Optimizing road repair funding considering deadweight losses of taxes and fees

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We simultaneously optimize multiple tax instruments (fuel tax, car-ownership tax, and tolls) and maintenance cost when these instruments are used as public funds with distortionary labor tax, accounting for pollution, congestion, accident externalities, and fiscal constraints of the tax-related agency and the toll-collecting agency. We quantitatively optimize taxes and tolls using parameters for Japan under three scenarios: 1) imposition of peak and off-peak tolls at different rates and simultaneous optimization of all tax instruments, 2) optimization of only car-related taxes without consolidation of the toll-collecting agency's fiscal constraints, 3) optimization of only fuel tax. We find that by raising tolls and fuel taxes on truck, Scenario 1 can improve welfare by 1,000 to 2,900 dollars/household compared to present level, and scenarios 2 and 3 can achieve more than 90% and 8–37% of the welfare gain in scenario 1, respectively.

***Key Words**: Optimal taxation, Marginal cost of public funds, Toll, Fuel tax, Car-ownership tax, Externality, Road maintenance*

1. Introduction

Road maintenance costs have recently increased quickly due to aging roads. Road maintenance costs are financed by fuel taxes, car-ownership taxes and tolls, which inevitably generate deadweight losses. Such deadweight losses are burdens for road users. Furthermore, maintenance costs increase, they bring about more burden. So, the maintenance costs and the levels of car-related taxes and tolls should be simultaneously optimized.

Extending Kono et al. (2019) to include multiple car-related taxes (fuel taxes, vehicle ownership taxes, and tolls) for passenger cars and trucks, we optimize road maintenance cost and all the car-related taxes and tolls. In addition, we explore the effects of consolidation of the tax-related agency and the toll-collecting agency, in which the revenue comes from car-related taxes, tolls and labor tax.

2. The model

Our model represents the annual trip behavior of consumers and firms by assuming a static situation. Each individual i maximize utility expressed as $U^i = u^i(x^{i*}_{Hk}, x^{i*}_{Ho}, x^{i*}_{k}, x^{i*}_{o}) + \Theta(y^i, Y^i) + v^i(E_H, E) + Z^i$. u^i represents utility from traffic behavior both on highway and local load, Θ represents utility from leisure, v^i represents environmental externalities, and Z^i represents synthetic goods. Since we have set up a quasilinear utility function, we can add up theutilities of all consumers. We maximize the sum of the utilities.

Firms maximize profit with the product function as a constraint. Firms are heterogenous, but we assume that they are perfectly competitive because their production functions are homogenous of degree one. Owing to this assumption, we can regard the firms as one firm.
The firm maximizes the profit function shown below.

$$\Pi = Z - f(X^*_{Hrd}, X^*_{rd}, k, L)$$

f represents the cost function and consists of the following elements. X^*_{Hrd} and X^*_{rd} is highway and general road trips by trucks, respectively. k is the number of trucks owned. L is labor time.

To express the maintenance cost, we use the following equation presented by Kaito et al. (2005).

$$\theta = [I - \beta P^d]^{-1} e^d$$

β is the discount factor, P^d is the probability transition matrix considering maintenance, and e^d is the expected maintenance cost. d represents the repair strategy. We minimize the maintenance costs by optimizing d. Local road and highway administrators pay this optimized maintenance costs. Matrix P includes a term that varies with traffic volume and can account for changes in maintenance costs as traffic volume changes.

We optimize car-related taxes, labor tax and tolls for the purpose of maximizing social welfare based on the following scenarios.

Scenario1: We consolidate government and the highway toll agency's fiscal constraints. All taxes and tolls are optimized.

Scenario2: Government and highway toll agency have a several fiscal constraints. There is no difference between peak and off-peak toll.

Scenario3: We consolidating government and the highway toll agency's fiscal constraints. Optimizing fuel tax and labor tax. There is no difference between peak and off-peak toll, and tolls and ownership tax are set at current rate.

Table1: Optimal tolls and taxes under three scenarios

	Scenario	present	1	2	3
Car-related taxes	Toll(cent/km)				
	Peak	30.0	41.5	22.5	present
	Off peak	30.0	23.6	22.5	
	Fuel tax (cents/liter)	58.8	103	100	101
	Ownership tax (dollars/year)	650	509	512	present
Labor tax (cents/hour)		109	69.4	76.7	66.6
Truck-related taxes	Toll(cent/km)				
	Peak	48.8	144.9	58.4	present
	Off peak	48.8	63.2	58.4	
	Fuel tax (cents/liter)	32.1	247.1	236.6	234
	Ownership tax (dollas/year)	961	661	692	present
Welfare gain (dollars/household/year)			1003	909.2	368.2
Ratio of welfare gain to Scenario 1			100%	90.6%	36.7%
Road maintenance cost (bil. dollars/year)		402	365	372	364

3. Simulations and results

We optimize the levels of taxes and fees considering the marginal cost of public funds (MCPF). We set MCPF at 1.2.

Table 1 shows the optimal levels of car-related taxes and tolls for each scenario and the degree of improvement in social welfare from the present. In each scenario, the optimal fuel tax is significantly higher than the present level. On the other hand, the optimal labor and ownership taxes are lower than the present level.

Scenarios 1 and 2 show that when the fiscal constraint are integrated, setting tolls and fuel tax for truck higher than the current level leads to the maximization of social welfare.

The decrease in the maintenance costs reflects changes in traffic demand of trucks due to changes in taxes and fees. However, the decrease in pavement costs is smaller than the decrease in traffic demand in terms of percentage. (see Table2).

In all scenarios, environmental externalities for both car and truck are significantly reduced, contributing to improved social welfare.

One of the important policy implications obtained from comparing scenario 1 with scenario 2 is that a high welfare gain can be achieved by consolidating different transportation agencies' fiscal constraints. This result implies that it is important to take into account the interdependency among multiple tax instruments' distortions.

Moreover, although the toll level in scenario 2 does not change much from the current level, we can achieve a higher welfare gain by just changing the fuel tax and car-ownership tax.

As shown in scenario 3, the welfare gain by optimizing a single tax item can be relatively small even if considering the revenue change of toll and car ownership tax resulting from the change in transportation demand.

Table2: The impact of scenarios on travel demand, full external costs, and welfare

	Scenario	present	1	2	3
Car	Demand (bil. km・vehicle)				
	Peak Highway	7.2	-13.3%	17.0%	7.0%
	Off-peak Highway	58.3	14.8%	12.7%	1.8%
	Peak local road	44.2	-13.4%	-17.0%	-15.9%
	Off-peak local road	357.9	-17.5%	-17.0%	-15.9%
	Car stock(millions)	57.9	4.0%	4.0%	-0.6%
	Full external costs (10^6 dollars/year)				
	Peak Highway	1,765	1,531	2,066	1,891
	Off-peak Highway	9,969	11,446	11,236	10,154
	Peak local road	3,526	3,061	2,927	2,959
	Off-peak local road	24,947	20,616	20,711	20,937
	Total	40,208	36,654	36,940	35,940
Truck	Demand (bil. km・vehicle)				
	Peak Highway	3.5	-3.2%	33.8%	36.2%
	Off-peak Highway	28.0	3.0%	-4.6%	-1.2%
	Peak local road	7.3	-48.3%	-55.6%	-56.7%
	Off-peak local road	59.1	-59.1%	-55.6%	-56.7%
	Car stock(millions)	15.5	1.1%	1.2%	-4.4%
	Full external costs (10^6 dollars/year)				
	Peak Highway	2,860	2,652	3,827	3,895
	Off-peak Highway	21,061	21,813	20,099	20,798
	Peak local road	4,818	2,597	2,139	2,082
	Off-peak local road	38,393	16,196	17,045	16,590
	Total	67,131	43,257	43,111	43,366

4. Conclusion

In this paper, we developed a model that considers two vehicle types, car and truck, and optimizes multiple taxes and tolls including maintenance costs. Maximizing the social welfare, we found that per household welfare improves by $254 to $2,900.

5. References

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