed Persons:** This category includes those identified as "completely unemployed" in the national census. These individuals did not engage in any income-generating work during the survey week and were actively seeking employment, being capable of taking up

a job. This includes those who have registered with Hello Work (public employment security offices) or have otherwise actively searched for work.

- **Value of Manufactured Goods, Shipments, etc. (VMGS):** This variable captures the total yearly amount from the value of manufactured goods shipped, processing fees received, the value of scrap and waste shipped, and other income amounts, including consumption tax, liquor tax, tobacco tax, and gasoline tax, measured in millions of Japanese Yen. [2]

4.2.3 Description of the Derived Variables

For the analyses conducted in this thesis, additional variables derived from the primary data were necessary. Consequently, four supplementary variables were generated:

- **Income per Capita:** This variable calculates the average income per resident by dividing the Gross Taxable Income by the Total Population. This measure helps gauge the economic status and average income level of a municipality's inhabitants.
- **Unemployment Rate:** This variable is calculated by dividing the Number of Unemployed Persons by the total labor force, which is the sum of Unemployed and Employed persons. The construction of infrastructure, such as high-speed rail, often correlates with job creation, potentially influencing labor market dynamics and unemployment rates in affected municipalities.
- **Employment Rate:** This variable is calculated similarly to the Unemployment Rate but uses the Number of Employed Persons divided by the Total Population. This ratio provides insights into the employment levels within a municipality, reflecting the proportion of the population that is actively engaged in the workforce.
- **Manufacturing Intensity:** This variable is calculated by dividing the Value of Manufactured Goods, Shipments, etc., by the Gross Taxable Income. This ratio indicates the proportion of a municipality's taxable

[2] Due to the effects of the Great East Japan Earthquake, the Economic Census - Activity Survey for 2012 and 2018 excludes some regions.

income that is derived from industrial activities, thus shedding light on the economic orientation and industrial significance of the municipality.

4.2.4 Partitioning of Datasets

For the effective testing of the hypotheses outlined earlier, it is crucial to analyze sub-samples of thesis's dataset. This segmentation allows for a more nuanced understanding of how different economic and demographic variables effects the impact of HSR construction. Sub-samples were created by dividing the municipalities in the dataset according to key parameters: Manufacturing Intensity, Income per Capita, and Population Size.

For instance, each of the 624 municipalities in the dataset is evaluated based on the "Manufacturing Intensity" variable value at Relative Time Zero ($k = 0$), which refers to the last available record before the introduction of HSR (as k stands the years since treatment). This variable effectively indicates whether a municipality's economy is predominantly service-oriented or industrially oriented. The dataset was further divided into two lists of municipalities from Treated and Control group. Both lists were then sorted in descending order and the top and bottom 35% are selected. The samples from the top 35% are then merged together and the samples from the bottom 35% are merged together. From the whole municipality sample two sub-samples are selected based on their "Manufacturing Intensity" at relative time $k = 0$, resulting in one subgroup predominantly comprising service-oriented economies and the industrially oriented economies. This pair of sub-samples is labeled "Service/Industry."

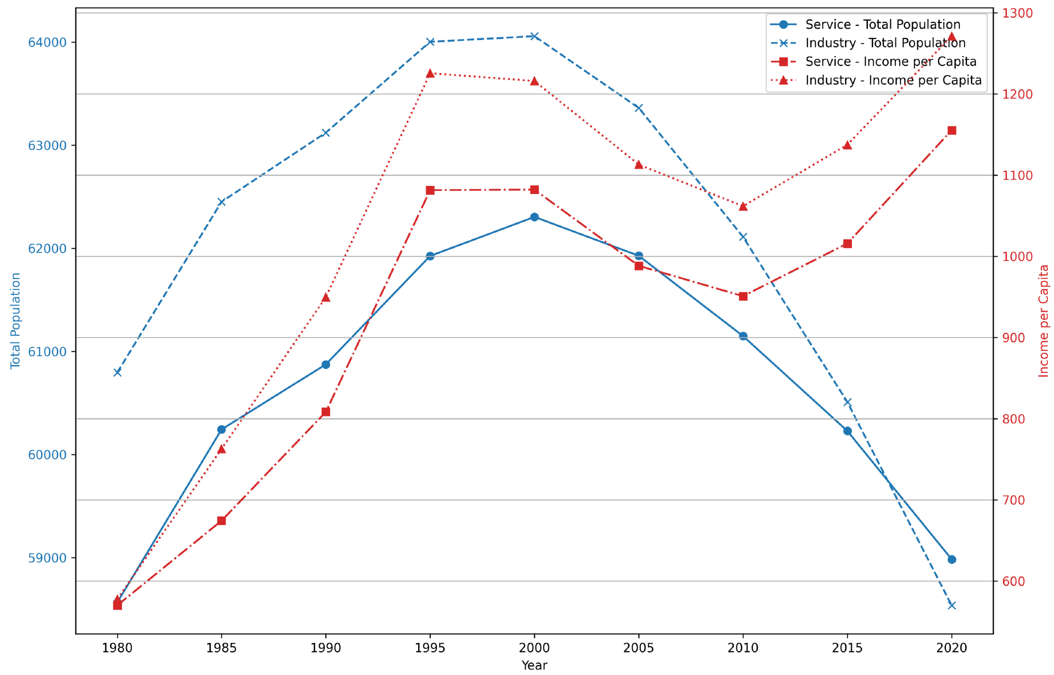
This partitioning process is replicated for the other two variables. By dividing municipalities based on Income per Capita variable, the "Rich/Poor" sub-samples were created, and by using "Total Population" the "Large/Small" sub-samples were created. This approach not only enhances the validity of the results but also allows for a detailed exploration of how various factors might influence the economic impacts of HSR development differently across different municipal characteristics.

Sub-samples

After dividing the list of all municipalities into individual sub-samples based on a given variable, the next stage was to assess how this division was reflected in the average values of other variables in these sub-samples, i.e., what samples of what municipalities were obtained by this division.

Figure 4.1 depicts the average values of Taxable Income and Total Population for municipalities from Service/ Industry groups, providing insights into their demographic and economic profiles.

Figure 4.1: Comparison of Service and Industry Oriented Municipalities

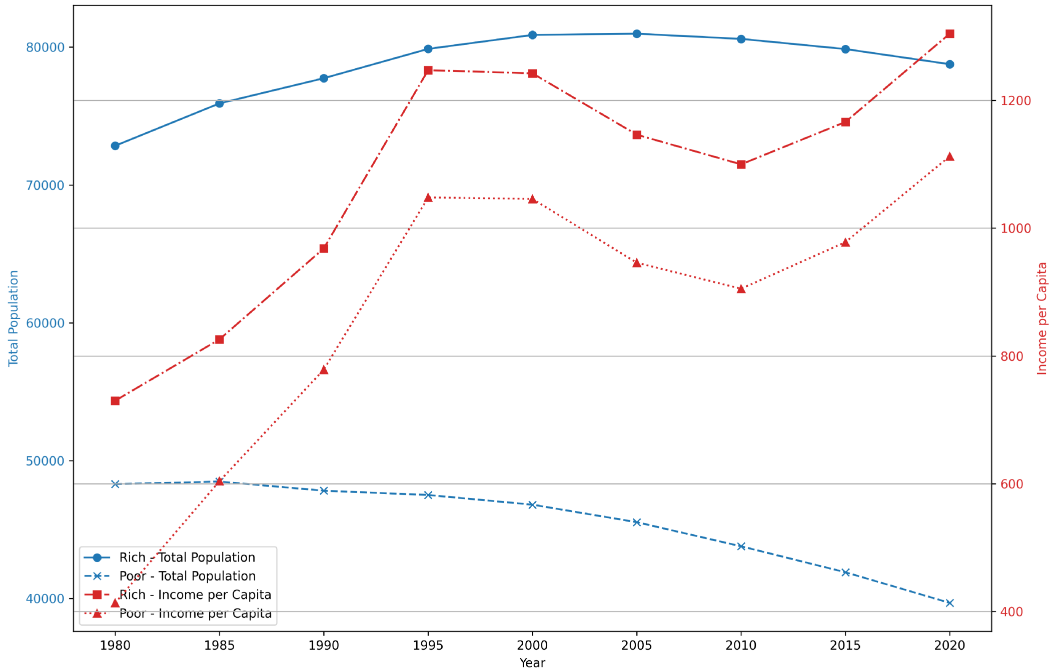


The x-axis represents the years, while the y-axis represents the total population on the left side, while income per capita in thousands of Japanese Yens is represented on the right side.

Interestingly, the Industry group exhibits a slightly larger average population and marginally higher per capita income. Another interesting observation is that while the gap between subgroups was substantial and constant over time at the end of the 20th century, the decline in the overall population at the beginning of the 21st century also started the convergence of these groups. Thus, it can be seen that in the latest available record from 2020, the group of municipalities whose economies are service-oriented have overtaken the manufacturing-oriented municipalities in population size. Despite these differences, the remarkable similarity between the two samples underscores the suitability of comparing these groups to determine the influence of economic orientation on the impact of HSR construction.

Figure 4.2 then illustrates notable differences between the groups of Rich and Poor municipalities. Rich municipalities (with higher per capita incomes) generally have larger populations, ranging between 70,000 and 80,000, whereas poorer municipalities typically have populations between 40,000 and 50,000. Furthermore, there is a divergent trend in population dynamics: Richer municipalities exhibited growth until about 2005, after which a decline or stabilization occurred, contrasting with the earlier and more consistent population declines in Poorer municipalities.

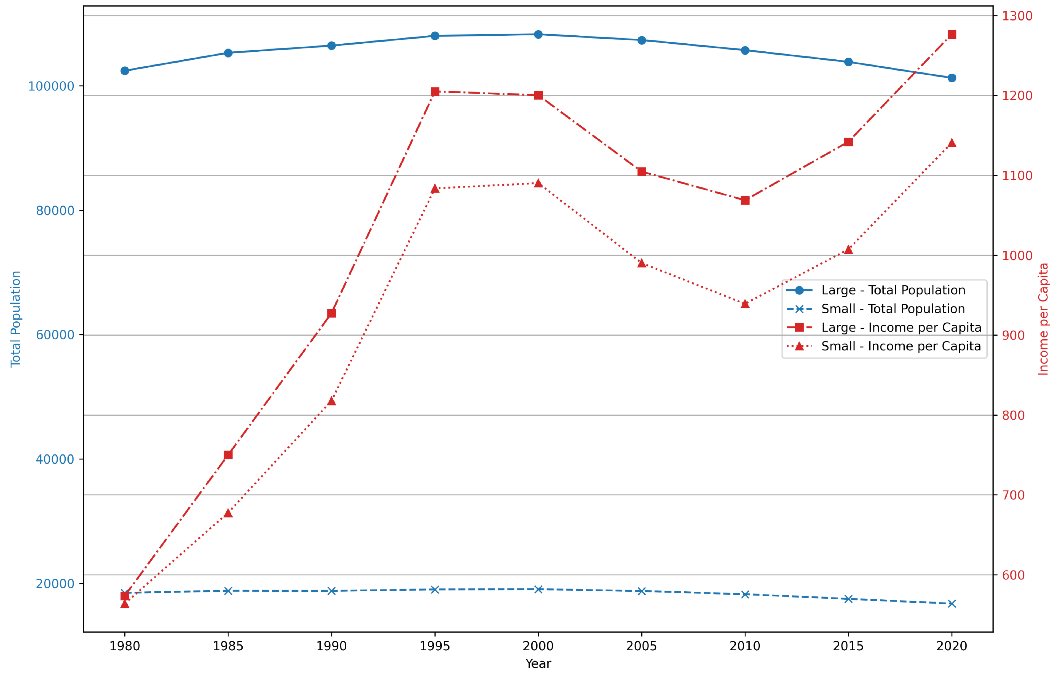
Figure 4.2: Comparison of Municipalities with High and Low Income per Capita



The x-axis represents the years, while the y-axis represents the total population on the left side, while income per capita in thousands of Japanese Yens is represented on the right side.

Figure 4.3 illustrates the differences in Income per Capita and Total Population between Large and Small municipalities, confirming initial expectations that larger municipalities typically exhibit higher average income. The graph reveals a stark contrast in population size between the groups, with larger municipalities averaging populations well over 100,000, while smaller ones hover around 20,000.

Figure 4.3: Comparison of Large and Small municipalities



The x-axis represents the years, while the y-axis represents the total population on the left side, while income per capita in thousands of Japanese Yens is represented on the right side.

4.2.5 Robustness Testing

After selecting the data that was used to test the stated hypotheses, other sub-samples were also selected and used to test the robustness of the methods used.

The first test sample is a sample in which the condition set by Chen & de Abreu E (2013) is not be used to select the municipalities to be included in the Control group, but even the smallest municipalities are included in the Control group. This significantly reduce the average population size of municipalities in the Control group which contains approximately 100 more municipalities.

Second test sample is drawn from the same Treated Group, but municipalities from other regions of Japan and from prefectures through which no HSR line passes is be used as Control municipalities.

The third test sample consist of the same list of selected municipalities as the main sample, but the group assignment based on the selected variable is subject to a different procedure. Whereas the above procedure involved proportional splitting based on the state variable, in this sample there is executed a pure and direct split of the dataset based on the given variable, regardless of which group the municipality originally belonged to.

4.3 Methodology

This section discusses the methods applied to test the hypotheses mentioned above, namely, to accurately estimate whether HSR construction positively impacts the socio-economic conditions of municipalities lying in proximity to HSR stations, and if the magnitude of this impact is influenced by various indicators of these municipalities. To accurately assess the proposed hypotheses, it is crucial to select an appropriate model that meets the specific requirements and to determine the variables on which the impact of construction is examined.

4.3.1 Key Variables Tested

In this study, the variables VMGS was initially selected, Income per Capita, and Total Population to categorize the sub-samples for analysis. However, due to the significant impact of the GEJE on the reliability of VMGS data, this variable was excluded from further analysis. Consequently, the research focused on examining the effects of HSR construction using only the Total Population and Income per Capita. The Local Taxes variable is also included, as it was the primary variable of interest in the study by Wetwitoo & Kato (2019), enabling a comparison between Wetwitoo & Kato (2019)'s results and those of this thesis. Additionally, to observe the effects of construction on the economic performance of affected municipalities, the variables Taxable Income is alos selected among the observed variables. Furthermore, several studies, such as those by Inoue *et al.* (2017) and Matas & Roig (2020), have noted the association of HSR construction with job creation; therefore, the Unemployment and Employment Rate variables are included to examine if HSR construction also impacts the labor market in the affected municipalities. Consequently, to test the proposed hypotheses, the effects of HSR construction on six key variables were analyzed: Total Population, Taxable Income, Income per Capita, Local Taxes, Unemployment Rate, and Employment Rate.

In the case of variables expressed in absolute terms (Total Population, Taxable Income, Local Taxes), a natural logarithm transformation was used, which allows us to interpret the estimated ATT in percentage terms.

To accurately estimate the impact of discussed HSR construction on treated municipalities, chosen approach involves contrasting these municipalities with counterparts unaffected by this construction. This analysis tracks the dynamics of key variables over time in both sets of municipalities to estimate the HSR construction impact as precisely as possible.

4.3.2 Design and Assumptions

To further process with description of methodology used in this paper, design of the methodology with several assumptions have to be introduced. This paper use the notation set by Freedman *et al.* (2023), which is common for papers discussing similar topics. Individual observations is indexed by by $i = 1 \dots N$, groups by $s = 1 \dots S$, and time periods by $t = T_1 \dots T_T$. In case of this thesis, there was a focus on situation where treatment occurs at the $group \times time$ level and remains until the study's conclusion (as none of the Shinkansen lines built have been decommissioned). Let A_s denote the calendar year when units in group s first receive treatment, with $A_s = \infty$ indicating groups never treated during the study period. In the dataset, A_s defines 8 groups adopting in years 1983, 1986, 1997, 2002, 2004, 2011, 2015, 2016, and ∞. The binary variable $D_{st} = 1(t \geq A_s)$ indicates whether treatment is active in group s in year t. [3]

Potential outcomes represent causal relationships. $Y_{ist}(0)$ is the outcome for municipality i from group s in year t under the scenario where it never receives treatment. $Y_{ist}(a)$ is the outcome in year t if first treated in year a. The causal effect of adopting treatment in period a compared to no treatment is $\beta_{ist}(a) = Y_{ist}(a) - Y_{ist}(0)$. The primary interest is in the average treatment effect on the treated (ATT) at a specific time, denoted $ATT(a,t) = E[\beta_{ist}(a)|A_s = a]$. The actual outcome depends on the treatment adoption date, such that $Y_{ist} = Y_{ist}(0) + \sum_{\tau=T_1}^{T_T} \beta_{ist}(\tau) \times 1(A_s = \tau)$.

Two main assumptions are essential for further ATT estimations of HSR construction: non-anticipation and common trends.

- **Assumption 1. No Anticipation:** The average causal effect of adopting treatment in period a is equal to zero for all calendar periods prior to period a.

[3] Since the data are available on a 5-year basis, it is assumed that the first available record prior to the treatment year is relative year zero, and thus each subsequent observation is then $k \times 5$ years of relative time since treatment (the same can be applied to the time before treatment).

$$E[Y_{ist}(a) - Y_{ist}(0)|A_s = a] = 0 \text{ for } t < a$$

- **Assumption 2. Common Trends:** In the absence of treatment exposure, the average change across post-treatment time periods would be the same in the treatment group ($A_s = a$) and the comparison group ($A_s > a$).

$$E[Y_{ist}(a) - Y_{ist}(0)|A_s = a] = E[Y_{ist}(a) - Y_{ist}(0)|A_s > a] \text{ for } t > a$$

These assumptions hinge on counterfactuals, and while assumption 2 is not directly testable, it is supported by the comparability of the treated and control municipalities based on economic performance, population size and mutual proximity. Confirmation or rejection of Assumption 1 can be observed after the application of the model presented below.

Before the discussion can move on, to how to construct these different aggregated parameters, it is imperative to reexamine the two primary metrics for summary measures of treatment effects often utilized in such frameworks (setups comparing Treated/ Control groups, i.e. DiD estimations). The foundations for these metrics are the "static" and "dynamic", respectively, modalities of the two-way fixed effects (TWFE) in linear regression formulas.

$$Y_{i,t} = \alpha_t + \alpha_a + \beta D_{i,t} + \varepsilon_{i,t} \tag{4.1}$$

$$Y_{i,t} = \alpha_t + \alpha_a + \sum_{k=-K}^{-2} \delta_k^{anticip} \cdot D_{i,t}^k + \sum_{k=0}^{L} \beta_k \cdot D_{i,t}^k + \nu_{i,t} \tag{4.2}$$

where α_t is a time fixed effect, α_a is a group fixed effect, $\varepsilon_{i,t}$ and $\nu_{i,t}$ are error terms, $D_{i,t}^k = 1\{t\text{-}G_i = k\}$ is an indicator for unit i being k periods away from initial treatment at time t, and K and L are positive constants. The parameter of interest in the "static" TWFE specification is β, which, in practical applications, is typically interpreted as an overall effect of participating in the treatment across all *group* $\times$ *time* periods. In the "dynamic" TWFE specification, researchers usually focus on the β_k, $k \geq 0$ where these parameters can be interpreted as measuring the effect of participating in the treatment for k periods of exposure to the treatment.

Despite the popularity of these specifications, recent studies underscore the necessity for caution when assigning causal inferences to these aggregate parameters. For instance, Goodman-Bacon (2018) and de Chaisemartin & D'Haultfoeuille (2022) have demonstrated that, in general, β recovers a weighted average of some underlying treatment effect parameters but some of the weights on these parameters can be negative. Such a situation could yield paradoxical scenarios where every individual unit experiences a positive treatment effect, yet the TWFE approach yields a negative estimate for β. Additionally, even when negative weights do not occur, the weights on underlying treatment effect parameters effect parameters is highly dependent on the TWFE approach, which is, in turn, influenced by the proportional sizes of the groups, the sequencing of the treatment, and the aggregate number of time periods under consideration.

As discussed by Goodman-Bacon (2018), the “negative weight problem” associated with β arises when treatment effects evolve over time. When treatment effects display heterogeneity and change distinctively across units as time progresses, the TWFE framework may produce skewed/ biased estimations due to its presumption of a uniform treatment effect. The question arises as to whether such problems would still be present when considering more general, “dynamic” specifications such as Equation 4.2. Sun & Abraham (2021) show that this is still the case as the β_k' s associated with Equation 4.2 do not recover easy-to-interpret causal parameters and still generally suffer from the same sorts of “negative weighting problems”.

In contrast to this, the Callaway & Sant'Anna (2021) method allows each unit to have its own treatment effect that can change over time, thus providing a more accurate estimate when treatment effects are indeed heterogeneous. Also in the matter of robustness, the Callaway & Sant'Anna (2021) method is specifically designed to address the complexity of staggered adoption timelines by accurately attributing effects to the correct time periods and units, while the TWFE DiD models, on the other hand, might incorrectly estimate treatment effects because they implicitly weight the treatment effects by the number of treated and untreated periods. Therefore, this paper further utilize the insights gained by Callaway & Sant'Anna (2021) to answer the hypotheses presented in Section 4.1.

4.3.3 Model Chosen for Estimations

The complexity of staggered treatment, that had been implemented in numerous stages across several Japanese prefectures, necessitates a robust econometric model. The staggered adoption DiD model by (Callaway & Sant'Anna, 2021) is, as explained above, particularly suited for analysis of this thesis, allowing us to account for multiple groups receiving treatment at different times. In case of this study: 1983, 1986, 1997, 2002, 2004, 2011, 2015 and 2016.

This model enables the estimation of varied ATT(a,t) parameters under the standard assumptions of no anticipation and common trends. It applies the traditional DiD estimator in a nuanced manner across different periods and groups. The generalized ATT for any post-treatment period k is derived as follows:

$$\begin{aligned}
\Delta_{SA}^{a+k} &= E[Y_{is,a+k} - Y_{is,a-1}|A_s = a] - E[Y_{is,a+k} - Y_{is,a-1}|A_s > a+k] \\
&= E[\beta_{is,a+k}(a)|A_s = a] - \{E[Y_{is,a+k}(0) - Y_{is,a-1}(0)|A_s = a] \\
&\quad - E[Y_{is,a+k}(0) - Y_{is,a-1}(0)|A_s > a+k]\} \\
&= E[\beta_{is,a+k}(a)|A_s = a] \\
&= ATT(a, a+k)
\end{aligned}$$

This model leverages all available control observations by defining the treatment group through the adoption date and the control group as those adopting later than the focal post-period $a + k$.

Therefore, this thesis used the recently published model of Callaway & Sant'Anna (2021) and summary of recent related econometric literature complied by Freedman *et al.* (2023), to explore the effects of HSR construction on Japanese municipalities, using data sourced from the SBJ.

4.3.4 Model Application

To test the hypotheses effectively, it's crucial to aggregate the ATT for each *group* × *time* combination that allows for a comprehensive evaluation of the HSR's impacts across different variables and time frames. In the context of this thesis, it is important to examine the dynamics of the treatment effect of HSR construction, i.e., how the effect of the treatment varies with the length of exposure to the treatment. For instance, it is crucial to evaluate whether the ATT increases or decreases with the elapsed treatment time. Indeed, answering this type of question is often the main motivation for using the event study regression in Equation 4.2, though, as it is mentioned above, that sort of regression may not be suitable for such a task. In this section, it is propose an aggregation scheme that is suitable to highlight treatment effect heterogeneity with respect to length of exposure to the treatment that does not suffer from the drawbacks associated with the event study regression in Equation 4.2.

Let k denote the Relative Time since treatment, i.e., $e = t - a$ denotes the time elapsed since treatment was adopted. Recall that G denotes the time period that a unit is first treated. Thus, a way to aggregate the ATT(a, t)'s to highlight treatment effect heterogeneity with respect to k is:

$$\theta_{es}(k) = \sum_{a \in G} 1\{a + k \leq T\} P(a = G | a + k \leq T) ATT(a, a + k). \tag{4.3}$$

This is the average effect of participating in the treatment k time periods after (or k taking negative values for time before) the treatment was adopted across all groups that are ever observed to have participated in the treatment for exactly k time periods. Here, the "on impact" average effect of participating in the treatment occurs for $k = 0$. $\theta_{es}(k)$ is the natural target for this event study regressions that , though it completely avoids the shortcomings associated with the "dynamic" TWFE specification, mentioned in Equation 4.2. In the case of this study, focus is put on the estimation of the ATT on each of the key variables (listed in the beginning of this section) in relative time since treatment.

Chapter 5

Results

This chapter presents the findings from the analysis conducted on the comprehensive dataset that merges all relevant data concerning Japanese municipalities affected by the construction of the Shinkansen network.

Initially, the analysis focuses on determining the general Average Treatment Effect on the Treated (ATT) of HSR construction across Japan. This assessment is crucial for confirming Hypothesis 1, which posits a positive social-economic impact on municipalities located near Shinkansen stations. By employing the Callaway & Sant'Anna (2021) Staggered DiD methodology described in the Section Section 4.3, it is evaluate whether the proximity to these stations can be associated with significant changes in local economic indicators.

Subsequent analyses involve applying the same Staggered DiD model to various sub-samples within the unified dataset. These sub-samples are segmented based on specific parameters: 1) Analyzing whether municipalities with a service-oriented economy benefit more compared to those with an industrial base. 2) Investigating whether higher income levels in municipalities lead to greater benefits from HSR construction. 3) Assessing whether larger municipalities experience greater socio-economic impacts from HSR compared to smaller ones.

This detailed analysis assists in confirming or rejecting Hypothesis 1, 2, 3 and 4 described in Section 4.1, by examining whether specific economic characteristics amplify or moderate the effects of HSR construction. The methodology of Callaway & Sant'Anna (2021) is employed to evaluate the impact of HSR construction on six key variables, introduced in Section 4.2. This approach provides a clear understanding of the role of HSR in shaping the socio-economic landscape of Japanese municipalities. The results of this comprehensive analysis are summarized and detailing whether the HSR construction has generally achieved the expected economic impacts outlined in the hypotheses.

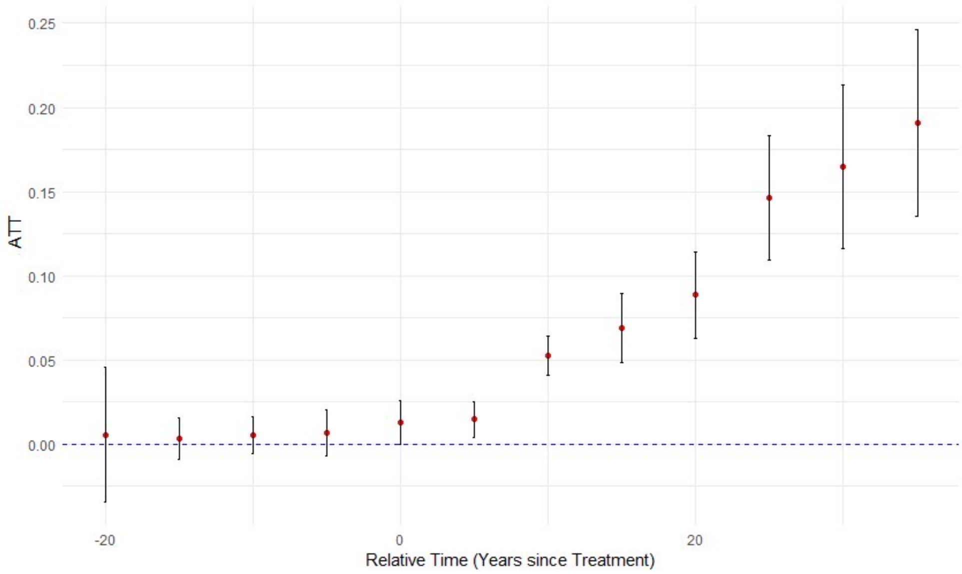
5.1 Overall Impact of HSR Construction on Municipal Populations

Previous studies, as reviewed in the Chapter 3, have reported mixed results concerning the impact of HSR network construction on affected municipalities. In this section, the study aims to build on the findings of Wang *et al.* (2022), who tracked the impact of HSR construction and focused on the total population development of affected municipalities. Employing the Staggered DiD methodology outlined by Callaway & Sant'Anna (2021), this section estimates the effect of HSR construction on the total population of municipalities impacted by new HSR lines.

5.1.1 Estimated ATT on Population Size

The estimated ATT on Total Population expressed in natural logarithmic form from whole sample is presented in Table 5.1 and visualized in Figure 5.1. These values are aggregated to reflect ATT in relative time since construction. Not only is this expression a robust representation of how ATT developed over time post-treatment, but it is also possible to discern whether it exhibited some systematic pre-trend. By being able to detect potential pre-treatment, a robust method to confirm (or reject) the validity of Assumption 1 was obtained.

Figure 5.1: Overall ATT on log Total Population



The graph shows the relative time since treatment with treatment on x-axis and the ATT value on Total Population on y-axis. The hatched horizontal line indicates an ATT value equal to zero as a comparison for the other values. Lines coming from each point indicate 95% CIs.

The confidence intervals, depicted by whiskers extending from each point, help gauge the statistical significance of the estimates. Points where the 0 value lies within the whisker indicate that the estimate is not statistically different from zero at the 5% significance level, and it is therefore possible to confirm the given effect of HSR construction with a high degree of certainty.

Table 5.1: Overall ATT on log Total Population

Relative Time	ATT	Std. Error	Significance
-20	0.005	0.030	
-15	0.003	0.019	
-10	0.005	0.012	
-5	0.007	0.015	
0	0.011	0.014	*
5	0.015	0.016	**
10	0.052	0.013	***
15	0.069	0.022	***
20	0.089	0.027	***
25	0.146	0.033	***
30	0.165	0.036	***
35	0.191	0.041	***

The table shows ATT in relative time since treatment along with the corresponding Standard Errors. The Significance column shows '***', '**', '*' or Empty Space if ATT is at 1%, 5%, 10% or not even at 10% significant level different from zero, respectively.

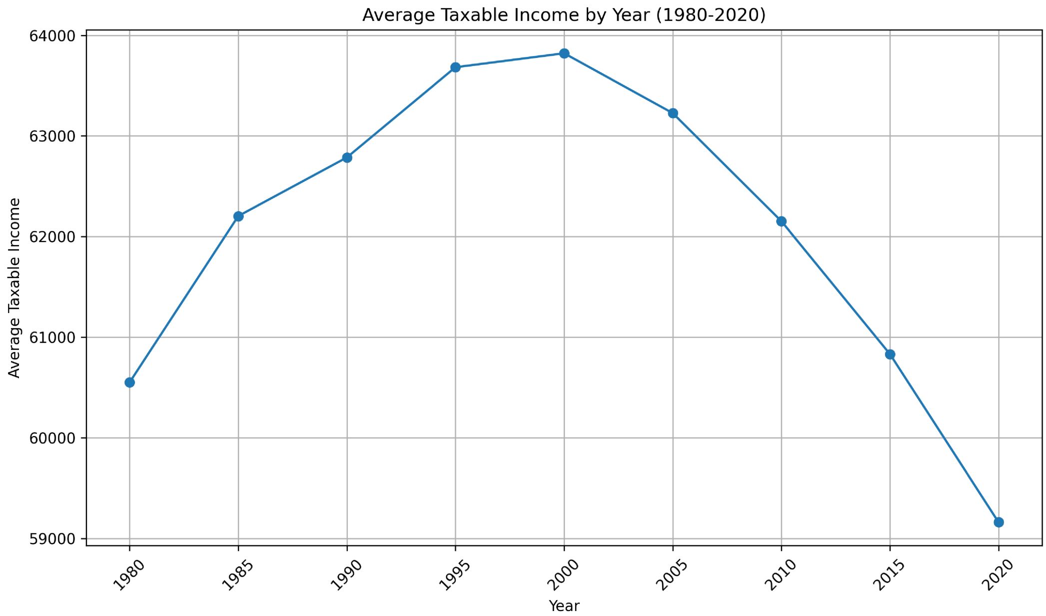
Analysis of the data prior to the operational start of the HSR indicates no significant population trend differences between the Treated and Control groups, confirming the satisfaction of First Assumption mentioned in Subsection 4.3.2. A notable exception is the significant positive value in Relative Time Zero ($k = 0$), the first record before treatment. This increase might be attributable to public anticipation of the new HSR construction, as discussed by Garrison & Levinson (2014), who noted that large infrastructure projects can temporarily boost local populations due to new employment opportunities even before they become operational.

For $k \geq 0$, a consistently increasing and significant impact of HSR construction on the total population of affected municipalities is observed. Interestingly, it is also observed that the effects continue to grow with time even more than 20 years after the introduction. However, as mentioned in the Section 4.3 section, the Total Population variable is converted to the natural logarithm and thus the resulting ATT needs to be correctly converted to a percentage ATT. Fro the treatment exceeding 20 years, the average ATT is approximately 0.167. This ATT corresponds to a 18.2% advantage of HSR-connected municipalities in comparison to non-connected, in the matter of population size.[1].

Despite initial indications of population increase due to HSR construction, broader demographic trends in Japan must be considered. The country has faced significant aging, a low birth rate, and overall population decline since the turn of the millennium. The following Figure 5.2 shows on the sample that Japan did indeed reach a population peak at the turn of the millennium, followed by a massive population decline.

[1]Percentage Treatment Effect = exp(ATT)-1

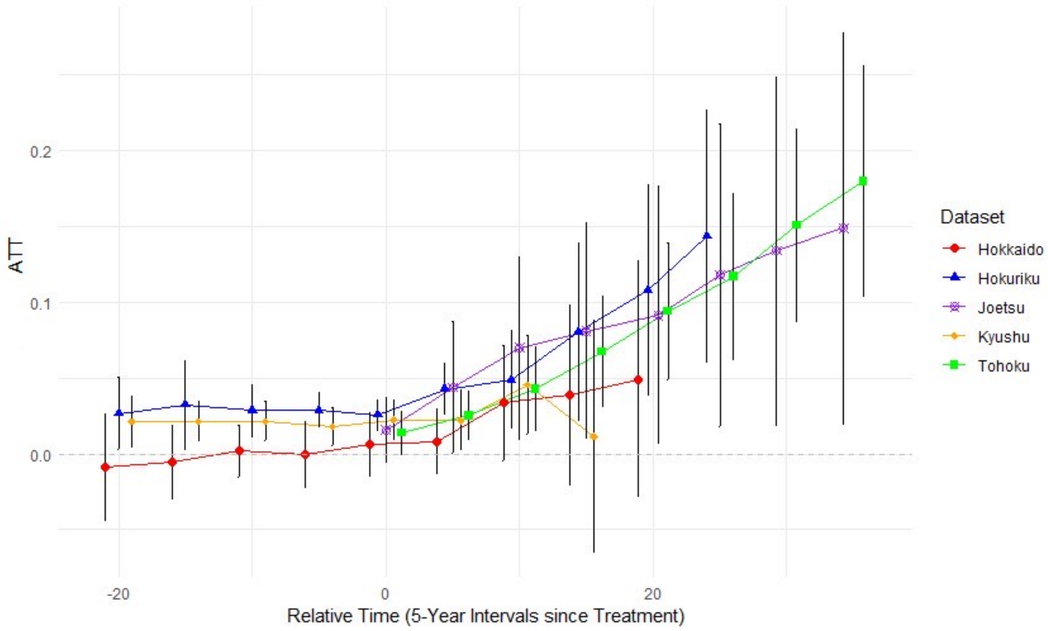
Figure 5.2: Average Total Population Development



The figure shows the development of the average population size of the municipalities included in the study. The x-axis shows the individual years of observations and the y-axis shows the average population of municipalities.

Combination of results visualized in Figure 5.2 and Figure 5.1 suggests that, notwithstanding the national trend of population decrease, HSR construction has had a predominately mitigating effect on population decline in affected municipalities. Furthermore, it may also be interesting to see whether this trend has been presented in all the lines mentioned or whether it is driven by only one of them. In the following Figure 5.3, it is possible to observe a similar chart as Figure 5.1, just showing the ATT on Total Population according to the line from which the data are obtained.

Figure 5.3: Overall ATT on log Total Population by Lines



The figure shows the distribution of ATT per log Total Population among the individual Shinkansen lines. Relative time since treatment on the x-axis, ATT is plotted on the y-axis. Whiskers extending from each point indicate 95% CI.

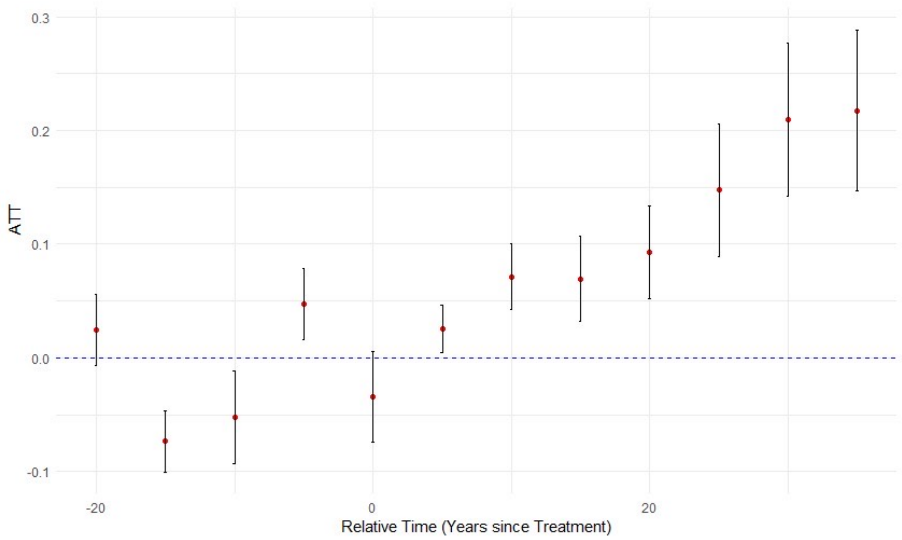
From Figure 5.3, it can be seen that almost all the individual records match. Only one record, and that is from 2020 for the part of the Kyushu line opened in 2004 (i.e. 15 years after treatment), shows a disturbance in the otherwise ubiquitous trend of gradually increasing ATT with increasing time since construction. Combining these observations with the exclusion of a substantial pre-treatment trend in the Treated group supports the findings of Wang *et al.* (2022), asserting that HSR construction significantly positively affects the overall population of affected municipalities.

Building upon the initial findings related to population growth, this section extends the analysis to other crucial economic indicators such as Total Taxable Income and Local Taxes, which are likely influenced by the demographic changes brought about by HSR construction.

5.1.2 Estimated ATT on Total Taxable Income

Figure 5.4 and 5.2 displays the ATT on Total Taxable Income (in logarithmic representation), revealing a trend similar to that observed with Total Population. However, unlike Total population variable, the pattern in relative time before the treatment shows greater variability, though it is still possible to discount any systematic pre-treatment trends.

Figure 5.4: Overall ATT on log Taxable Income



The graph shows the relative time with years from treatment on x-axis and the ATT value on Taxable Income on y-axis. The hatched horizontal line indicates an ATT value equal to zero as a comparison for the other values. Whiskers extending from each point indicate 95% CI.

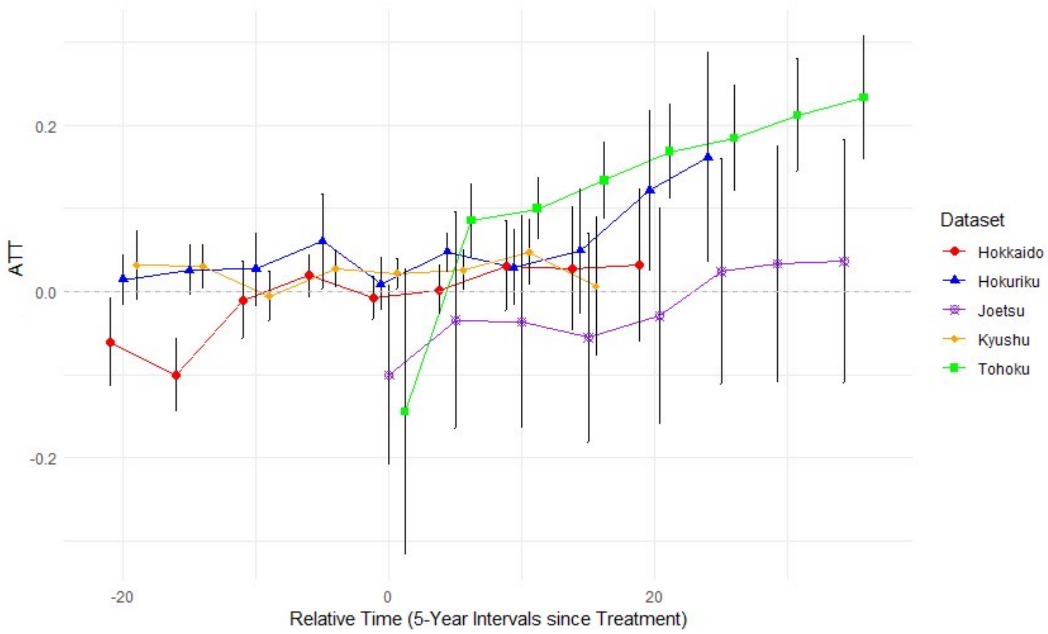
Table 5.2: Overall ATT on log Taxable Income

Relative Time	ATT	Std. Error	Significance
-20	0.024	0.023	
-15	-0.074	0.024	***
-10	-0.052	0.041	**
-5	0.047	0.031	***
0	-0.034	0.045	*
5	0.026	0.028	**
10	0.071	0.034	***
15	0.069	0.040	***
20	0.093	0.042	***
25	0.148	0.052	***
30	0.210	0.050	***
35	0.218	0.052	***

The table shows ATT in relative time since treatment along with the corresponding Standard Errors. The Significance column shows '***', '**', '*' or Empty Space if ATT is at 1%, 5%, 10% or not even at 10% significant level different from zero, respectively.

Notably, the ATT for periods exceeding 20 years post-treatment shows an increase, with ATT values taking up to 22% (also converted from logarithmic form). This suggests a substantial and lasting economic benefit from HSR construction. It might also reflect increased economic activity and production output levels within these municipalities. However, it is again important here to determine whether these conclusions are applicable to all of the regions of interest. The following Figure 5.5 again shows the distribution of total ATT on Taxable Income per each of the followed line.

Figure 5.5: Overall ATT on log Taxable Income by Lines



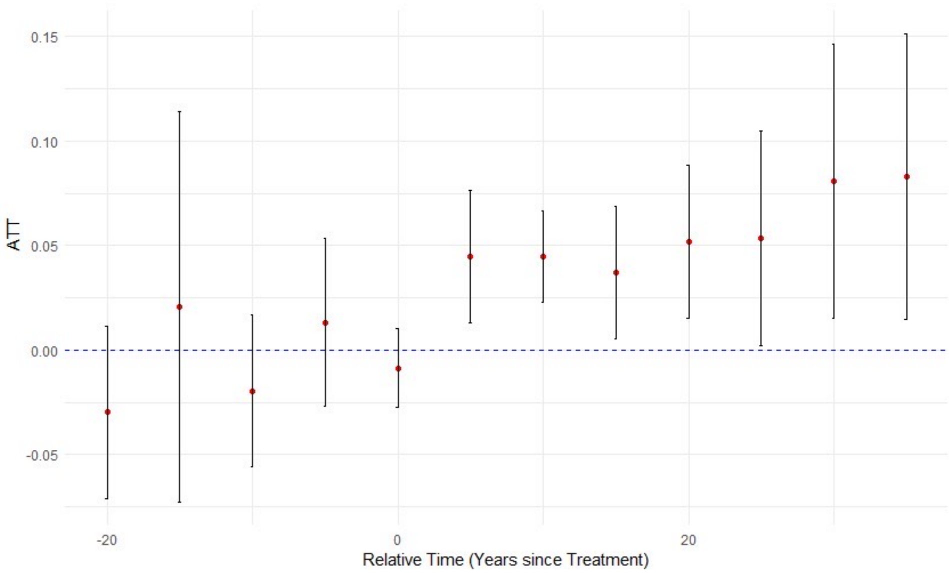
The figure shows the distribution of ATT per log Taxable Income among the individual Shinkansen lines. Relative time since treatment on the x-axis, ATT is plotted on the y-axis. Whiskers extending from each point indicate 95% CI.

From the Figure 5.5 it can be seen that, in the matter of Taxable Income, the distribution between the individual lines differs more substantially. Here, it appears that the positive and significant impact shown in Figure 5.4 is mostly driven by the results of the Tohoku and Hokuriku lines, respectively, but they also contain the largest sample of municipalities. While the Joetsu line, for example, shows rather negative and insignificant results.

5.1.3 Estimated ATT on Local Taxes

Following the trends in taxable income, Figure 5.6 and Table 5.3 explores the ATT on Local Taxes. The outcomes here align closely with those of previous research, indicating no pre-trends and a significantly positive ATT across various post-treatment periods.

Figure 5.6: Overal ATT on log Local Taxes



The graph shows the relative time in years from treatment on x-axis and the ATT value on Local Taxes on y-axis. The hatched horizontal line indicates an ATT value equal to zero as a comparison for the other values. Whiskers extending from each point indicate 95% CI.

Table 5.3: Overall ATT on log Local Taxes

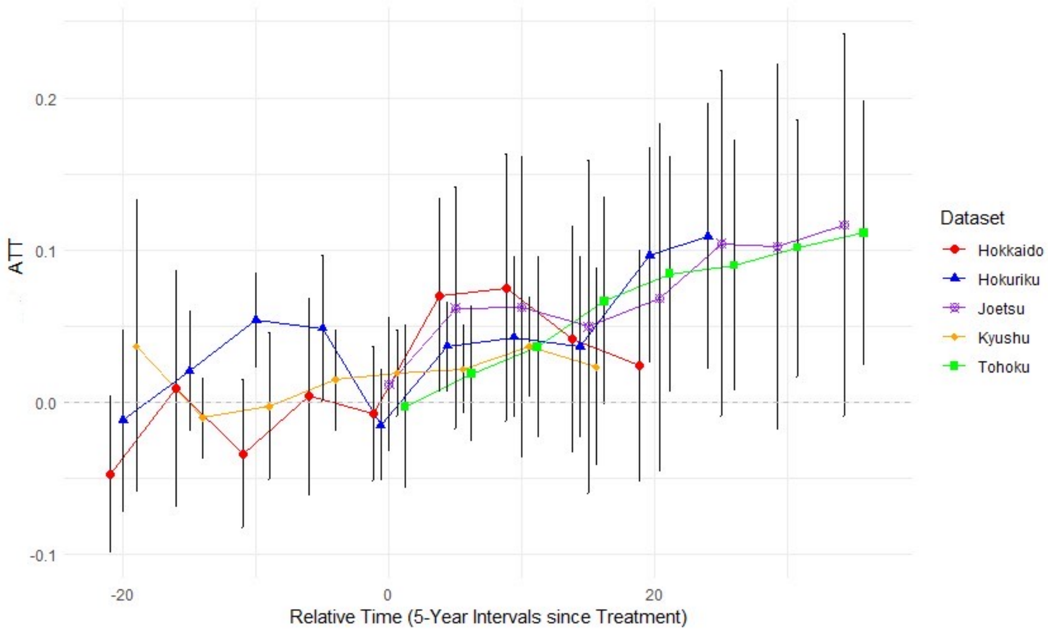
Relative Time	ATT	Std. Error	Significance
-20	-0.030	0.028	
-15	0.021	0.082	
-10	-0.020	0.036	
-5	0.013	0.039	
0	-0.009	0.021	
5	0.045	0.042	***
10	0.045	0.025	***
15	0.037	0.032	**
20	0.052	0.035	***
25	0.054	0.043	**
30	0.081	0.044	**
35	0.083	0.047	**

The table shows ATT in relative time since treatment along with the corresponding Standard Errors. The Significance column shows '***', '**', '*' or Empty Space if ATT is at 1%, 5%, 10% or not even at 10% significant level different from zero, respectively.

It can be observed, that while the magnitude of the ATT for Local Taxes does not reach the levels observed for Taxable Income, the consistent positive impact underscores the enhanced fiscal capacity of municipalities due to HSR construction.

As in the previous sections, it may be further interesting to look at the distribution of ATT among the observed lines. Figure 5.7 shows a similar distribution to that seen for Total Population, confirming the slightly positive trend of increasing ATT with increasing time since treatment, in majority of observations and lines.

Figure 5.7: ATT on Local Taxes by Lines

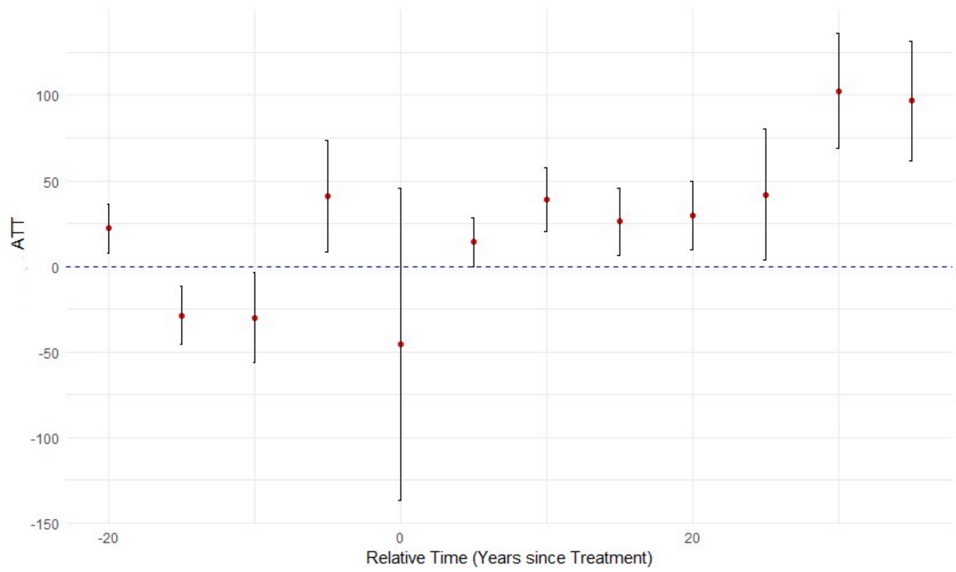


The figure shows the distribution of ATT per log Local Taxes among the individual Shinkansen lines. Relative time since treatment on the x-axis, ATT is plotted on the y-axis. Whiskers extending from each point indicate 95% CI.

5.1.4 Estimated ATT on Income Per Capita

The analysis of Income per Capita, as shown in Figure 5.8 and Table 5.4, provides insights into the average economic benefit per resident.

Figure 5.8: ATT on Income per Capita



The graph shows the relative time in years from treatment on x-axis and the ATT value on Income per Capita on y-axis. The hatched horizontal line indicates an ATT value equal to zero as a comparison for the other values. Whiskers extending from each point indicate 95% CI.

Table 5.4: Overall ATT on Income per Capita

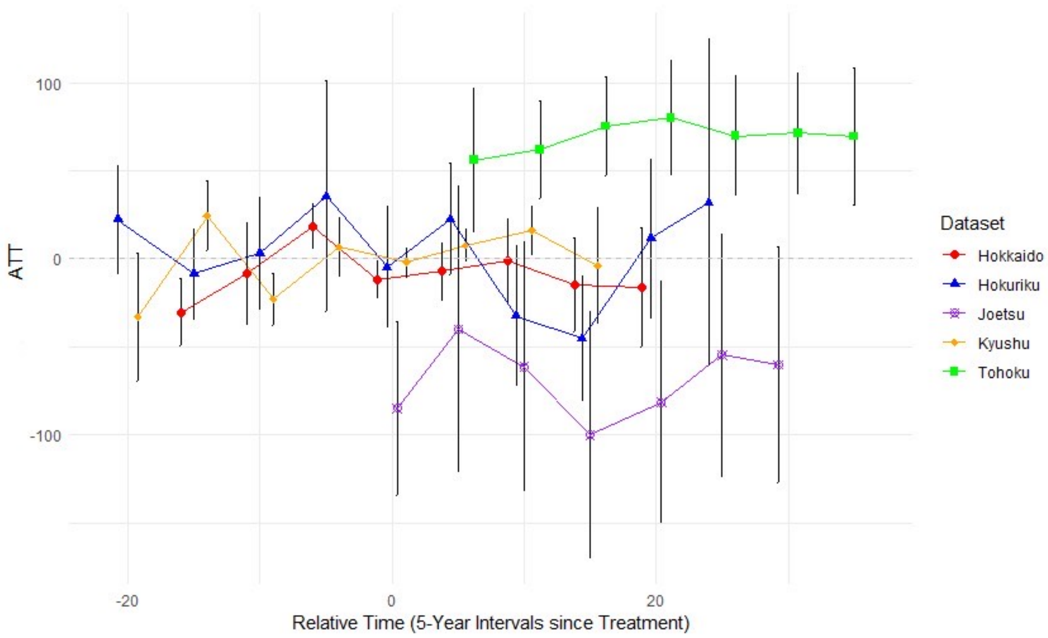
Relative Time	ATT	Std. Error	Significance
-20	22.192	9.985	***
-15	-28.682	14.640	***
-10	-30.085	26.439	**
-5	41.227	32.734	**
0	-45.455	103.025	
5	14.063	17.320	**
10	39.028	20.560	***
15	26.065	19.585	***
20	29.828	19.798	***
25	41.837	32.880	**
30	102.469	22.224	***
35	96.655	23.995	***

The table shows ATT in relative time since treatment along with the corresponding Standard Errors. The Significance column shows '***', '**', '*' or Empty Space if ATT is at 1%, 5%, 10% or not even at 10% significant level different from zero, respectively.

Unlike the more straightforward results previously seen with other variables, Income per Capita exhibits less stability and more nuanced responses post-treatment. While no significant pre-trend is evident, several periods post-treatment show a significant rise in Income per Capita, particularly in municipalities connected to the HSR network for over 25 years.

This observation also supports the hypothesis that long-term connections to the HSR network bring at average substantial economic benefits to residents. However, looking at the distribution of ATT among the individual lines, it can be seen that this is not the same phenomenon as seen in the case of the Total Population. Figure 5.9 shows that the trend described in Figure 5.8 is again clearly driven by the results from the Tohoku line, while the results from the Joetsu line show the nearly opposite (however with larger standard deviations).

Figure 5.9: ATT on Taxable Income per Capita by Lines



The figure shows the distribution of ATT per Income per Capita among the individual Shinkansen lines. Relative time since treatment on the x-axis, ATT is plotted on the y-axis. Whiskers extending from each point indicate 95% CI.

5.1.5 Estimated ATT on Employment and Unemployment Rates

Further insights into the effects of HSR construction on job market are gleaned by analyzing changes in employment and unemployment rates. Contrary to expectations, the results showed in Figure 5.10, 5.11 and Table 5.6, 5.5 for these variables suggest counter intuitive outcomes:

Figure 5.10: Overall ATT on Unemployment Rate

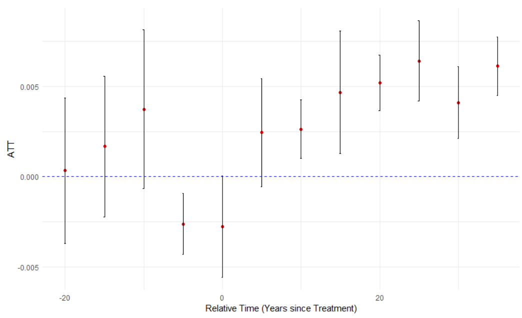
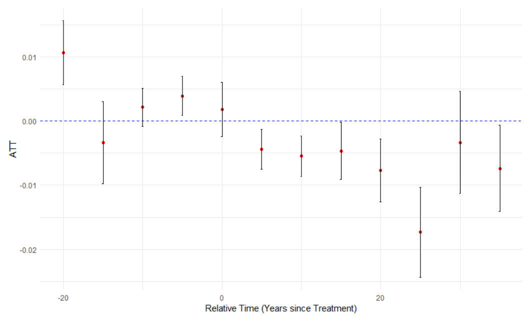


Figure 5.11: Overall ATT on Employment Rate



The Figure 5.10 and 5.11 show the relative time in years from treatment on x-axis and the ATT value on Unemployment and Employment rates on y-axis. The hatched horizontal line indicates an ATT value equal to zero as a comparison for the other values. Whiskers extending from each point indicate 95% CI.

Table 5.5: Overall ATT on Unemployment Rate

Relative Time	ATT	Std. Error	Significance
-20	0.000	0.003	
-15	0.002	0.003	
-10	0.004	0.004	*
-5	-0.003	0.002	***
0	-0.003	0.003	*
5	0.002	0.004	
10	0.003	0.002	***
15	0.005	0.004	***
20	0.005	0.002	***
25	0.006	0.002	***
30	0.004	0.001	***
35	0.006	0.001	***

The table shows ATT in relative time since treatment along with the corresponding Standard Errors. The Significance column shows '***', '**', '*' or Empty Space if ATT is at 1%, 5%, 10% or not even at 10% significant level different from zero, respectively.

Table 5.6: Overall ATT on Employment Rate

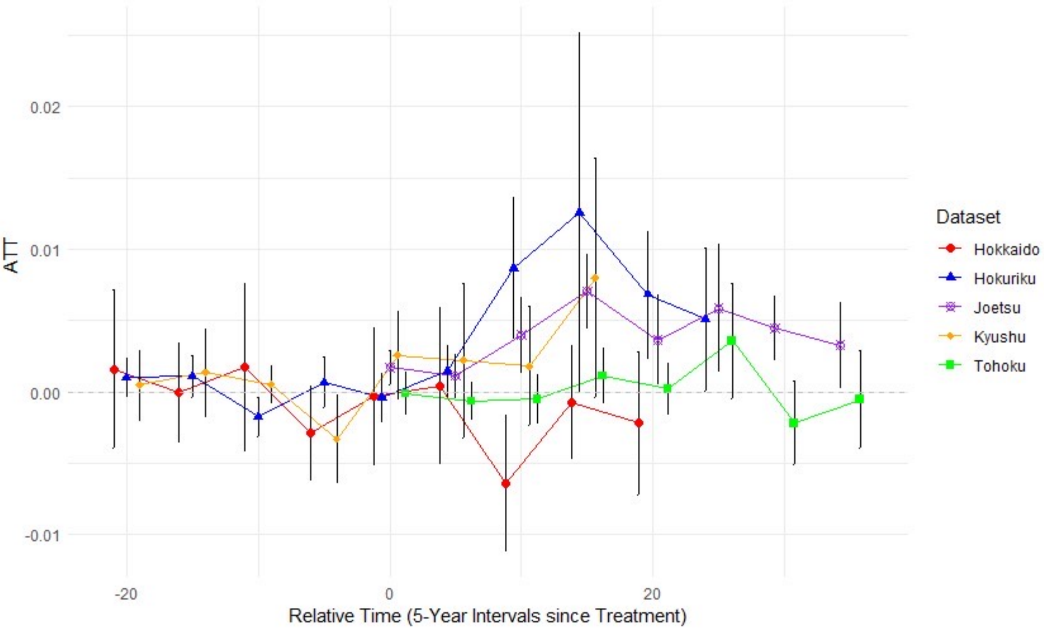
Relative Time	ATT	Std. Error	Significance
-20	0.011	0.004	***
-15	-0.003	0.006	
-10	0.002	0.003	
-5	0.004	0.003	***
0	0.002	0.005	
5	-0.004	0.004	***
10	-0.005	0.004	***
15	-0.005	0.004	**
20	-0.008	0.005	***
25	-0.017	0.006	***
30	-0.003	0.006	
35	-0.007	0.005	**

The table shows ATT in relative time since treatment along with the corresponding Standard Errors. The Significance column shows '***', '**', '*' or Empty Space if ATT is at 1%, 5%, 10% or not even at 10% significant level different from zero, respectively.

Surprisingly, the construction of the Shinkansen HSR appears to correlate with an initial increase in unemployment and a decrease in the proportion of actively working within the total population. These unexpected results, featuring high standard errors yet significant ATTs for most periods post-construction, challenge the conventional understanding that infrastructure development unequivocally boosts local employment.

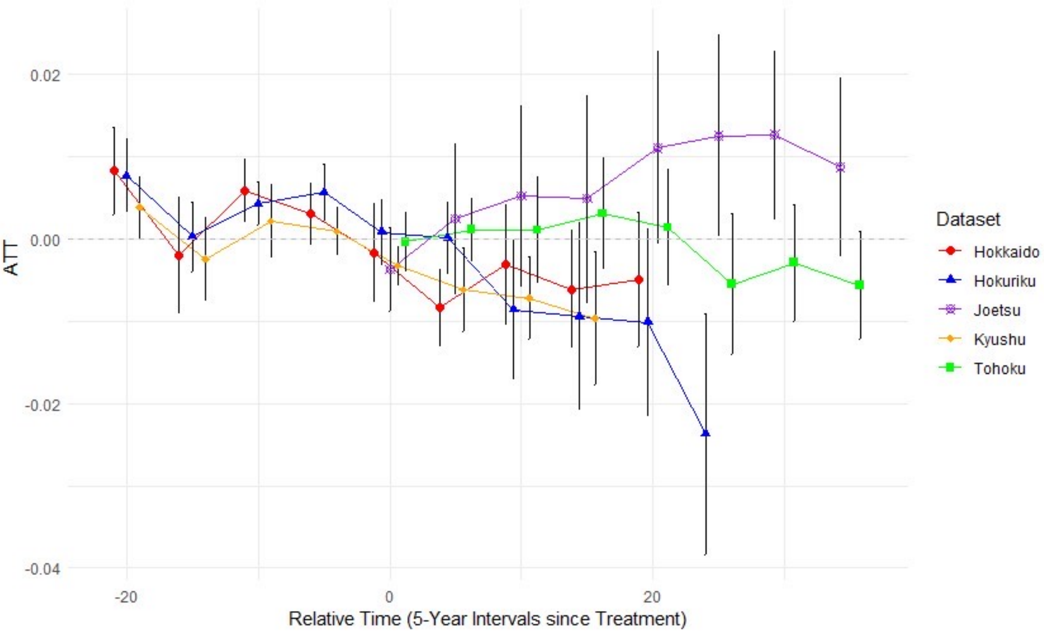
From the Figure 5.12 and Figure 5.13, showing the distribution of ATT for employment and unemployment, into various lines, it can be seen that even in this case the variables did not behave very similarly between the lines. This fact is most noticeable in the Employment variable, where ATT for the Hokuriku and Joetsu lines are diametrically opposed.

Figure 5.12: ATT on Unemployment by Lines



The figure shows the distribution of ATT per Unemployment rate among the individual Shinkansen lines. Relative time since treatment on the x-axis, ATT is plotted on the y-axis. Whiskers extending from each point indicate 95% CI.

Figure 5.13: ATT on Employment by Lines



The figure shows the distribution of ATT per Employment rate among the individual Shinkansen lines. Relative time since treatment on the x-axis, ATT is plotted on the y-axis. Whiskers extending from each point indicate 95% CI.

5.1.6 Implications and Conclusions

These varied findings illustrate a complex picture of the impacts of HSR construction. Although it was possible to observe clear positive impacts of HSR construction on the Total Population size, the amount of Taxable Income generated or the increase in Local Taxes collected, it was also possible to observe that HSR construction had a significantly negative impact on employment in the affected regions. These aspects warrant further investigation, possibly comparing similar phenomena in other countries with lately introduced HSR networks. Overall, while it is clear that HSR construction has mostly positive economic impacts, the nuanced results, especially concerning employment, highlight the need for a careful and comprehensive evaluation of such large-scale infrastructure projects.

However, what was the most important insight gain from these results is that Hypotheses 4 can be confirmed and it can be concluded that the HSR construction indeed has positive and significant impact on affected municipalities. This analysis not only challenges but also enriches existing knowledge by ensuring existence of positive HSR impact on municipalities affected by its construction and following commissioning.

5.2 Factors Influencing the Impact of HSR Construction

As stated in the thesis proposal and reflected in the title of this work, one of the main goals of this thesis is to explore the factors associated with varying levels of HSR construction impact. This section specifically addresses Hypotheses 2, 3 and 4, stated in Section 4.1, by applying the Staggered DiD methodology to different economic and demographic sub-samples identified in the Section 4.2.

5.2.1 Economics Orientation and Its Influence

To be able to test Hypothesis 2, the same methodology already used in Section 5.1 to two different Service/ Industry sub-samples is used. By comparing the estimated ATT between these groups, it is possible to determine whether the magnitude of the impact of HSR construction is related to the orientation of the municipality's economy.

Results of the analysis, depicted on Figure 5.14 to Figure 5.19, reveals that the Service group generally exhibits a higher ATT across most indicators compared to the Industry group. However, predominately overlapping CI indicate that these differences are not significant enough to confirm a distinct impact based on economic orientation.

The only significant difference between these groups is estimated in variables Unemployment rate and Employment rate. However, interpretation of these results is quite problematic, as there is no obvious reason why any of these groups should record higher unemployment as an impact of HSR construction.

Interpretation and Hypothesis Evaluation

Despite observing higher ATT values for the Service group, the absence of statistically significant differences leads us to reject Hypothesis 2, which posited that economic orientation significantly affects the impact of HSR construction. This outcome suggests that while HSR construction can facilitate and support certain sectors of economy, its effect is not sufficiently pronounced to differentiate the impacts of HSR construction on municipalities of different orientation of their economy, under the conditions and metrics analyzed in this study.

Figure 5.14: ATT on log Total Population by Economy Orientation

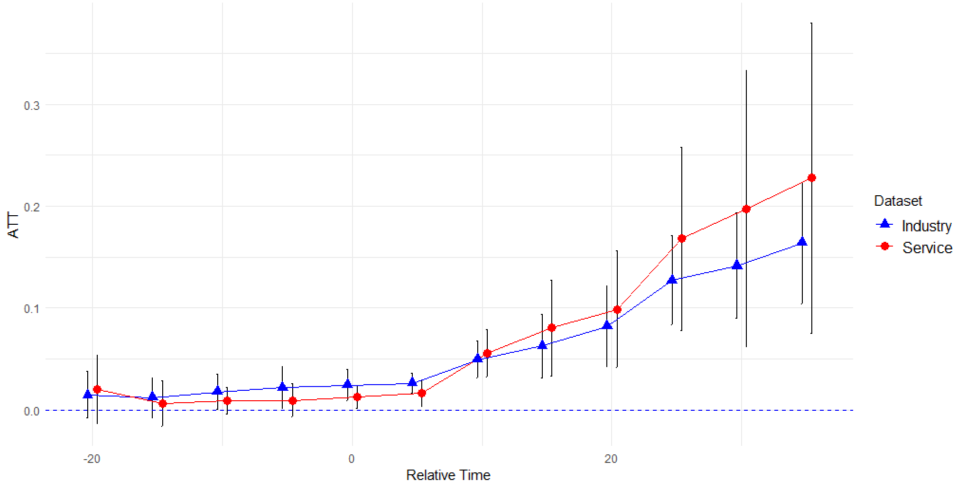


Figure 5.15: ATT on log Taxable Income by Economy Orientation

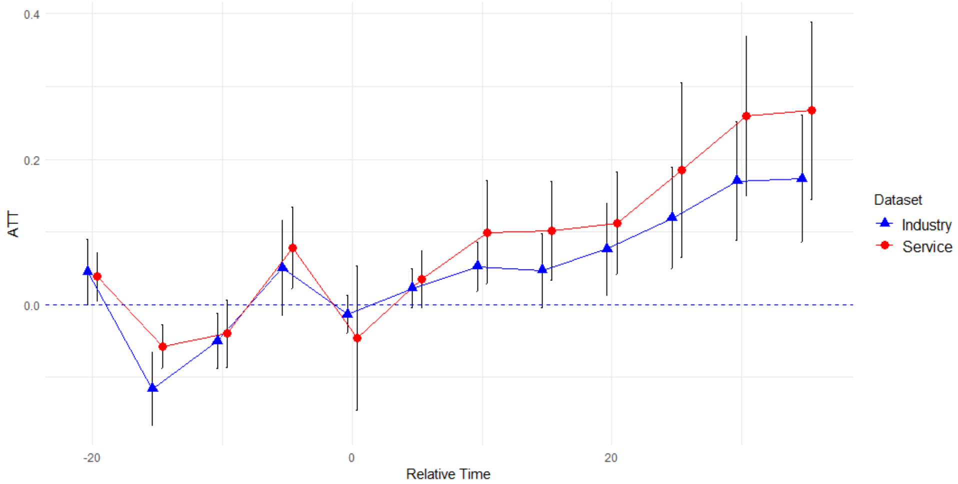
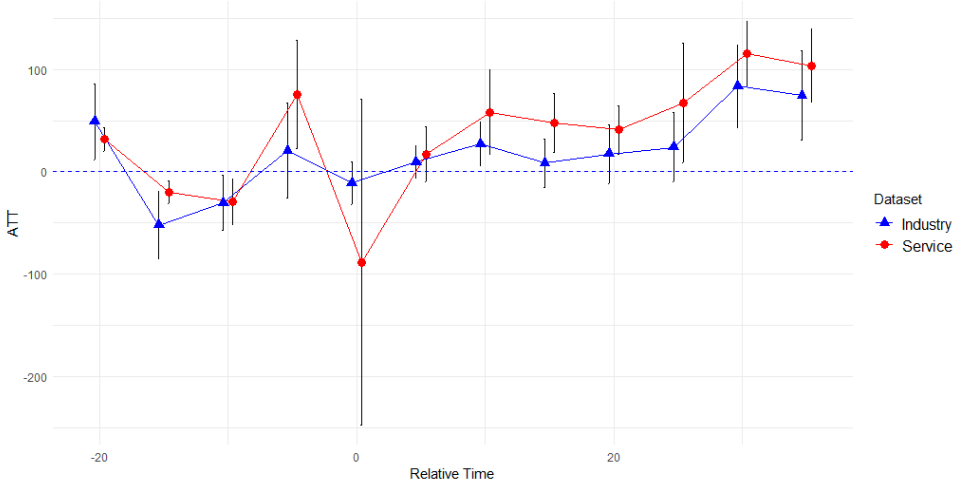


Figure 5.16: ATT on Income per Capita by Economy Orientation



The Figure 5.14, 5.15 and 5.15 shows the ATT on y-axes, the relative time since treatment on the x-axes, for sub-samples Service and Industry. Whiskers extending from each point indicate 95% CI.

Figure 5.17: ATT on log Total Population by Economy Orientation

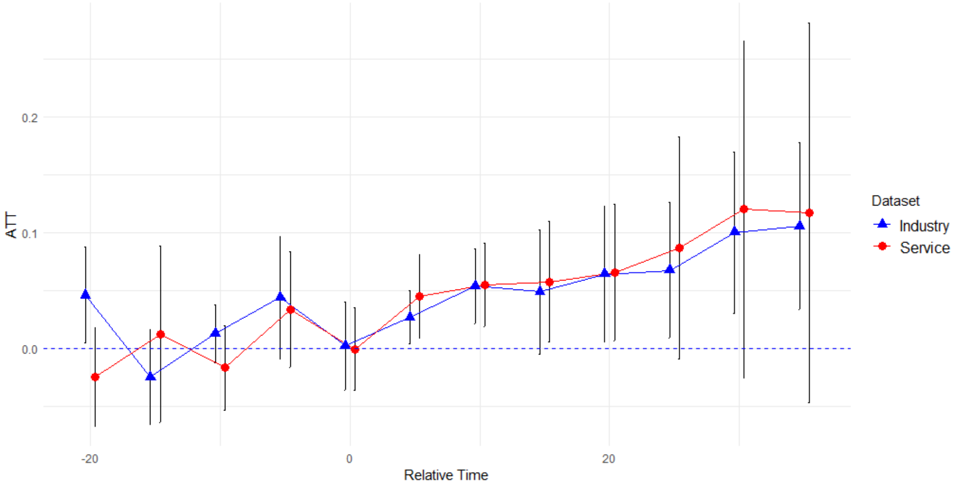


Figure 5.18: ATT on log Taxable income by Economy Orientation

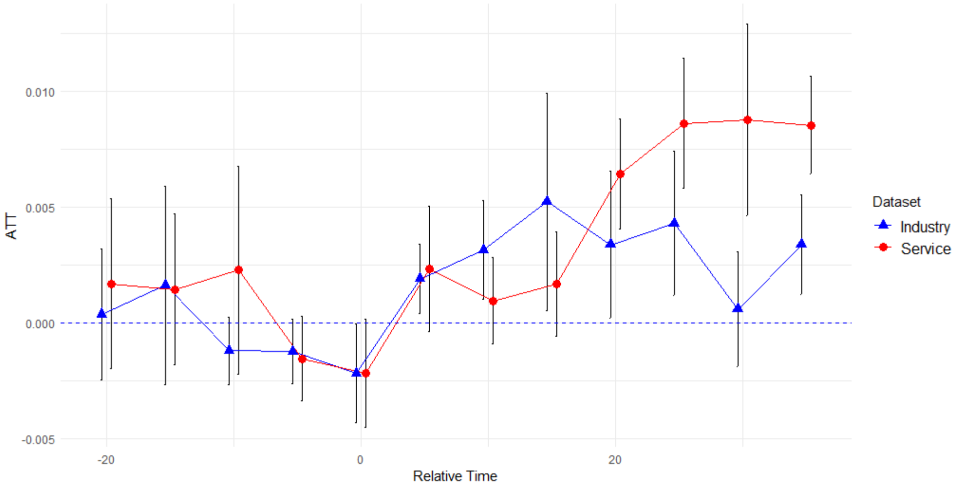
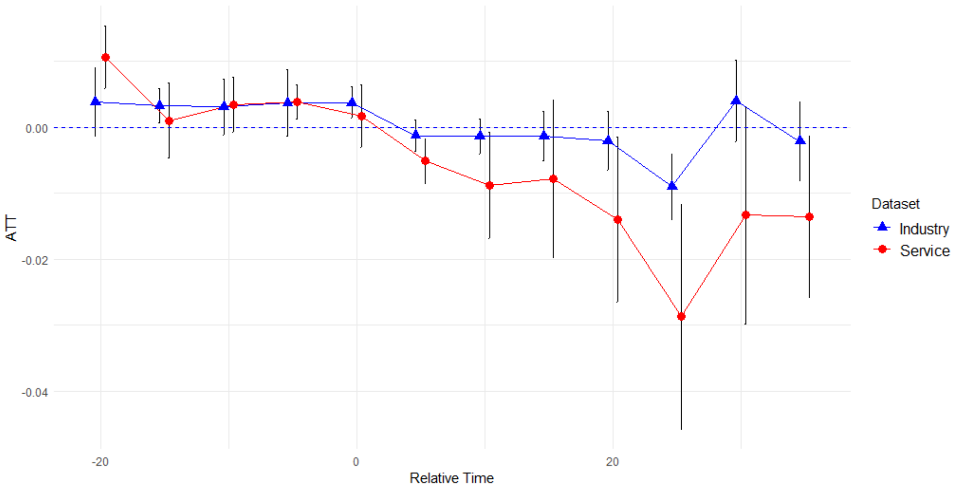


Figure 5.19: ATT on Income per Capita by Economy Orientation



The Figure 5.17, 5.18 and 5.19 shows the ATT on y-axes, the relative time since treatment on the x-axes, for sub-samples Service and Industry. Whiskers extending from each point indicate 95% CI.

5.2.2 Income per Capita and Its Influence

In exploring the varying impacts of HSR construction across different economic groups within municipalities, this section delves into Hypothesis 3. This hypothesis suggests that richer municipalities with higher average incomes might experience more pronounced benefits from HSR developments. it is possible to assess this by comparing the HSR construction impact on key variables between sub-samples classified as "Rich" and "Poor" (The process of this division was described in Section 4.2).

From the results depicted in Figure 5.20, 5.21, 5.22, 5.24 and 5.25, it is possible to see that the two groups were not significantly different from each other. The only exception is Figure 5.23, which shows truly remarkable results. The Figure 5.23 demonstrate that while there are no substantial differences within the sub-samples, in the matter of tax collection, the post-treatment effects vary significantly between the rich and poor municipalities. The Richer municipalities do not show a significant difference in the growth rate of Local Taxes compared to Poorer municipalities, which see a substantial increase.

Interpretation and Hypothesis Evaluation

Despite the initial expectations, the data does not conclusively show that wealthier municipalities benefit more significantly from HSR construction. Thus, Hypothesis 3, which posited that municipalities with higher incomes would experience stronger positive impacts from HSR construction, cannot be confirmed based on the current analysis. This result underscores the complexity of infrastructural impacts and suggests that factors other than mere economic wealth might play crucial roles in determining the benefits derived from major projects like HSR.

In conclusion, while HSR construction appears to offer broad economic benefits, its impact does not disproportionately favor wealthier municipalities as initially hypothesized. This finding also reveals a completely unexpected finding regarding tax collections that would require further detailed analysis, which is beyond the scope of this paper.

Figure 5.20: ATT on log Total Population by Income Level

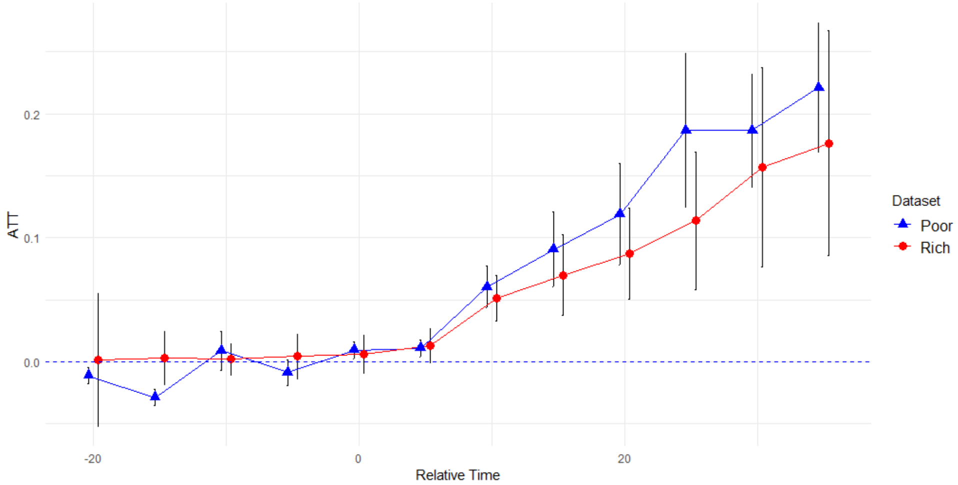


Figure 5.21: ATT on log Taxable income by Income Level

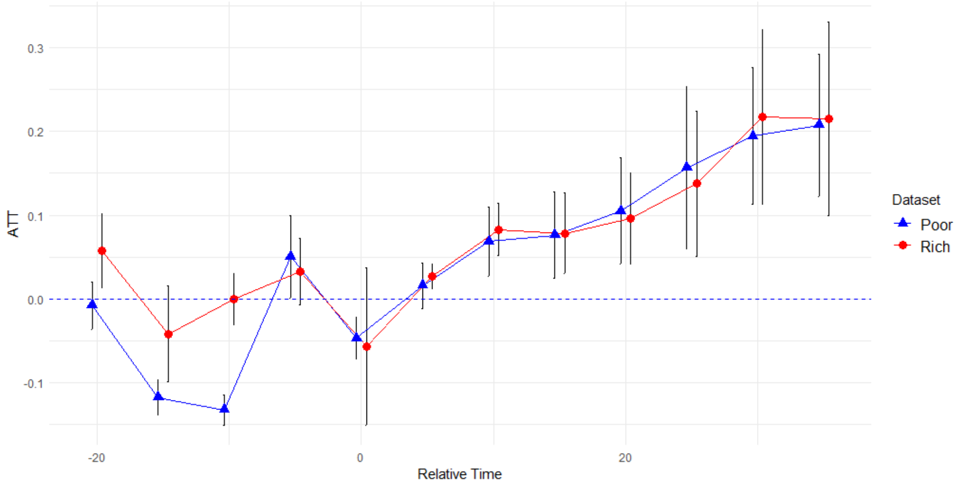
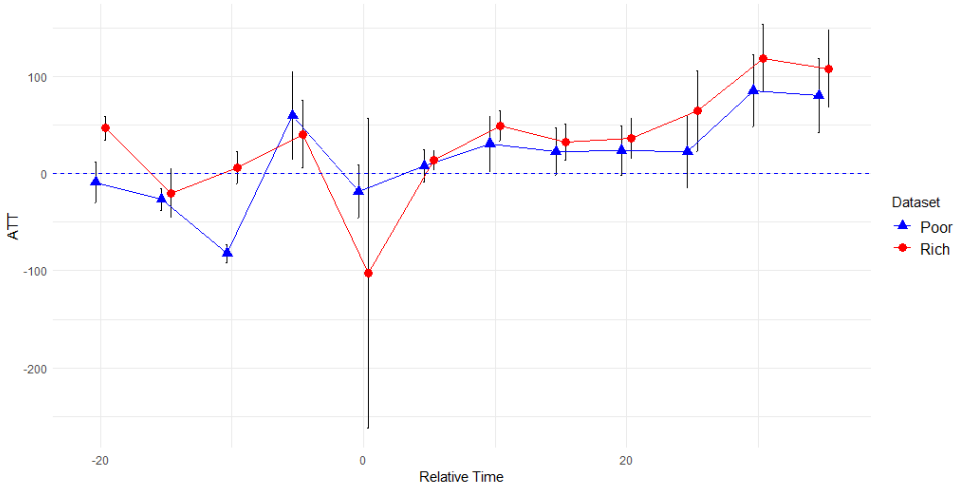


Figure 5.22: ATT on Income per Capita by Income Level



The Figure 5.20, 5.21 and 5.22 shows the ATT on y-axes, the relative time since treatment on the x-axes, for sub-samples Rich and Poor. Whiskers extending from each point indicate 95% CI.

Figure 5.23: ATT on log Local Taxes by Income Level

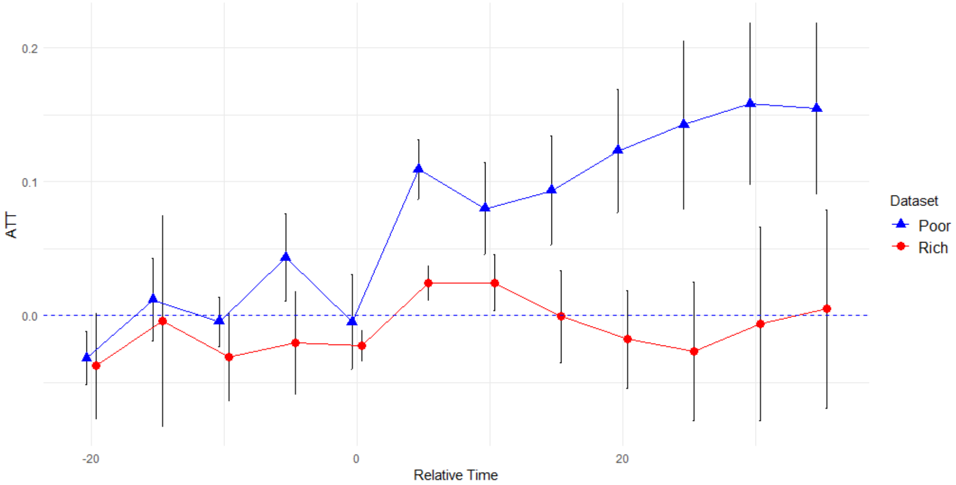


Figure 5.24: ATT on Unemployment Rate by Income Level

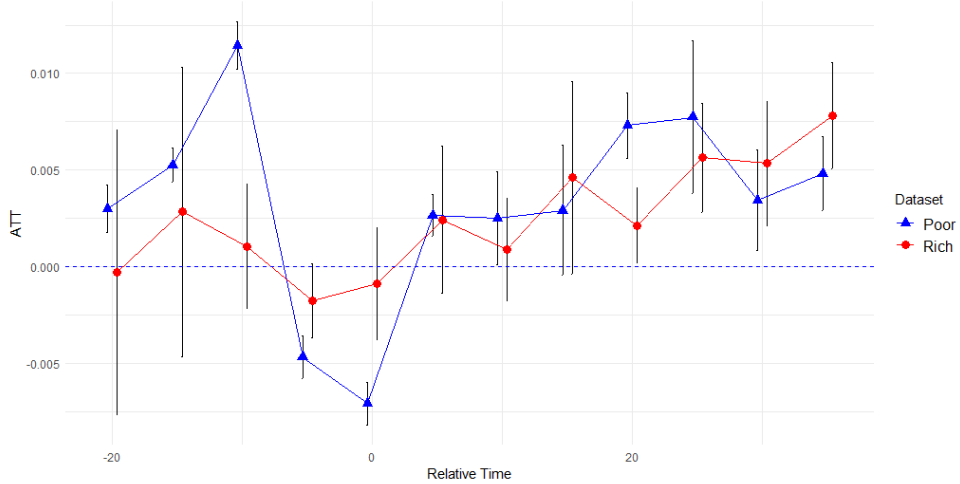
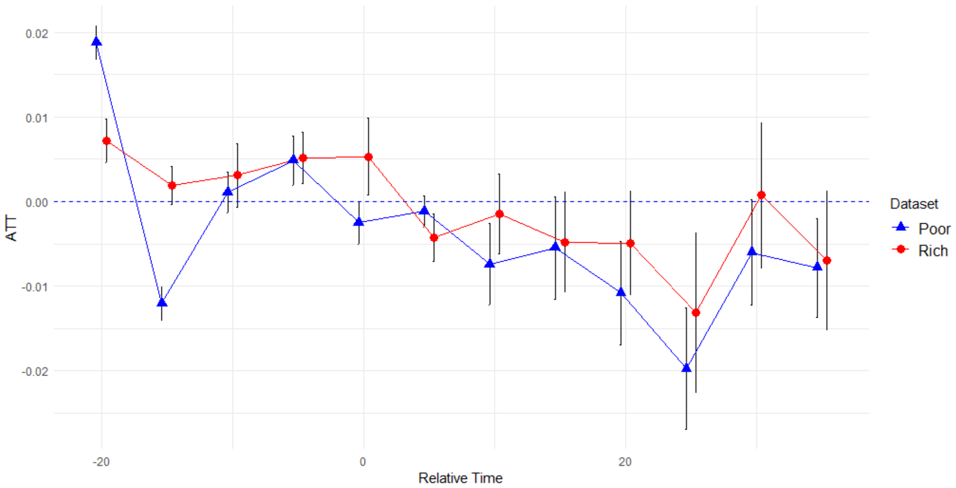


Figure 5.25: ATT on Employment Rate by Income Level



The Figure 5.23, 5.24 and 5.25 shows the ATT on y-axes, the relative time since treatment on the x-axes, for sub-samples Rich and Poor. Whiskers extending from each point indicate 95% CI.

5.2.3 Municipality Size and Its Influence

In this section, the ATT for key variables is estimated to evaluate the hypothesis that the population size have direct effect on magnitude of HSR construction impact.

Based on the findings depicted on Figure 5.26 to Figure 5.31, it can be seen that while both Large and Small municipalities show a gradual increase in ATT for Total Population and Taxable Income over time, the differences between them are minimal and statistically insignificant. However, the analysis of Income Per Capita, depicted on Figure 5.28, unveils significant and noteworthy trends. Within five years post-treatment, a pronounced increase in Income Per Capita is observed in larger municipalities compared to their smaller counterparts. This divergence grows over time, reaching substantial levels of significance by the 25-year mark post-treatment.

It is also worth noting that although this is the case in most countries around the world, in the sample it is not necessarily true that the more populous and larger municipalities are also the richer ones. If the Figure 5.29 and Figure 5.23 are compared, it can be seen that although there is a significant difference in response to HSR construction between the Rich and Poor groups, in context of Local Taxes variable, nothing similar can be observed for the Large and Small groups. It is possible, therefore, to conclude that the Large/ Rich and Small/Poor samples are indeed significantly different from each other.

5.2.4 Implications and Conclusions

The notable rise in per capita income for larger municipalities may be ascribed to the 'Siphon effect', as suggested by Wang *et al.* (2018). This concept posits that bigger cities, with their advanced infrastructure and connectivity, tend to attract companies that provide high-value employment opportunities. Consequently, these cities can tap into a wider commuting labor force from the nearby smaller municipalities and expanding their per capita income.

Based on these comprehensive analyses, it is possible to confirm Hypothesis 4: larger municipalities indeed benefit more from HSR connectivity compared to their smaller counterparts. This conclusion not only supports the hypothesis but also highlights the role of urban scale in maximizing the benefits of major infrastructural investments like HSR.

Figure 5.26: ATT on log Total Population by Muni. Population Size

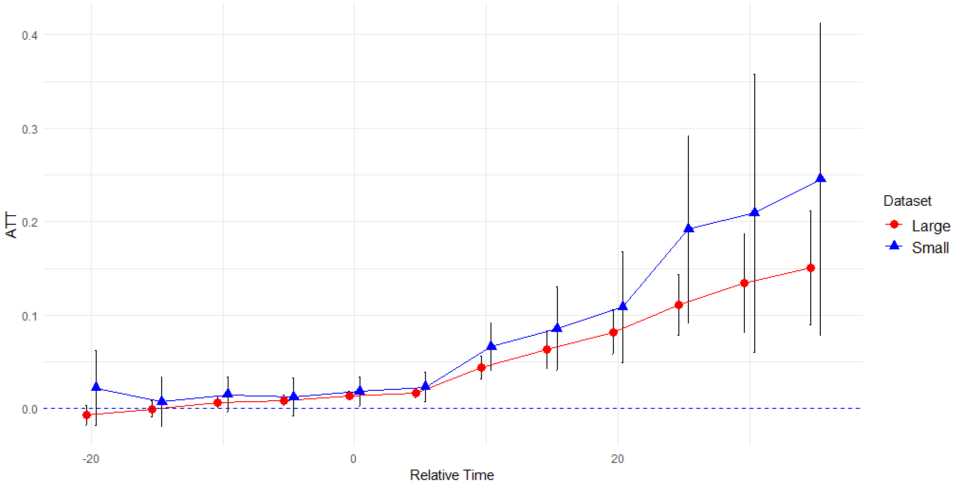


Figure 5.27: ATT on log Taxable income by Muni. Population Size

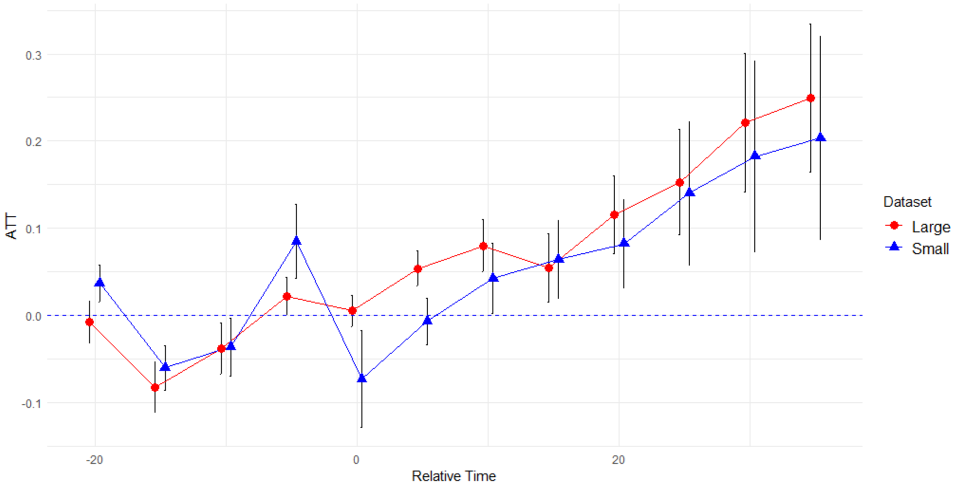
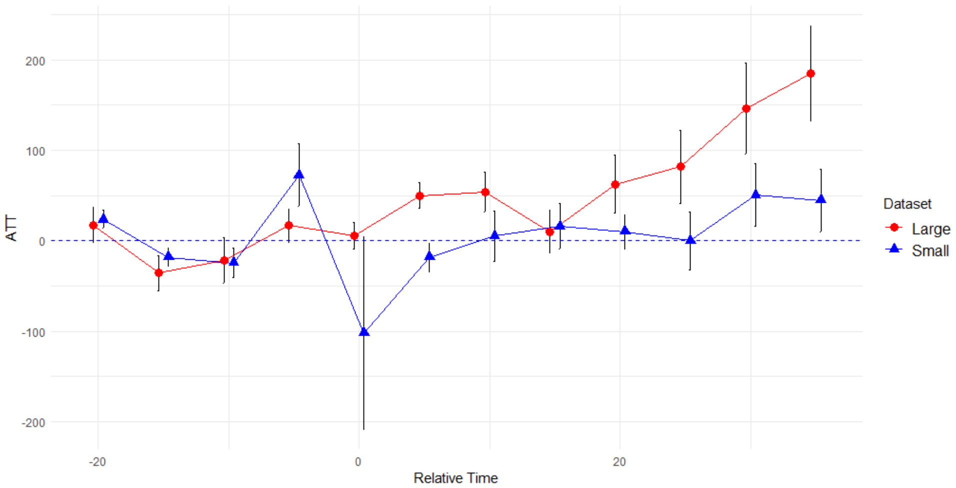


Figure 5.28: ATT on Income per Capita by Muni. Population Size



The Figure 5.26, 5.27 and 5.27 shows the ATT on y-axes, the relative time since treatment on the x-axes, for sub-samples Large and Small. Whiskers extending from each point indicate 95% CI.

Figure 5.29: ATT on log Local Taxes by Muni. Population Size

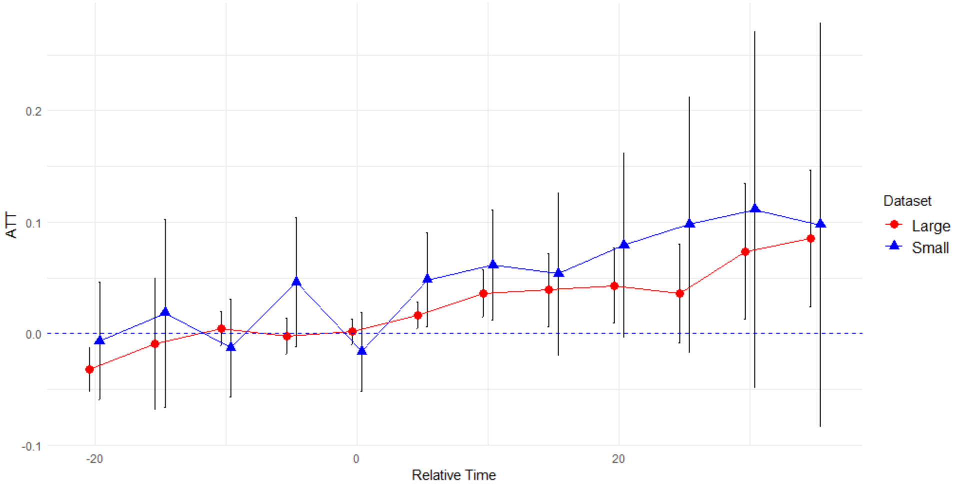


Figure 5.30: ATT on Unemployment Rate by Muni. Population Size

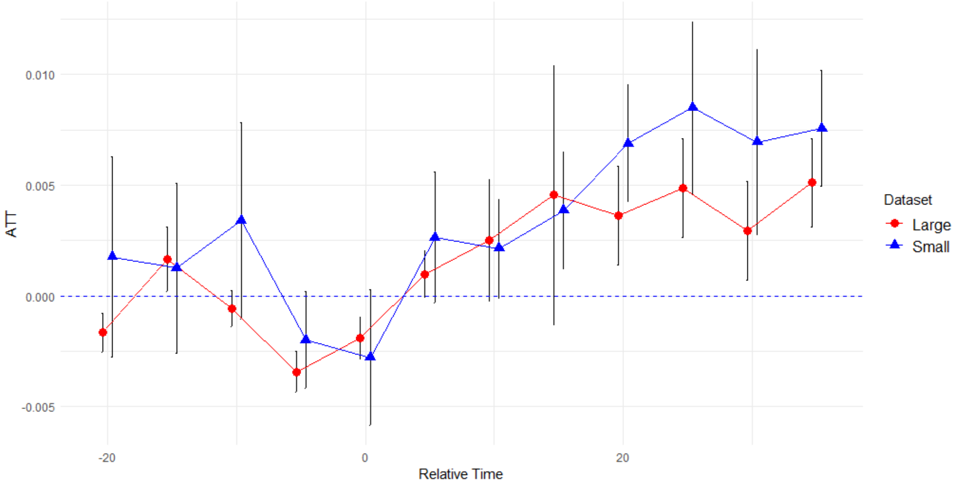
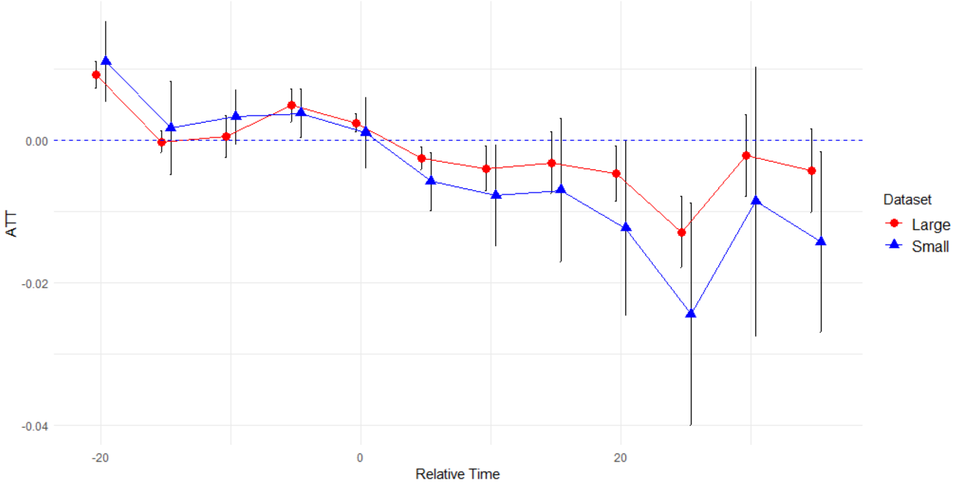


Figure 5.31: ATT on Employment Rate by Muni. Population Size



The Figure 5.29, 5.30 and 5.31 shows the ATT on y-axes, the relative time since treatment on the x-axes, for sub-samples Large and Small. Whiskers extending from each point indicate 95% CI.

5.3 Robustness Checks

Once the tests of this analysis were performed and the results were obtained, it is convenient to perform robustness checks and decide whether the methods used are robust and can be relied upon. Thus, the same methods as used in the previous Section 5.1 and 5.2 were performed on 3 different sets of samples described in the Chapter 4.

5.3.1 No Chen & de Abreu E (2013) Assumption

The absence of assumption used by Chen & de Abreu E (2013) meant to not exclude approximately the 100 smallest municipalities (in the vast majority, villages with a few hundred inhabitants) from the Control group. From the series of tests performed on the new Control group, the absence of Chen & de Abreu E (2013) assumption proved significant only for the variables Total Population and Taxable Income.[2]. In the following Figure 5.32 and Figure A.7 the results for the new Control group can be seen and the ATT appears even stronger.

Such a result is quite expected. Ever since the beginning of the JEM, described in Chapter 2, Japan has experienced a trend of urbanization. When combined with the decline in total population and the trend described above (i.e., smaller cities experiencing a greater population decline than larger cities), one would expect the addition of the smallest municipalities to the Control Group to bring about such a change.

Another interesting indicator can be observed in the following Figure 5.34. It can be seen that same as ATT for the Total Population and Taxable Income variables changed significantly and substantially with this new Control group, there was also significant increase in the ATT measured in the context of tax collection. This reaction can also be explained since the efficiency of tax collection in these smallest municipalities is not expected to reach such a level as in the larger developed cities. Therefore, such a shift can be quite expected.

However, for the sake of robustness of the model, it is important to note that although there was a change in ATT for some of the variables of interest, it occurred in the expected direction or the difference is not significant and does not affect the significance of the results. Thus, it can be concluded that this procedure rather served as a reassurance about the robustness of the test.

[2]Therefore, only Figures expressing the results of interest are depicted within the paper. The rest can be found in the Appendix

Figure 5.32: ATT on log Total Population - New Control Group

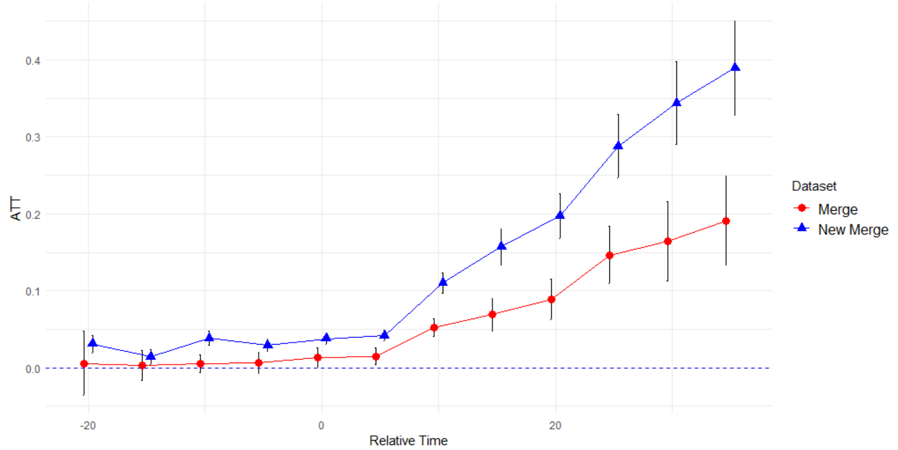


Figure 5.33: ATT on log Taxable Income - New Control Group

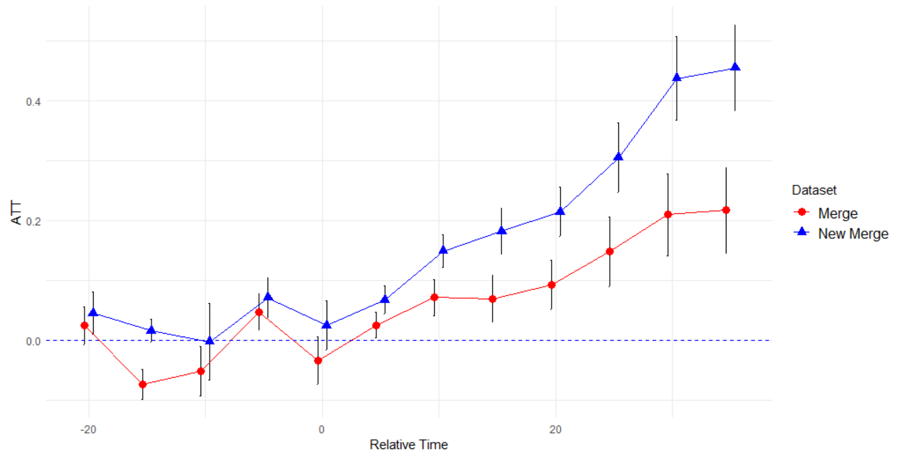
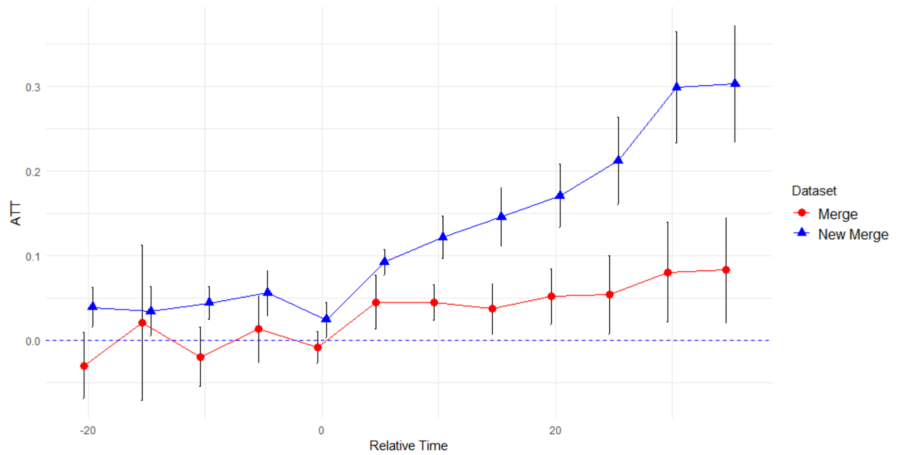


Figure 5.34: ATT on log Local Taxes - New Control Group



The Figure 5.32, A.7 and 5.34 shows the ATT on y-axes, the relative time since treatment on the x-axes, for original Merge sample and new Merge obtained by not applying Chen & de Abreu E (2013) Assumption. Whiskers extending from each point indicate 95% CI.

5.3.2 Control Group from Different Prefectures

In this case, where a Control Group from municipalities from completely different prefectures were assembled, the findings were very comparable to almost identical to those described in the previous chapter. Out of the 47 prefectures that Japan has, only 15 prefectures are not crossed by one of the lines of the Shinkansen network. These prefectures are often separated from the rest of Japan by mountain ranges or do not lie on the main islands of Hokkaido, Honshu or Kyushu. It is therefore to be expected that these prefectures do not enjoy the same accessibility as those that are connected by HSR infrastructure and therefore, can be compared to the sample containing the smallest municipalities. Thus, this change in estimated ATT is again well explained and occurred as expected. It can therefore be concluded that this test also confirms the robustness of the method.

5.3.3 Direct Division

The next and last way to test the robustness of the chosen method is to observe the change that occurs depending on the direct distribution of the dataset according to a certain variable. In the previous section discussing the parameters affecting the ATT rate, it is possible to observed that the most significant results for the Local Taxes variable when split into Rich and Poor municipalities and then for the Income per Capita variable when split into Large and Small municipalities.

Thus, a split of the initial dataset purely based on the Income per Capita and Total Population variables at $k = 0$ is performed. In the following Figure 5.35 to Figure 5.39, it can be seen that the resulting ATT for the newly created sub-samples. [3]

Especially Figure 5.37 and Figure 5.39 show, that with a different method, the results are almost identical to results depicted in Figure 5.23 and 5.28. Thus, these findings again confirm the robustness of chosen method and shows very comparable results for different Treated/ Control Group settings as well as for different dataset sorting decisions.

[3]Same as in the case above, only figures of interest are depicted within the thesis, the rest can be found in the Appendix.

Figure 5.35: ATT on log Total Population - New Rich/Poor

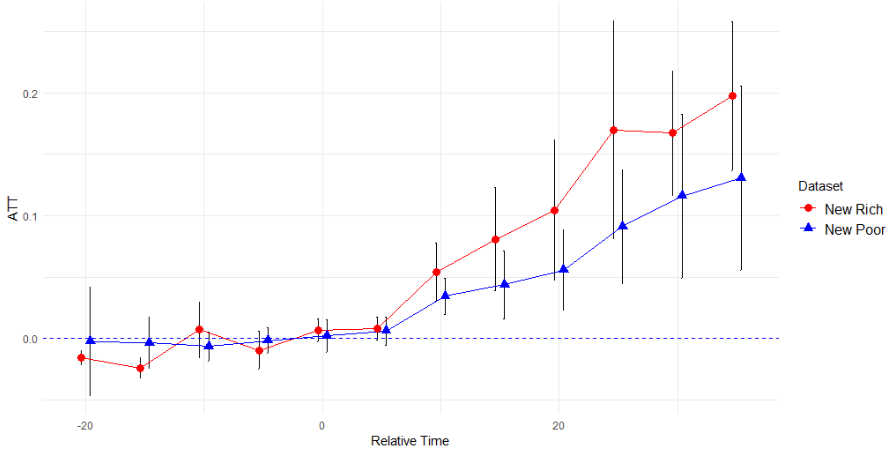


Figure 5.36: ATT on log Income per Capita - New Rich/Poor

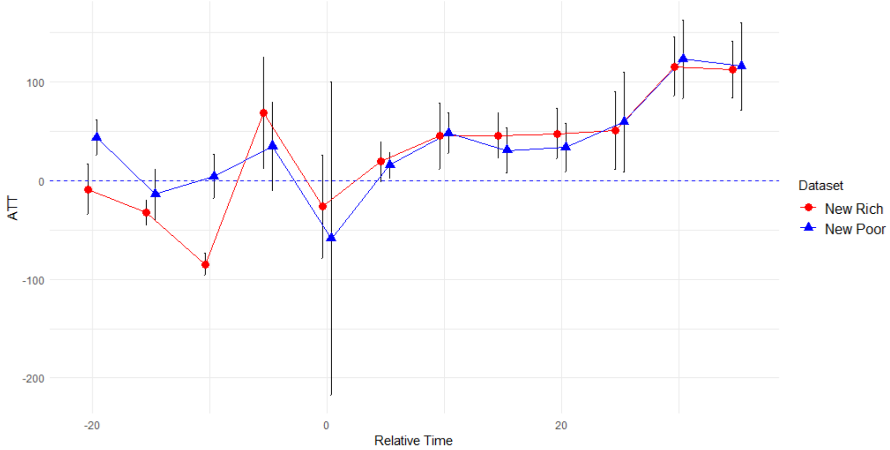
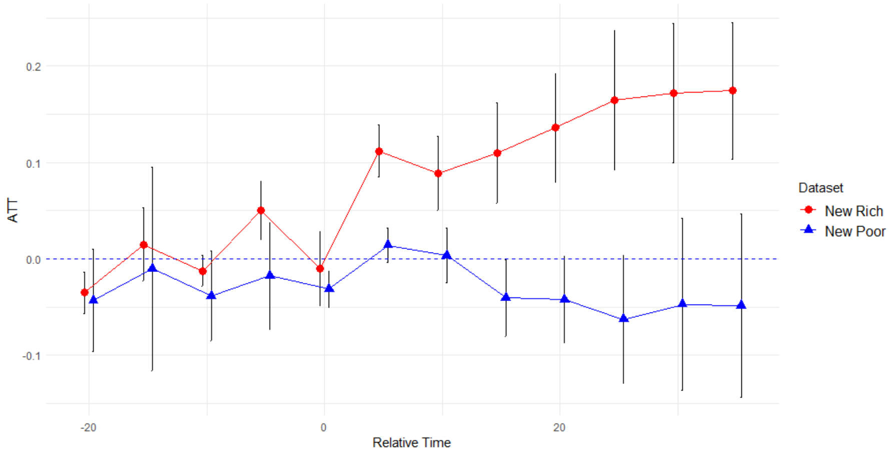


Figure 5.37: ATT on log Local Taxes - New Rich/Poor



The Figure 5.35, 5.36 and 5.37 show the ATT on y-axes, the relative time since treatment on the x-axes, for new sub-samples Rich and Poor, obtained by Direct Division. Whiskers extending from each point indicate 95% CI.

Figure 5.38: ATT on log Total Population - New Large/Small

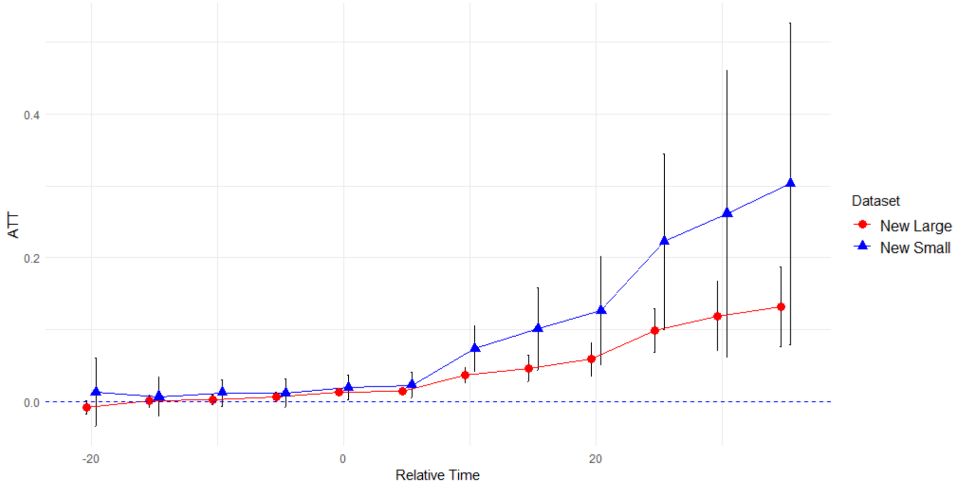


Figure 5.39: ATT on log Income per Capita- New Large/Small

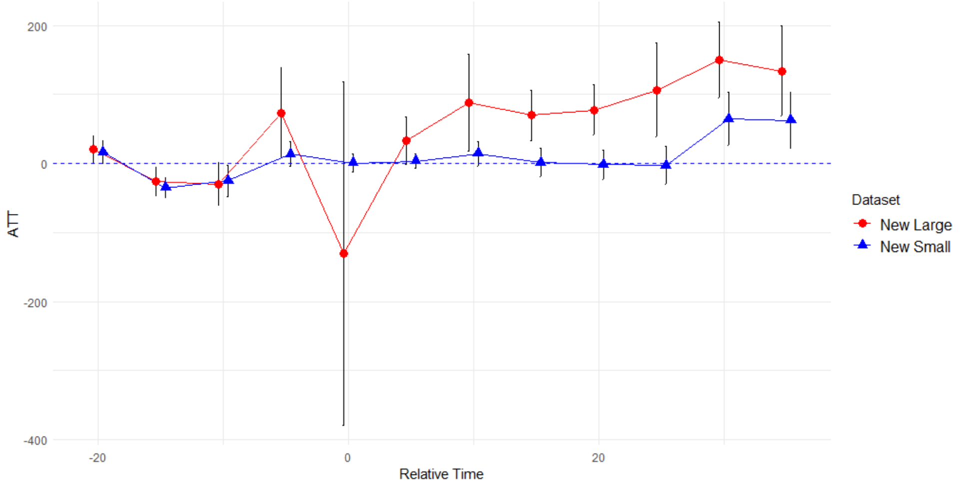
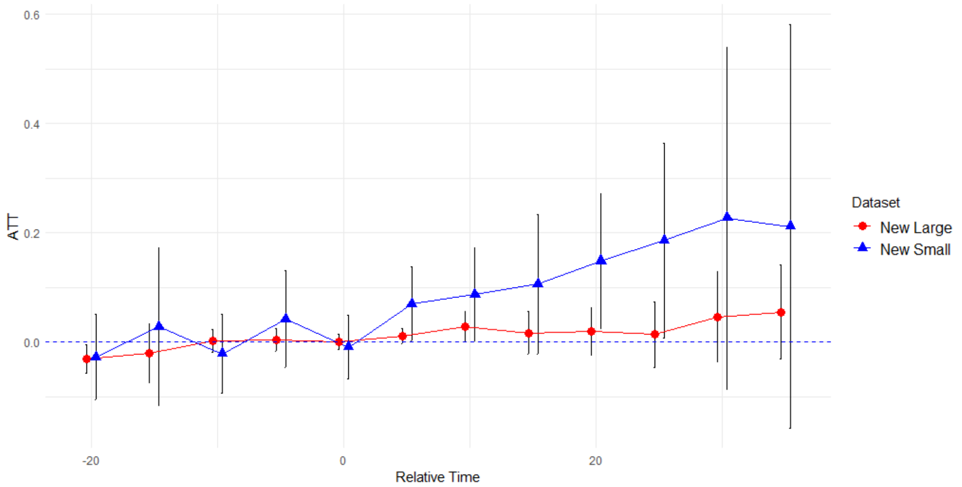


Figure 5.40: ATT on log Local Taxes - New Large/Small



The Figure 5.38, 5.39 and 5.40 show the ATT on y-axes, the relative time since treatment on the x-axes, for new sub-samples Rich and Poor, obtained by Direct Division. Whiskers extending from each point indicate 95% CI.

5.4 Discussion

This section reflects on the findings from the Hypotheses testing, introduced in Section 4.1, regarding the impacts of HSR construction on various economic and demographic indicators in Japanese municipalities. The discussion evaluates the efficiency and robustness of the Staggered DiD model used, considers the implications of the results, and acknowledges the limitations inherent in the study.

5.4.1 Evaluation of Hypotheses

The study sets out to explore four main hypotheses concerning the effects of HSR construction on municipalities lying in the proximity to Shinkansen network stations, also focusing on how the impact differ in connection to the economic orientation, average income levels or population size of affected municipalities.

Proximity to HSR Stations: Hypothesis 1 present a positive economic impact on municipalities near HSR stations. The results confirmed this hypothesis, showing a significant improvement in both the population growth and economic indicators such as local taxes and taxable income in these areas.

Economic Orientation: Hypothesis 2 explored whether the economic orientation of municipalities affects the impact of HSR. The analysis revealed that while service-oriented municipalities generally showed higher ATTs, the differences were not statistically significant, leading to the rejection of this hypothesis.

Average Income per Capita: Hypothesis 3 proposed that municipalities with higher average incomes would experience stronger positive impacts from HSR construction. However, the results did not support this hypothesis. Both higher-income and lower-income municipalities benefited from HSR, however the difference between them was not statistically significant.

Municipality Size: Hypothesis 4 suggested that larger municipalities would benefit more from HSR construction than smaller ones. This hypotheses was confirmed, with larger municipalities showing a more pronounced increase in economic indicators Income per Capita. This supports the notion that larger urban centers are better positioned to take the advantages offered by major transportation infrastructure.

5.4.2 Model Application

The Staggered DiD approach, developed by Callaway & Sant'Anna (2021), was instrumental in disentangling the time-varying effects of HSR introduction across different municipalities with varying characteristics. This model was particularly effective in accounting for the staggered implementation of HSR across Japanese prefectures, allowing for a dynamic analysis that could be adjusted for different treatment times and varying durations of exposure to HSR.

5.4.3 Limitations

Several limitations need acknowledgment. Firstly, the reasons that led the planners of the whole Shinkansen project to choose the routes that Shinkansen lines subsequently took, were not included in any way in estimating the impact of HSR construction. It is therefore possible that there is a hidden bias in the estimates due to the omission of this variable. It is also important to highlight that only 5 of the 7 Japanese lines were examined in this paper, and it is therefore possible that the actual ATT for the whole of Japan may differ from the measured estimates on an incomplete sample. Furthermore, data limitations, particularly the gaps caused by events like the GEJE or the lack of more pre-treatment periods, may have affected the robustness of the findings related to economic orientation.

5.4.4 Future Research Directions

This study has performed numerous tests and reached several conclusions. Most results align with existing research literature, however two particular findings prompt further investigation.

Firstly, there's an anomaly: It is suggested, despite the large Standard Errors, that HSR construction leads to an increase in unemployment in the affected municipalities and contributes to a decline in proportion of working people in the total population. This contradicts current literature, posing a counter-intuitive scenario. Future research could dissect Japan's labor market specifics to validate this observed impact of HSR and seek a systematic rationale for such a trend.

Secondly, the paper notes an intriguing point: HSR seems to boost tax revenues in affected municipalities, however this upswing is solely attributed to lower-income per capita areas. To shed light on this, further analysis could explore intricacies within Japan's taxation framework to understand how HSR could specifically increase the tax collection in less affluent regions.

Moreover, upcoming studies ought to broaden their scope beyond these two issues. A comparative global perspective, incorporating data from diverse geographical regions like Europe, could offer valuable insights. Europe presents a different cultural and economic landscape compared to East Asian countries, and such comparative research could contextualize the effects of HSR construction on a broader scale.

Chapter 6

Conclusion

This thesis has systematically explored the socioeconomic impacts of High-Speed Rail (HSR) construction on Japanese municipalities based on the empirical observations from 1980 to 2020. Employing a robust Staggered Difference-in-Differences (DiD) methodology developed by Callaway & Sant'Anna (2021), the research analyzed a comprehensive dataset to discern the influence of HSR on local economies and demographics.

The results corroborate the research by Wang *et al.* (2022) and Jin *et al.* (2020), confirming that municipalities near HSR stations see on average beneficial effects on population size, economic output, and tax revenue, thereby supporting the hypothesis that proximity to HSR enhances local economic development. However, the data also revealed a complex dynamic where HSR connectivity is associated with increased unemployment and a decreased proportion of working individuals in the total population, suggesting some adverse effects alongside the benefits.

A notable variation in the impact of HSR construction was observed across different Shinkansen lines and regions. For instance, while the Tohoku line showed consistently positive outcomes, the Joetsu, Kyushu or Hokkaido lines exhibited mixed or occasionally even a slightly negative effects. These disparities highlight the regional differences in HSR's socio-economic impact.

Contrary to expectations, the hypothesis that economic orientation significantly influences HSR's impact was not supported. This indicates that while HSR construction can bring uneven benefits across various economics sectors, the difference is not strong enough to statistically favor certain groups of municipalities. Moreover, the study found no substantial evidence that higher average income levels in municipalities correlate with enhanced economic outputs or population growth. Interestingly, tax revenue increases were more pronounced in poorer municipalities, suggesting that HSR benefits are not confined to wealthier areas.

The size of municipalities emerged as a significant factor, with larger municipalities benefiting more from HSR connectivity. This finding suggests that HSR fosters the centralization of high-value economic activities in larger cities, potentially drawing resources and investment away from smaller municipalities. These insights are crucial for urban planning and infrastructure development, especially in strategically placing HSR stations to maximize economic outputs. This study underscores the importance of considering transport connectivity as a catalyst for regional growth, advocating for integrated development strategies that encompass both connected and non-connected regions.

Further studies could expand this research by comparing Japan's HSR experience with other countries to extract broader lessons on optimizing infrastructure investments for balanced economic and social development. Expanding the dataset to data coming from other countries could allow for more detailed investigations into the reasons behind the varied impacts of different HSR lines, particularly the nuances influencing unemployment and employment patterns.

In conclusion, while HSR construction in Japan has yielded generally positive outcomes, the effects vary significantly based on the specific line and municipality size, with less variation attributed to economic orientation or income levels. This thesis contributes a nuanced perspective to the discourse on how transformative infrastructure projects like Japanese Shinkansen can reshape economic landscapes, offering valuable insights for policymakers, infrastructure planners, and researchers focused on leveraging infrastructure for sustainable growth.

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Appendix A

Additional Figures

The appendix of this thesis contains figures showing the tests performed as part of the Robustness Checks, but these figures were not included in the main body of the thesis.

Figure A.1: ATT on log Taxable Income - Comparison of the Rich and Poor Samples

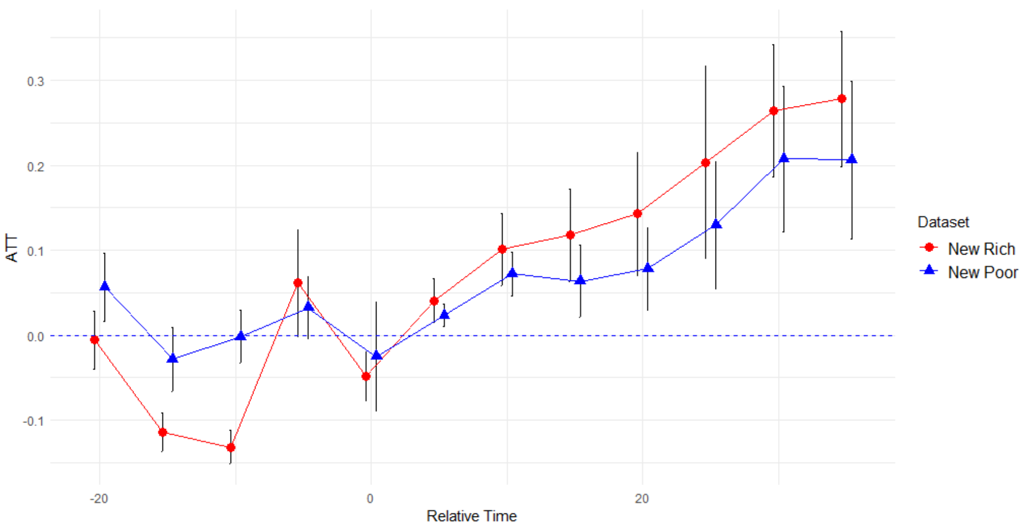


Figure A.2: ATT on Unemployment Rate - Comparison of the Rich and Poor Samples

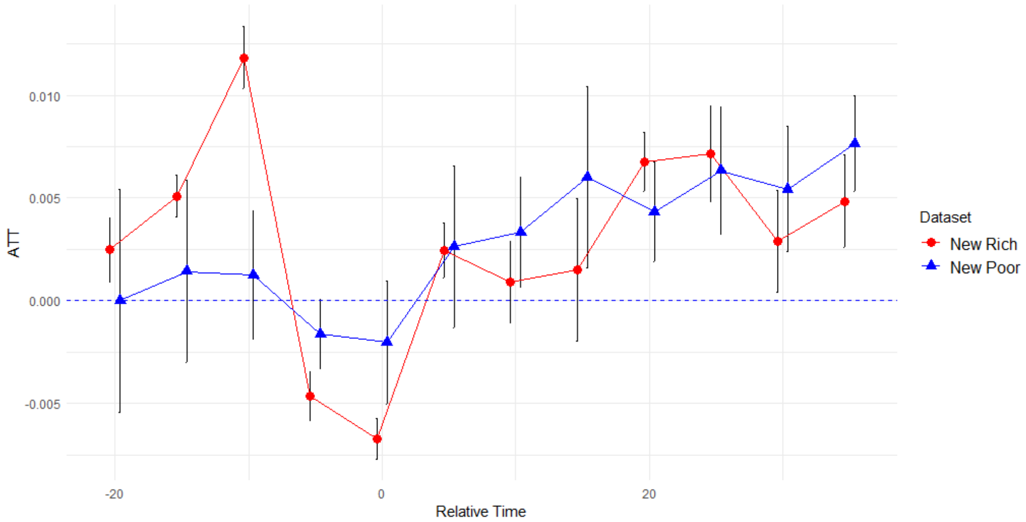
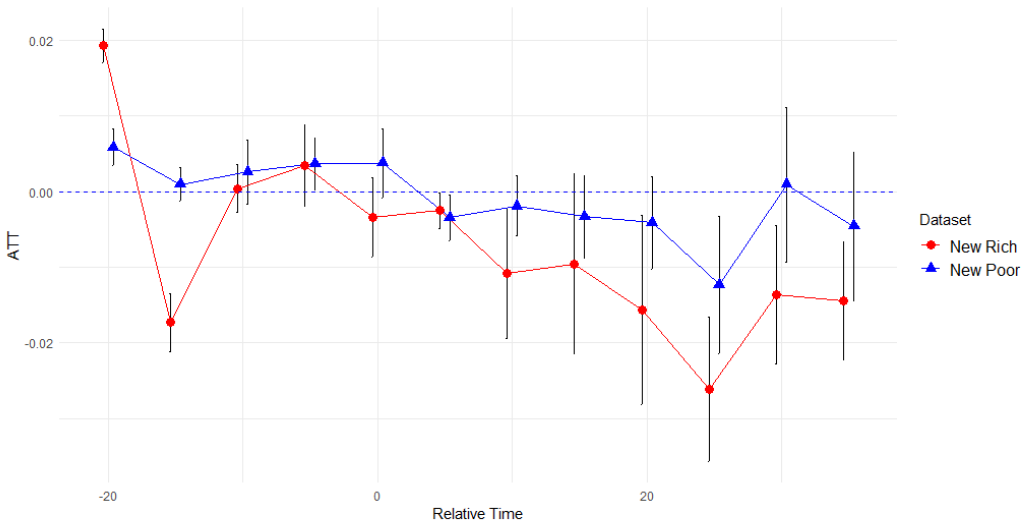


Figure A.3: ATT on Employment Rate - Comparison of the Rich and Poor Samples



The Figure A.1, A.2 and A.6 show the ATT on y-axes, the relative time since treatment on the x-axes, for new sub-samples Rich and Poor, obtained by Direct Division. Whiskers extending from each point indicate 95% CI.

Figure A.4: ATT on log Taxable Income - Comparison of the Large and Small Samples

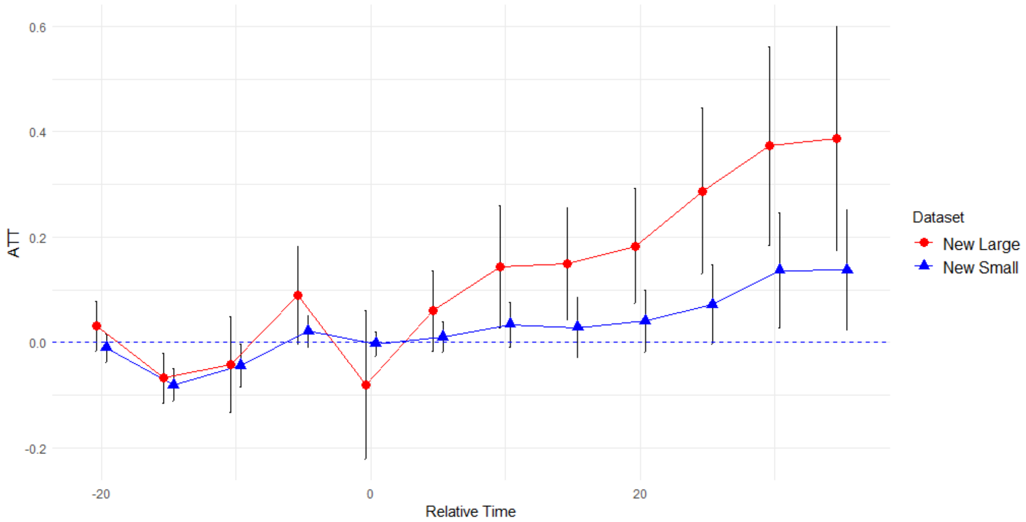


Figure A.5: ATT on Unemployment Rate - Comparison of the Large and Small Samples

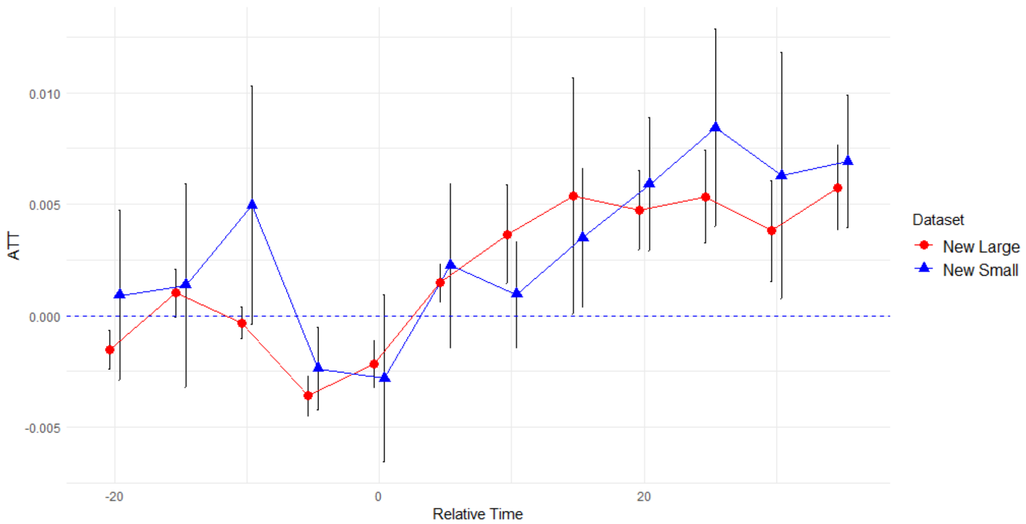
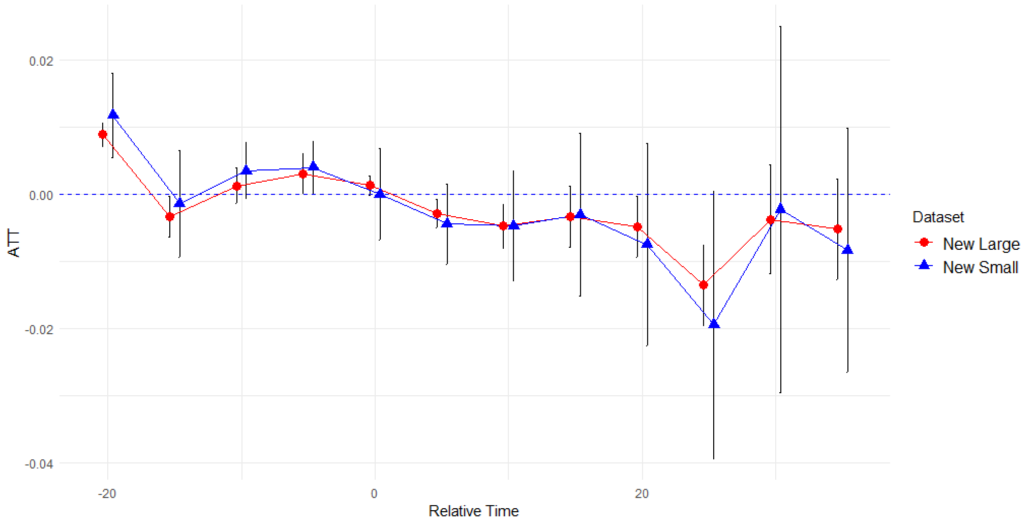


Figure A.6: ATT on Employment Rate - Comparison of the Large and Small Samples



The Figure A.4, A.5 and A.6 show the ATT on y-axes, the relative time since treatment on the x-axes, for new sub-samples Large and Small, obtained by Direct Division. Whiskers extending from each point indicate 95% CI.

Figure A.7: ATT on log Taxable Income - Comparison of the Merge and New Merge Samples

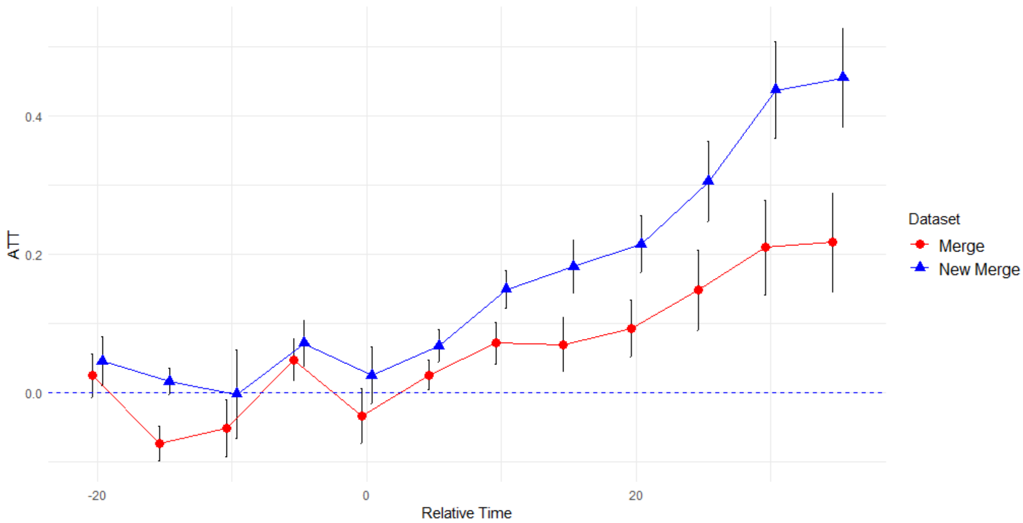


Figure A.8: ATT on Unemployment Rate - Comparison of the Merge and New Merge Samples

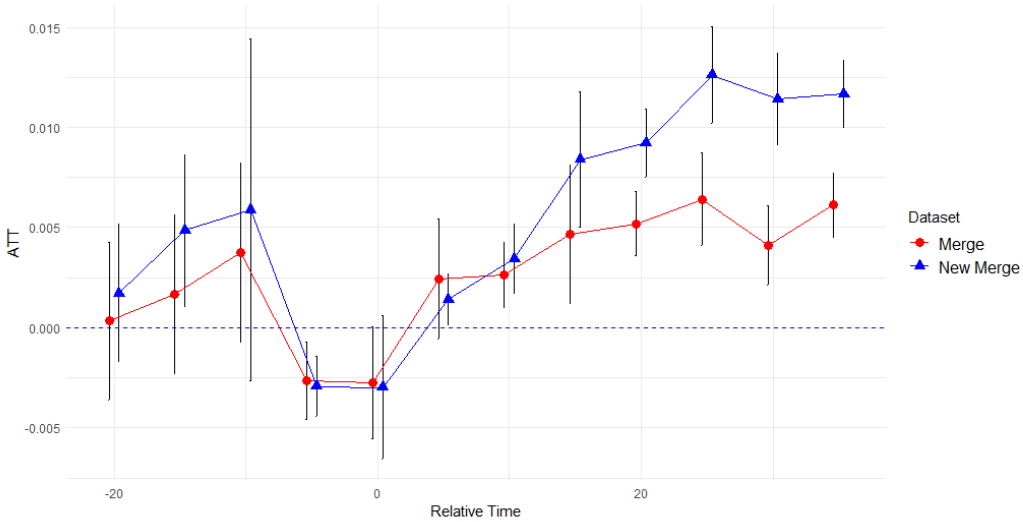
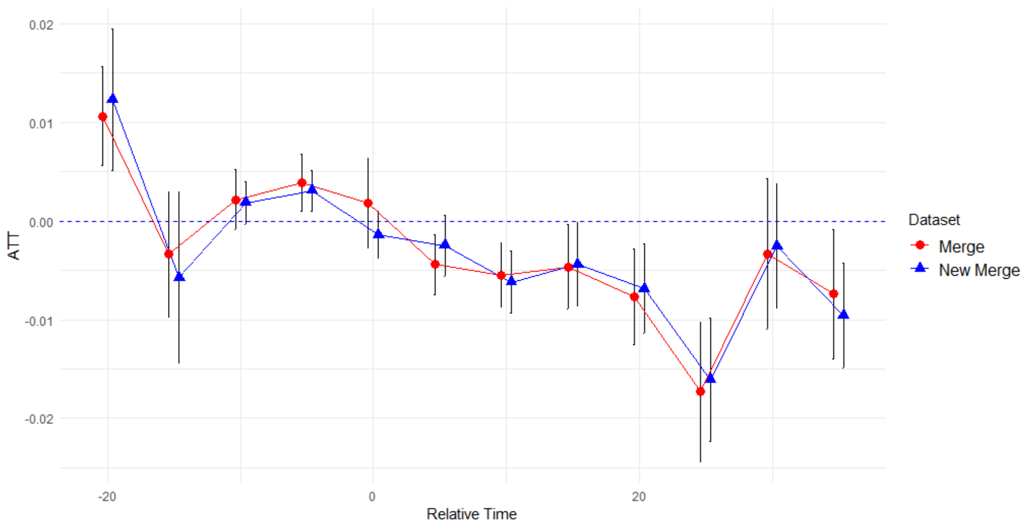


Figure A.9: ATT on Employment Rate - Comparison of the Merge and New Merge Samples



The Figure A.7, A.8 and A.9 show the ATT on y-axes, the relative time since treatment on the x-axes, for new sub-samples Merge and New Merge, obtained by not applying Chen & de Abreu E (2013) assumption on Control Group. Whiskers extending from each point indicate 95% CI.