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Spatial Transition of Innovation Focused on Railway Stations: A Case Study of Patent Applications in Japan from 1980 to 2019

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ABSTRACT

This paper investigates the relationship between railway systems and innovation by analyzing Japanese patent data from 1980 to 2019. It explores the impact of proximity to railway stations on innovation generation. As for methods, a microscopic approach from a station-central perspective is taken in addition to a macroscopic approach from a nationwide perspective under the hypothesis that a distance from the nearest station is related to patent application status. Results show that innovation is higher in grids near metropolitan stations and other stations. The frequency of grids with patent applications increases initially and then decreases beyond 300-700 m from conventional stations, consistent across categories. Innovation surged near stations from 1980 to 2000, decreased from 2000 to 2010 particularly in metropolises, and saw some rise around newly opened high-speed rail (HSR) lines. This highlights the ongoing influence of railway proximity on innovation, especially HSR's potential impact in other areas.

Keywords: Innovation, Railway station, Spatial transition, Patent application, Local Moran's I

1. INTRODUCTION

1.1 Background and Objective

Considering the future of transportation infrastructure for a society with a declining population, there have been active discussions focusing on the relationship between the development of railways and the development of regions along the lines.

However, although the relationship of railways and economic growth has been revealed to some extent, the relationship with innovations, a source of economic value which provokes the transformation of economy and society, is extremely limited. Therefore, there is an urgent need to elucidate this relationship in a comprehensive and long-term manner.

The Japanese railway system has several major characteristics. It plays an important role in public transportation, with lines extending over many regions. Thus, it serves a very large number of passengers, with a total annual ridership greater than 7 billion. In addition, the Shinkansen, Japan's first bullet train, is known as the pioneer of high-speed rail (HSR).

Regarding the background mentioned above, the purpose of this study is to empirically clarify the relationship between railway development and innovation generation. To clarify the relationship between railway systems and innovations, this paper uses patent data covering Japanese patent applications from 1980 to 2019 to analyze the spatial transition of innovations, focusing on the distance from the locations where innovations were developed to the nearest railway station.

1.2 Definition of Innovation

The Oslo Manual, an international standard jointly developed by the OECD and Eurostat (European Commission Directorate-General for Statistics), defines innovation activities as a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process).

The manual also categorizes innovation into four types as shown in Table 1.

Among these four types, product and process are considered technological innovations, while organization and marketing are considered non-technological innovations.

Table 1. Four types of innovation (Oslo Manual).

Product innovation	A good or service that is new or significantly improved. This includes significant improvements in technical specifications, components and materials, software in the product, user-friendliness or other functional characteristics.
Process innovation	A new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.
Marketing innovation	A new marketing method involving significant changes in product design and packaging, product placement and promotion, and/or in the pricing of goods and services.
Organizational innovation	A new organizational method involving changes in business practices, workplace organization or external relations.

Recently, it is expected that the technological innovations promote the development in the region. For example, in the manufacturing sector, regional development and urban planning such as coastal industrial area development and new town development used to work together to attract outside firms, but as large firms continue to expand overseas, the approach that relies solely on attracting firms for regional development is reaching its limits. Therefore, in the age of globalization and the knowledge economy, there is a need for guided urban development, in which new businesses, employment, and entrepreneurship are initiated by small and medium-sized companies within a region, aiming to eliminate subcontracting, rather than the passive approach of preparing a box and waiting.

From a policy perspective, it has been considered essential to create innovation to realize regional development. In the Fifth Science and Technology Basic Plan approved by the Cabinet in January 2016, in order to build an innovation system that contributes to regional development, the government has established a regional-led science and technology. It points out that it is necessary to root independent and sustainable innovation systems in the regions by supporting innovation.

As mentioned above, the background of the increased attention to regional innovation is often focused on the industrial structure. Hence, in this study, it is appropriate to focus on technological approaches rather than innovation within firms.

1.3 Organization of Previous Studies and Positioning of This Study

Ahlfeldt et al. (2017) focused on the time-distance of HSR in Europe and found that the market potential decreases by 50% when the travel time exceeds 30 minutes and by 1% when the travel time exceeds 200 minutes. Inoue et al. (2015) conducted a quantitative analysis of the relationship between the opening of the Nagano Shinkansen and the innovation activities of offices along the Shinkansen line, including causal relationships, and concluded that the innovation activities of the offices along the line improved both in quantity and quality.

Furthermore, by focusing on patent citation relationships, the results suggest the promotion of collaborative research relationships among offices along the railway line and the absorption of patent information from other regions, especially Tokyo. Miwa et al. (2022) measured the causal relationship between HSR and patent application relations in Japan over the past 40 years and found that the opening of the HSR system had a significant positive impact on innovation activities in areas along the HSR. Through a comparison of Shinkansen and expressways, the paper also shows that Shinkansen has a greater impact. In addition, Hensher et al. (2012) focused on HSR in Australia and analyzed the influence of agglomeration on innovation. Baum-Sow et al. (2012) and Kopecky et al. (2010) refer to the facilitation benefits in other areas connected to metropolises by transport infrastructure.

As shown above, numerous studies have analyzed innovation from a geographical perspective, focusing on the important role that shorter time-distances play in stimulating regional innovation. However, few studies have examined the relationship between railways that include intra-city transportation railways on a national scale and over an extended period.

To address this gap, this paper examines the spatial shift of innovations, concentrating on the distance from the nearest station of not only an HSR, but also a conventional railway. Especially, we analyze the relationship in a high resolution with a unit of a square kilometer, which is an initial approach in the academic field. This approach is meaningful especially when analyzing the relationship with conventional railways since its station area is smaller than that of HSR.

As for the approaches, first we analyze the spatial changes using local Moran's I. In the second approach, the relationship between patent applications and new railway openings is categorized based on increase/decrease.

Figure 1 indicates the relationship of each sector in this study. Namely, the two approaches applied in the Chapters 4 and 5 can be united into one major analytical framework to meet the objective of this study, and obtain new findings and the conclusion. As for the approaches, while Chapter 4 takes a macroscopic approach from a nationwide perspective, Chapter 5 takes a microscopic approach from a station-central perspective.

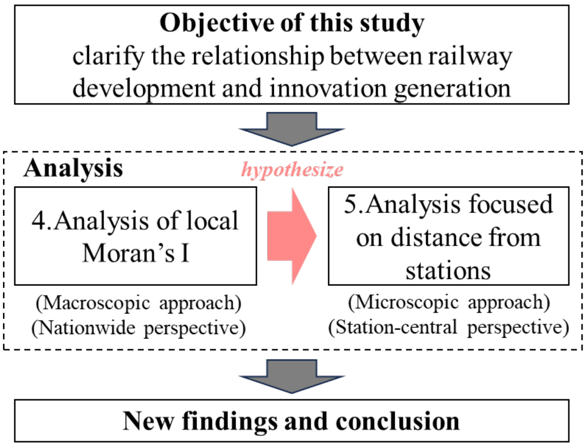

Figure 1. Flow of analysis in this paper.

In detail, as a result of the analysis in Chapter 4, we found a relationship between the nearest railway station from the time-series changes in the concentration and geographic distribution of patent applications. We then formulated a hypothesis that a distance from the nearest station is related to patent application status based on the findings. In order to clarify the hypothesis, a microscopic approach was conducted in Chapter 5, focusing on the increase or decrease of patent applications by distance zone. The red arrow in Figure 1 expresses the hypothesizing on receiving the macroscopic result in Chapter 4.

The macroscopic-to-microscopic approach mentioned above aims to obtain profound findings and increase the robustness of the results in this paper.

2. DATA

The subject of this study is technological innovation. A widely used indicator to measure technological innovation generation is patent data.

The use of patents as an indicator of innovation generation has the following advantages. First, the application date, inventor, address, industry category, etc. are systematically recorded, and can be easily handled as analytical data not only in space but also in time series. Second, the quality of patents can be evaluated by analyzing citation information. Third, the technical classification of patents is internationally standardized, so it is easy to analyze specific industries in each country. In Japan, it is customary to register the address of the inventor's place of business, not his/her home address, when filing a patent application.

On the other hand, the following points should be noted when using patents as an indicator of innovation generation. First, patent is a measure of technological novelty, not a one-to-one correspondence with the definition of innovation as typified by the Oslo Manual, defined by OECD. Second, there are technologies that are not patentable, such as an expertise that is difficult to describe in a specification. Finally, there are technologies which are not applied to patents intentionally, leading the result of not reflecting all the patentable technologies.

By accepting these caveats, understanding innovation through patent data has been widely used in empirical studies on innovation, as seen in Jaffe et al. (1993), Kerr et al. (2015), etc., and is recognized as an appropriate indicator. Based on the above, in this study, we use patent data as an indicator for evaluating innovation generation.

We analyzed the geographic distribution of innovation generation using the following data:

- Institute of Intellectual Property (IIP) Patent Database
- Public data offered by the Japan Patent

Office (JPO)

- National Land Numerical Information offered by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
  - Data on land use (2010)
  - Data on research institutes (2012)
  - Railway data (2011)

The IIP Patent Database contains all the patent information in Japan from 1964 to 2020, including the inventor's name, inventor's address, International Patent Classification (IPC), and the citation information. However, insufficient data are available for analysis before 1980 and part of the address information is unavailable after 2013. Therefore, we extracted the patent data from 1980 to 2013 from the first database. For the data from 2014, we used the database offered by the JPO in the flow shown in Figure 2. For both databases, we converted inventor addresses listed in the IIP Patent Data into longitude–latitude information if the address is in Japan. With these processes, numerous numbers of samples have been counted as shown in the Table 2.

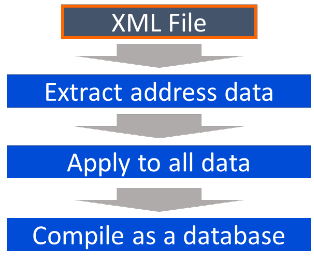

Figure 2. Procedures for compiling the JPO database.

In this study, in order to comprehensively grasp the status of patent applications, the patent data, which are originally point data, were plotted within a 1 km square mesh. It is because this study targets conventional train and subway stations in urban areas with a high station density, which is difficult to handle overlapping concentric polygons, while previous studies have set up polygons concentrically from stations.

Table 2. Patent applications by year.

year	Patent Applications	Number of samples			year	Patent Applications	Number of samples		
		Metropolises	Other areas	Total			Metropolises	Other areas	Total
1980	153,165	235,391	78,092	313,483	2000	353,781	567,272	194,653	761,925
1981	183,555	286,161	91,620	377,781	2001	353,956	573,539	192,996	766,535
1982	204,149	323,399	97,401	420,800	2002	335,999	550,546	181,677	732,223
1983	221,579	355,682	107,582	463,264	2003	326,791	535,570	176,892	712,462
1984	249,516	407,032	119,483	526,515	2004	328,820	541,217	173,395	714,612
1985	265,083	429,896	129,702	559,598	2005	330,504	543,178	175,141	718,319
1986	278,667	452,427	132,155	584,582	2006	313,367	516,965	168,057	685,022
1987	296,023	483,925	134,856	618,781	2007	300,809	500,941	161,153	662,094
1988	292,987	471,535	134,724	606,259	2008	296,850	500,489	160,379	660,868
1989	300,272	486,394	137,902	624,296	2009	263,243	449,917	142,932	592,849
1990	314,667	505,434	144,521	649,955	2010	254,356	446,856	137,849	584,705
1991	315,757	502,093	145,816	647,909	2011	251,082	446,185	135,667	581,852
1992	315,972	507,697	154,429	662,126	2012	250,091	450,935	136,815	587,750
1993	309,798	506,925	158,315	665,240	2013	217,759	421,487	122,378	543,865
1994	297,056	470,785	152,747	623,532	2014	210,368	385,108	105,653	490,761
1995	310,688	490,317	162,852	653,169	2015	200,276	369,273	98,758	468,031
1996	314,704	490,730	165,651	656,381	2016	199,146	527,630	137,220	664,850
1997	324,386	509,788	170,052	679,840	2017	198,386	708,938	182,501	891,439
1998	331,750	520,847	175,787	696,634	2018	191,827	572,662	140,257	712,919
1999	328,129	516,929	181,311	698,240	2019	180,069	373,057	91,997	465,054

3. METHODS

3.1 Measurement of Innovation

As described in Section 1.2, the target of this study is technological innovation. A widely used indicator to measure technological innovation generation is patent data. Understanding innovation through patent data has been widely used in empirical studies on innovation, as seen in Jaffe et al. (1993), Kerr et al. (2015), etc., and recognized as an appropriate indicator. Based on the above, in this study, we also use patent data as an indicator for evaluating innovation creation.

3.2 Nationwide Trend of Patent Applications

The first approach focuses on spatial transitions at the small spatial scale of a 1 km^2 grid and analyzes spatial autocorrelation to gain detailed insights into the trends. Anselin outlines a new general class of local indicators of spatial association (LISA) and shows how they allow for the decomposition of global indicators, such as Moran's I, into the contribution of each observation. The LISA statistics may be interpreted as indicators of local pockets of nonstationarity, or hot spots. In this study, the entire Japanese region of the target area was divided into grids (geographic space as an array of equally sized square cells arranged in a pattern of straight rows and columns).

The grid classification in this study is required to count all innovations, i.e., to have a high coverage rate. On the other hand, in order to increase the accuracy of the subsequent analysis, areas where innovation cannot be created (rivers, forests, etc.) should be eliminated as much as possible. In detail, the grids in which the areas of rice paddies, other agricultural land, forests, river lands and lakes, beaches, saltwater areas, and golf courses are 812,683 m^2 or less are taken into analysis. This value corresponds to 90% of the area of the smallest grid, or 902,981 m^2. Specifically, to determine the geographic distribution of agglomerated regions of patent applications, each region is classified into four categories on the basis of two measures: the standardized index in a grid and the standardized index in the peripheral grid. In this study, "index" refers to the number of patent applications in a designated year.

Figure 3 shows the four categories of agglomerated regions; this figure is called the Moran scatterplot.

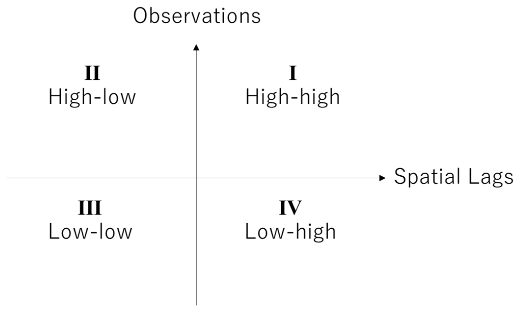

Figure 3. The Moran scatterplot.

The first quadrant is the High-high region, where the value of the patent applications is relatively high in both the subject region and the surrounding region. The second quadrant is the High-low region, where the value of the patent applications in the subject region is relatively high but the value of the patent applications in the surrounding region is relatively low. The third quadrant is the Low-low region, where the value of the patent applications is relatively low in both the subject region and the surrounding region. The fourth quadrant is the Low-high region, where the value of the patent applications in the subject region is relatively low but the value of the patent applications in the surrounding region is relatively high.

The formula for calculating local Moran's I is

$$I_i = \frac{1}{m}(y_i - \bar{y}) \sum_j w_{ij} (y_j - \bar{y}) \quad (1)$$

Where

y_i = Number of patent applications in a designated year at observation grid *i*
y_j = Number of patent applications in a designated year at observation grid *j*
$\bar{y}$ = Sample mean
m = Constant of proportionality
w_{ij} = Weighting coefficients

3.3 Relevance with Railway Stations

The second approach attempts to evaluate the relationship between patent applications and new railway openings by using histograms with distance from the nearest station on the horizontal axis. As mentioned in Chapter 1, this microscopic approach is attributed to the findings in the macroscopic approach in **3.1**, with the hypothesis that a distance from the nearest station is related to patent application status. In this approach, we use Mann-Whitney U Test to quantitively confirm the significant difference between the two groups on a single, ordinal variable with no specific distribution.

In this study, we classify grids and patent applications using various methods to grasp the detailed trend. First, stations are classified into HSR and conventional railways because their role is different: HSR is designed to connect cities, whereas conventional railways are designed for intra-city transport. Second, patent applications are classified into increase or decrease to identify the breakdown of the fluctuations. Third, we classify the grids into metropolises and other areas because the distribution trend greatly differs, as revealed in the result of the Moran scatterplot. Therefore, grids in the following prefectures, composing the three major cities in Japan, are defined as metropolises in this study.

Metropolises: Prefectures of Tokyo, Kanagawa, Saitama, Chiba, Aichi, Osaka, Kyoto, and Hyogo

Under these classifications, increase/decrease tends to show distinctive patterns in comparisons of grid areas, whereas emergence/loss has a similar consequence in metropolises and other areas.

4. ANALYSIS OF LOCAL MORAN'S I

Figure 4 and Figure 5 show the values of the local Moran’s I in the 1980s and 2010s for the Kansai and Chubu Regions. The darker the red, the larger the value of the local Moran’s I, indicating a tendency to have a positive spatial correlation with the surrounding grids. On the other hand, the darker the blue color, the smaller the value of the local Moran’s I, indicating a tendency to have a negative spatial correlation with the surrounding grid. The red color of the grids around large cities is very dark, indicating that grids with many patent applications are concentrated. On the other hand, many dark-colored grids can be observed in other areas far from large cities. This is since few patent applications are filed, especially in mountainous areas.

Comparing the results for urban areas in the 1980s and 2010s, we can confirm that there are relatively few dark red grids in the 2010s, while there are many blue grids. This is a result of the increased concentration of innovation locations. Overall, the color in mountainous areas is confirmed to be darker than that in urban areas, which is the same tendency observed for the surrounding grids. This result is attributed to fewer patent applications in mountainous areas, resulting in zero patent applications for most of the grids in these areas.

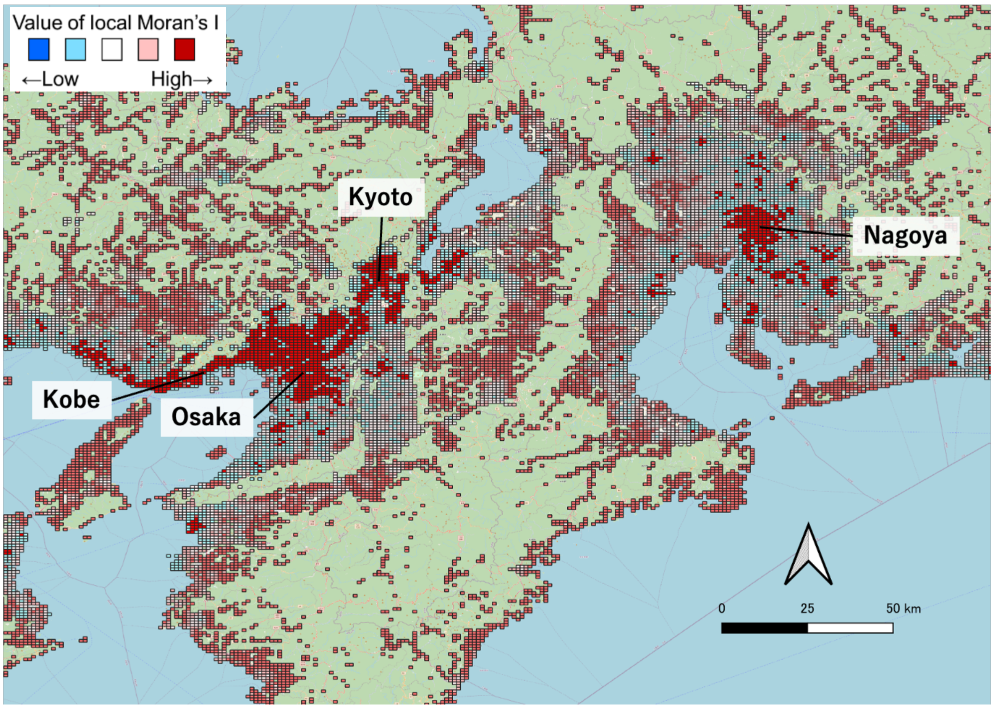

Figure 4. Visualization of local Moran's I in the Kansai and Chubu Regions (1980s).

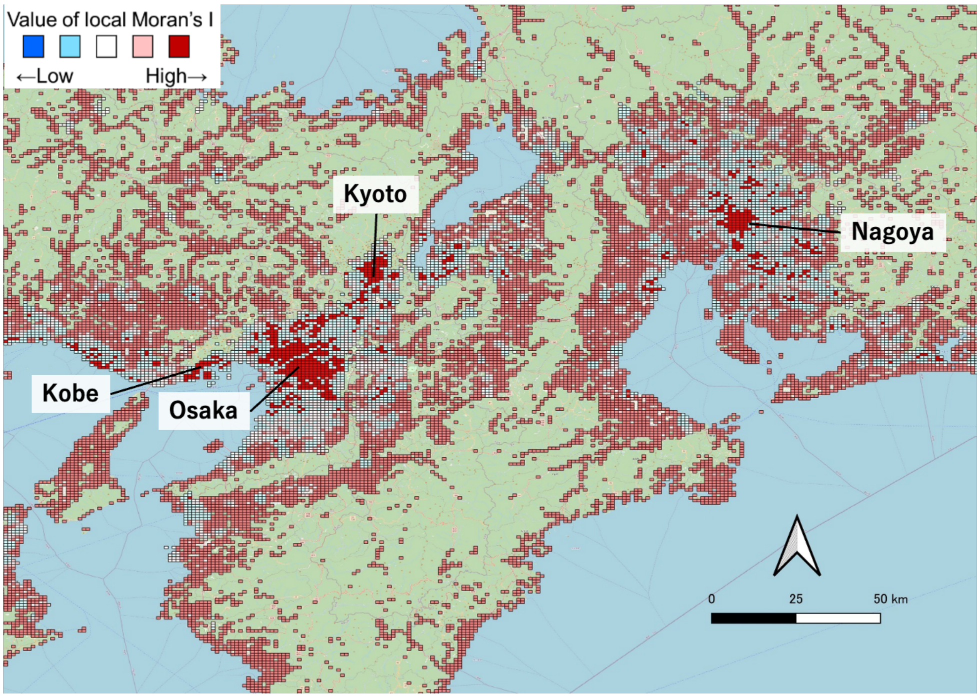

Figure 5. Visualization of local Moran's I in the Kansai and Chubu Regions (2010s).

Table 3 shows the results of classifying the patents filed in the 2010s according to the Moran scatterplot. Each grid is assigned to one of the classification categories, and the average distance of High-high and Low-high is shorter than that of High-low and Low-low, respectively, suggesting that innovation generation is more active along railway lines.

Figure 6 and Figure 7 show the grids that yielded significant results in the Moran scatterplot classification. High-high grids are mostly found in the metropolises, while High-low grids are found in areas outside the center of the metropolis and the seaside areas of large cities. No significant grids were observed for Low-high and Low-low. Figure 5 confirms that most High-high grids have high values on local Moran's I. However, a High-high grid does not necessarily have a high value on local Moran's I. It is because Figure 5 includes all the grids, regardless of the p-value of its local Moran's I.

Table 3. Classification results from Moran scatter plots (2010s).

Category	Metropolises				Other areas			
	Average Patent Applications	Distance from the nearest CON station (m)	Distance from the nearest HSR station (m)	Number of grids	Average Patent Applications	Distance from the nearest CON station (m)	Distance from the nearest HSR station (m)	Number of grids
High-high	53.445	1,367	17,821	8,372	6.553	3,006	57,308	18,325
High-low	4.704	4,501	30,202	53	1.416	7,065	75,284	2,127
Low-high	0.000	2,801	25,898	3,403	0.000	5,721	68,416	43,062
Low-low	0.000	5,072	30,652	366	0.000	14,305	183,736	76,555

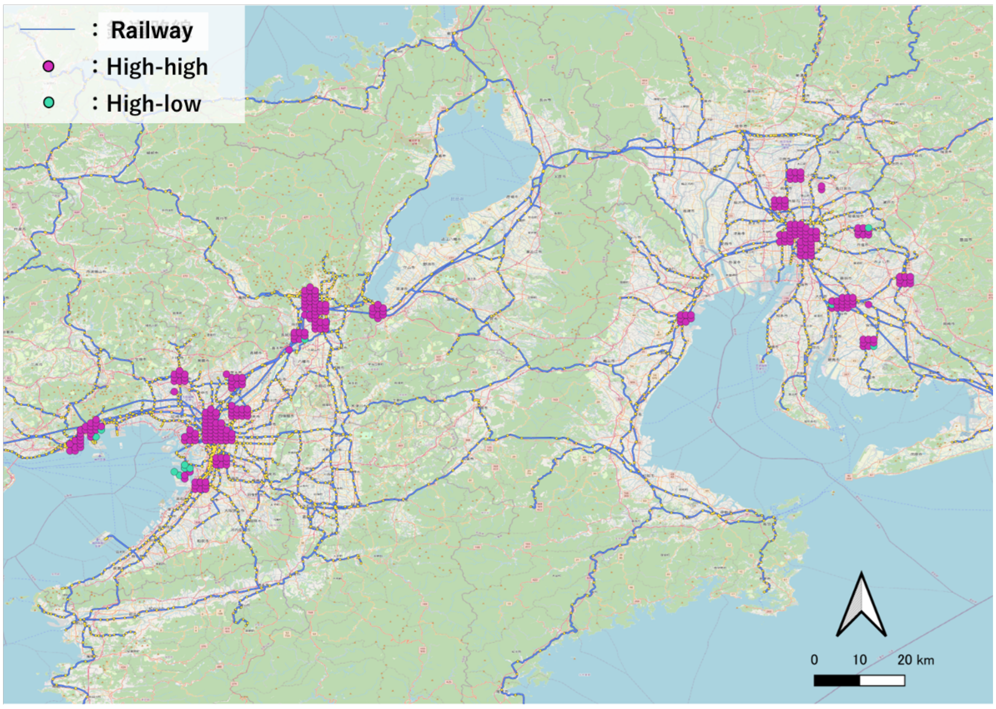

Figure 6. Significant grids in Moran scatter plots (Kansai and Chubu, 2010s).

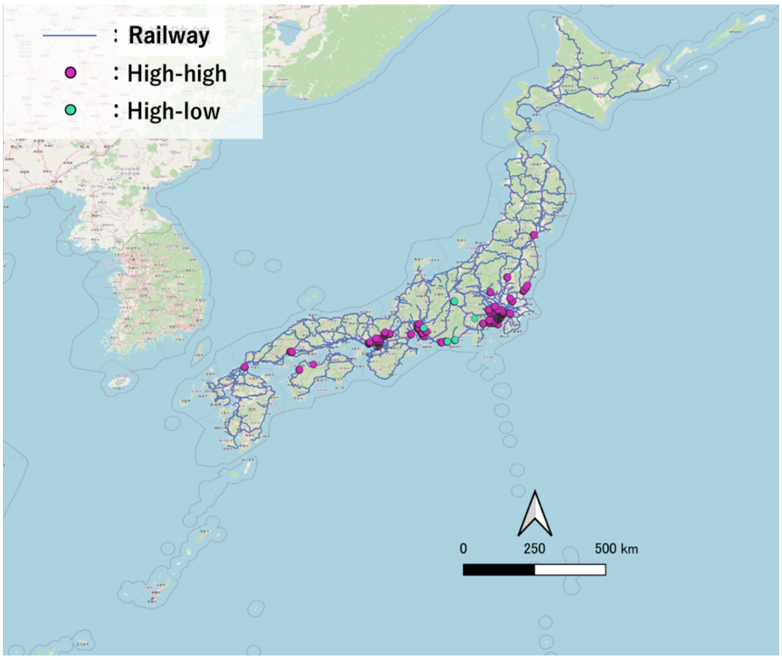

Figure 7. Significant grids in Moran scatter plots (All Japan, 2010s).

The results of Table 3 and Figures 4 to Figure 7 yielded several results. First, innovation is generated in large numbers in metropolises, and suggest that the trend of concentration has strengthened over time in the metropolises. Second, High-high grids with high local Moran's I value tend to locate in metropolises because of the concentration. Third, distance from the nearest station greatly differs in metropolises and other areas especially in Low-low grids.

These results imply the importance of agglomeration from the perspective of the local Moran's I quantitative analysis. In particular, the High-high result suggests that distance from a train station may strongly affect the number of innovation generations.

5. ANALYSIS FOCUSED ON DISTANCE FROM STATIONS

Regarding the importance of the distance from the nearest station for innovation generation, which we obtained in Chapter 4, this chapter attempts to evaluate the relationship between patent applications and new railway openings by using histograms with distance from the nearest station on the horizontal axis.

In addition. In order to check whether there is a significant difference between the two groups, the Mann-Whitney U Test, a statistical method, was performed. Namely, when a particular population tends to have a larger value than the other, the null hypothesis that the two populations are the same can be rejected and we can conclude that the two populations differ.

5.1 Overall Trend

The analysis focusing on the distance from the station yielded the following findings. First, from the comparison of the increased/decreased category, grids with constant patent applications tend to be located closer to conventional railway stations than to HSR stations. We speculate that the influence of inviting new research institutions is relatively high in HSR. Next, the number of grids increases with increasing distance from the nearest conventional railway station, reaches a maximum between 300 and 700 m, and then gradually decreases. This result was common irrespective of the area and the category of fluctuations.

5.2 Transition from 1980 to 2000

Figures 8 and 9 show histograms of the fluctuation of patent applications from 1980 to 2000 as a function of the distance from conventional railway stations in metropolises and other areas, respectively. "Increase" indicates that there were more patent applications in 2000 compared to 1980 and "decrease" indicates that there were fewer patent applications in 2000 compared to 1980. From 1980 to 2000, the number of patent applications increased substantially near stations. Both the increase and the decrease in the number of patent applications are found to have a large variation in the grid at a distance of approximately 500 m from the station.

Table 4 shows the results of Mann–Whitney U tests for both metropolises and other areas from 1980 to 2000. It is a nonparametric test for judging a difference between two groups in unpaired data. Because the p-values in both areas are less than 0.05, the null hypothesis is rejected, leading to the conclusion that a significant difference exists between the increased/decreased distribution trends.

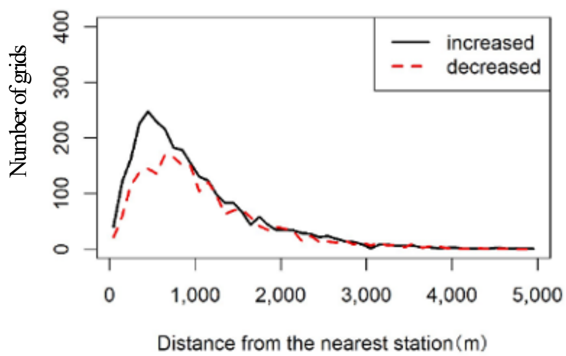

Figure 8. Number of grids classified by the fluctuation of patent applications (metropolises from 1980 to 2000).

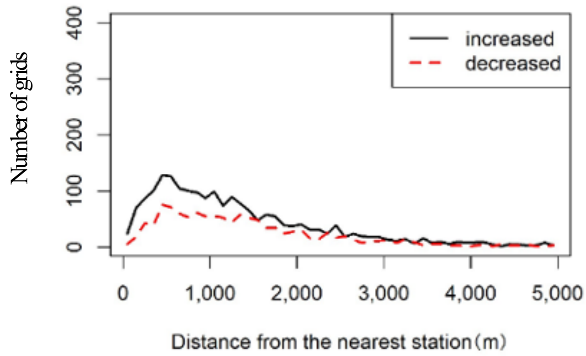

Figure 9. Number of grids classified by the fluctuation of patent applications (other areas from 1980 to 2000).

Table 4. Results of Mann–Whitney U test (from 1980 to 2000).

		Number of Samples	U Statistic	*p*-Value
Metropolises	Increased	2,828	6,289,472	$<2.2\times10^{-16}$
	Decreased	2,224		
Other areas	Increased	2,001	2,385,192	$<2.2\times10^{-16}$
	Decreased	1,192		

From 1980 to 2000, the technology in each industry has been sophisticated. Therefore, the concentration has been begun to be required.

5.3 Transition from 2000 to 2010

Figures 10 and 11 show histograms of fluctuation of patent applications from 2000 to 2010 as a function of the distance from conventional railway stations in metropolises and other areas, respectively. "Increase" indicates that there were more patent applications in 2010 compared to 2000 and "decrease" indicates that there were fewer patent applications in 2010 compared to 2000. From 2000 to 2010, the trend observed from 1980 to 2000 reversed, with a significant decrease in patent applications, especially in the vicinity of stations in metropolises (grid of 400 m to 700 m from the nearest station).

Initially, decreased surpassed increased in almost all the classes. This is attributed to the change of the trend of patent applications, namely, companies tend to avoid patent applications intentionally in order to save money for registrations. On the other hand, distance classes can be seen in the same area. This can be attributed the reverse trend which occurred from 1980 to 2000. The main reason of the trend can be attributed to the emergence of alternatives to face-to-face communication, such as e-mail or online meetings. The trends continue until 2019, but the tendency is modest.

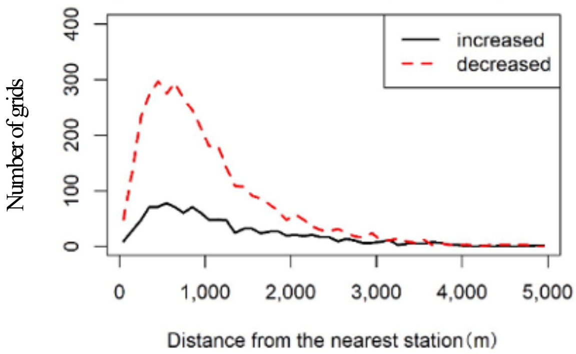

Figure 10. Number of grids classified by the fluctuation of patent applications (metropolises from 2000 to 2010).

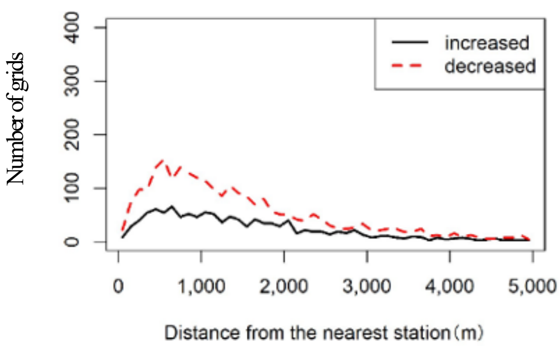

Figure 11. Number of grids classified by the fluctuation of patent applications (other areas from 2000 to 2010).

Table 5 shows the results of the Mann–Whitney U test in both metropolises and other areas from 2000 to 2010. Because the p-values in both areas are lower than 0.05, we concluded that a significant difference exists between the increased/decreased distribution trends.

Table 5. Results of Mann–Whitney U test (From 2000 to 2010).

		Number of Samples	U statistic	*p*-Value
Metropolises	Increased	1,117	4,235,664	$<2.2\times10^{-16}$
	Decreased	3,792		
Other areas	Increased	1,222	3,169,868	$<2.2\times10^{-16}$
	Decreased	2,594		

5.4 Transition of Grids with HSR Openings

In this section, we focus on the recent opening of HSR lines in Japan, connecting metropolises and relatively small cities. Although the effect of HSR openings is inferred along each line, we focus on the HSR opened in Nagano in 1997, which had the most massive time shortening in recent years. It connected Nagano and Tokyo in 1 hour and 23 minutes—a significant reduction of approximately 1 hour and 30 minutes from the time before the opening of the new service.

Figures 12 and 13 show histograms of the fluctuation of patent applications from 1990 to 2000 as a function of the distance from conventional railway stations along the HSR. Grids composing Figure 11 were extracted under the condition of a distance of 20 km or less from the nearest HSR station in Nagano Prefecture (i.e., Annaka-Haruna, Karuizawa, Sakudaira, Ueda, or Nagano Station).

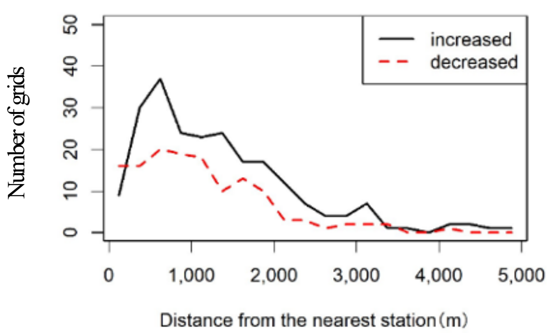

Figure 12. Fluctuation of patent applications

near HSR stations in Nagano (from 1990 to 2000).

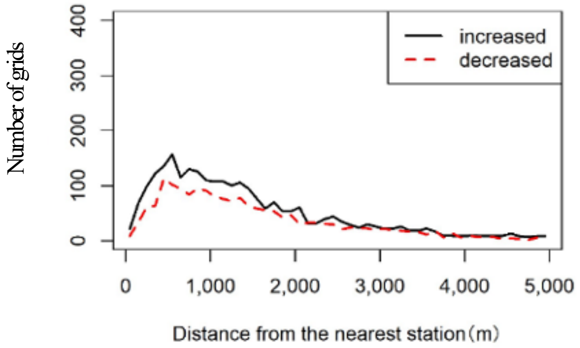

Figure 13. Fluctuation of patent applications in other areas (from 1990 to 2000).

Compared with the other areas in Japan, Nagano has a relatively large gap between increase and decrease in the sense of composition ratio. Figure 14 visualizes the increase-to-decrease ratio in each distance class. The lines show the frequency of increased grids among decreased grids. Because some of the distance classes longer than 3,000 m near a station tend to have no decreased grids, the figure indicates the results for distance classes shorter than 3,000 m.

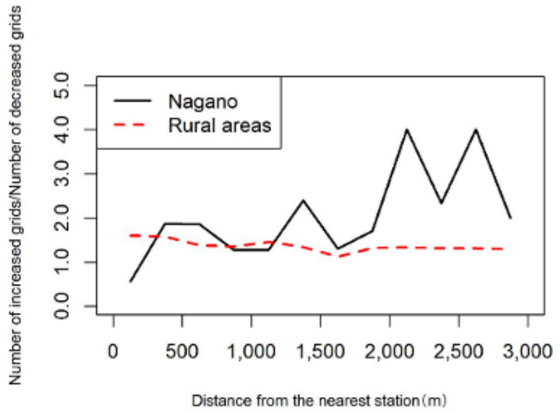

Figure 14. Ratio of the number of increased grids to decreased grids in each distance class.

The figure shows that the values in Nagano mostly surpass the whole of the other areas, suggesting a clear relationship between a new HSR opening and an increase in innovation.

As a whole, Nagano showed increase trend, which is the different trend from other other areas. The result can be attributed to the existence of HSR, which is also referred by Miwa et al (2022).

6. CONCLUSION

6.1 Overall Trends

The paper has investigated the relationship between railway systems and innovation by analyzing Japanese patent data from 1980 to 2019, with the purpose of empirically clarifying the relationship between railway development and innovation generation.

In the analysis of local Moran's I, a macroscopic approach from a nationwide perspective, the concentration of patent applications in metropolis and the increased concentration of innovation locations has been inferred. Furthermore, we classified the location trends of patent application sites into four patterns. By comparing the distance from the nearest station in each pattern, it can be hypothesized that a distance from the nearest station is related to patent application status. These results can be attributed to our initial approach in the academic field, which is an analysis in a high resolution with a unit of a square kilometer.

The analysis focusing on distance from train stations, a microscopic approach from a station-central perspective, yielded the following new findings. First, the frequency of grids increases with increasing distance from the nearest conventional train station, reaches a peak at 300 to 700 m, and then gradually decreases at distances greater than 700 m. This result was commonly observed irrespective of the categories of increase or decrease. Second, especially from 1980 to 2000, patent applications increased significantly near stations. Third, the trend reversed in the period from 2000 to 2010, when patent applications near stations significantly decreased, especially in metropolises. The trend continued until 2019, but the tendency was modest. Fourth, some areas with newly opened HSR lines have shown relatively large increases in patent applications.

These results suggest that the relationship between places of innovation generation and the distance from the nearest station is becoming modest but still plays an important role. In particular, the results suggest that development of HSR may be highly effective for generating innovation in other areas.

6.2 Future Works

As a future issue, elucidating the reasons why the opening of HSR lines has had such a significant impact is critical. Specifically, we would like to focus on the differences between the HSR and conventional railways, such as the difference between inter-city and intra-city transportation, and to consider the contributions of HSR to innovation generation. Moreover, in terms of measuring the effectiveness of HSR precisely, a new specialized analysis of the High-low category should be conducted.

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