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The Regional Passenger Rail Fare System and Its Characteristics in Japan

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Main Purpose of This Study

- Main Purpose: This study analyzes the structure of passenger rail fare of railway operators in Japan.
- Motivation
  - Recently, the fare system has been reconsidered because of the rapid decrease in the number of rail passengers due to COVID19.
  - Because of changes in working style brought about by COVID19, rail demand in large metropolitan areas has not yet recovered.
  - In smaller metropolitan areas, rail ridership continues to decline, prompting the introduction of vertical separation to supply rail service, replacing traditional vertically integrated systems.
  - As a result, the heretofore used full cost principle may no longer be maintainable.

Main Purpose of This Study

- Specifically, this study will analyze

  (i) what kinds of fare systems actually exist,

  (ii) whether there is any relationship between the fare system and the demand structure and costs of railway operators,

  (iii) whether the average fare of railway operators is close to the marginal cost or the average cost,

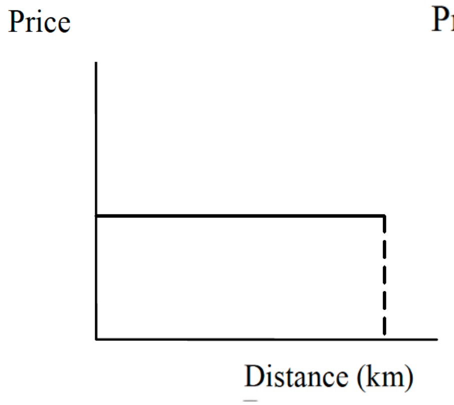
  (iv) whether there are any rules for the discount rate of regular fares,

  (v) whether there is any relationship between the types of railway industry (e.g. ownership, vertical structure, regulatory policy) and the aforementioned items.

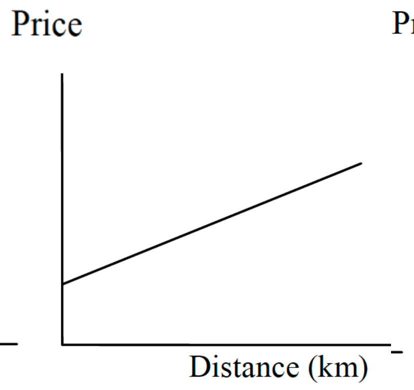
Table 1 Major Fare Systems and their Characteristics

Fare system	Number of operators	Initial fares (yen)	Discount rate of commuter rail pass (%)	Discount rate of student rail pass (%)	Route-km (km)	Station spacing (km)	Average travel distance (km)	Passenger density (1000person/route-km)
Flat fare	12	221	35.0	53.0	8.1	0.34	3.3	1,320
Fare based on km	5	158	38.4	55.0	43.9	2.19	14.5	328
Fare based on block-km	120	178	38.1	62.6	59.5	1.69	14.1	9,403
Zone fare	3	183	39.2	60.9	15.2	0.84	5.1	1,305
Others	2	190	45.5	69.7	99.7	4.53	13.9	920

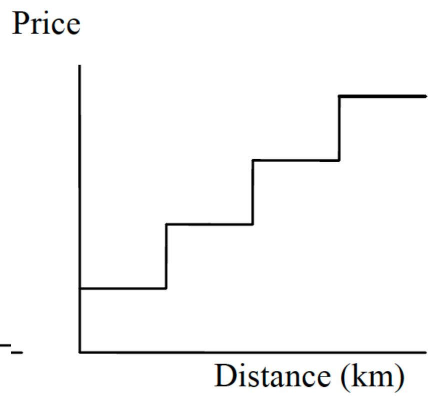
(Notes) :(1) In this table, "others" indicates a combination of other fare systems. (2) Average travel distance is defined as passenger-kilometers divided by the number of passengers. (3) Passenger density is defined as the number of passengers divided by route-km. (4) This value is calculated based on the fiscal year 2020 value.



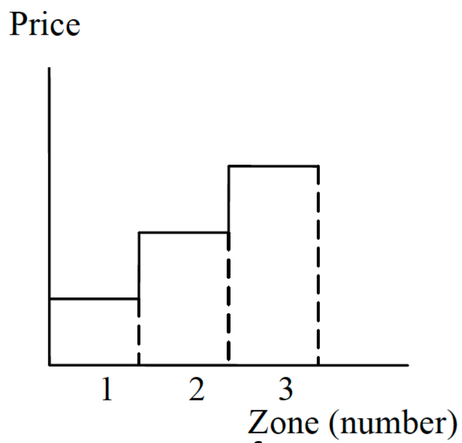
Flat fare



Fare based on km



Fare based on block-km



Zone fare

Calculation of Fare Level

- Simulation model for three different markets: (i) non-pass regular fares, (ii) work commuter pass fares,and (iii) student commuter pass fares.
- Maximize welfare under budget constraint.

$$max_{q_i} \sum \int p_i\,(q_i)dq_i - \sum cq_i$$

$$s.t.\;\; \left(\sum p_i\,(q_i)\cdot q_i - (F + \sum cq_i)\right) = 0$$

where $p_i(q)$: the inverse demand function for railway services,

q_i : the provided service volume,

F : the common fixed cost, and

c : the variable cost per unit (marginal cost).

We can see the relationship between Price level and markup ratio, marginal cost etc. from these equations.

- After all, price is obtained.

$$p_i = \frac{c}{1-(R/\varepsilon_i)}$$

or

$$p_i = MK_i \cdot c$$

where $\varepsilon_i\ (\varepsilon_i = -\frac{dq_i}{dp_i}/\frac{q_i}{p_i})\ (\varepsilon_i > 0)$: the price elasticity of demand for railway services,

$R\ (R \equiv \lambda/(\lambda+1))$: the Ramsey index,

MK_i : the markup rate for each demand group , $1/\left(1-(R/\varepsilon_i)\right) = MK_i$

(Data) : 133 private railways and public subways excluding JR from 2016 to 2020.

(Railway classification): Railway companies are also divided into three types: (i) large private railways, (ii) subways, and (iii) small and medium-sized private railways.

Table 2 Fare Comparison of Each Demand Groups

	Overall average fare	Non-pass regular fare	Work commuter pass fare	Student commuter pass fare
Whole railways	33.48	36.46	20.72	13.04
Large private railways	13.39	19.32	10.19	3.54
Subways	28.36	35.56	20.49	12.53
Small-medium private railways	36.75	38.92	22.20	14.41

(Note): (1) Unit: yen/passenger-km (2) These numbers are 2020 values for the average between 2016 and 2020. (3) Subways include Tokyo Metro and Osaka Metro.

Table 3 Fare Coverage Rate to Average Costs of Each Demand Group				
	Overall average fare	Non-pass regular fare	Work commuter pass fare	Student commuter pass fare
Whole railways	1.18	1.52	0.72	0.38
Large private railways	1.14	1.65	0.87	0.30
Subways	1.05	1.32	0.76	0.46
Small-medium private railways	1.20	1.52	0.70	0.39

(Note): (1) These numbers are coverage rate of fare to the average costs. (2) These numbers are the average between 2016 and 2020. (3) Subways include Tokyo Metro and Osaka Metro.

(Points of Findings):

(1) Overall average fare : all railway company groups exceed the average cost.

(2) Among them, the large private railways and subways maintain relatively low fares.

(3) The measure for student commuter pass fares is extremely low: only 38% of the average cost level is covered.

(4) In contrast, non-commuter regular fares are set very high.

(5) From this, it can be seen that non-commuter regular fares cross-subsidize student pass fares.

Table 4 Markup Ratio of Each Demand Group				
	Overall average fare	Non-pass regular fare	Work commuter pass fare	Student commuter pass fare
Whole railways	1.80	2.33	1.08	0.56
Large private railways	1.41	2.04	1.07	0.37
Subways	1.34	1.69	0.97	0.59
Small-medium private railways	1.90	2.43	1.09	0.59

(Note): (1) Markup ratio is the ratio of fare to the marginal costs. (2) These numbers are the average between 2016 and 2020. (3) Subways include Tokyo Metro and Osaka Metro.

(Points of Findings):

(1) Large private railways have the largest markup ratio, followed by subways.

(2) Small and medium-sized private railways keep their markup ratio at a level around 7% above marginal cost.

(3) The level of student commuter pass fares is just under 50% of marginal cost.

(4) It is interesting to note that commuter pass fares for subways are almost at a level close to marginal cost pricing.

Analysis of Factors related to Fare Level

- Next, we investigate factors related to the rail fare level.
- In the previous section, we can see that fare level is related to the demand condition, marginal cost, and the markup ratio, etc.
- Furthermore, in this study, since we consider three types of rail fares (i.e. work commuter pass fare, student commuter pass fare, and non-pass regular fare), the factors related to fare system (e.g. rail pass discount rates, initial fare, marginal fare by distance), demand structure (e.g. network length, average travel length) and managerial and institutional situations (e.g. yardstick regulation, public ownership) are also considered.
- Therefore, the fare equations are specified as follows.
- *Fare level* = *f* (*Fare system*, *Demand structure*, *Managerial and institutional situations*)

Regression Model and Estimation Method

- Main purpose: To find factors related to fare levels.
- $ln\ p_i = \alpha_i + \sum_k \beta_{ik}\ ln\ FS_k + \sum_m \gamma_{im}\ ln\ DS_m + \sum_n \delta_{in}\ MS_n$

where p_i is fare level of each rail demand type
($i = nc$ (non-rail pass), wc (work commuter pass), sc (student commuter pass)).

FS_k is factors related to fare system
($k = mc$ (marginal cost), $infare$ (initial fare), mg (marginal fare by distance), $wcdict$ (work commuter pass discount rate), $scdict$ (student commuter pass discount rate)) ,

DS_m is factors related to demand structure
($m = nl$ (network length), $tlvol$ (total rail passenger volume), $rlsh$ (rail share), $tlleg$ (travel length), $passh$ (share of rail pass)),

MS_n is factors related to managerial and institutional situations
($n = prfrt$ (profit level), $ydst$ (yardstick regulation dummy), pub (public ownership dummy), $vest$ (vertical structure type)).

- Estimation Method: SUR (Seeming Unrelated Regression)

(Data):by using 732 railway observations between 2015 and 2020.

Table 5 Statistics of used variables					
Variable	Definition	Mean	Std. dev.	Min	Max
p_{wc}	yen per passenger-km (2020 value)	20.19	10.24	1.69	179.24
p_{sc}	yen per passenger-km (2020 value)	12.62	6.67	0.70	73.69
p_{nc}	yen per passenger-km (2020 value)	34.10	14.43	3.15	174.57
FS_{mc}	marginal cost (yen per passenger-km) (2020 value)	36.9	61.7	6.5	1368.8
FS_{infare}	initial fare (yen per passenger-km) (2020 value)	175.6	28.3	100.0	260.0
FS_{mgfare}	marginal fare by distance (yen per km) (2020 value)	19.6	9.9	2.9	51.0
$FS_{wcdisct}$	discount rate (%) of work commuter rail pass	38.1	6.0	25.0	66.1
$FS_{scdisct}$	discount rate (%) of school commuter rail pass	62.1	9.5	37.5	82.3
DS_{nl}	network length (route-km)	56.4	74.6	2.2	501.1
DS_{tlvol}	annual million passenger	108	301	0.014	2,766
DS_{rlsh}	% of rail users for all transport modes	21.04	20.26	0.41	64.02
DS_{tlleg}	average travel length (km) per passenger	11.07	6.63	1.80	48.80
DS_{passh}	% of rail pass users	55.11	16.01	0.00	93.18
MS_{prfrt}	profit level from 1 to 4	1.775	1.102	1.000	4.000
MS_{ydst}	yardstick regulation dummy (1=yes, 0=others)	0.189	0.392	0.000	1.000
MS_{pub}	public ownership dummy (1=public, 0=others)	0.061	0.239	0.000	1.000
MS_{vest}	vertical structure type from 1 to 4	1.273	0.770	1.000	4.000

Notes on Vertical Structure Types in Japan

- It should be noted that this study considers vertical structure types. Vertical separation in Japan is different from that in Europe.
- Oshima (2022b) classifies vertical separation in Japan into four types.

  (i) complete separation,

  (ii) holding rolling stock,

  (iii) separation of land for rail track,

  (iv) virtual vertical separation.
- Here, there are four types: 1 is integrated vertical separation, 2 is virtual vertical separation, 3 is where the land or vehicles are separated, and 4 is complete separation.

Table 6 Estimation results: Coefficient and Standard errors			
Dependent variable	Work commuter pass fare ($ln\ p_{wc}$)	Student pass fare ($ln\ p_{sc}$)	Non-pass regular fare ($ln\ p_{nc}$)
Marginal cost ($lnFS_{mc}$)	0.0482** (0.0249)	0.0023 (0.0255)	0.1126*** (0.0211)
Initial fare ($lnFS_{infare}$)	0.4006*** (0.0621)	0.2622*** (0.0647)	0.3181*** (0.0535)
Marginal fare by distance ($lnFS_{mgfare}$)	0.2006*** (0.0221)	0.2056*** (0.0230)	0.2556*** (0.0190)
Disct. rate of work commuter pass ($lnFS_{wcdisct}$)	-0.4060*** (0.0481)	-	-
Disct. rate of school commuter pass ($lnFS_{scdisct}$)	-	-1.3235*** (0.0606)	-
Network length ($ln\ DS_{nl}$)	0.0912*** (0.0198)	0.0995*** (0.0206)	0.0594*** (0.0171)
Passenger volume ($ln\ DS_{tlvol}$)	-0.0916*** (0.0123)	-0.0964*** (0.0127)	0.0072 (0.0105)
Share of rail transportation ($ln\ DS_{rlsh}$)	0.1229***(0.0150)	0.0186 (0.0155)	0.0467*** (0.0129)
Average travel length ($ln\ DS_{tlleg}$)	-0.5085*** (0.0309)	-0.5670*** (0.0323)	-0.4365*** (0.0264)
Share of rail pass users ($ln\ DS_{passh}$)	-0.1608*** (0.0238)	-0.1043*** (0.0248)	-0.0690*** (0.0205)
Profit level (MS_{prfrt})	0.0566*** (0.0120)	0.0530*** (0.0124)	0.0285*** (0.0103)
Yardstick regulation dummy (MS_{ydst})	-0.1453*** (0.0436)	-0.2344*** (0.0461)	-0.2241*** (0.0376)
Public ownership dummy (MS_{pub})	0.1807*** (0.0492)	0.3093*** (0.0527)	0.1614*** (0.0422)
Vertical structure type (MS_{vest})	-0.0078 (0.0118)	-0.0378*** (0.0122)	-0.0218** (0.0101)
Constant	3.4875*** (0.3851)	8.0317*** (0.4224)	1.5340*** (0.3058)
R-squared	0.7121	0.8258	0.6905
Chi-squared	1872.26	3735.19	1655.25

(Note): (1) Numbers are coefficients and numbers in parenthesis are standard errors. (2) Numbers of observation are 742. (3) Significant at 1% (***), 5% (**), 10% (*).

Summary of Results related to Fare Levels

Major factors	Positive effects	Negative effects	Not significant effects
Fare system	(i) marginal cost, (ii) initial fare, (iii) marginal fare by distance	(i) work commuter pass discount rate, (ii) student commuter pass discount rate	(i) marginal cost (in student commuter pass fare equation)
Demand structure	(i) network length, (ii) share of rail transportation	(i) total rail passenger volume, (ii) average travel length, (iii) share of rail pass users	(i) total rail passenger volume (in non-pass regular fare equation) (ii) share of rail transportation (in student commuter pass fare equation)
Managerial and institutional situations	(i) profit level, (ii) public ownership	(i) yardstick regulation, (ii) vertical structure type	(i) vertical structure type (in work commuter pass fare equation)

Thank you