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Regulatory Reform and the Congestion of Urban Railways

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Abstract: Using a spatial model with a railway line in which the congestion rate, defined as the ratio of the number of commuters to a railway's nominal capacity, is explicitly included, this paper numerically simulates the impacts of railway regulation reform in Japan. We show that while the regulatory shift from rate-of-return regulation to price-cap regulation makes railway firms operate efficiently, it substantially shrinks railway capacity and lowers social welfare. We then consider modified versions of price-cap regulation, which are consistent with relief of congestion.

Keywords: price-cap regulation; rate-of-return regulation; congestion; railways

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1 Introduction

Extremely high population densities in Japan's large cities[2] have made it possible for many private railways to provide transportation services. Urban railways, including public and private railways, play an important role in Japan's urban transit system. For example, railways in the Tokyo metropolitan area provide 56% of travel needs. Such a high concentration of population, however, causes extreme railway congestion during rush hours. The congestion rate, which is the ratio of the number of commuters to a railway's nominal capacity, is about 200% on almost every line in the Tokyo metropolitan area. Typically, Tokyo railway firms have been operating their lines with very short headway and very long train configurations during peak time. Therefore, peak-time congestion cannot be relieved without constructing new lines or enhancing the current double-track lines to four-track lines.

Why is the transportation capacity of urban railways in Japan's large cities too small for the demand? This problem is analysed by Kanemoto and Kiyono (1993, 1995) and Kidokoro (1998), all of whom demonstrate that the present regulation imposed on railway firms increases congestion. Kanemoto and Kiyono (1993, 1995) point out that under the present regulation system, i.e., rate-of-return (ROR) regulation, the regulator sets the rate of return on capital investments lower than the true cost of capital, taking into account the profits from side businesses associated with the railway business. They suggest that this low rate of return on capital investment hinders railway firms from enhancing their capacity. Kidokoro (1998) focuses on another aspect of the present ROR regulation. The present ROR regulation values railroad right-of-way (the land used for running the trains) at its book value, which is much lower than its market value. He shows that this under-valuation of railroad right-of-way decreases profits substantially and thus railway firms' incentives to enhance their capacity are very much weakened.

The purpose of this paper is to investigate whether or not the congestion problem stated above

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[2] For example, the population density in Tokyo was 5384/km^2 and that in Osaka was 4650/km^2 in 1995.

can be resolved in the current era of regulatory reform in Japan, and to propose a regulatory method that is consistent with the relief of congestion. The paper focuses on the regulatory reform from ROR regulation to price-cap (PC) regulation, which is now under way in many industrialized countries. Many authors, such as Train (1991), Braeutigam and Panzar (1993), Liston (1993), and Bös (1994), have discussed the merits and demerits of ROR and PC regulations. However, they do not provide a comprehensive analysis that explains the effects of the regulatory shift from ROR regulation to PC regulation on railways' performances, explicitly taking into account the congestion problem. Thus, we here narrowly focus on the regulatory reform for congested urban railways, rather than address the general regulatory reforms that are now taking place in many regulated industries[3]. For that purpose, we build a simple spatial land-use model of a commuter railway. The reason why we employ a spatial land-use model is that the current bottleneck input in Japan, which hinders an enhancement of transportation capacity from the current double-track to four-track lines, is railroad right-of-way. Using a spatial model also enables us to implement a cost-benefit analysis of various regulatory methods in a closed-form system and to show the impacts of the regulatory change.

Using data from the Tokyu To-Yoko line, which is one of the major railway lines in the Tokyo metropolitan area, we numerically simulate the various regulatory methods and examine the effects of the regulatory change in terms of social welfare. Our main results are as follows:

(1) Introducing PC regulation without properly addressing the congestion problem is problematic, because it enhances a railway firm's cost-reducing efforts and increases efficiency, but cannot relieve congestion.

(2) PC regulation with a cap contingent on transportation quality, which is the inverse of the congestion rate, can relieve congestion without distorting cost-reducing efforts.

(3) PC regulation, in which the cap is made contingent on investment, can also correct the congestion, but decreases railway firms' cost-reducing efforts and thus has an adverse influence on their efficient

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[3] See, for example, Armstrong et al. (1994) and Helm and Jenkinson (1998).

operations.

(4) PC regulation, in which investment levels are fixed in advance and cost pass-through for investments is allowed, can correct the congestion without damaging cost-reducing efforts, if the elasticity of substitution among inputs is low and the regulator properly determines the target investment level.

Although our primary concern is the regulatory reform for congested urban railways in Japan, our analysis is relevant for other countries for several reasons. First, in the UK, the owner of the railway network (Railtrack) is vertically separated from train operators. As Welsby and Nichols (1999) point out, Railtrack has no incentives to provide additional railway capacity under the current regulatory regime. In fact, the Booz Allen Report (1999) shows that there has been little increase in railway network capability. Our analysis gives hints on how to provide appropriate investment incentives to the owners of railway networks, such as Railtrack. Second, although our analysis focuses on the congestion problem, it can easily be extended to other dimensions of transport quality, such as delays, comfort, and safety, which would be more important policy targets outside of Japan. Third, in many countries, urban railways are operated by the public sector. Even in this case, how to provide appropriate incentives to a railway operator is a significant issue and mechanisms similar to the regulatory method proposed in this paper are promising alternatives.

The structure of the paper is as follows. In Section 2, we set up a simple spatial model. In Section 3, we briefly summarize the merits and the demerits of various regulatory methods. In Section 4, we conduct a numerical simulation and show the effects of the regulatory change on social welfare. Section 5 concludes our analysis.

2 Model

Our model is a variant of the model, outlined in Kidokoro (1998), that is based on an open-city and absentee-landlord model used in the urban economics literature[4]. Before explaining the details of our model, let us briefly state the main characteristics of the model. In our model, a railway and housing development are perfectly complementary, and a railway provides positive externality to its surrounding area. The total social welfare is the sum of the railway firm's profits and the residential land rents along the railway line. If the railway firm owned all of its surrounding area, then marginal cost pricing would hold. The reason is as follows. If the railway firm raises its fare and gains monopoly profits, land rents in the residential area decrease. Given that a railway and housing development are perfectly complementary in our model, the upshot is that raising the fare is a mere transfer of profits from the residential land rents to the railway's profits. Thus, a railway firm would have no incentives to distort the fare above its marginal costs. In reality, however, a railway firm owns a tiny fraction of the residential area along its line, which means that the externality is only partly internalized. Thus, in market equilibrium, railway capacity is underprovided and the fare is higher than its marginal cost. This market failure is the reason for the regulation. Throughout our analysis, the regulation is *partial* in the sense that the regulator regulates only the railway sector. This corresponds to the actual situation in Japan. The Ministry of Land, Infrastructure, and Transport can impose regulations on its railway business, but it cannot impose them on its side businesses, which are, for example, housing development and running department stores.

Now we describe our model in detail. Consider a residential city of fixed size $\overline{H}$. All residents in this city, N in number, commute to the central business district (CBD) by commuter railway. A single railway firm connects the city with the CBD. For simplicity, there are no transportation costs within the residential city. We assume that many competitive absentee-landlords own the residential city as well as the railway firm.

The utility level outside the city is given by $\overline{u}$. Residents and potential residents can freely move out of and into the residential city. As a result, residents attain exactly $\overline{u}$ in equilibrium. The

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[4] See, for example, Kanemoto (1980).

railway firm supplies transportation service by setting a nominal capacity, Q. This value Q is nominal in the sense that the railway firm can pack as many commuters as it wishes into railway cars, providing that the congestion does not reduce the individual commuter's overall utility below $\overline{u}$. The congestion rate is defined as $\frac{N}{Q}$. To allow analytical simplicity, we use the inverse of the congestion rate, $q \equiv \frac{Q}{N}$, as the quality of transportation service. The production function for railway capacity is $Q = F(L, Z, e)$, where L is railroad right-of-way, Z is non-capital input, and e is cost-reducing efforts. We assume that $F_i \equiv \frac{\partial F}{\partial i} > 0$ and $F_{ii} \equiv \frac{\partial^2 F}{\partial i^2} < 0$, where $i = L$, Z, and e. Both the cost-reducing efforts and the production function itself are unobservable to the regulator. This means that the regulator cannot calculate the value of e based on Q, L, and Z. Thus the regulator cannot implement the regulation based on the level of e. We ignore capital inputs other than railroad right-of-way for simplicity, because our focus is on railroad right-of-way, which is the bottleneck input that hinders an enhancement of railway capacity. The price of Z is fixed and normalized at one. A railway firm incurs disutility $\varphi(e)$ from cost-reducing efforts, e, where we assume $\varphi'(e) > 0$ and $\varphi''(e) > 0$.

Railway firms in Japan own much land along their railway lines. This is used as railroad right-of-way or as residential land. The book value of the land they own is very low; for example, in the Tokyo metropolitan area the book value is less than 10% of its market value using 1993 prices. To replicate such a situation in our simulation, we assume that a railway firm owns $\alpha\overline{H}$ of the residential area, the purchase price of which is zero (α is any number between 0 and 1). The railway firm uses $\alpha\overline{H}$ in two ways: the railway firm uses $\alpha_1\overline{H}$ as its own railroad right-of-way, and $\alpha_2\overline{H}$ as residential land that is rented to residents, where $\alpha_1 + \alpha_2 = \alpha$. The railway firm's revenue sources are thus dual: railway fares and rental income from residential land. We assume that the regulatory authority imposes regulations only on the firm's railway sector, as is the case in Japan. For simplicity we assume that the provision of residential land is the only side business.

We assume that all residents are homogeneous with a quasi-linear and additively separable utility function, $U(z,h,q) = z + u(h) + v(q)$, where h is residential lot size, z is the composite consumer good including housing, and q is the quality of transportation service. This form of utility function enables us to conduct a simulation based on the actual estimate of $v(q)$. We assume that $u(h)$ and $v(q)$ are strictly increasing and strictly concave: $u'(h) > 0$, $u''(h) < 0$, $v'(q) > 0$, $v''(q) < 0$. As is well known, the income effects are zero under the quasi-linearity assumption[5] and cross elasticities are zero under the separability assumption. As a result, this form of the utility function yields a demand function for land that depends only on land rent, which simplifies our analysis. For simplicity, we assume that the composite consumer good is the same good as the non-capital input. The price of the consumer good is therefore one.

Each resident solves his or her utility maximization problem subject to a budget constraint: $z + Rh + t = \overline{w}$, where R, t, and $\overline{w}$ denote land rents, transportation fares, and the fixed income of a resident, respectively. Utility maximization under this budget constraint yields the bid rent function, $R(\overline{y} - t, q)$, where $\overline{y}(\equiv \overline{w} - \overline{u})$ denotes real income, and the transport demand function, $N(t,q,L)$, the derivations of which are shown in Appendix 1.

Now we can express the profits of the railway firm as

$$\pi(t,q,L,Z,e) \equiv tN(t,q,L) + R(\overline{y} - t,q)\alpha\overline{H} - Z - R(\overline{y} - t,q)L - \varphi(e).$$

In our closed-form model, social welfare is the sum of the railway firm's profits and the residential land rent that does not accrue to the railway firm. Social welfare is then

$$SW(t,q,L,Z,e) \equiv \pi(t,q,L,Z,e) + R(\overline{y} - t,q)(1 - \alpha)\overline{H}.$$

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[5] See, for example, Varian (1992).

3 The Merits and Demerits of Various Regulatory Methods

In this section, we consider the merits and demerits of various regulatory methods. For brevity, we state the results only. A detailed theoretical analysis is in Kidokoro (2001).

3-1 ROR Regulation

First, we consider a railway firm's behaviour under ROR regulation, the general formula for which is

$$\begin{aligned}\text{(allowed rate of return)} \geq {} & \frac{\text{(revenue)-(non-capital cost)}}{\text{(value of capital stock=rate base)}} . \\ & (= \text{a firm's rate of return}).\end{aligned}$$

ROR regulation has the following properties:

(1) The marginal benefit of the investment in the non-capital input, Z, equals its marginal cost.

(2) If the allowed rate of return, ρ, is higher (lower) than the true cost of capital, r, then the marginal rate of technical substitution between the non-capital input, Z, and railroad right-of-way, L, is lower (higher) than their relative price. If $\rho = r$, then the marginal rate of technical substitution equals their relative price.

(3) The marginal rate of technical substitution between the non-capital input, Z, and cost-reducing efforts, e, exceeds their relative price.

The first point shows that ROR regulation provides no incentive to lower non-capital input. This is because the railway firm is allowed to raise its price when investing in non-capital input. The second point shows the modified Averch-Johnson effect, originally pointed out by Kanemoto and Kiyono (1993, 1995). As Averch and Johnson (1962) showed, capital input is over-invested compared with non-capital input, if the allowed rate of return exceeds the true cost of capital. However, if the allowed rate of return is set lower than the true cost of capital by the regulator who implicitly takes the profits of side businesses into consideration, which would be the case in Japan, capital input is under-invested compared with non-capital input. This under-investment in capital input, which results in a lack of railway capacity, is one of the major causes of congestion on urban railways[6]. When the allowed rate of return equals the true cost of capital, the choice of capital input is not distorted. The third point shows that ROR regulation distorts cost-reducing efforts. If a railway firm reduces its costs by its effort, its profits increase. However, given this increase in profits, a firm's actual rate of return goes up and becomes higher than the allowed rate of return. In this case, the firm must reduce its revenue to meet ROR regulation. This implies that the railway firm cannot capture the increase in profits that cost-reduction yields, and has weaker incentives for cost-reduction. Thus, under ROR regulation, the railway firm operates inefficiently.

3-2 PC Regulation

Second, we consider a railway firm's behaviour under PC regulation, which can be written as

$$tcap \geq t$$

where $tcap$ is the fixed ceiling price.

PC regulation has the following properties:

(1) The marginal benefit of the investment in the non-capital input, Z, exceeds its marginal cost.

(2) The marginal rate of technical substitution between the non-capital input, Z, and railroad right-of-way, L, equals their relative price.

(3) The marginal rate of technical substitution between the non-capital input, Z, and cost-reducing efforts, e, equals their relative price.

The first point shows that PC regulation causes under-investment in non-capital input. This distortion occurs for the following reason. As long as the transportation fare is suppressed by PC regulation, the railway firm cannot raise the fare even though it invests in non-capital input. The incentive to invest in non-capital input is then discouraged. The second and third points state the merits of PC regulation; under PC regulation, the railway firm employs the optimal input mix of non-capital input, Z, railroad right-of-way, L, and cost-reducing efforts, e, because it regulates the

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[6] Kidokoro (1998) focuses on another cause of the lack of railway capacity. He shows that book-based valuation of rate base results in

ceiling price only.

The above results demonstrate that the regulatory shift to PC regulation causes another source of distortion in investments, which leads to congestion. Under PC regulation, non-capital inputs are under-invested, which also leads to under-investment in railroad right-of-way and cost-reducing efforts, provided that the marginal rates of technical substitution among all inputs are optimal. That is, as long as the ceiling price is binding, PC regulation causes under-investment in all inputs and thus causes congestion. The congestion problem never disappears as a result of the regulatory shift from ROR to PC regulation.

3-3 Modified PC Regulation

The analyses in Section 3-2 show that the regulatory shift to PC regulation cannot alleviate congestion. We consider here “PC-like” regulation that is consistent with the relief of the congestion.

First, let us focus on PC regulation with a cap contingent on transportation quality, which is the inverse of the congestion rate. PC regulation thus modified can be written as

$$tcap + \bar{t}(q) \geq t,$$

where $\bar{t}(q)$ is the variable part of the ceiling price that depends on transportation quality, q. We call this quality-contingent PC regulation (QPC). Quality-contingent PC regulation eliminates the under-investment in non-capital input, without damaging the input mix. Under quality-contingent PC regulation, a railway firm is allowed to set a higher price when alleviating congestion. Since the railway firm can obtain profits from its investments in railway capacity, it has no actual incentive to decrease the investment in railway capacity (which thereby increases congestion). Thus, the railway firm has no incentive to under-invest in non-capital inputs. If $\bar{t}'(q) = v'(q)$, i.e., the marginal increase in the cap equals a commuter’s marginal benefit of transportation quality, then a commuter’s cost accompanied by decreasing congestion equals his or her received benefit and all input choices

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under-investment in railroad right-of-way when land prices rise.

become optimal.

In many cases, it would be difficult to measure a commuter's marginal benefit of transportation quality, $v'(q)$. Then, we consider PC regulation in which the cap is contingent on capacity investment, which would be easier to implement, because the data on investment are easier for the regulatory authority to obtain. This kind of PC regulation can be written as

$$tcap + \bar{t}(L, Z) \geq t\,,$$

where $\bar{t}(L, Z)$ is the variable part of the ceiling price that depends on railroad right-of-way, L, and the non-capital input, Z. We call this method investment-contingent PC regulation (IPC). Investment-contingent PC regulation can alleviate congestion, provided that the marginal investment costs of non-capital and railroad right-of-way are fully recovered through the increase in the ceiling price. In this case, the under-investment in non-capital input is removed, holding the marginal rate of technical substitution between the non-capital input and railroad right-of-way equal to their relative price. However, it distorts the choice of cost-reducing efforts. This feature stems from the fact that investment-contingent PC regulation lowers the investment costs of railroad right-of-way and non-capital, but leaves the cost of cost-reducing efforts, e, unchanged. Suppose that the marginal investment costs are fully recouped by the increase in the allowed price. In this case, if a railway firm invests in non-capital and railroad right-of-way, the allowed price goes up and the investment costs are virtually zero. If it invests in cost-reducing efforts, however, the allowed price remains unchanged. This asymmetry weakens cost-reducing incentives, and leads to the railway firm operating less efficiently.

4 Numerical Simulations

In Section 3, we argued the merits and the demerits of ROR, PC, quality-contingent PC, and investment-contingent PC regulations. Now, we conduct a simulation to consider the effects of the regulatory change from the present ROR regulation on railways' performances. We use data from the Tokyu To-Yoko line in 1993, a typical railway line in the Tokyo metropolitan area, and apply the transport-engineering studies by Shida et al. (1989) and Ieda (1995), which focus on the disutilities of congestion in Japanese urban railways. In many urban railways operating in the Tokyo metropolitan area, railroad right-of-way is a bottleneck input, which cannot be substituted for other inputs. Thus, the Leontief function is a natural candidate for the production function[7]. In addition, we use the Cobb-Douglas production function to ascertain the effects of the elasticity of substitution among inputs. Table 1 summarizes the cases we consider in the simulation. The bases of the parameters are justified in Appendix 2.

Table 1 is here.

First, we duplicate the present ROR regulation and compare the results with the actual data. The results are presented in Table 2.

Table 2 is here.

In both the Leontief (Case 1-0) and Cobb-Douglas (Case 2-0) cases, our results duplicate the actual data satisfactorily. As Mizutani (1994) points out, Japanese urban railways are found to be seriously in deficit if we calculate depreciation based on replacement cost, i.e., economic opportunity cost. It is, therefore, not surprising that the profits of railway businesses are negative in our results when cost calculations are based on economic opportunity cost.

4-1 First Best

We obtain the first best optimum in both the Leontief (Case1-1) and Cobb-Douglas (Case 2-1) cases as a policy target, given our parameters, assuming that a railway firm owns the entire city, i.e., $\alpha_2 = 1 - \alpha_1 = 0.983$. The results are presented in Table 3.

Table 3 is here.

These results show that social welfare increases by 24.1 - 26.4 (billion yen) a year in the Tokyu To-Yoko line area if the first best is attained. In the first best situation, the congestion rate is about

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[7] All properties we obtained in Section 3 are valid even if the production function is the Leontief-type, because it is a limiting case of

130%, which shows that congestion is noticeably relieved. We hereafter evaluate each regulatory method based on the incremental social welfare that arises when the regulatory method is changed from the present ROR regulation.

4-2 PC Regulation

We focus on the case where the authority changes the regulatory method from the present ROR regulation to PC regulation. The results are shown in Table 4.

Table 4 is here.

First, we look at the results in the Leontief case. Case1-2-0 deals with the regulatory shift to PC regulation in which the ceiling price is set at the same level as under the present ROR regulation. The railway firm's free choice of input mix under PC regulation enables the railway firm to operate efficiently, and lowers operating costs. PC regulation, however, has a significant negative effect on congestion through a substantial decrease in investment in railroad right-of-way. As a result, social welfare would shrink compared to the present ROR regulation. This result supports Helm and Thompson's (1991) suggestion that under-investment in transport infrastructure is seriously harmful to social welfare. This result holds true even if the ceiling price is set at the first best level (Case 1-2-1) or at lower than the present level, i.e., $tcap = 0.8 \times 8.13$ (Case1-2-2), 0.6×8.13 (Case1-2-3). The simulation results of Cases 1-2-2 and 1-2-3 show that a lower ceiling price leads to a higher congestion rate and lower social welfare. This suggests that the disutility from the increase in congestion is so severe as to upset the gain from the decrease in the fare. Thus PC regulation would not be suitable for crowded urban railways.

Even in the Cobb-Douglas production function case (Cases 2-2-0 - 2-2-3), the same results hold true, except that there exists an additional effect brought about by the substitution among inputs. Under the present ROR regulation, in which the allowed rate of return is lower than the true cost of

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the CES production function.

capital, the investment in railroad right-of-way is substantially suppressed. Since the elasticity of substitution among inputs is high in the Cobb-Douglas production function case, the regulatory shift to PC regulation corrects this distortion in the input mix, i.e., it increases the investment in railroad right-of-way and decreases that in non-capital input. Thus, when the elasticity of substitution among inputs is higher, railroad right-of-way is increased and operating costs are decreased, compared with the Leontief production function case.

4-3 Modified PC Regulation

To remove the adverse effect on congestion from PC regulation, we consider modifications of PC regulation. First, we focus on quality-contingent PC regulation, the form of which is

$$tcap + \overline{t}(q) = tcap - 0.722q^{-4.52} \geq t .$$

Since $v(q) = -0.722q^{-4.52}$, as we show in Appendix 2, this form of quality-contingent PC regulation always satisfies $\bar{t}'(q) = v'(q)$ and then all input choices are socially optimal. We consider two cases: one is the case in which $tcap$ is set at the break-even level of the railway business (Cases 1-3-1 (Leontief) and 2-3-1 (Cobb-Douglas)), and the other is the case in which $tcap$ is set at the first-best price level (Cases 1-3-2 (Leontief) and 2-3-2 (Cobb-Douglas)). The results are in Table 5.

Table 5 is here.

This quality-contingent PC regulation alleviates congestion without damaging the cost-reducing efforts. As a result, it can attain almost the same social welfare as the first-best optimum. This result holds regardless of the elasticity of substitution among inputs.

Next, we analyse investment-contingent PC regulation, the form of which is

$$tcap + k_1(L - L^{ROR}) + k_2(Z - Z^{ROR}) \geq t ,$$

where L^{ROR} and Z^{ROR} are the values of railroad right-of-way, L, and non-capital input, Z, respectively, under the present ROR regulation. The formula shows that investment in excess of the present ROR level is compensated by an increase in the allowed price. The parameters k_1 and k_2 are set so that the investment costs of L and Z are fully recovered through the increase in the ceiling price, i.e., no distortions exist regarding the choice of L and Z. The level of $tcap$ is set in the same way as in the analyses of quality-contingent PC regulation, i.e., at the break-even level of the railway business (Cases 1-4-1 (Leontief) and 2-4-1 (Cobb-Douglas)), and at the first-best price level (Cases 1-4-2 (Leontief) and 2-4-2 (Cobb-Douglas)). The results are presented in Table 6.

Table 6 is here.

We first look at the results in the case of the Leontief production function (Cases 1-4-1 and 1-4-2). The results show that investment-contingent PC regulation can ease congestion in a fair way. However, cost-reducing efforts are 0.674 – 0.703, which is about only one fifth of that under quality-contingent PC regulation. These low effort levels result in higher operating costs and lower incremental social welfare than under quality-contingent PC regulation.

In reality, the elasticity of substitution among inputs is probably low, and consequently, the above results in the case of Leontief production function would hold. However, if the elasticity of substitution were high, another result would hold. The results in the case of the Cobb-Douglas production function (Cases 2-4-1 and 2-4-2) show that the high elasticity of substitution among inputs mitigates the distortion brought about by low cost-reducing efforts under investment-contingent PC regulation. The problem of investment-contingent PC regulation is no return for cost-reducing efforts; if the railway firm invests in railroad right-of-way and non-capital input, it can raise the price, but if it invests in cost-reducing efforts, it cannot raise the price. Thus, if the elasticity of substitution is high, the railway firm substitutes other inputs for cost-reducing efforts and consequently, the distortion brought by low cost-reducing efforts is lessened. This result suggests that investment-contingent PC regulation approaches quality-contingent PC regulation when the elasticity of substitution is higher.

Finally, we consider a regulatory method in which the regulator contracts with the regulated firm for its investments in advance, and costs of investment are added onto the ceiling price. This regulation is equivalent to PC regulation with a direct designation of investment levels. Office of the

Rail Regulator (2000) proposes such a regulatory method as an appropriate regulation for Railtrack. We call this method price-cap regulation with cost pass-through (PCCP). Price-cap regulation with cost pass-through is a version of investment-contingent PC regulation in that the regulator uses information on investments. Denoting the designated levels of railroad right-of-way and non-capital by L^* and Z^*, respectively, price-cap regulation with cost pass-through can be written as

$$tcap \geq t,\ L = L^*, \text{ and } Z = Z^*.$$

We set L^* and Z^* at the first-best levels of railroad right-of-way and non-capital. The level of $tcap$ is set at the break-even level of the railway business (Cases 1-5-1 (Leontief) and 2-5-1 (Cobb-Douglas)), and at the first-best price level (Cases 1-5-2 (Leontief) and 2-5-2 (Cobb-Douglas)). The results are presented in Table 7.

Table 7 is here.

The results in Table 7 suggest that price-cap regulation with cost pass-through approaches investment-contingent PC regulation when the elasticity of substitution among inputs is large, while it approaches quality-contingent PC regulation when the elasticity of substitution is small. In the Leontief production function, in which the elasticity of substitution is zero, investments in railroad right-of-way and non-capital input determine the level of cost-reducing efforts. Thus, if L^* and Z^* are set at their first-best levels in price-cap regulation with cost pass-through, cost-reducing efforts are also at their first-best level. Since congestion is relieved without damaging cost-reducing efforts, price-cap regulation with cost pass-through in this case has the same effects as quality-contingent PC regulation. On the other hand, in the Cobb-Douglas production function, in which the elasticity of substitution is one, the designation of railroad right-of-way and non-capital by price-cap regulation with cost pass-through decreases cost-reducing efforts through the substitution of inputs. In this case, the results in price-cap regulation with cost pass-through approach those in investment-contingent PC regulation.

In real urban railways in Japan, railroad right-of-way is a bottleneck input, and consequently, the Leontief production function would approximate reality. Thus, price-cap regulation with cost pass-through would closely resemble quality-contingent PC regulation. To implement price-cap regulation with cost pass-through, the regulator has to know the desirable investment levels. If the regulator can obtain information on desirable investment levels more easily than a commuter's marginal benefit of transportation quality, price-cap regulation with cost pass-through is a desirable candidate as a regulatory tool for relief congestion.

5 Conclusion

Our analysis stated above shows that (pure) PC regulation would not be suitable for Japanese urban railways that are extremely congested because it has adverse effects on congestion through decrease in investments although it removes the distortion in the input mix. In modified PC regulations, quality-contingent PC regulation is consistent with the relief of congestion and is free of distortions in its cost-reducing efforts. Although investment-contingent PC regulation also alleviates congestion and is easier to implement, it distorts incentives for cost-reduction. When the elasticity of substitution among inputs is small, which would be the case for Japanese urban railways, price-cap regulation with cost pass-through yields almost the same result as quality-contingent PC regulation, and thus is a strong candidate as a regulation method for relieving congestion.

Before concluding our analysis, we consider dynamic incentives of each method of regulation, which we have not focused on so far[8]. In the present ROR regulation for Japanese urban railways, there exists no dynamic incentive for cost-reduction. The current procedure is as follows[9]. First, the railway firm files for a rise in fares when it wants to, and next, the regulator approves it after inspecting its costs and claimed fare levels. Periodical review is not built in. That is, in the regulatory system for Japanese urban railways, railway firms have the initiative in raising fares. Since railway firms can almost freely file for a rise in fares, they have no dynamic incentive to reduce their costs. If

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[8] For dynamic incentives of ROR and PC regulations, see Baumol and Klevorick (1970), Cabral and Riordan (1989), and Armstrong et al. (1995).

[9] See Moriya (1996) for a detailed analysis on the process of the revision of fares in Japan.

periodical review is introduced, coupled with the regulatory shift to PC regulation, dynamic cost-reducing incentives emerge, because railway firms can obtain profits entirely by cost-reducing efforts until the next review. This dynamic cost-reducing incentive caused by periodical review works equally for PC regulation and its variants, such as quality-contingent PC regulation, investment-contingent PC regulation, and PC regulation with cost pass-through. Taking a periodical review system into account, our analysis would underestimate the cost-reducing effects of PC-type regulation, and consequently, the merits of the regulatory shift to PC-type regulation would be much larger.

	Case 1-0 (Status-quo: ROR)	Case 1-1	Case 1-2-0	Case 1-2-1	Case 1-2-2	Case 1-2-3	Case 1-3-1	Case 1-3-2	Case 1-4-1	Case 1-4-2	Case 1-5-1	Case 1-5-2
Regualtory Shift to …		First Best	PC without Changing the Fare	PC with the First Best Fare	PC with Lower Fare	PC with Lower Fare	QPC with the Profits of Railway Business Break-even	QPC with the First Best Fare	IPC with the Profits of Railway Business Break-even	IPC with the First Best Fare	PCCP with the Profits of Railway Business Break-even	PCCP with the First Best Fare
Production Function	Leontief	Leontief	Leontief	Leontief	Leontief	Leontief	Leontief	Leontief	Leontief	Leontief	Leontief	Leontief
Feature	$\rho=0.068<$ $r=0.073$	$\alpha_1+\alpha_2=1$	$tcap=8.13$	$tcap=11.3$	$tcap=8.13$ $\times0.8$	$tcap=8.13$ $\times0.6$	$tcap=10.6$	$tcap=13.8$	$tcap=7.94$, $L^{ROR}=228{,}000$, $Z^{ROR}=1{,}290{,}000$, $k_1=2.45\times10^{-5}$, $k_2=5.49\times10^{-6}$	$tcap=8.82$, $L^{ROR}=228{,}000$, $Z^{ROR}=1{,}290{,}000$, $k_1=2.46\times10^{-5}$, $k_2=5.51\times10^{-6}$	$tcap=7.91$, $L^{*}=351{,}000$, $Z^{*}=545{,}000$	$tcap=11.3$, $L^{*}=351{,}000$, $Z^{*}=545{,}000$

	Case 2-0 (Status-quo: ROR)	Case 2-1	Case 2-2-0	Case 2-2-1	Case 2-2-2	Case 2-2-3	Case 2-3-1	Case 2-3-2	Case 2-4-1	Case 2-4-2	Case 2-5-1	Case 2-5-2
Regualtory Shift to …		First Best	PC without Changing the Fare	PC with the First Best Fare	PC with Lower Fare	PC with Lower Fare	QPC with the Profits of Railway Business Break-even	QPC with the First Best Fare	IPC with the Profits of Railway Business Break-even	IPC with the First Best Fare	PCCP with the Profits of Railway Business Break-even	PCCP with the First Best Fare
Production Function	Cobb-Douglas	Cobb-Douglas	Cobb-Douglas	Cobb-Douglas	Cobb-Douglas	Cobb-Douglas	Cobb-Douglas	Cobb-Douglas	Cobb-Douglas	Cobb-Douglas	Cobb-Douglas	Cobb-Douglas
Feature	$\rho=0.068<$ $r=0.073$	$\alpha_1+\alpha_2=1$	$tcap=7.62$	$tcap=11.3$	$tcap=7.62$ $\times0.8$	$tcap=7.62$ $\times0.6$	$tcap=9.51$	$tcap=13.7$	$tcap=7.36$, $L^{ROR}=237{,}000$, $Z^{ROR}=1{,}170{,}000$, $k_1=2.44\times10^{-5}$, $k_2=5.46\times10^{-6}$	$tcap=11.4$, $L^{ROR}=237{,}000$, $Z^{ROR}=1{,}170{,}000$, $k_1=2.49\times10^{-5}$, $k_2=5.56\times10^{-6}$	$tcap=6.54$, $L^{*}=423{,}000$, $Z^{*}=183{,}000$	$tcap=11.3$, $L^{*}=423{,}000$, $Z^{*}=183{,}000$

Table1: Cases in the simulation

	Tokyu To-Yoko Line (peak time)(1993)	Case 1-0 (Leontief)	Case 2-0 (Cobb-Douglas)
Annual fare per commuter (= t) (10,000yen)	6.61	8.13	7.62
Congestion rate (= $100/q$) (%)	197	197	199
Railroad right of way (= L) (m^2)	227,000	228,000	237,000
Average land price (= V/r) (10,000yen/m^2)	56.6	56.5	56.5
Rate Base (billion yen)	24.7	21.1	26.3
Operating costs(= Z) (billion yen)	13.8	12.9	11.7
Number of commuters (= N)	176,000	177,000	177,000
Effort (= e)	/	0.169	0.152
Annual profits of railway business (billion yen)	3.31	-0.111	-0.136
Annual profits of side businesses (billion yen)	3.63	3.56	3.56
Annual total profit (billion yen)	6.94	3.45	3.42

Table 2: Actual data and the present ROR regulation

	Case 1-1 (First Best, Leontief)	Case 2-1 (First Best, Cobb-Douglas)
Annual fare per commuter (10,000yen)	11.3	11.3
Congestion rate (%)	132	131
Railroad right of way (m^2)	351,000	423,000
Average land price (10,000yen/m^2)	58.8	58.8
Operating costs (billion yen)	5.50	1.83
Number of commuters	182,000	181,000
Effort	3.24	1.70
Annual profits of railway business (billion yen)	6.06	7.92
Annual profits of side businesses (billion yen)	472	472
Annual total profit (billion yen)	478	480
Annual incremental social welfare (billion yen)	24.1	26.4

Table 3: First best

	Case 1-2-0 (*tcap* =8.13)	Case 1-2-1 (*tcap* =11.3)	Case 1-2-2 (*tcap* =8.13 ×0.8)	Case 1-2-3 (*tcap* =8.13 ×0.6)
Annual fare per commuter (10,000yen)	8.13	11.3	6.50	4.87
Congestion rate (%)	261	246	270	282
Railroad right of way (m^2)	149,000	164,000	139,000	127,000
Average land price (10,000yen/m^2)	48.5	50.4	46.9	44.8
Operating costs (billion yen)	3.01	3.22	2.87	2.69
Number of commuters	153,000	159,000	148,000	141,000
Effort	2.29	2.38	2.22	2.14
Annual profits of railway business (billion yen)	9.83	14.5	7.53	5.35
Annual profits of side businesses (billion yen)	3.05	3.17	2.95	2.82
Annual total profit (billion yen)	12.9	17.7	10.5	8.17
Annual incremental social welfare (billion yen)	-54.7	-34.8	-69.5	-89.2

Table 4-1: Price-cap regulation: Leontief

	Case 2-2-0 (*tcap* =7.62)	Case 2-2-1 (*tcap* =11.3)	Case 2-2-2 (*tcap* =7.62 ×0.8)	Case 2-2-3 (*tcap* =7.62 ×0.6)
Annual fare per commuter (10,000yen)	7.62	11.3	6.10	4.57
Congestion rate (%)	262	245	272	283
Railroad right of way (m^2)	187,000	208,000	177,000	141,000
Average land price (10,000yen/m^2)	48.3	50.5	46.8	44.8
Operating costs (billion yen)	0.661	0.773	0.600	0.531
Number of commuters	152,000	158,000	147,000	141,000
Effort	0.879	0.978	0.823	0.755
Annual profits of railway business (billion yen)	10.8	16.2	8.70	6.66
Annual profits of side businesses (billion yen)	3.04	3.18	2.94	2.82
Annual total profit (billion yen)	13.9	19.4	11.6	9.48
Annual incremental social welfare (billion yen)	-55.0	-31.9	-69.2	-87.5

Table 4-2: Price-cap regulation: Cobb-Douglas

	Case 1-3-1 ($tcap$ =10.6)	Case 1-3-2 ($tcap$ =13.8)	Case 2-3-1 ($tcap$ =9.51)	Case 2-3-2 ($tcap$ =13.7)
Annual fare per commuter (10,000yen)	8.06	11.3	7.06	11.3
Congestion rate (%)	132	132	131	131
Railroad right of way (m^2)	355,000	351,000	432,000	425,000
Average land price (10,000yen/m^2)	59.5	58.8	59.7	58.8
Operating costs (billion yen)	5.55	5.50	1.83	1.81
Number of commuters	184,000	182,000	183,000	181,000
Effort	3.26	3.24	1.70	1.68
Annual profits of railway business (billion yen)	0	6.06	0	7.87
Annual profits of side businesses (billion yen)	3.75	3.70	3.76	3.70
Annual total profit (billion yen)	3.75	9.76	3.76	11.6
Annual incremental social welfare (billion yen)	24.1	24.1	26.3	26.4

Table 5: Quality-contingent price-cap regulation

	Case 1-4-1 ($tcap = 7.94$)	Case 1-4-2 ($tcap = 8.82$)	Case 2-4-1 ($tcap = 7.36$)	Case 2-4-2 ($tcap = 11.4$)
Annual fare per commuter (10,000yen)	10.6	11.3	6.98	11.3
Congestion rate (%)	140	140	139	134
Railroad right of way (m^2)	331,000	330,000	430,000	448,000
Average land price (10,000yen/m^2)	58.7	58.6	59.6	58.7
Operating costs (billion yen)	13.1	12.9	2.34	1.99
Number of commuters	182,000	182,000	183,000	180,000
Effort	0.674	0.703	0.0695	0.118
Annual profits of railway business (billion yen)	0	1.58	0	7.32
Annual profits of side businesses (billion yen)	3.70	3.67	3.75	3.70
Annual total profit (billion yen)	3.70	5.26	3.75	11.0
Annual incremental social welfare (billion yen)	17.9	18.2	25.0	25.3

Table 6: Investment-contingent price-cap regulation

	Case 1-5-1 (*tcap* =7.91)	Case 1-5-2 (*tcap* =11.3)	Case 2-5-1 (*tcap* =6.54)	Case 2-5-2 (*tcap* =11.3)
Annual fare per commuter (10,000yen)	7.91	11.3	6.54	11.3
Congestion rate (%)	133	132	145	141
Railroad right of way (m^2)	351,000	351,000	423,000	423,000
Average land price (10,000yen/m^2)	59.5	58.8	59.5	58.6
Operating costs (billion yen)	5.50	5.50	1.83	1.83
Number of commuters	184,000	182,000	183,000	180,000
Effort	3.24	3.24	0.07416	0.156
Annual profits of railway business (billion yen)	0	6.06	0	8.45
Annual profits of side businesses (billion yen)	3.75	3.70	3.75	3.69
Annual total profit (billion yen)	3.75	9.76	3.75	12.14
Annual incremental social welfare (billion yen)	24.1	24.1	24.7	25.2

Table 7: Price-cap regulation with cost pass-through

Appendix 1: Derivation of the Bid Rent Function and the Transport Demand Function

Maximizing the utility function, $U(z,h,q) = z + u(h) + v(q)$, under the budget constraint, $z + Rh + t = \overline{w}$, yields $u'(h) = R$. Inverting this function yields the demand function for land:

$$h = h(R) \equiv u'^{-1}(R).$$

Following the usual procedure in the urban economics literature, we derive the bid rent function, which gives the maximum possible rent, providing utility level $\overline{u}$. The bid rent function is

$$R(\overline{y} - t, q) = \max_{\{z,h\}}\{\frac{\overline{w} - t - z}{h} : z + u(h) + v(q) \geq \overline{u}\},$$

where $\overline{y}(\equiv \overline{w} - \overline{u})$ is real income. This function satisfies $R_I = \frac{1}{h} > 0$, $R_t = -\frac{1}{h} < 0$, and $R_q = \frac{v'(q)}{h} > 0$, where $I \equiv \overline{y} - t$.

Substituting the bid rent function into the demand function for land yields a lot size function from which we eliminate the land rent, R,

$$\hat{h}(I,q) = h(R(I,q)).$$

This function satisfies $\hat{h}_I = \frac{h_R}{h} < 0$, $\hat{h}_t = -\frac{h_R}{h} > 0$, and $\hat{h}_q = \frac{h_R v'(q)}{h} < 0$.

We assume that the railway firm uses L as railroad right-of-way within the city area $\overline{H}$. (We ignore railroad right-of-way used outside of the city area.) The residential area left for housing is thus $\overline{H} - L$. We assume that railroad right-of-way can be converted without cost into residential land and vice versa. Given $\overline{u}$, the equilibrium number of residents is then defined as

$$N(t,q,L) = \frac{\overline{H} - L}{\hat{h}(\overline{y} - t, q)}.$$

To the railway firm, $N(t,q,L)$ is synonymous with the equilibrium transport demand function given $\overline{u}$. The transport demand function satisfies $N_t = \frac{Nh_R}{h^2} < 0$, $N_q = -\frac{Nh_R v'(q)}{h^2} > 0$, and $N_L = -\frac{1}{h} < 0$.

Appendix 2: The Bases of Parameters

Rate of return: $\rho = 0.068$**, interest rate:** $r = 0.073$

Since the allowed rate of return, ρ, as of 1993 is 0.068, we use that value. Taking into consideration the argument in Kanemoto and Kiyono (1993, 1995) that an allowed rate of return below the true cost of capital resulted in under-investment in railway capacity, we make the interest rate, r, a little higher than the allowed rate of return. The interest rate is then 0.073.

Utility function: $U = z + 256\log h - 0.722q^{-4.52}$

We select this functional form because of the clear meaning of each parameter. First, the coefficient of $\log h$ shows the housing expenses of a household. The "Publication of Land Price (Chika Koji)" reports that the average land price was 56.6 (10,000 yen/m^2) in the Tokyu To-Yoko line area in 1993. We multiply the figure by the interest rate, 0.073, to obtain the land rent, 3.96 (10,000 yen/m^2). Since the area of floor space per dwelling in Tokyo was 62.1 m^2 in 1993, which is based on the "Housing Survey of Japan (Jyutaku Tokei Chosa)," annual housing expenses are then estimated to be 256 (10,000 yen).

The third term, $-0.722q^{-4.52}$, expresses the disutility of congestion. Shida et al. (1989) estimate the disutility of congestion in the Tokyu To-Yoko line to be $-0.019 \times (\text{commuting time}) \times q^{-4.52}$. We assume that all residents take local trains in the To-Yoko line, travelling 9.2 km in both the morning and evening peak periods. This assumption is based on the "Urban Transportation Annual Report (Toshi Kotsu Nempo)," in which the average passenger-km per pass user in the Tokyu To-Yoko line in 1993 was 9.2 km. We assume that the morning peak time and the evening peak time each last three hours. In peak time, it takes about 21 minutes on average to commute 9.2 km using the To-Yoko line. We suppose that the residents worked 236.4 days in 1993, based on the "Monthly Labour Survey - Prefectural Survey - (Maitsuki Kinro Tokei Chosa Chiho Chosa)" in Tokyo. Annual commuting time is $\frac{21}{60}\times 236.4\times 2=165.5$ hours. The annual total of labour hours in Tokyo, which was 1,860 hours in 1993, is also calculated from the survey. According to the "Family Savings Survey (Chochiku Doko Chosa Hokoku)," the yearly household income in the Keihin (Tokyo and Kanagawa) industrial area was 854 (10,000 yen) in 1993. The hourly wage in Tokyo is then $\frac{854}{1{,}860}=0.459$ (10,000 yen) in 1993. We assume that the opportunity cost of commuting is half the average wage, as Small (1992) suggests. As a result, the monetary value of annual commuting time a year is $165.5\times\frac{0.459}{2}=38.0$ (10,000 yen) in 1993. The money-metric disutility of congestion is then $-0.019\times 38.0\times q^{-4.52}=-0.722q^{-4.52}$ in 1993.

Production function: (Leontief) $Q=0.0592\min\left\{6.65L,(1+e)Z\right\}$**,**

(Cobb-Douglas) $Q=0.32L^{0.91}\left\{(1+e)Z\right\}^{0.09}$

Disutility of efforts: $\varphi(e)=20000e^2$

We assume that the efforts by a railway firm multiplicatively expand the non-capital input. We also assume that the function of disutility of efforts is quadratic for the sake of simplicity. Although the Tokyu Corporation has many lines besides the To-Yoko line, we have no data on railroad right-of-way, operating costs, or profits per line. We allocate railroad right-of-way depending on line length, and allocate operating costs and profits depending on boardings per line.

Our analysis focuses on railways' performances in peak time. Since we have no data on operating costs or profits in peak time, we assume that they account for half of the total values. In the same way, we assume that user costs of railroad right-of-way ($=RL$) in peak time account for half of the total value. In actual data on Tokyu To-Yoko line in 1993, railroad right-of-way is 454,000 m^2 and land rent is 3.96 (10,000 yen). From these values, user costs of railroad right-of-way in peak time are

$\frac{3.96 \times 454,000}{2} = 899,000$ (10,000 yen). Dividing this value by land rent, we obtain $\frac{454,000}{2} = 227,000$ m^2, which we regard as railroad right-of-way in peak time. We fix the parameters of the production function and the disutility of efforts so that operating costs, railroad right-of-way and the congestion rate under the present ROR regulation in our simulation will match the peak-time values.

Real income: $\bar{y} \equiv \bar{w} - \bar{u} = -754$

The Tokyu To-Yoko line carried 58,700 passengers per hour during peak time in 1993, based on the "Urban Transportation Annual Report (Toshi Kotsu Nempo)." Since we assume that the morning peak time and the evening peak time each lasts three hours and that all residents use the line on their way to and from work, the number of commuters is estimated at 176,000 in 1993. We fix real income, $\bar{y}$, to satisfy this number of commuters under the present ROR regulation.

Size of the residential city: $\bar{H} = 11{,}200{,}000$

Since the size of the residential city, $\bar{H}$, is (the number of commuters) × (the average floor space) + (the area of railroad right-of-way), we estimate it to be 11,200,000 m^2 in 1993.

Ratio of railroad right-of-way owned by a railway firm to the entire city: $\alpha_1 = 0.017$

Ratio of residential land owned by a railway firm to the entire city: $\alpha_2 = 0.0077$

The size of the rate base depends on α_1. In 1993, the book value of the rate base was 189 (billion yen). Allocating it depending on line length and adjusting it for peak time, we obtain the book value of rate base of the To-Yoko line, which is 24.7 (billion yen). We fix α_1 at 0.017, so that the size of rate base under the present ROR regulation will match that value.

The α_2 parameter is related to the profits of the side businesses that are complementary to the railway business. Japanese private railways are well known for their diversified side businesses, such as housing development, supermarkets, and department stores. Since there is no clear evidence to show what side businesses are complementary to railway businesses, we use the profits of real estate businesses as a proxy for those of all side businesses. In the same way as we allocated the profits of the railway business, we allocate the profits of the side business depending on boardings per line and assume that half of the profits arise in peak time. As a result, we set α_2 at 0.0077.

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