Effect of Market Competition on Passengers' Time Cost by Conventional Rail

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Abstract

Due to heavy deficits, the privatization of Japanese National Railways (JNR) was initiated on April 1, 1987 and was geographically divided into six different railway companies for transporting passengers. This paper investigates the impact of market competition on conventional rail (CR) passengers' time cost by using a difference-in-differences (DID) approach and directional origin-destination (OD) pair level data in four periods: two years before JNR's privatization (1976 and 1986) and two years after JNR's privatization (1996 and 2006). It investigates the effect of market competition on passengers' time cost in the regions where CR competes with high-speed rail (HSR), when comparing with monopoly region after JNR privatization. The result of this analysis shows that market competition leads to an increment in passengers' time cost by CR in duopoly regions when comparing with the change of time cost by CR in monopoly region, but it is not statistically significant.
Key words: Conventional Rail, Competition, Difference-in-differences

1. Introduction

Among a number of theoretical & empirical studies in the field of economics, the topic of market competition has attracted the attention of many researchers (Chamberlin, 1933; Lerner, 1934; Fujita, 1988; Parenti et al., 2017). Therefore, a number of studies try to investigate whether this kind of relationship or even casual inference exists between market competition and service/product quality. Many studies find that competition improves service/product quality (Mazzeo, 2003; Greenfield, 2014; Pan et al., 2015; Bergman et al., 2016). Some papers show the negative effect of competition on service quality. Propper et al. (2004) found the relationship between competition and quality of care to be negative, while the estimated effect was quite small. Forder and Allan (2014) found that higher competition pushed down quality as the price and revenue decreased, while the lower quality was due to decrease in price instead of competition. Lahiri and Ono (1988) found that by eliminating or impairing minor firms, a government can actually increase welfare.

This study investigates the impact of market competition between CR and HSR transport service on passengers' time cost by using CR. By using a difference-in-differences (DID) approach, it compares passengers' time cost on certain origin-destination (OD) pair before and after 1987. The data was collected from timetables published in four different years under by same company-Japan Travel Bureau (JTB) Foundation. The two years before 1987 are year 1976 and 1986, and the other two years after 1987 are year 1996 and 2006. In this research, only local & rapid trains that just need base fare are included. Table 1 shows the different types of CR services on the Tokyo-Osaka route that are provided by JR companies.

Table 1. Different Types of Conventional Rail (CR) Services

Train Type	Base Fare	Express fee	Stops
Local	Need	No need	Every station
Rapid	Need	No need	Less than local, but more than express
Express	Need	Express fee	Less than rapid, more than limited express
Limited Express	Need	Limited Express fee	Only stop at main stations

Note: For reserved seats, extra reservation fee is necessary.

Due to heavy deficits, JNR, a state-owned public corporation, was divided into six railway companies for transporting passengers after April 1, 1987. The six Japanese Railway (JR) companies for transporting passengers are Hokkaido Railway company (JR Hokkaido), East Japan Railway Company (JR East), Central Japan Railway Company (JR Central), West Japan Railway Company (JR West), Shikoku Railway Company (JR Shikoku) and Kyushu Railway Company (JR Kyushu). Each of them is in charge of CR and parallelly-running HSR services in certain region (if HSR service is available in that region).

For the busy Tokyo-Osaka route, CR service provided by three different companies. CR service between Tokyo and Atami is provided by JR East; between Atami and Maibara, it is provided by JR Central; and between Maibara and Osaka, it is provided by JR West. However, HSR service on the Tokyo-Osaka route is provided only by JR Central. Therefore, CR and HSR on the Tokyo-Atami route and the Maibara-Osaka route compete with each other, since they belong to different companies. As both CR and HSR services are provided by JR Central on the Atami-Maibara route, rail transport service is in monopoly. Figure 1 shows the operating condition of HSR and CR on the Tokyo-Osaka route. All these conform to the research design of this study, for measuring the difference in the impact of duopoly and monopoly, before and after JNR's privatization.

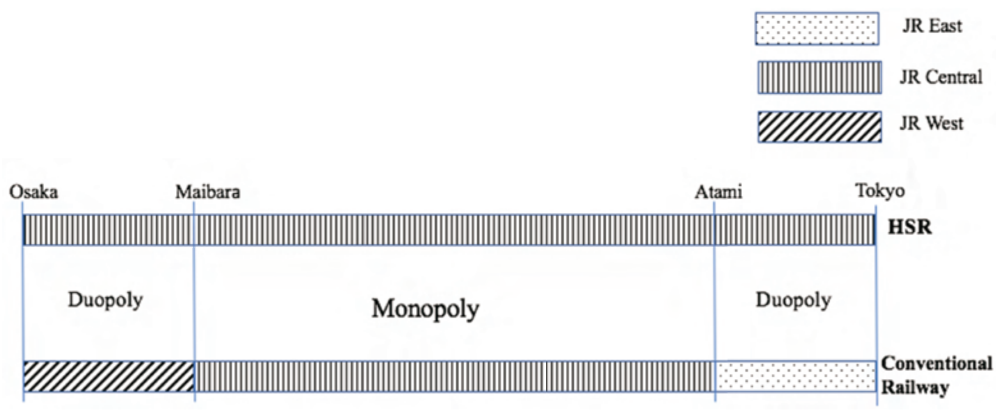

Figure 1. Operating Condition of HSR and CR for Tokyo-Osaka Route

CR service on the Tokyo-Osaka route existed for many years, before HSR service first parallelly operated in 1964. CR provides low-cost transport services that compete with HSR in some regions. Even though no CR provides direct transport service for the Tokyo-Osaka route, the trip can be easily completed through transfers. When comparing with HSR, CR has some disadvantages, such as more time cost and unavoidable transfers. As CR's speed is just half of HSR's and it needs transfer time, time cost of travelling through CR is more than twice of HSR (shown in Table 2). Fortunately, the selection of transfer stations is flexible, and transfer is convenient, without the need to get out of the stations. Therefore, CR has its advantages with disadvantages, when compared to HSR.

Table 2. CR V.S HSR (Tokyo Station ⟷ Shin-Osaka Station, 1982)

Type	Distance	Time cost (shortest)	Least Transfer	Ticket Price (JPY)	Frequency
CR	552.6km	More than 9h	3	6,600	Less than HSR
HSR	552.6km	3h10min	0	11,000	80

Note: Here CR just considers the non-reserved seat service which only cost base fare. Ticket price for HSR here is price of non-reserved seat which is the base fare.

Data source: JR Timetable, published by Japan Travel Bureau Foundation, 1982.

The rest of this paper is organized as follows: Section 2 provides a literature review of related studies on the effect of market competition in different industries. Identification strategy and a description of the data are separately showed in section 3 and 4. Section 5 presents the analysis results and its interpretations, as well the discussion. Section 6 provides the conclusion.

2. Literature review

As competition is important in a market system, many economists are interested in analyzing the effect of market competition. Previous studies have discussed about the impact of market competition, especially theoretical works (Spence, 1975; Gabszewicz and Thisse, 1979; Perry and Porter, 1985; Suzumura and Kiyono, 1987; Maskin and Tirole, 1988; Hsu et al., 2010; Xia and Zhang, 2016; Tsunoda, 2018) and empirical studies, which investigated the relationship between market competition and service/product quality (Propper, 2004; Greenfield, 2014; Pan, 2015). However, only a few empirical studies discuss the causal inference of market competition on service quality.

Among the limited empirical studies that estimate the causal inference of market competition, most of them investigate the effect of competition on health care services (Forder and Allan, 2014; Bergman et al., 2016) and the impact of competition between HSR and airlines (Albalate, 2015; Wan et al., 2016; Zhang et al., 2017). Empirical literatures exist for other industries, such as education industry (Hoxby, 2000), supermarket industry (Bonanno and Lopez, 2009) and newspaper industry (Tang and Wang, 2005), while their number is less. Besides, many of them are not perfect in research design, as they analyze the problem without observation fixed effect, existing reverse causality or confounders. As panel data in this study is analyzed with year and OD fixed effects and taken consideration for heterogeneity, it can be a better way for examining the impact of competition in transportation field, where randomized experiment is almost impossible.

Almost all the studies that discuss about competition between HSR and CR use theoretical approach for analysis. Hsu et al. (2010) analyzed competition and cooperation between HSR and CR by studying two roughly-parallel rail systems in Taiwan, although they just used game theoretical approach and the data used to test their models was only one year. Raturi and Verma (2013) used game theoretical approach to analyze the impact of HSR introduction and used passengers' time cost and monetary cost data to analyze the sensitivity of equilibrium state, although only simulation data was used. Different from these theoretical studies, this study randomly generates different target arrival time (TAT), collects time cost data for them from published JR timetables, and then takes average as time cost for each origin-destination (OD) pair. This study proceeds by using panel data and difference-in-differences approach to analyze causal inference in railway industry. As rail transportation accounts for a high percentage in transportation industry and is closely related to quality of daily lives, it is necessary to carry out this research.

3. Identification strategy

As described in the introduction part, rail transport services for the Tokyo-Atami and the Maibara-Osaka routes changed from monopoly to duopoly after 1987, and all the OD pairs on these two routes are included in the treatment group; rail services for the Atami-Maibara route is in monopoly for all the years, and all the OD pairs on this route are included in the control group. To estimate the effect of changes in market competition between the treatment and control groups, this study uses the difference-in-differences (DID) approach as the identification strategy.

This study estimates the impact of market competition along with year and OD pair fixed effects by using four years data (1976, 1986, 1996, 2006). By using year and OD pair fixed effects, it can eliminate omitted variable bias. DID approach measures the average treatment effect as a difference between the changes in the outcome variable of treatment and control groups over the same period.

Basic DID model in this study is as follows:

$$Y_{it} = \alpha(Treat_i \times Post_t) + \beta X_{it} + \phi_i + \varphi_t + u_{it} \qquad (1)$$

Where Y_{it} as outcome variable and it is time cost for directional OD pair i in year t in this study, $Treat_i$ is a treated-group dummy that takes a value of one if OD pair is located on the Tokyo-Atami route or the Maibara-Osaka route and zero otherwise, $Post_t$ is a after treatment year (1987) dummy, and it equals to 1 if the year is 1996 or 2006, and 0 otherwise. ϕ_i and φ_t are OD and year fixed effects, respectively. α is the estimator of treatment effect in this study. Variable X_{it} is a set of control variables which depend on model specification. Finally, u_{it} is the error term.

4. Data

4. 1 Data sources

Time cost data used in this research for all four years (1976, 1986, 1996 and 2006) are collected from JR timetables published by Japan Travel Bureau (JTB) Foundation. Other variables include: (1) Population data collected from national survey (Kokusei Chosa, five years one time). For year 1976, this study uses year 1975 survey data; for year 1986, this study uses year 1985 survey data; for the year 1996, this study uses year 1995 survey data; and for 2006, this study uses year 2005 survey data; (2) Per capita income data from central government website (Cabinet Office, Government of Japan); (3) GDP deflator from World Bank national accounts data and OECD National Accounts data files; (4) Number of stops means the number of conventional rail stations between the origin and destination station for each OD pair and is collected from JR timetables published by Japan Travel Bureau (JTB) Foundation; (5) The number of private railway companies that compete with JR company for same OD pair (from JR companies).

4.2 Details about the data

In this research, unit of analysis is directional origin-destination station pair (OD pair) within each region (three regions in total). Therefore, two kinds of OD pairs exist here: one kind is where both origin and destination stations are on the Tokyo-Atami or the Maibara-Osaka route which is the treatment group; the other kind is where both origin and destination stations are on the Atami-Maibara route which is set as control group.

Stations that included in this study are stations which provide both HSR and CR services for all four years (details are shown in following Table 3). Therefore, stations without HSR service or established after 1976 are not included in this analysis. As shown in Table 3, the maximum distance for OD pairs in the control group (341.3 km) is nearly three times that of the maximum distance for OD pairs in the treatment group (110.5 km). To keep the balance, this study picks up OD pairs in the control group which near the borders (Atami and Nagoya) and within the maximum distance of OD pairs in the treatment group (110.5km). As shown in Table 3, 12 OD pairs in the control group with 18 OD pairs in the treatment group for each year, making a total of 120 OD pairs for all four years.

Table 3. OD Pairs in the Analysis for One Year

Group	Number of OD Pairs	Maximum Distance	Number of OD Pairs Near Borders and Within 110.5km
1. Treatment Group			
Tokyo-Atami	12	104.6	12
Maibara-Osaka	6	110.5	6
Total	18	110.5	18
2. Control Group			
Atami-Maibara	56	341.3	12
All	74	341.3	30

Note: Stations between Tokyo and Osaka included in this research are: Tokyo, Yokohama (Shin-Yokohama for HSR), Odawara and Atami, Mishima, Shizuoka, Hamamatsu, Toyohashi, Gifu (Gifu-hashima for HSR), Maibara, Kyoto and Osaka (Shin-Osaka for HSR). As Atami and Maibara station are boundary stations, they are considered in charged by JR companies on both sides.

In this study, time cost consists of in-vehicle time and schedule delay. In-vehicle time is the time difference between train's actual arrival time and actual departure time (both available in published timetables); schedule delay is the time gap between target arrival time and actual arrival time. Target arrival time are 50 randomly generated time points between 6:00 and 24:00 pm in this study and actual arrival time is available in published timetables. For each target arrival time, the train that minimizes time cost is selected and recorded for all OD pairs. Average of the time cost for all target arrival time is generated as final time cost for each OD pair in each year. As delay in arrival is supposed to be not allowed in this study, schedule delay in this research is schedule delay early (not schedule delay late). Besides, CR services included in this study are non-reserved seats and without express fee. Seasonal trains that run for short periods or trains that run on weekends are not included as well.

5. Results and interpretations

5.1 Summary statistics

In Table 4, it shows that the average time cost for all OD pairs used in this study is 74.68 minutes. Besides, information for time-variant and time-invariant control variables are shown in Table 4 as well.

Table 4. Summary Statistics of Empirical Variables (OD Pairs Near Border and Within Distance)

Variables	Observations	Mean	Standard Deviations	Min	Max
Time cost (minutes)	120	74.68	32.56	24.03	140.67
Time-variant Controls					
Log of Population (City/Ward Level)	120	12.92	1.89	10.58	15.97
Log of Income per Capita (Prefecture Level)	120	7.76	0.54	6.74	8.46
Number of Stops	120	11	6.37	1	26
Time-invariant Controls					
Treatment Group Dummy	30	0.60	0.50	0	1
Number of Competing Private Railway Companies	30	0.40	0.72	0	2

Note: Treatment group dummy is 1, if OD pair is located in treatment group (OD pairs on Tokyo-Atami and Maibara-Osaka route), otherwise it is 0. Number of competing private railway companies is the number of private railways that do not belong to JR but provide transport service for the OD pairs.

5.2 Balance check

To verify the validity of common trend assumption, balancing test of baseline characteristics was executed as showed in the following Table 5. Table 5 presents the balance checks of baseline characteristics between OD pairs in monopoly and duopoly areas for the years before JNR's privatization (1976 and 1986).

Table 5. Balancing Test of Baseline Characteristics

	Control Group		Treatment Group		(2) - (4)
	Observations	Mean (Standard Deviations)	Observations	Mean (Standard Deviations)	Differences [Standard Errors]
	(1)	(2)	(3)	(4)	(5)
Panel A: Comparison by Level (using 1976 and 1986 data)					
Time cost/Distance (minutes/km)	24	1.641 (0.324)	36	1.327 (0.262)	0.314 [0.076]***
Other characteristics					
Population/10,000	24	52.504 (73.89)	36	239.159 (299.273)	-186.655 [62.479]***
Income per Capita	24	1,658.734 (773.155)	36	1,823.859 (853.925)	-165.125 [216.839]
Number of Stops / Distance	12	0.153 (0.047)	18	0.171 (0.042)	-0.018 [0.016]
Number of Competing Private Rail Companies	12	0.167 (0.389)	18	0.556 (0.856)	-0.389 [0.265]*
Panel B: Comparison by Change (Between 1976 and 1986)					
Changes in Time cost/Distance	12	-0.153 (0.089)	18	-0.106 (0.104)	-0.048 [0.037]
Other characteristics					
Changes in Population/10,000	12	1.164 (1.420)	18	0.114 (20.447)	1.050 [5.947]
Changes in Income per Capita	12	1,497.425 (101.183)	18	1,586.379 (258.153)	-88.954 [78.602]

Note: Standard deviations are given in parentheses and standard errors are given in square bracket. Significant differences are indicated as: * means p value<0.1, **means p value<0.05, *** means p value <0.01.

As shown in panel A in Table 5, mean of time cost per distance in control group is significantly higher than that in treatment group (duopoly) at 1% level. This might be due to speed difference that affects in-vehicle time or frequency difference that affects schedule delay early. Besides, population in treatment group is significantly higher than population in control group at 1% level. This is because Tokyo, Yokohama and Osaka stations (in treatment group) all located in big cities. Population of these cities are much higher when compared with population of cities that OD pairs in control group (Atami-Maibara) are located. As for per capita income and number of stops per distance, there is no significant difference among the treatment and control group. As shown in table 5, the number of competing private companies in treatment group is higher than that in control group at 10% significant level. This is reasonable as OD pairs in treatment group are located in Tokyo and Osaka regions and have relatively higher passengers' volume along with more private railway companies that compete with JR companies. Additionally, number of competing private rail companies for both groups in this study does not change over the years.

Panel B of Table 5 shows the changes between year 1976 and 1986 in treatment and control group. It is necessary to check whether the changes between treatment group and control group is balanced before treatment, which is a common trend assumption in this study. The result shows that there is no significant difference in the change of time cost per distance, population and per capita income among treatment and control group between year 1976 and 1986.

5.3 Effect of Market Competition on Conventional Rail

Table 6. Reduced Form Regressions of Time Cost (Duopoly Effect)

	(1)	(2)	(3)
Treatment × Post1987 (Duopoly)	5.573 [3.439]	3.790 [2.600]	2.968 [2.833]
OD and Year Fixed Effects	Yes	Yes	Yes
Time-variant Controls	No	Yes	Yes
Time-invariant Controls × Post Dummies	No	No	Yes
Observations	120	120	120
R-squared	0.804	0.849	0.868

Note: Clustered robust standard errors for undirectional OD pairs are showed in brackets, *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Time-variant controls include ln(population in the origin city), ln(population in the destination city), ln(real income per capita in the origin prefecture), ln(real income per capita in the destination prefecture) and number of stops between each OD pair. Time-invariant controls include the number of competing private railway companies.

The result of the OD and year fixed effects analysis in row (1) of Table 6 shows that market competition leads to an increment in time cost for the treatment group by 5.573 minutes when comparing with the change of time cost in control group, but it is not statistically significant. The row (2) shows the regression result after additional including time-variant controls. The reduced form regressions result in row (2) show that coefficient of duopoly is 3.790, which means market competition leads to an increment of time cost in treatment group by 3.790 minutes on an average when comparing with the change of time cost in control group, but it is still not statistically significant. The row (3) shows regression result after additionally including Time-invariant controls × Post dummies. The reduced form regressions result shows that the coefficient of duopoly is 2.968, which means market competition leads to an increment of time cost in treatment group by 2.968 minutes on an average when comparing with the change of time cost in control group, but it is not statistically significant as well.

Base on the model used in row (3) of Table 6, another specification by using cross term between Treatment dummy and Year is used for additional analysis. Therefore, Treatment × Year 1986, Treatment × Year 1996, Treatment × Year 2006 are used instead of Treatment × Post1987, and analysis result is showed in Table 7. As shown in Table 7, coefficient of treatment effect in 1996 is 3.559 and coefficient of treatment effect in 2006 is -3.119, and both are not statistically significant. Therefore, no statistically significant treatment effect is found on passengers' time cost in treatment group.

Table 7. Reduced Form Regressions of Time Cost (Duopoly Effect)

	(4)
Treatment × Year 1986	2.413
	[3.211]
Treatment × Year 1996	3.559
	[3.217]
Treatment × Year 2006	-3.119
	[1.879]
OD and year fixed effects	Yes
Time-variant controls	Yes
Time-invariant controls × Post dummies	Yes
Observations	120
R-squared	0.877

Note: Clustered robust standard errors for undirectional OD pairs are showed in brackets, *** p<0.01, ** p<0.05, * p<0.1. Time-variant controls include ln(population in the origin city), ln(population in the destination city), ln(real income per capita in the origin prefecture), ln(real income per capita in the destination prefecture) and number of stops between each OD pair. Time-invariant controls include the number of competing private railway companies. Treatment × Year 1986 is the cross term between treatment dummy and year 1986. Treatment × Year 1996 is the cross term between treatment dummy and year 1996. Treatment × Year 2006 is the cross term between treatment dummy and year 2006.

5.4 Discussion

Regression results in Table 6 show that market competition after JR privatization in 1987 led to an increment of time cost in treatment group when comparing with change of time cost in control group, but it is not statistically significant. After using the Treatment × Year specification used in the analysis of Table 7, we still could not find any statistically significant treatment effect in treatment group when comparing with control group. Different from this empirical analysis, theoretical analysis of market competition on passengers' time cost by CR is shown in the appendix. There exist following three possible reasons for why above empirical analysis results are different from the theoretical analysis results showed in the appendix.

First of all, after privatization of JNR in 1987, JR Central improved its CR transport service (by either speed or frequency) on the entire route they were in charge of, rather than only improving services around Nagoya station. After the privatization in 1987, JR Central replaced the trains it inherited from JNR by new type of trains on whole route (not just around Nagoya) and until 2006, 80% percentage of its local trains was replaced by the new types of trains. The new type of trains has characteristics like larger maximum speed, acceleration and deceleration. Since JR Central used new type of trains, its conventional rail transport service could get much improvement in its service like speed and then have potential to increase frequency (link showed in references part). Besides, JR Central actually reduced the trains frequency for some low demand route and increased the frequency for the busy lines it in charged to obtain more profit (link showed in references part).

Second, CR services in the regions which were going to be in charged by JR East company and JR West companies probably already improved before 1987, as they probably could receive the detailed information on JNR's privatization before it was publicly announced. Those regions could have the chance and incentive to do so, since in July 1982, the central government had approved the suggestion of JNR's privatization and had started taking appropriate actions in 1983. And finally, the public announcement was made in 1987. After isochronous operation policy was operated, timetable for some regions changed on March 14th, 1985, such as in Sendai (belong to JR East after 1987), Nagano (belong to JR East after 1987) and Keihanshin regions (Kyoto, Osaka and Kobe regions, which belong to JR West after 1987). Along with the change of timetable, the number of local trains operated those regions (belong to JR East and JR West after 1987) got huge increasement.

Third, but not the least, different from HSR service which is only provided by JR Central company for the Tokyo-Osaka route after 1987, three different JR companies are in charge of CR transport services between Tokyo and Osaka. As these three JR companies are so different in population density and operating net income, their behavior might be different and that probably led to the estimated market competition results shown in this study. For conventional rail service, the population density somehow can reflect the demand which could be he incentive for the JR companies to improve their services. The population density on Tokyo-Atami route (JR East) is much higher than Maibara-Osaka (JR West), and the population density on Maibara-Osaka (JR West) is much higher than that on Atami-Maibara (JR Tokai). For JR companies, their operating net income somehow can show their ability and their budget to invest on infrastructure and their machines to improve their transport services. Take 2000-2001 fiscal year as an example, the operating net income for JR East, JR Tokai and JR West was 69.2 billion JPY, 53.0 billion JPY and 31.0 billion JPY respectively, which is much different in amount (link showed in references part).

6. Conclusion

Due to the privatization of Japanese National Railways (JNR) in 1987, it was geographically divided into six different railway companies for passenger transport service. This paper investigated the impact of market competition on passengers' time cost by conventional rail through using difference-in-difference approach. Results of the analysis which includes OD and year fixed effects (time-variant controls and time-invariant control), show that market competition leads to an increment in passengers' time cost by CR in duopoly regions when comparing with the change of time cost in monopoly region, but it is not statistically significant. After including the Treatment × Year analysis, statistically significant treatment effect is still not found in the treatment group (duopoly region). As a conclusion, market competition leads to an increment in passengers' time cost by CR in duopoly regions when comparing with the change of time cost by CR in monopoly region, but it is not statistically significant.

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Appendix: Market Structure and Travel Time of Parallel Railway

Let us suppose there are two types of train services in parallel denoted by i = 1, 2. Demand of type i train service is a function of its own price as well as that of another are shown below:

$$Q_i = Q_i(P_{i\,,}\, P_j)\,,$$

which we specify as $Q_i = a_{i0} - a_{i1}P_i + a_{i2}P_j$, for $i \neq j \in \{1,2\}$ and a_{i0}, a_{i1}, a_{i2} being positive parameters, where Q_i is the demand and P_i is the price of the type i train. Price consists of two parts: ticket price f_i and passengers' time cost t_i, then $P_i = f_i + t_i$ for i = 1, 2. Time cost t_i of type i train determines the amount of required investment $K_i(t_i)$. Here assume $K_i > 0, K_i' < 0$

$$K_i = k_{i0} - k_{i1}t_i + \frac{1}{2}k_{i2}t_i^2$$

In duopoly condition, two types of train services are provided by two different companies; while in monopoly condition, two types of train services are provided by one company. In duopoly case, each company tries to maximize its profit with respect to ticket price f_i and time cost t_i which can be written as

$$\begin{aligned}\max_{t_i} \pi_i &= f_i Q_i\,(P_i,\ P_j) - K_i\,(t_i)\\ &= f_i(a_{i0} - a_{i1}P_i + a_{i2}P_j) - (k_{i0} - k_{i1}t_i + \frac{1}{2}k_{i2}t_i^2)\\ &= f_i[a_{i0} - a_{i1}(\,t_i + f_i\,) + a_{i2}(\,t_j + f_j\,)] - (k_{i0} - k_{i1}t_i + \frac{1}{2}k_{i2}t_i^2)\end{aligned}$$

First order condition (FOC) is $f_i(-a_{i1}) - (-k_{i1} + k_{i2}t_i^D) = 0$

Then $a_{i1}f_i = k_{i1} - k_{i2}t_i^D$

$$\frac{a_{i1}f_i - k_{i1}}{-\,k_{i2}} = t_i^D$$

Then

$$t_i^D = \frac{-a_{i1}f_i + k_{i1}}{k_{i2}}$$

For the monopoly condition, one company provides both kinds of train service,

$$\max_{t_1 t_2} \pi_1 + \pi_2 = \sum_{i=1}^{2} \left[f_i \left(a_{i0} - a_{i1} P_i + a_{i2} P_j \right) - \left(k_{i0} - k_{i1} t_i + \frac{1}{2} k_{i2} t_i^2 \right) \right]$$

$$\max_{t_1 t_2} \pi = \pi_1 + \pi_2 = \sum_{i=1}^{2} \left\{ f_i \left[a_{i0} - a_{i1}(t_i + f_i) + a_{i2}(t_j + f_j) \right] - \left(k_{i0} - k_{i1} t_i + \frac{1}{2} k_{i2} t_i^2 \right) \right\}$$

FOC is $\frac{\partial \pi}{\partial t_i} = f_i(-a_{i1}) - \left(-k_{i1} + k_{i2} t_i^M\right) + f_j a_{j2} = 0$

$$\frac{-a_{i1} f_i + a_{j2} f_j + k_{i1}}{k_{i2}} = t_i^M$$

$$t_i^M = \frac{-a_{i1} f_i + a_{j2} f_j + k_{i1}}{k_{i2}}$$

$$t_i^D = \frac{-a_{i1} f_i + k_{i1}}{k_{i2}}$$

So $t_i^M > t_i^D$