The Impact of High-Speed Rail on the Trajectories of Shrinking Cities. The Case of the Extension of the Shinkansen Network in Northern Japan

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Abstract
As more countries witness depopulation, the expansion of High-Speed Rail (HSR) to reach shrinking cities in peripheral regions is renewing the debate on the effects of this infrastructure. This is the case in Japan, a country that continues to extend its highly developed HSR network hoping to curb regional decline. This paper investigates whether HSR had a positive effect on the shrinking trajectories of connected medium and small-sized cities in peripheral regions by examining the impact of extending the Shinkansen network on five municipalities in the prefectures of Iwate and Aomori, northern Japan. Although depopulation decelerated in some of the case studies, the findings highlight that HSR did not reverse shrinkage and benefits are mainly found in increased accessibility, albeit unevenly distributed. This suggests that, rather than uniformly uplifting socio-economic outlooks, the Shinkansen contributed to reshaping the trajectories of the connected cities and reproduced core-periphery dynamics at the regional level.

Keywords: shrinking cities, High-Speed Rail, Japan, trajectories, accessibility

1. Introduction

Across the world, many cities are shrinking. Diverse and often overlapping causes are weakening their socio-economic profile resulting in depopulation—including deindustrialisation in Northwest England, and the USA's Rustbelt (Cowie & Heathcott, 2003); rural–to–urban migration and ageing in Japan and Spain (Matanle & Sáez-Pérez, 2019); and rapid urbanisation-driven economic development in China (He et al., 2017). But above all, shrinkage is a direct consequence of ongoing globalisation and the spatial reorganisation of economic functions and population leading to uneven territorial development patterns (Pallagst, 2010; Rieniets, 2009). While the understanding of urban shrinkage is still limited (Großmann et al., 2013), the negative connotations of this phenomenon have prompted responses from all levels of governments, in most cases adopting a pro-growth stance focusing on curbing and reversing population decline but ignoring the systemic causes of unbalanced territorial development (Hospers, 2014; Ortiz-Moya, 2015).

The spread of high-speed rail (HSR) to connect shrinking cities in countries that are suffering from acute depopulation in peripheral areas—such as Japan, Spain and Germany—is one example of the pro-growth

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approach to confront shrinkage. This strategy has been backed up by existing research emphasising the role HSR plays in improving accessibility, urban competitiveness, the agglomeration of economic activities, and possibly regional equity (Chen et al., 2019; Garmendia et al., 2012; Givoni, 2006; Loukaitou-Sideris et al., 2013; Monzon et al., 2019; Yin et al., 2015). However, the evidence is contradictory, with other studies suggesting that HSR might contribute to exacerbating inequalities among and within urban regions (López et al., 2008), or even aggravate population outmigration in already shrinking cities (Deng et al., 2019).

The paper explores the role of HSR in the context of shrinkage by examining the impact of extending the Shinkansen network[1] in five municipalities in the prefectures of Aomori and Iwate, northern Japan. The case study is particularly relevant to the debate since Japan is not only experiencing nationwide depopulation but also expanding its already highly developed HSR network into remote and sparsely populated regions as a key intervention to address decline (Matanle & Rausch, 2011). This strategy builds on previous achievements of the Shinkansen—for example, the positive correlation between the country's rapid GDP growth between 1969 and 1999 and the ridership of the Tokaido Shinkansen (Smith, 2003). At the same time, and similar to other policies recently put in place by Japan, this approach aims to address the country's extremely unbalanced territorial development by promoting decentralisation from large metropolitan areas to regional cities (Buhnik, 2017; Cabinet Secretariat, 2015). However, dispute still remains as to whether and how HSR can positively contribute to readdress territorial inequalities and improve the outlook of Japan's rapidly declining peripheral regions.

Does HSR have a positive effect on the shrinking trajectories of connected medium and small-sized cities in peripheral regions? To address this research question, the paper takes Japan as a case study and focuses on the following indicators to examine the impacts of HSR:

- Population change, unemployment trends, and industrial classification to gauge whether HSR cities present better socio-economic trajectories than non-HSR municipalities in the region.
- Travel times, number of HSR services, HSR passengers, and measures of accessibility to explore the territorial impact of the Shinkansen on connected cities.

Given the limited amount of studies about HSR in the context of depopulating regions, we believe these factors need to be considered together to provide new empirical evidence, bring a more significant contribution, and serve as a reference for future studies.

Following the introduction, Section 2 provides a critical overview of the literature on the socio-economic and territorial effects of HSR, along with the planning challenges in shrinking and sparsely populated

[1] Japanese HSR.

regions. Section 3 presents the case studies, the methodological approach and the data used in the paper. Section 4 articulates the findings while the final section concludes and discusses the results.

2. Literature Review: Socio-Economic and Territorial impacts of HSR and planning challenges in shrinking cities and peripheral regions

While the possibility of extending HSR to improve the socio-economic performance of cities and regions has received much attention, there is no consensus on the viability of such investment in peripheral or shrinking areas. The cost associated with opening and maintaining new HSR lines is usually justified based on the promise of future economic development. However, HSR has been found to be a risky investment that is competitive and profitable only when it connects major centres located over medium distances, and if the line can intercept a high demand for transit (Campos & de Rus, 2009; Vickerman, 2015). Additionally, further development in peripheral regions may be very costly, especially in countries like Japan that have developed HSR networks as exclusive corridors (Perl & Goetz, 2015). Moreover, it is hard to prove the correlation between HSR and socio-economic dynamics, with recent research highlighting that more nuanced and context-specific analysis is needed to gauge the reality of the economic benefits promised by HSR (Chen & Vickerman, 2017; Givoni, 2006; Preston & Wall, 2008).

If there is contrasting evidence on the wider economic impact of HSR, the expansion of high-speed services determines significant territorial and local impacts on cities and urban regions (Chen et al., 2019; Garmendia et al., 2012; Givoni, 2006; Loukaitou-Sideris et al., 2013). Scholars have particularly explored the transformative role of HSR on accessibility, inter-city relationships, and the difference in trajectories of development between connected and non-connected cities and regions (Chen & Hall, 2011; Coronado et al., 2019; Hall, 2009; Yin et al., 2015). Recent studies have started to focus more robustly on spatial equity issues (Monzon et al., 2019) and the effects of HSR in the context of urban shrinkage (Deng et al., 2019).

Regarding inter-city relationships, core urban centres and large intermediate cities are usually thought to be those benefiting the most from HSR investments (Givoni, 2006; Ureña et al., 2009; Vickerman & Ulied, 2009). Despite HSR locations gaining more accessibility, wider economic effects and HSR services tend to be especially concentrated near the commanding nodes of the system—typically capital cities or first-tier regional hubs—further promoting metropolitan integration and agglomeration of economic opportunities at the expense of more remote and sparsely populated regions (Deng et al., 2019; Vickerman, 2015). Nevertheless, other studies report positive effects are also felt in medium and small-sized cities along HSR lines depending on their pre-existing conditions and their territorial framework (Coronado et al., 2019; Garmendia et al., 2012; Loukaitou-Sideris et al., 2013).

The increased polarisation between connected and non-connected cities is another known territorial effect associated with HSR. In Japan, for example, the Shinkansen reinforced the dominance of the Tokaido-Sanyo axis over the rest of the country (Flüchter, 2012; Ohta, 1989; Sands, 1993). In France, major urban areas like Lille and Lyon capitalised the effects of HSR at the expense of smaller centres in their surroundings (Vickerman, 2015). Although some HSR benefits are transitory and hard to isolate from other socio-economic dynamics, studies suggest that non-connected areas suffer from a competitive gap with adverse effects on their economic performance. More specifically, disconnected areas risk becoming the perfect breeding ground for sustained shrinkage (Hoekveld, 2012; Matanle & Rausch, 2011). Whether HSR can produce a more equitable and sustainable territorial development remains contested, so being connected to the HSR network might still be preferable.

The location and characteristics of HSR stations also have a significant impact on the local success of investments (Chen et al., 2019; Mohíno et al., 2019). At the same time, the frequency of services and the presence of intermodal connections between HSR and conventional lines are often mentioned as a key to successfully redistribute the economic effects, resulting in more equitable and cohesive regional development (Martínez Sánchez-Mateos & Givoni, 2012; Vickerman, 2015). HSR ex-metropolitan stations have also been found to play a positive role in population growth, albeit with mixed results on employment levels and stations area development (Mohino et al., 2014).

Given that the development of HSR has traditionally concentrated on linking densely inhabited areas to take advantage of growing economic synergies, shrinkage poses unexplored questions to planners and policymakers. As an example in Japan, having a Shinkansen station meant that a connected city had positive population growth up until the early 2000s. However, as depopulation advances it seems that this influence is decreasing (Matanle & Rausch, 2011). Hood (2010) noted a negative impact on those municipalities left outside the Shinkansen network. In China, HSR harmed some shrinking cities and favoured population outflow (Deng et al., 2019). In Spain, HSR has resulted in some improvement to inter-regional cohesion and equity (Monzon et al., 2019) but there is also not much evidence that it promotes development in sparsely populated and shrinking regions.

In brief, given the limited studies focusing on HSR in the context of depopulation, additional research is needed to gain a more nuanced understanding of its impact on shrinking cities. More evidence is especially necessary for countries like Japan that are currently investing or planning to invest in HSR expansion hoping to ameliorate the economic fortunes of peripheral and depopulating regions.

3. Case Studies, Methodology and Data

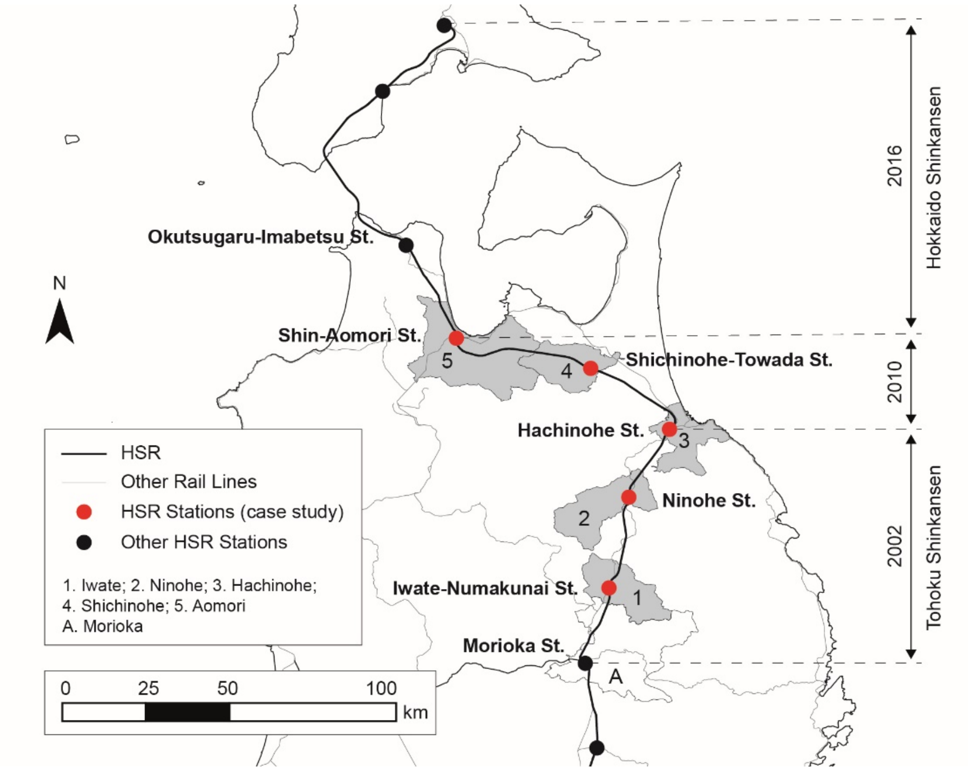

Figure 1: Case studies and extension of the Shinkansen network in Iwate and Aomori prefectures.

Table 1: Case studies plus Morioka, an overview.

	Type of municipality	Special Designation	Current Population (2015)	Year of Shinkansen Arrival
Iwate	Town (Machi)	Kaso	13,692	2002
Ninohe	City (Shi)	Kaso	27,611	2002
Hachinohe	City (Shi)	Core City	231,257	2002
Shichinohe	Town (Machi)	Kaso	15,709	2010
Aomori	City (Shi)	Core City / Prefectural Capital	287,648	2010
Morioka	City (Shi)	Core City / Prefectural Capital	297,631	1982

Looking at the impact of HSR on the trajectories of medium and small-sized shrinking cities, this paper focuses on five municipalities served by the Shinkansen in the peripheral prefectures of Iwate and Aomori, northern Japan (Table 1). The exodus of younger people to large metropolitan areas, as well as an ageing population have made these two of the fastest shrinking regions in Japan, leaving their future uncertain (Masuda, 2014; Matanle & Rausch, 2011). Two of the case studies, Hachinohe and Aomori, are designated as core cities by the national government[2]— the latter being the capital of Aomori Prefecture. Ninohe is a small city of less than 30,000 inhabitants, while Iwate and Shichinohe are towns. These three are also designated as '*kaso*' by the Japanese authorities, meaning they are experiencing severe depopulation and will have difficulty in maintaining their socio-economic life in the future. The paper contrasts the trends of the five case studies with that of Morioka (the capital of Iwate Prefecture and a core city), where the Shinkansen arrived in 1982 during the last years of Japan's rapid economic growth period. Imabetsu—the latest municipality reached by the HSR in the region in 2016 along the newly constructed first section of the Hokkaido Shinkansen—is excluded from the analysis since data are still insufficient to grasp evidence of the impact of HSR.

There are two main reasons to consider these cases studies. First, they represent different types of municipalities within the same region. Second, the gradual extension of the Shinkansen over the last two decades (Table 1 and Figure 1) adds a temporal nuance to the analysis. Therefore, while we can reasonably expect similar socio-economic dynamics, differences between the case studies allow comparative observations of the effects of HSR in the region.

To address the research question, the paper first analyses population change and economic strength in each of the case studies based on census data before and after the arrival of the extension of the Tohoku Shinkansen north of Morioka. In line with previous studies on shrinking cities, population change[3] is used as the key variable to study urban decay since it indicates the general state of a place (Hospers, 2014; Turok & Mykhnenko, 2007). Three time spans are considered, to detail population trends happening during the gradual opening of the Shinkansen in the region and coinciding with years when Japan conducted a population census—i.e. 2000-2005, 2005-2010, and 2010-2015. Similarly to Chen and Hall (2011), and based on data availability, the paper takes unemployment as a proxy for measuring the evolution of local economic strength. This is complemented with data on changes to economic structure, to make further nuances to transformations in the local economy of each case study between 2000 and 2015. To ensure better control for HSR impacts, results are compared with non-HSR municipalities north of Morioka that are connected to conventional railway lines; averages are considered for cities as well as for towns.

[2] A core city is a local administrative division made by the Japanese authorities that includes cities with a population of around 200,000 and that have applied to be recognised as such. Core cities are responsible for the provision of services that would be carried out otherwise by prefectural governments such as welfare, health, education, or city planning.

[3] All population and economic data is from the Population Census of Japan (Ministry of Internal Affairs and Communications). This data accounts for changes that happened in municipalities until the last available census of 2015. The census can be accessed online at https://www.stat.go.jp

The paper includes a multiple linear regression to further explain the changes in population between 2000 and 2015, and how this might be related to the presence of the Shinkansen and other socio-economic factors. The regression uses five explanatory variables: HSR presence (a binary variable that is 1 when a municipality is connected to the Shinkansen and 0 in the other cases), years of HSR, total population (2015), unemployed population per 1,000 people (2015), and population employed in the tertiary sector per 1,000 people (2015). The sample cities include those served by HSR in the region by 2015 (the case study plus Morioka (N=6), and non-HSR cities along conventional railway lines north of Morioka as a control group (N=29).

Similar to previous studies, this paper then employs a mix of variables to assess the territorial impact of HSR (Beyazit, 2015; Knowles & Ferbrache, 2016; Yin et al., 2015). Travel time savings, number of HSR services per day, and average number of HSR daily passengers are used to assess the levels of HSR services in the region. Variation of different accessibility indicators is employed to make a more in-depth analysis of the spatial benefits brought by the Shinkansen in terms of regional interconnection, extension of reachable areas, and interactions within the region. Taken together, these indicators allow investigation of the changes in inter-city relationships and offer indications that help discuss the impact of HSR on the socio-economic trajectories in the case study locations.

Regarding the calculation of accessibility, the paper adopts a 'location-based' perspective (Geurs & van Wee, 2004), by focusing on travel times and the spatial distribution of opportunities to and from a certain place, and includes different indicators to offer a broader perspective on the impact of HSR (López et al., 2008). The number of connected municipalities (CM_i) is calculated to capture variations in regional interconnections, while reachable area (RA_i) is a contour measure that estimates the area that can be reached from each of the case studies. An accessibility potential indicator (AP_i) is employed to express the possibility for actual interactions and offer a more nuanced representation of the relationship between accessibility and population dynamics. Based on Ureña et.al (2009) and Mohíno et al. (2016), the study uses three time thresholds—set at 30, 60, and 90 minutes—to examine the variation of accessibility in catchment areas where HSR is a competitive transport solution and travel for different purposes might take place. The paper analyses values in two temporal scenarios, one in 2000 and one in 2019. These scenarios cover the period before the opening of the Morioka-Hachinohe extension, and the completion of all Shinkansen lines currently operating in the region.

The accessibility potential indicator (AP_i) formulation is as follows:

$$AP_i = \frac{P_i}{T_{ii}^{\alpha}} + \sum_{j=1}^{n} \frac{P_j}{T_{ij}^{\alpha}}$$

where AP_i is the accessibility potential in the node i, Pj the population living in zone j, Tij is the travel time between the node i and the centroid of zone j's municipality, and α=1 is the gravity parameter[4]. P_i and Tii are, respectively, the population and the travel time internal to node i[5].

To offer a more realistic representation of travel times, the paper considers a multimodal network road/HSR in its calculations. Travel matrixes and shortest paths were calculated in a GIS environment using the centroids of each case study as origins in relation to the centroids of other municipalities as destinations. To compute travel times, train timetables in the 2000 scenario were taken from archive sources (Kotsu Shimbun, 2014; Nihonkoutsoukousha, 1988; Ouchi & Akita, 2017), while times for current HSR services have been obtained from the JR East website[6]. Similarly to Miura (2006), a waiting time of 20 minutes has been added to the calculation to account for the elapse of time necessary to access/egress HSR stations as well as the time spent waiting for the train. Regarding calculations on the road network, road speed has been set to 40km/h by considering speed limits in Japan and based on the average speed surveyed in Iwate and Aomori Prefecture (MLIT, 2015).

4. The influence of the Shinkansen on the case studies

A. The trajectories of HSR municipalities after the arrival of the Shinkansen

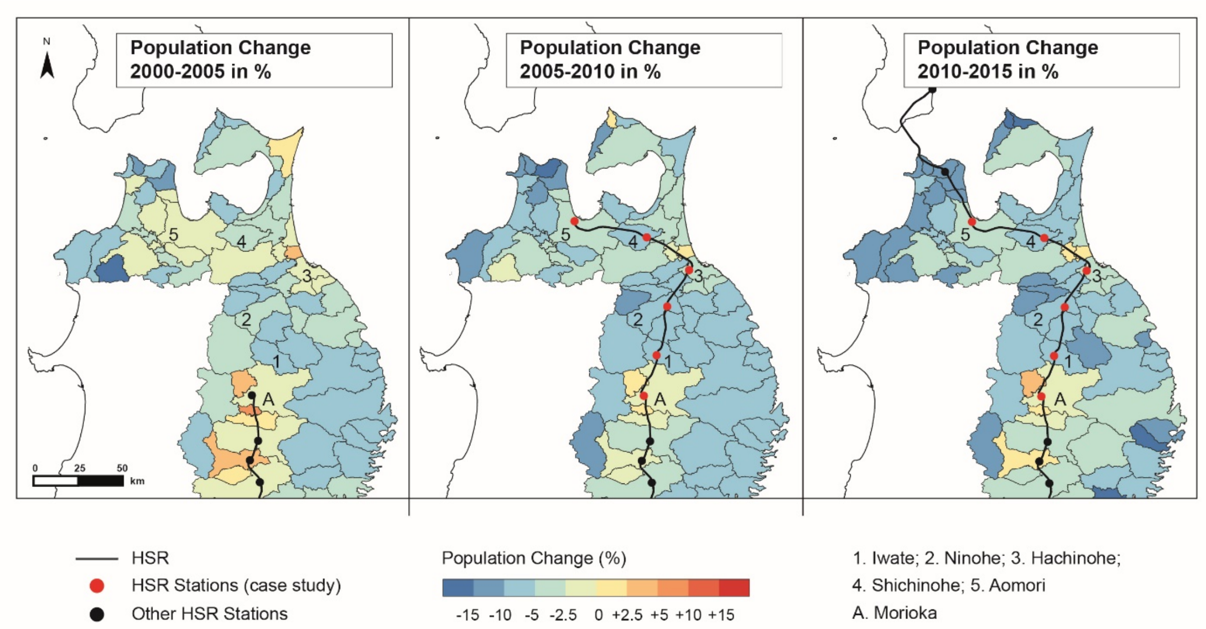

Figure 2: Population change 2000-2005, 2005-2010, and 2010-2015 in the Prefectures of Iwate and Aomori.

[4] According to Condeço-Melhorado et al. (2013), this value is usually between 1 and 2. As a detailed study of this parameter is out of the scope of this empirical study, we follow the suggestion of Lopez et al. (2008) and set α=1

[5] As recommended by Mohíno et al. (2016), internal travel times have been set at ten minutes for the core cities, one minute for municipalities under 10000 inhabitants, and two minutes for the all the others.

[6] https://www.eki-net.com, last accessed 01/07/2019.

Table 2: Population change in the five case studies and Morioka, the average for cities and for towns.

	Population Change 2000-2005	Population Change 2005-2010	Population Change 2010-2015	Population Change 2000-2015	
				%	Counts
HSR municipalities					
Iwate	-6.44%	-7.81%	-8.62%	-21.18%	-3,680
Ninohe	-4.91%	-5.64%	-7.04%	-16.59%	-5,491
Hachinohe	-1.57%	-2.90%	-2.68%	-6.98%	-17,351
Shichinohe	-4.58%	-9.27%	-6.27%	-18.85%	-3,648
Aomori	-2.27%	-3.85%	-3.96%	-9.75%	-31,084
Morioka	-0.70%	-0.80%	-0.24%	-1.73%	-5,226
Non-HSR municipalities					
City Average	-1.81%	-4.01%	-3.95%	-9.48%	-5,966
Town Average	-4.62%	-6.64%	-7.62%	-17.49%	-2,680

As illustrated in Figure 2, shrinkage has been nearly ubiquitous across small and medium-sized municipalities in the prefectures of Iwate and Aomori after 2000, even when Japan's population was still growing[7]. Similar intra- and inter-regional dynamics explain such a pervasive population loss. First, there was outmigration to more prosperous metropolitan areas within the Tokaido megalopolis, particularly Tokyo. Second, there was an internal redistribution of population toward prefectural core cities, resulting in uneven territorial development. Population size is a determining factor to understand these differences in population trajectories. Medium and small-sized municipalities exhibit quite a significant fall in population figures in every time span—especially those far from the main infrastructure corridors—while larger cities have witnessed more moderated population losses.

Data shows that the gradual opening of HSR stations did not significantly reverse existing shrinking trends in the case studies (Table 2). Among the municipalities where HSR arrived in 2002—Iwate, Ninohe, and Hachinohe—shrinkage has accelerated in the two smaller locations. Iwate's population losses have increased in every time span, always underperforming as compared to the average of non-HSR towns; in total, Iwate lost 21.18% of its population between 2000 and 2015. Similarly, Ninohe's depopulation has accelerated in every time span, underperforming as compared to the average for non-HSR cities. A possible explanation for this trend might be found in the urban profile of Ninohe, which has more resemblance to a town due to a series of mergers with different towns and villages since the 1950s. In comparison, Hachinohe benefitted more from the HSR connection. In the 2000-2005 period its population decreased by 1.57%, with a 2.90% decline between 2005 and 2010. This trend decelerated

[7] Japan's population peaked in 2010's census at 128,057,352 persons, and have decreased thereafter.

between 2010 and 2015 with a fall of 2.68%. As shown by these figures, the city performed better than the average of cities and better than Aomori, most likely due to the pull of the Shinkansen.

The impact of the Shinkansen on Shichinohe and Aomori's population trends is more nuanced. Shichinohe's population declined by 4.58% between 2000 and 2005, and then fell by 9.97% between 2005 and 2010, in both cases well below the average for non-HSR town. However, the arrival of HSR in 2010 seems to have ameliorated population dynamics. While losses for non-HSR towns worsened between 2010 and 2015, Shichinohe's pace slowed down to a fall of 6.27%, experiencing the largest improvement among all case studies. By contrast, the arrival of the Shinkansen seems to have had marginal impact on population dynamics in Aomori. The city population dropped by 2.27% between 2000-2005, by 3.85% between 2005 and 2010, and by 3.96% between 2010 and 2015, amounting to a 9.75% decline over the 15-year period. While figures indicate that Aomori has underperformed in comparison to Hachinohe, population trends in the last five years point to some deceleration in population decline, possibly indicating a positive impact from the Shinkansen on the city. However, a more extended period of observation would be needed to assert a positive correlation.

Due to a longer connection to the Shinkansen network and a geographical location closer to Sendai (the economic centre of North-eastern Japan), Morioka has fared better than any of the cases over the period examined in the study. Given that Japan developed its HSR as a corridor network, subsequent extensions of the Shinkansen in the region—such as the launch of the Akita Shinkansen in 1997 and the completion of the Tohoku Shinkansen in 2010—further advantaged the capital of Iwate Prefecture, as the city now occupies a relatively central position within northern Japan's HSR network. As a result, Morioka's population peaked in 2000 at 302,857 inhabitants, and has declined by 1.73% between 2000 and 2015. Notably, in 1980, Aomori outsized Morioka by more than 35,000 inhabitants, but this trend reversed by the time of the last available census, when Morioka surpassed Aomori by almost 10,000 people.

Table 3. Unemployment and industrial classification

	Unemployment		Industrial Classification: Primary Industry		Industrial Classification: Secondary Industry		Industrial Classification: Tertiary Industry	
	2000 (%)	2015 (%)	2000 (%)	2015 (%)	2000 (%)	2015 (%)	2000 (%)	2015 (%)
HSR municipalities								
Iwate	3.27%	3.68%	28.92%	26.97%	33.01%	26.25%	38.07%	46.78%
Ninohe	3.94%	3.53%	19.97%	18.86%	31.59%	26.16%	48.44%	54.99%
Hachinohe	6.13%	5.50%	4.55%	3.43%	27.62%	23.01%	67.83%	73.56%
Shichinohe	4.56%	4.63%	26.24%	18.86%	35.40%	22.72%	38.35%	58.43%
Aomori	5.46%	5.89%	4.15%	3.15%	19.80%	15.15%	76.05%	81.71%
Morioka	4.47%	4.26%	4.41%	3.43%	17.26%	14.31%	78.33%	82.26%
Non-HSR municipalities								
City Average	5.37%	4.95%	16.92%	14.50%	24.78%	20.29%	58.30%	65.21%
Town Average	5.05%	5.25%	24.85%	22.87%	29.75%	22.83%	45.39%	54.31%

When looking at unemployment (Table 3), data across the studied municipalities remained stable with only some decimal variations between 2000 and 2015. Two places improved their unemployment levels—Ninohe and Hachinohe—while three experienced a relative worsening—Iwate, Shichinohe and Aomori. All but Aomori followed the average for non-HSR municipalities in their respective classifications; unemployment rates fell in cities, and rose in towns. In general, the HSR municipalities outperformed non-HSR cities or towns, with the exception of Aomori and Hachinohe, both lagging behind by almost 1%. This reflects Aomori Prefecture's relatively low economic standing, which places Aomori 41st out of Japan's 47 prefectures in terms of income per person in 2014, the lowest in North-eastern Japan[8].

The comparative analysis of industrial classification in the region (Table 3) shows that between 2000 and 2015, there has been a progressive strengthening of the tertiary sector—a trend common to both HSR and non-HSR municipalities. The case studies behave largely as expected from their municipal classification with the exception of Shichinohe, which experienced the largest increase in tertiary industries. This might be explained by the town's active promotion of tourism—a shift that was favoured and accelerated by the presence of the Shinkansen. On the contrary, Iwate and Ninohe remain more dependent on primary and secondary industries. Given their role as core cities, and thus already concentrating public functions and advanced service activities, Aomori and Hachinohe undergo a lower increase in tertiary industries while remaining well above city averages—a trend similar to the one observable in Morioka.

[8] Prefectural income per person in Aomori was JPY 2.405 million; in contrast, Iwate ranked 29th with a prefectural income per person of JPY 2.716 million. The national average is JPY 3.057 million.

The regression used to explain the relationship between population trajectories, the presence of HSR, and selected socio-economic variables was significant and accounted for the 85% of the variations in population between 2015 and 2000 ($R^2 = 0.855$, $p < 0.01$) (see Appendix). The analysis of the explanatory variables shows that, in a region characterised by depopulation, cities with higher total population experienced greater outflows (B = -0.09, p = 0.00)—i.e. larger municipalities lost more population in absolute terms, on average. Against this backdrop, HSR implementation had nuanced effects. If the presence of the Shinkansen had no beneficial effect on population dynamics on its own—it rather determined negative change (B = -10.51, p = 0.00); a result possibly influenced by the fact that the Shinkansen connects some of the most populated cities of the sample—being connected to HSR for a higher number of years was found to have a mitigating and eventually positive effect in the long term (B = 0.80, p = 0.00). Unemployment levels were not statistically significant, whereas the number of tertiary jobs for every 1,000 people indicates the significantly positive effects towards mitigating depopulation (B = 0.04, p = 0.01).

B. The Shinkansen Territorial Impact and Changes in Inter-City Relationships

Table 4: Average number of daily HSR services for selected stations of the Tohoku Shinkansen in 2019; Fastest travel times from Aomori in 2000 and 2019; Average daily HSR passengers in 2019. In 2000, Aomori station is considered instead of Shin-Aomori; Numakunai instead of Iwate-Numakunai. In 2000, no railway station existed in Shichinohe. Travel times in italics are estimates for non-direct services.

	Number of direct HSR services								Travel Times from Aomori		Average daily HSR passengers	
HSR stations	Tokyo	Sendai	Morioka	Iwate-Nu.	Ninohe	Hachinohe	Shichinohe	Shin-Aomori	2000	2019	Total (commuters)	Ratio of commuters
Tokyo	---	49	29	7	10	14	10	16	*4h19min*	2h59min	75,004 (9,905)	13.27%
Sendai	55	---	29	8	11	15	11	17	*2h43min*	1h29min	26,653 (4,489)	16.84%
Morioka	26	28	---	8	12	16	12	18	1h58min	49min	7,673 (1,743)	22.72%
Iwate-N.	6	7	7	---	8	8	8	8	*2h12min*	52min	78 (11)	14.10%
Ninohe	9	10	11	7	---	12	12	12	1h25min	39min	760 (328)	43.16%
Hachinohe	14	15	16	7	11	---	12	16	54min	24min	3,400 (488)	14.35%
Shichinohe-T.	9	10	11	7	11	11	---	13	---	15min	761 (136)	17.87%
Shin-Aomori	15	16	17	7	11	16	11	---	---	---	4,111 (414)	10.07%

The extension of HSR north of Morioka brought a significant reduction in travel times (Table 4). In 2000 it took around four and a half hours to go from Aomori to Tokyo, whereas in 2019 the same journey took approximately three hours. Substantial reductions can also be observed for travel times between locations served by HSR stations in the region. In 2000 a trip between Aomori and Morioka took about two hours; in 2019 the fastest service took roughly 50 minutes.

Despite improved travel times, the number of HSR services—or rather, opportunities available to access HSR—is unevenly distributed among the case studies (Table 4). Compared with Sendai, the major transport hub along the Tohoku Shinkansen line outside Tokyo, Morioka has half the number of daily connections to the capital region (26). Numbers in Shin-Aomori (15) and Hachinohe (14) stations are even lower, thus relegating the two core cities of Aomori Prefecture to a less competitive position. Served by around 10 trains per day, Ninohe and Shichinohe-Towada stations have a service frequency comparable to other secondary HSR stations north of Sendai. Meanwhile, fewer than 10 trains make a stop at Iwate-Numakunai station on an average day.

Core cities fared better than smaller municipalities in terms of the total number of HSR passengers (Table 4). Unsurprisingly, Morioka station generated the highest number of average daily trips with HSR in the region (7,673) followed by Shin-Aomori (4,111) and Hachinohe stations (3,400). The capital of Iwate Prefecture had also the highest number of commuters using HSR (1,743 on a daily average) outpacing by far all the other stations. Conversely, with only 78 passengers per day, Iwate-Numakunai emerged as the least busy station among the case studies. Despite having a significantly lower population than Ninohe, the number of daily passengers boarding the Shinkansen at Shichinohe-Towada station was almost the same (760 and 761 respectively)—a figure that might be explained by the influx generated by the tourist industry. However, Ninohe station had a remarkably high percentage of commuters (43.16%), which hints at the favourable location of the city as a base for people commuting for work into the nearby cities served by the Shinkansen.

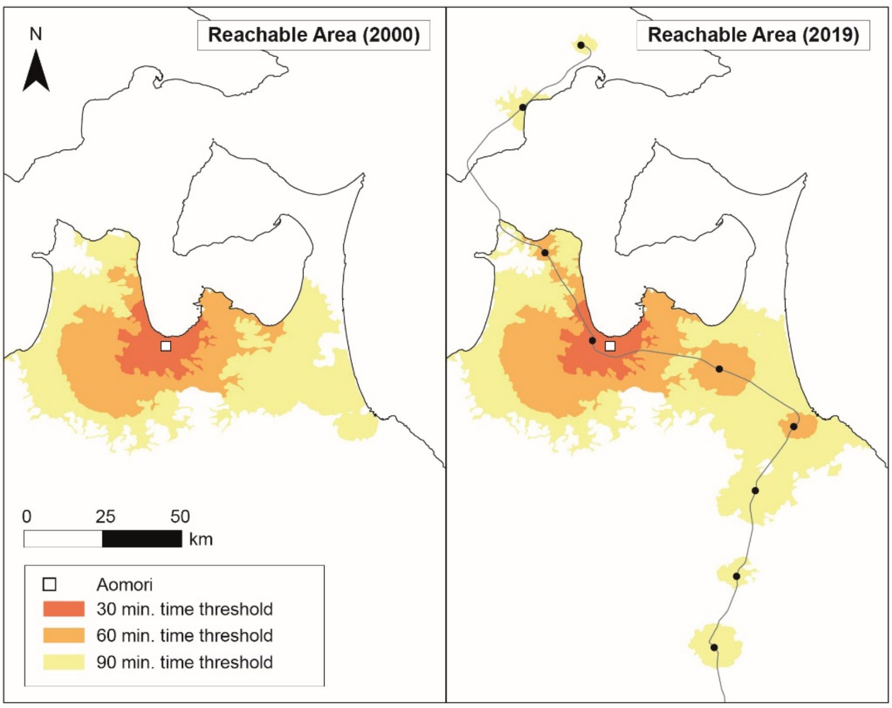

Figure 3: Aomori's reachable area expansion between 2000 and 2019.

Table 5: Change of connected municipalities, reachable areas (km²), and accessibility potential (absolute number) between 2000 and 2019

HSR municipalities		30 min. threshold			60 min. threshold			90 min. threshold		
		2000	**2019**	**Change**	**2000**	**2019**	**Change**	**2000**	**2019**	**Change**
Iwate	CM	0	0	---	6	8	33.33%	10	31	210.00%
	RA	489	489	---	1,892	2,347	24.06%	3,872	7,701	98.85%
	AP	10,157	8,076	-20.48%	17,124	19,802	15.64%	21,641	34,701	60.35%
Ninohe	CM	1	1	---	8	12	50.00%	24	31	29.17%
	RA	514	514	---	2,254	3,055	35.53%	5,394	7,983	48.01%
	AP	17,864	14,822	-17.03%	22,759	28,367	24.64%	33,852	40,984	21.07%
Hachinohe	CM	2	2	---	12	17	41.67%	20	31	55.00%
	RA	601	601	---	2,139	2,567	20.02%	4,516	7,035	55.77%
	AP	27,292	25,704	-5.82%	32,259	36,654	13.62%	35,869	45,367	26.48%
Shichinohe	CM	1	1	---	9	12	25.00%	16	32	100.00%
	RA	512	512	---	1,918	2,215	15.50%	3,829	5,968	55.85%
	AP	13,814	11,660	-15.59%	17,446	23,311	33.62%	25,4501	32,304	26.93%
Aomori	CM	0	0	---	11	13	18.18%	24	37	54.17%
	RA	451	451	---	2,026	2,469	21.89%	4,774	6,571	37.65%
	AP	30,719	28,606	-6.88%	39,982	39,589	-0.98%	44,918	44,848	-0.16%
Morioka	CM	4	4	---	8	9	12.50%	24	46	95.65%
	RA	775	775	---	2,692	3,263	21.22%	7,356	10,730	45.87%
	AP	36,806	36,731	-0.20%	43,677	47,460	8.66%	66,179	79,437	20.03%
Average	CM	1	1	---	9	12	31.48%	19	32	68.42%
	CA	513	513	---	2,046	2,531	23.71%	4,477	7,051	57.50%
	AP	19,969	17,774	-10.99%	25,914	29,544	14.01%	32,346	39,640	22.55%

While the model used to calculate accessibility does not give evidence of significant gains for trips under 30 minutes[9], the presence of HSR resulted in expanded reachable areas for longer journeys—with an average increase of 23.71% and 57.50% within the 60 and 90 minutes thresholds respectively (see Table 5 and, as a visual example, the case of Aomori in Figure 3). Similarly, all the case studies saw an improvement in their intraregional connections. The average number of connected municipalities from HSR cities grew from 9 to 12 within the 60 minutes time threshold, and from 19 to 32 for trips up to 90 minutes (Table 5). Additionally, by 2019 all the case studies gained access to at least two core cities in less than 90 minutes. For travel times of 60 minutes, Hachinohe displays the highest number of CM (17)—further strengthening its role as a sub-regional core in Tohoku. Meanwhile, Aomori has the highest number of CM (37) among the case studies for travel times of 90 minutes, but still remains far behind Morioka, whose position within the Shinkansen network was reinforced even further by the completion of the Tohoku Shinkansen. In the same time threshold, Iwate and Shichinohe also display significant gains.

[9] That is mainly due to the access/ egress time considered in the model.

Results from the analysis of accessibility potential are more nuanced. For trips within 30 minutes, the influence of depopulation determined an average decrease of 10.99%, with lows of -20.48% and -17.03% in Iwate and Ninohe respectively (Table 5). On the other hand, gains can be observed for higher travel times with an average increase of 14.01% and 22.55% for trips up to 60 and 90 minutes respectively. Core cities have accessibility potentials that are much higher than those observed in smaller municipalities. However, if compared to Hachinohe, Aomori—where shrinkage has been more pronounced—exhibits inferior performances and shows almost no gains in any of the time thresholds. Morioka's values are once again the best in the region, showing how the capital of Iwate Prefecture reaped most of the gains produced by the extension of the HSR corridor.

5. Connected but still shrinking: Understanding the role of HSR in peripheral and depopulating municipalities

As more advanced industrial countries continue expanding their HSR networks towards peripheral regions to trigger economic growth and improve inter-regional cohesion, more evidence is needed to gauge local effects of HSR investments in municipalities suffering from the consequences of shrinkage and a stagnant economy—a context that is different from those where HSR performances have been usually investigated. The paper contributes to this debate by considering the extension of the Tohoku Shinkansen in the prefectures of Iwate and Aomori, northern Japan, to discuss whether the presence of HSR had a positive influence on the shrinking trajectories of connected medium and small-sized cities. To address the research question, the paper considered a variety of factors to examine both the socio-economic and territorial impact of the Shinkansen.

An analysis of the population changes in the five case studies reveals that the Shinkansen did not reverse shrinkage. In two municipalities—Iwate and Ninohe—depopulation even accelerated. However, results from the other cases offers a more nuanced picture, as Hachinohe, Shichinohe and Aomori's shrinking trajectories decelerated after they were connected to the Shinkansen network. Moreover, with the exception of the capital of Aomori Prefecture, these municipalities outperformed the average of non-HSR cities and town. This suggests that HSR is not a positive factor in and of itself. Rather, its presence might contribute to population outflow in peripheral and shrinking regions unless other factors are present. Based on results from the study, and despite limited data, a longer connection to the HSR network and a more developed tertiary sector were found to be significant to mitigate population shrinkage.

Notwithstanding, it was difficult to establish a strong relationship of causation between the presence of HSR and wider economic results. The presence of the Shinkansen seems to have had an almost negligible effect on unemployment, as the situation in case studies is largely similar to that in non-HSR cities and towns. Similarly, all case studies show signs of tertiarization, a systemic trend that they share with non-HSR municipalities. In this context, the exception of Shichinohe is worth noting, as it highlights how the presence of HSR contributed to boost the tourist and service sector in an area were rail connections were not present before the arrival of the Shinkansen.

Findings confirms that HSR has a positive impact on the territorial standing of connected municipalities. The Shinkansen improved travel times at both the regional and national level. Moreover, for trips of 60 and 90 minutes—those more suitable for commuting and short business trips, and where the benefits brought by faster travel times surpass the local effects of depopulation—HSR determined better levels of regional integration as measured by the number of connected municipalities, reachable areas, and accessibility potential. Similar to other countries (Monzon et al., 2019), the most significant improvements were found in those case studies that were specially isolated before the advent of HSR—which in this case correspond to some of the smallest shrinking cities served by the Shinkansen in Japan. However, the analysis also found HSR services are unevenly distributed among the case studies and absolute values of accessibility potential remain far higher in core cities. This corroborates evidence showing that HSR ultimately tends to bolster larger urban centres (Deng et al., 2019; Givoni, 2006; Ureña et al., 2009; Vickerman, 2015). Similar conclusions can be reached when taking into consideration the average number of daily passengers.

So, does HSR have a positive effect on the shrinking trajectories of connected medium and small-sized cities in peripheral regions? Broadly, evidence from this paper suggests that, rather than uniformly uplifting the socio-economic outlook of the case studies, HSR rebalanced existing resources in the region and contributed to reshaping the trajectories of the cities connected to the network. This supports the previous observation that faster travel times and increased accessibility do not necessarily bring growth or wider socio-economic impacts. Against this backdrop, however, and in partial contrast with Deng et al. (2019), results also highlight that depopulation decelerated in some of the case studies—i.e. their trajectories somehow improved—after the arrival of the Shinkansen.

A closer look at the municipalities benefitting the most from the presence of the Shinkansen adds to the debate over the viability of HSR investments in the context of shrinking peripheral regions. Whilst the presence of HSR improved the territorial position and integration of the case studies, results suggests that the Shinkansen network—whose strongly uneven effects are well known at the national scale (Daluwatte & Ando, 1995; Hood, 2006; Sands, 1993; Sasaki et al., 1997)—tends to reproduce core-periphery patterns also at the intra- and inter-regional level. In addition, the presence of the Shinkansen reinforced already ongoing processes of intra-regional concentration in larger cities. As a result, in shrinking and peripheral regions, even among larger cities, only very few locations might be able to successfully take advantage of new HSR lines to curb decline in the long term—especially in the presence of corridor effects like those produced by the Japanese HSR network. On the other hand, small-sized cities and less competitive medium centres can only hope to see their decline partially mitigated.

From a planning and policy perspective, these findings need to be emphasised as they challenge the expectation for easy gains from new HSR connections anticipated by many medium and small-sized cities in peripheral regions around the world. As this paper has shown in the Japanese context, investment in HSR in and of itself is not sufficient to significantly alter shrinking trajectories, but it can be an opportunity for municipalities to limit the effects of decline. Based on the results of the study, in order to reap potential benefits, early-stage, holistic and area-wide planning around HSR is recommended to stimulate the local economy. This is especially key for small and intermediate towns along new or newly-extended lines, where the beneficial and cumulative effects of years of HSR presence have yet to appear and there is a higher risk of further depopulation and depletion of local resources towards major cities along the HSR corridor. Planning and policy measures should be complemented by more research around the nexus between shrinkage, HSR territorial impact, and other socio-economic dynamics, along with more comparative empirical evidence from international case studies. While the future of medium and small shrinking cities around the world remains uncertain, this might be the clue to ameliorate some of the pernicious effects associated with decline.

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Appendix – Regression Results Table

R Square	0.855
Adjusted R Square	0.830
Standard Error	2.492
Observations	35

	df	SS	MS	F	Significance
Regression	5	1064.102	212.820	34.247	0.000
Residual	29	180.215	6.214		
Total	34	1244.317			

Dimension	Variable	B	Standard Error	Beta Coefficient	t	Significance
Constant		-13.327	5.239		-2.544	0.017
HSR	HSR	-10.514	1.985	-.665	-5.296	0.000
	HSR_YEARS	0.801	0.116	0.906	6.903	0.000
Demographic and socio-economic	TOTPOP	-0.090	0.010	-1.146	-9.349	0.000
	UNEMP	0.011	0.076	0.011	0.140	0.890
	TERT	0.044	0.016	0.307	2.811	0.009