Time series analysis of Shinkansen construction impact on rail and air demand: Analysis with Tohoku data

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This study analyses how the Shinkansen construction in Tohoku and Kyushu has affected total demand and interregional travel patterns. Our focus is on the Tohoku region for which we have annual interregional traffic volume data for public transport modes from 1989 to 2012. We also make some comparison to high speed rail effects after the opening of the Sakura-Shinkansen to Kyushu. In Tohoku we find that results show that the Shinkansen increases rail and total PT trips soon and furthermore generates additional rail demand year by year. The "Mini-Shinkansen", that is the Shinkansen lines that branch from the main Tohoku Shinkansen line and operate with limited speed, instead do not increase trips as much when they start operation, however, to some degree, also motivate gradual changes in mode choice. For both Tohoku and Kyushu we further discuss specifically the impact of the Shinkansen on air demand.

Key Words : *Shinkansen, High Speed Rail, Travel Demand, Regression model, Adaptation Effect*

1. Introduction

For a balanced development among the different regions in Japan "The First Comprehensive National Development Plan[1)]" was adopted by the Japanese Cabinet in 1962. The plan was later revised to reflect the changing economic challenges of our time. Multiple interregional transport infrastructure projects such as Shinkansen and highway construction were agreed according to the plan. The infrastructures reduced travel time, thus the limit for one-day trips was extended. For example, Tokaido Shinkansen opened its operation, which passes through Tokyo, Nagoya, Osaka; the three largest cities in Japan. The opening initially reduced the travel time between Tokyo and Osaka from 6.5 to 4 hours. Nowadays, we can travel the section in 2.5 hours. Development of interregional transportation played one of the most significant roles for economic growth in Japan. Analyzing the High Way effects for economy, Nakazato[2)] (2001) showed constructing interregional Transportation in low industrial clusters area have positive effect for economic growth there.

As a case study first we analyze the interregional transportation pattern between Tokyo and Tohoku area, northern part of Japan, which is composed of 6 prefectures: Aomori, Iwate, Miyagi, Akita, Yamagata and Fukushima. Table 1 shows the time schedule of Shinkansen operations in Tohoku area.

Table 1 Tohoku Area Shinkansen Extension Schedule

Year	Tohoku Area Shinkansen Extensions Schedule		
	Full-Shinkansen	Mini-Shinkansen	
	Tohoku-Shinkansen	Yamagata-Shinkansen	Akita-Shinkansen
1982	Omiya(Saitama) - Morioka(Iwate)	-	-
1985	Ueno(Tokyo) - Morioka(Iwate)	-	-
1991	Tokyo - Morioka(Iwate)	-	-
1992	-	Fukushima - Yamagata	-
1997	-	-	Morioka(Iwate) - Akita
1999	-	Fukushima- Shinjyo（Yamagata)	-
2002	Tokyo - Hachinohe(Aomori)	-	-
2010	Tokyo - Shin-Aomori(Aomori)	-	-
2015 Total	Tokyo - Shin-Aomori(Aomori)	Fukushima- Shinjyo（Yamagata)	Morioka(Iwate) - Akita

Tohoku-Shinkansen was constructed as so called “Full-Shinkansen standard”, which allows maximum operation speed of over 200 km/h. On the other hand, Yamagata Shinkansen and Akita Shinkansen were constructed as so called “Mini-Shinkansen standard”, with maximum speed limits of 130 km/h, due to sharing track with other conventional rail in these sections. However Mini-Shinkansen trains are able to run at maximum speed of over 200km/h on Full-Shinkansen standard tracks.

The focus of this paper is the analysis of the impact of the constructions listed in Table 1 on total demand and modal split. In the final sections of this paper, in addition, we make some comparisons to demand developments for travel to Kyushu, where the Shinkansen has also been extended in recent years

The reminder of this paper is structured as follows. Section 2 reviews literature on interregional travel demand and the demand effect of large infrastructure projects. Section 3 presents the changes of travel demand between Tokyo and Tohoku from 1989 to 2012. The definition of potential explanatory factors are also included in the section. Time series regression analysis was proposed, where rail trips and modal share between Tohoku and Tokyo had been modeled and described in Section 4. Section 5 contains some comparison with the Shinkansen demand in Kyushu. Section 6 concludes this study.

2. Literature Review

Interregional transport plays a significant role for cultural exchanges and economic activities. For this reason, transport demand were analyzed or tried to predict following a various situations in long period.

For one, the operation of key transport infrastructures is focused. As an example, the impact of the extension of the highway network was estimated by Abe[3)] et al (2003). They estimated the impact of highway network extension on commodity flows. It showed that formation of highway network in local regions is effective to improve the conditions of commodity flows in the whole nation. The impact of long term operation stop of the Tokaido Shinkansen was also estimated by Asami[4)] (2001). He proved it caused not only modal change from rail demand within the section but also the number of trips decreased in multiple areas in Japan.

In addition, no matter how convenient the new transport system is, if the system is not well known so much, the demand is not adapted immediately. Schmöcker[5)] et al (2013) explained that “mass effects” can be significant factor for demand adaptation. That is, only after time people learn from each other and land-use effects come into play creating a positive feedback circle that can lead to continuous demand growth. Moreover Brakewood[6)] et al (2015) explained the effect of real-time information provided via web-enabled and mobile devices on public transit ridership. That is, owing to the real-time information, the ridership per each route increase by 1.7% of weekday.

Therefore Li[7)] et al (2014) defined a continuous variable for months since operation start as the “Adaptation Effect”. Using Adaptation Effect as an explanatory variable, they explained the time-lag from opening its operation until demand stabilized on Taiwan High Speed Rail system.

In conclusion, a number of authors have already analyzed interregional transport demand. However, the long term demand analysis focusing on the plural Shinkansen extensions seems under researched. Further, adaptation effect differences on new transport system scheme was not considered in Japan. In particular, the impact differences between Full-Shinkansen and Mini-Shinkansen are yet to be investigated.

3. Data Descriptions

3.1. Tohoku Interregional Transportation data

In order to distinguish travel demand in Tohoku area from overall trends, our dependent variables, interregional traffic volumes were collected from Japan Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The data matrices were composed of annual origin-destination trip numbers between prefectures by transport mode. Furthermore, we note that the annual trips are defined by the Fiscal Year (FY), which is calculated from April to next year March.

The trips data were identified from different travel modes, including Japan Railway (JR), private railway, airline, chartered bus, regular route bus, taxi and maritime transport. However, private car was omitted due to missing values in statistics. The JR trips and private rail trips were further combined as rail trips.

Total public transport trips are that of all transport modes. The amount of annual total PT trips demand between Tokyo and each prefecture in the Tohoku area over 24 years from 1989 to 2012 are shown in Figure 1.

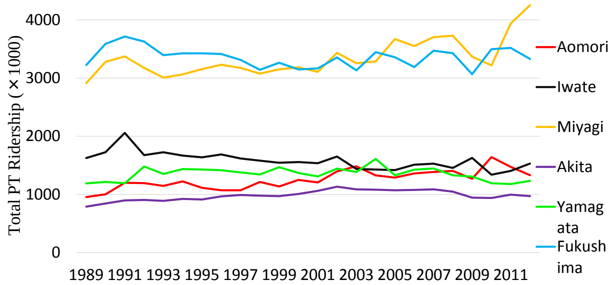

Figure 1 Annual total PT trips between Tokyo and Tohoku

Figure 2 shows the annual pattern in rail trips between the sections in the same period. The peak at 1990 or 1991 is observed as well as total trips in Miyagi, Fukushima and Iwate. The positive trend in Miyagi and Aomori is also shown. In addition to these findings, it can also be observed that rail are rapidly increasing. Some of them can be explained by the Shinkansen extension; the jump at 1992 in Yamagata can be due to the opening of the Yamagata Shinkansen between Fukushima and Yamagata; the jump in 2002 in Aomori can result from the extension of the Tohoku Shinkansen between Morioka (Iwate) and Hachinohe (Aomori). Furthermore, the figure shows the trips steadily increased after Shinkansen extension.

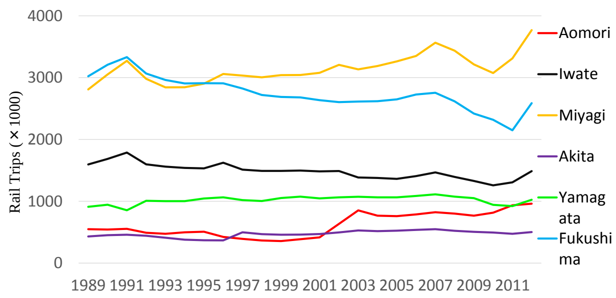

Figure 2 Annual Rail Trips between Tokyo and Tohoku

Figure 3 shows the annual pattern in air demand. Since no direct flight operate between Tokyo and Iwate, Miyagi and Fukushima, The Air Trips is 0 in the period. Air trips between Aomori and Tokyo sharply decrease from 2002, in which Tohoku Shinkansen extended to Aomori prefecture. Although the effects are not so pronounced as for Aomori, similar decreases can be found for Akita and Yamagata when the Shinkansen operation started. One reason for the less pronounced decline might be the difference between the impact of Full-Shinkansen and Mini-Shinkansen.

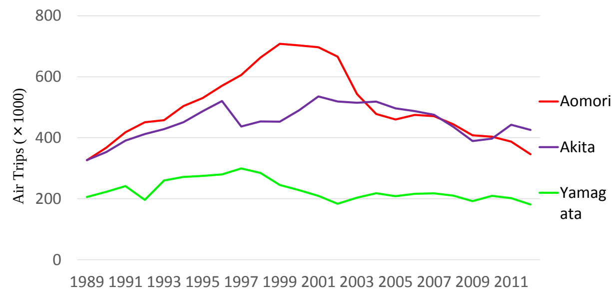

Figure 3 Annual Air Trip between Tokyo and Tohoku

3.2. Explanatory Factors

Considering the basic examination in Chapter 3.1, three impacts of Shinkansen extensions might be distinguished.

Firstly, the existence of the Shinkansen itself will improve regional connectivity and convenience in travel. Therefore in our subsequent analysis Shinkansen dummy variables are used as proxy variables to explain the "existence effect".

Secondly, considering speed improvements due to the Shinkansen, rail travel times T_{it} are estimated by:

$$V_{it}^{S} = \frac{\bar{V}_{i,2014}\hat{V}_{it}}{\hat{V}_{i,2014}} \ (\text{km/h}) \quad (1)$$

$$D_{2it} = \sum_k d_{2kit} \ (\text{km}) \quad (2)$$

$$T_{it} = 15C + \frac{D_{1it}+D_{2it}}{60\times(V_{NS}D_{1it}+V_{S\,it}D_{2it})/(D_{1it}+D_{2it})} \ (\text{min}) \quad (3)$$

The subscript i denotes the trips between representative stations from each prefecture; Tokyo, Aomori, Morioka (Iwate), Sendai (Miyagi), Akita, Yamagata and Fukushima station (Fukushima). V_{it}^{S} and V_{it}^{NS} denote the estimated speed of the Shinkansen and conventional train (non Shinkansen) in the target year. D_{1it} is the railway length of conventional rail and D_{2it} is that of Shinkansen. $\bar{V}_{i,2014}$ is the mean speed of Shinkansen between Tokyo and prefecture i which is estimated by the time schedule in 2014. $\hat{V}_{it}$ is the weighted mean of the maximum speed of Shinkansen between Tokyo and prefecture i. C denotes the number of transfers needed during travel, we assumed that each transfer would require on average 15 minutes, for example from Tokyo to Morioka no transfer is needed but from Tokyo to Aomori one change is needed at Shin-Aomori. Speed of conventional rail (non-Shinkansen trains), V_{it}^{NS} is defined as 80km/h between Morioka and Aomori, 70km/h in other sections considering the rail track situation. T_{it} is the resulting travel time of the rail between Tokyo and prefecture i in year t measured in minutes.

Thirdly, some of the effects will have only become important over time, therefore we also define the adaptation effect among individual prefectures in this research. Although Li[7] *et al* (2014) use integer from 1 which increases monthly since operation, defined by logarithm can be more appropriate for the annual data in this research. Therefore adaptation effect is defined as common logarithm from log(2) in the next year of the Shinkansen extension as log(2), log(3), log(4), etc. From our assumptions, adaptation effect was presumed to be a positive effect for rail trips. (See Table 2)

Table 2 Definition of Shinkansen Effects

Variables		Definition/Notes
Shinkansen Dummy	Existence : Full (or Mini)-Shinkansen Dummy	Existence Full (or Mini)−Shinkansen in Prefecture is 1, not is 0
	Existence(2) : Full (or Mini)-Shinkansen Dummy	Extension Full (or Mini)−Shinkansen in Prefecture ***second time(2)***, The dummy turns 1from 0
Travel Time of Rail	Travel Time	Travel time of rail from Tokyo which calculated based on Time schedule in 2014 considering Shinkansen extension
Adaptation Effect	ADAP : XXXX Extension (1) Full-Shinkansen	$\log_{10}(2)$,log10(3),log10(4),…From the next year of the **first** Full−Shinkansen extension in XXXX
	ADAP : XXXX Extension (2) Full-Shinkansen	$\log_{10}(2)$,log10(3),log10(4),…From the next year of the **second** Full−Shinkansen extension in XXXX

Besides the impacts from Shinkansen extensions, clearly socio-economic factors might have affected the trips demand and modal share. The definition of the factors we utilized in the research are shown in Table 3.

Table 3 Definition of Explanatory Variables

Variables		Definition/Notes	Unit
Socio-Economic Factors	Population		1000(person)
	※Gasoline Price	※divided by CPI ratio (2010 is 100)	Yen
	※Mean Personal Income	※divided by CPI ratio (2010 is 100)	million (Yen)
	Number of Company		
	※Total Company Income	※divided by CPI ratio (2010 is 100)	million (Yen)
	※GDP	※divided by CPI ratio (2010 is 100)	billion (Yen)
	Unemployment Ratio(Japan)	mean in Japan	%
	Car Ownership	Include all car such as private vehicles, Bus and Track.	
	Higashi-Nihon Earthquake	Surmise based on the number of completely destroyed building by Higashi-Nihon Earthquake	
Prefecture Dummy	Prefecture Dummy	dummy per Prefecture	
High Way	Length of Highway		km
Rail	Travel Time of Rail	Estimated by Time Schedule in 2014 with considering Shinkansen extension and maximum speed change	minute
	Shinkansen Dummy		
Adaptation Effect	ADAP Effect	Assumed that effects grow larger after the extension	

In addition to these transitions, the massive earthquake, Higashi-Nihon Earthquake in March 2011, has caused great damage to the Tohoku region. The damage was very serious especially in the pacific side; Iwate, Miyagi and Fukushima prefecture. Therefore the indicator of Higashi-Nihon Earthquake is defined based on the number of completely destroyed buildings by Higashi-Nihon Earthquake (DB). Considering Higashi-Nihon Earthquake happened at the end of financial year (FY) 2010, that is March 2011, and rehabilitation year by year, the definition of the Higashi-Nihon Earthquake term are estimated for each prefecture by:

$$X_{kt} = {DB}/{12} \qquad t = 2010 \quad (4)$$

$$X_{kt} = {DB}/{\exp(t-2010)} \qquad t \geq 2011 \quad (5)$$

In this definition, X_{kt} is Higashi-Nihon earthquake term for prefecture k in FY t. DB is the number of completely destroyed building by Higashi-Nihon Earthquake. Earthquake effect appears to be strongest when it happens and gradually to weaken owing to rehabilitation. In order to explain this situation, Higashi-Nihon Earthquake term is defined as DB divided by $\exp(t-2010)$ with $t \geq 2011$. Further since Higashi-Nihon Earthquake happened in March, the end of FY 2010, X_{kt} is defined as (4) in FY 2010.

4. Regression analysis with Tohoku data

4.1. Rail Trips

We examine Shinkansen extension effects and its adaptation effects for demand. The dependent variables are rail trips between Tokyo and each Tohoku prefecture. Stepwise regression are adopted for our analysis. The models are given by:

$$Y_{klt} = \sum_{i} \alpha_{li} X_{kit} + C_l + \beta_{kl} D_k + \varepsilon_{kl} \qquad (6)$$

Y_{kt} is the rail trips for FY t between Tokyo and prefecture k. X_{kit} is explanatory variable i for FY t in prefecture k. C is constant. D_k is Prefecture Dummy per prefecture k. ε_{kl} is an error term for prefecture k. C, α_{li} and β_{kl} are estimated by the least square method. As the rail trips between Tokyo and 6 Tohoku prefectures are analyzed in one model, we now have 6x24 observations for our model.

As a Shinkansen Effects, travel time of rail is utilized in Model 1; Shinkansen Dummy and Adaptation Effects are utilized in Model 2. Result of these models are shown in Table 4.

Table 4 Result of Model 1 and Model 2

	Model 1		**Model 2**	
	coefficient	t value	coefficient	t value
Constant	−729. 168 ***	−3. 674	−5008. 562 ***	−10. 411
Population	1. 126 ***	6. 204	3. 434 ***	11. 097
※Gasoline Price	5. 993 ***	6. 445	6. 628 ***	8. 859
※Mean Personal Income	145. 956 ***	3. 589	178. 851 ***	6. 270
Number of company	−0. 013 *	−1. 670		
※Total company Income				
※GDP	1. 205 *	1. 740		
Unemployment Ratio(Japan)				
Car Ownership				
Higashi-Nihon Earthquake			0. 008 **	2. 340
Length of Highway				
Aomori Dummy			−1166. 181 ***	−16. 715
Iwate Dummy				
Miyagi Dummy			−1734. 539 ***	−5. 828
Akita Dummy			−289. 607 ***	−4. 861
Yamagata Dummy	−141. 546 ***	−3. 062		
Fukushima Dummy			−1198. 292 ***	−5. 407
Travel Time of Rail	−6. 320 ***	−22. 160		
Existence：Full-Shinkansen Dummy			207. 102 ***	3. 984
Existence：Mini-Shinkansen Dummy				
Extension（2）：Full-Shinkansen Dummy				
Extension（2）：Mini-Shinkansen Dummy				
ADAP：Aomori（1）Full-Shinkansen			475. 943 ***	4. 701
ADAP：Aomori（2）Full-Shinkansen			481. 351 **	2. 019
ADAP：Iwate（1）Full-Shinkansen				
ADAP：Yamagata（1）Mini-Shinkansen			367. 848 ***	6. 896
ADAP：Yamagata（2）Mini-Shinkansen				
ADAP：Akita（1）Mini-Shinkansen			464. 664 ***	8. 195
R	0. 992		0. 995	
R-square	0. 985		0. 990	
adjusted R-square	0. 984		0. 989	

***:p<0.01, **:p<0.05, *:p<0.10

We find that gasoline prices have a significant positive effect on both models. Further, population and mean personal income show significant positive effects; this could be explained by considering population as the basic factor to generate trips; where personal income was an important factor that allows one to make more trips in general. In addition, Higashi-Nihon Earthquake has a significant positive effect in Model 2. Though Higashi-Nihon Earthquake caused immense damage in the Tohoku area; however, on the other hand, the demand for rehabilitation and reconstruction in Tohoku eventually produced massive additional trips. Length of highway is not significant in both models.

In Model 1, we discuss Shinkansen extension effect using "Travel Time of Rail". As we expected, it has a significant negative effect on rail trips. In Model 2, "Existence: Full-Shinkansen Dummy" has a significant positive sign, however "Existence: Mini-Shinkansen Dummy" has no significant sign. Further, "Extension(2) Full-Shinkansen Dummy" and "Mini-Shinkansen Dummy" are both insignificant in the models.

Adaptation effect for Full-Shinkansen extension has, as we expected, significant positive effect for rail trips except for Iwate. Moreover, the adaptation effect for “Mini-Shinkansen Extension(1)” in Akita and Yamagata, showed significant positive sign as well.

To sum up, Full-Shinkansen extension were found as an effective stimulus for rail trips. In particular, Full-Shinkansen induced additional demand for rail year by year. The impact of Mini-Shinkansen extension is not so strong when it opened its operation, but gradually increase the rail demand after its opening.

4.2. Modal Share

In this section, a few factors were discussed on the modal share impacts between Tokyo and Tohoku area regarding public transport modes respectively. Since mainly Shinkansen and air are utilized for long distance trips to the North of Tohoku, rail share and air share between Tokyo and Tohoku are analyzed as dependent variables in our research. The analysis further suggests potential insights from previous section.

The explanatory variables are based on model 2 in Section 4.1. Therefore this model includes “Socio-Economic Factors”, “Length of Highway”, “Shinkansen Dummy”, “Prefecture Dummy” and “Adaptation Effect” as explanatory variables. For analyzing common effect of these variables in Tohoku area, modal share is estimated between Tokyo and all of Tohoku prefectures taken together same as in Section4.1. The models are given by:

$$Y_{klt} = \sum_{i} \alpha_{li} X_{kit} + C_l + \beta_{kl} D_k + \varepsilon_{kl} \qquad (7)$$

In the models *l* is defined by which dependent variable is used, rail share or air share. Y_{klt} is the modal share for FY *t* between Tokyo and prefecture *k* for *l*. X_{kit} is explanatory variable i for FY *t* in prefecture *k*. C_l is constant in the dependent variable *l*. D_k is the prefecture dummy per prefecture *k*. ε_{kl} is an error term for prefecture *k* for dependent variable *l*. C_l, α_{li} and β_{kl} are estimated by the method of least square.

Results of this model are shown in Table 5.

Table 5 Modal Share

Modal Share	Rail Share		Air Share	
	coefficient	t value	coefficient	t value
Constant	80. 603 ***	46. 455	9. 151 ***	4. 450
Population				
※Gasoline Price			−0. 077 ***	−4. 527
※Mean Personal Income				
Number of company				
※Total company Income				
※GDP				
Unemployment Ratio(Japan)	−2. 059 ***	−4. 722		
Car Ownership				
Higashi-Nihon Earthquake	0. 000 ***	−2. 799		
Length of Highway				
Existence：Full-Shinkansen Dummy	21. 849 ***	16. 799		
Existence：Mini-Shinkansen Dummy				
Extension （２） ：Full-Shinkansen Dummy			−4. 963 **	−1. 998
Extension（2）：Mini-Shinkansen Dummy			−3. 285 **	−2. 474
Aomori Dummy	−33. 852 ***	−26. 994	46. 664 ***	48. 847
Iwate Dummy				
Miyagi Dummy				
Akita Dummy	−28. 287 ***	−14. 486	45. 832 ***	60. 641
Yamagata Dummy			18. 755 ***	17. 332
Fukushima　Dummy	−12. 391 ***	−10. 541		
ADAP：Aomori Extension （１） Full-Shinkansen			−14. 719 ***	−7. 471
ADAP：Aomori Extension （２） Full-Shinkansen				
ADAP：Iwate Extension （１） Full-Shinkansen				
ADAP：Yamagata Extension （１） Mini-Shinkansen				
ADAP：Yamagata Extension （２） Mini-Shinkansen	7. 168 ***	3. 527		
ADAP：Akita Extension（1）Mini-Shinkansen	6. 337 ***	2. 931		
Ｒ	0. 988		0. 988	
Ｒ-square	0. 976		0. 976	
adjusted R-square	0. 975		0. 975	

***:p<0.01, **p:<0.05, *:p<0.10

First socio-economic effects and the effects of the highway are discussed. For rail share, “unemployment ratio (Japan)” has a significant negative effect which indicates that travelers might swop to cheaper modes such as highway bus if unemployment ratio increases. Further “Higashi-Nihon Earthquake Effect” shows a negative sign, also meaning that after the Tohoku disaster, highway bus share is increasing. We further find that the Length of Highway has no significant sign for rail share.

For air ridership, “Gasoline Price” has a significant negative sign as expected. That is, possibly since fuel price tend to some degree, reflect air fares, increasing fuel price motivates one’s travel mode from air to others. “Length of highway” is also not significant to predict the air share.

Next Shinkansen extension and its adaptation effects are inspected. “Existence: Full-Shinkansen Dummy” shows a significant positive sign. That means rail is utilized more between Tokyo and the prefectures connected directly to Tokyo by Full-Shinkansen. In addition, the result suggests that Shinkansen has an impact on rail demand once it reach out to a new prefecture. Further “Extension (2) Full-Shinkansen Dummy” and “Mini-Shinkansen Dummy” have a non-significant effect for rail trip, however, they have significant negative effects for the air share as we expected. The Mini-Shinkansen appears to be non-significant for modal share.

Finally, the discussion extends to adaptation effect. Adaptation effect for Full-Shinkansen Extension(1) in Aomori has, as expected, a significant negative sign for air share, but a non-significant sign for rail share. Other adaptation effects for Full-Shinkansen are not significant. Adaptation effect for Mini-Shinkansen have a positive effect for rail except for the effect for Extension(1) in Yamagata. All of Mini-Shinkansen adaptation effect have no significant sign for air.

To summarize the main findings, Full-Shinkansen increases rail share at opening its operation. On the other hand, air share is reduced at Full-Shinkansen extension and keeps reducing after opening its operation. The Mini-Shinkansen does not have a significant effect immediately at start of its operations, however, in some cases Mini-Shinkansen motivates to change one's transport mode to rail.

5. Comparison to Kyushu Shinkansen demand

Regarding the demand analysis and discussion in previous sections, we highlight that the demand in Kyushu is quite different from our case in Tohoku. As shown in Table 6, the construction of Kyushu Shinkansen was divided into two segments; the southern segment between Kagoshima-Chuo and Shin-Yatsushiro was opened in March 2004, the northern segment between Shin-Yatsushiro and Hakata was completed after March 2011.

As shown in Table 6, this extension has enabled the through-services to Shin-Osaka from the southern part of Kyushu, and has significantly changed the rail and air demand within and outside of Kyushu Island.

Table 6 Kinki & Kyushu Area Shinkansen Extension Schedule

Year	Kinki & Kyushu Area Shinkansen Extensions Schedule
	Full-Shinkansen
	Sanyo-Shinkansen & Kyushu-Shinkansen
-2003	Shin-Osaka(Osaka)-Hakata(Fukuoka)
2004	Shin-Osaka(Osaka)-Hakata(Fukuoka) & Shin-Yatsushiro(Kumamoto) - Kagoshima-chuo(Kagoshima)
2011	Shin-Osaka(Osaka) - Kagoshima-chuo(Kagoshima)
2015 Total	Shin-Osaka(Osaka) - Kagoshima-chuo(Kagoshima)

The Ministry of Land, Infrastructure, Transport and Tourism[8)] (MLIT) (2013) has reported the shift in mode share before and after the extension in 2011. In Kagoshima, the demand of rail versus air to Osaka had a ratio of approximately 1 to 10 in 2010 and immediately drops to a ratio of 1 to 1.8 at the end of 2011. Another OD pair they looked at is Kumamoto-to-Osaka, where rail to air ratio was 1:2.75 before, and 6:5 after the extension. The Kyushu Shinkansen monthly ridership had an immediate increase from 380,000 passenger per month to around 1 million, and since then the demand stays fairly constant, the gap of demand seems to be satisfied between southern Kyushu to northern Kyushu or to Osaka. (see Figure 4).

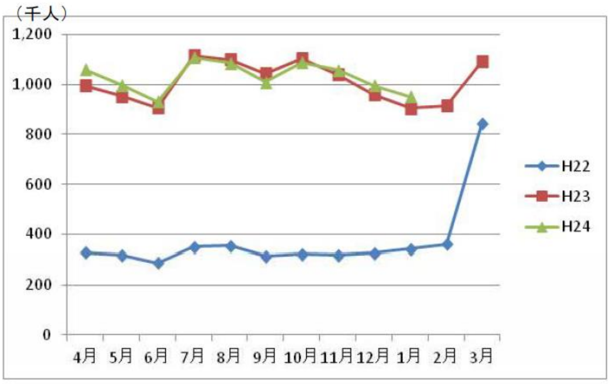

Figure 4 Kyushu Shinkansen Monthly ridership
Source: MLIT[8)] (2013)

One reason to explain the increase in demand is possibly because of the sudden travel time reduction from Kagoshima to Shin-Osaka. Before the extension, it would need 2 transfer for railway and the travel time would take 5 hours and 2 minutes from Shin-Osaka to Kagoshima; after the completion of Kyushu Shinkansen, the travel time has reduced to 3 hours and 44 minutes. We note that the pattern of travel time improvement was very different from Tohoku region, where in Tohoku area, a number of Shinkansen extensions reached out from Tokyo to other prefectures, so that travel time gradually reduced.

Another possible reason is the difference of travel experience between 2 regions, travelers in southern Kyushu utilized Shinkansen since 2004, the experience of optimizing/conducting one's trip by Shinkansen was widely adopted by travelers in Kyushu compared to Tohoku area. Once the direct connection to Shin-Osaka via through-service of Sanyo-Kyushu Shinkansen in 2011, the decision to switch mode, would possibly be easier compared to travelers in Tohoku area. That is, from the adaptation prospective, the significant drop of air demand and the demand shifted to rail in Kyushu possibly suggest that the travelers adopt to Shinkansen, are faster than the case in Tohoku.

Indeed, due to our limited analysis on Kyushu case, obtaining demand data for further investigations and detail analysis is essential. Varies reasons influence one's mode choice or adaptation process to new scheme under different circumstances regarding spatial conditions. Though also in Tohoku we find that the Shinkansen induces demand and causes a modal shift for trips from/to Tokyo, the adaptation process seems to be even faster in Kyushu (particular for trips to Osaka). Possibly the direct connection effect of two existing Shinkansen systems has a different impact compared to "pure" network extensions in Tohoku.

6. Conclusion

This study reviewed the interregional transport patterns in the Tohoku area.

Discussion on the rail trips between Tokyo and Tohoku suggests that the Full-Shinkansen generates new demand, whereas the Mini-Shinkansen existence does not have much effect. Travel time reductions are estimated and found to be a strong predictor for demand changes. In addition this study quantified the effect of the Higashi-Nihon earthquake on demand developments.

We further found that the Full-Shinkansen not only has stimulated rail and total PT trip demand at the start of operation, but also induces additional rail demand annually. Meanwhile, as mentioned, the impact of Mini-Shinkansen extension is not so strong when it opens its operation, however, demand might still gradually increase in the years after its opening.

Our findings for impact of Shinkansen on modal share are similar: The Full-Shinkansen causes a transport mode change from air to rail at opening its operation and increased rail share year by year. In contrast, Mini-Shinkansen does not have much immediate effect but over time encourages a modal shift.

In future work on Kyushu, our finding should be confirmed with OD data for detailed analysis. Our initial finding might suggest a hypothesis that the adaptation effect is faster if gaps in the Shinkansen network are closed than if extensions to new areas are made.

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