Doshisha University

Cost-effectiveness of Vehicle Safety Regulation

Masayoshi Tanishita
Hiroaki Miyoshi
Masayuki Sano

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Masayoshi Tanishita
Associate Professor
Department of Civil Engineering
Faculty of Science and Engineering, Chuo University
and COE Visiting Fellow
Institute for Technology, Enterprise and Competitiveness, Doshisha University
1-13-27 Kasuga, Bunkyo-ku, Tokyo, Japan 112-8551
Tel: 03-3817-1810
Fax: 03-3817-1803
Email: tanishi@civil.chuo-u.ac.jp

Hiroaki Miyoshi
COE Research Fellow
Institute for Technology, Enterprise and Competitiveness, Doshisha University
Karasuma Imadegawa, Kamigyo-ku, Kyoto, 602-8580, Japan
Tel: 075-251-3837
Fax: 075-251-3139
Email: hmiyoshi@mail.doshisha.ac.jp

Masayuki Sano
LIBERTAS Consulting, Co. Ltd,
and COE Visiting Fellow
Institute for Technology, Enterprise and Competitiveness, Doshisha University
2-1802 Nishi-Shimbashi, Minato-ku, Tokyo
105-0003, Japan

Abstract:

Vehicle safety has been improved by safety regulations, which made automobile makers to introduce safer body or improve auto-parts such as safety belts and air bags. In order to respond to the introduction of such regulations, automobile makers have made R&D investments whose costs were reflected to vehicle prices. On the other hand, it should be noted that such safety improvement may cause a moral hazard of vehicle users, as they may drive carelessly. In addition, fuel economy and other emission efficiencies decrease as vehicles become heavier with additional parts introduced for the improvement of vehicle safety. Likewise, in assessing safety benefits, we should take changes in types of casualty (fatality, heavy and slight injury) into account. In the cost benefit analysis of vehicle safety regulations, we should consider such related issues in the same time. In this study, we have made an empirical cost benefit analysis of Japanese cases and found out gaps of 2-3 years among the commencement of R&D activities, change in parts costs and introduction of regulations. As a result, B/C is less than 1 though it depends on the value of statistical life. We have therefore concluded that active measures to comply with regulations, such as brake assist or other sensing technology, not passive measures for traffic accidents, might be more effective.

Keywords: Safety regulations, R&D investment, Cost-effectiveness

JEL codes: R42, H29, D58, D60

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Background

In order to reduce the number of crashes and risks of death and injuries, the government has introduced vehicle safety regulations, to complement their efforts for education of drivers as well as improvement of roads and insurance systems. For such purpose, safety belts, air bags and safer (energy absorbing) body structures have been recently introduced (Table 1). Such technologies are so-called passive technologies. The basic concept of such technologies are to minimize human damages caused by car crashes and not to minimize incidents of collision while the latter is currently one of major interests of automobile makers.

Table 1: Vehicle safety regulations regarding body and safety belts in Japan since 1993

Year	Body*	Safety belts
1993		Rear safety belt and alarm system for non safety belt drivers
1996	Standards for frontal impact protection	
1999	Standards for side impact protection	
2000	Standards for offset impact protections	

Note: Air-bags are essential to meet with standards on body

(Source: Ministry of Land, Infrastructure and Transport)

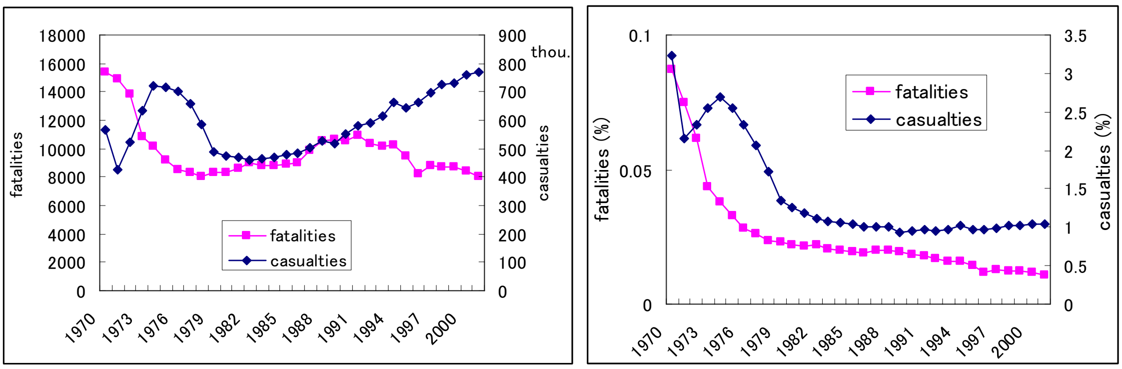


Figure 1: Changes in traffic accidents (left) and accident rates per vehicle (right)

(Source: Institute for Traffic Accident Research and Data Analysis and Automobile Inspection & Registration Association)

Since 1993, the number of fatalities in traffic accidents tends to decrease while that of casualties has been increasing (Figure.1 left). Considering the increase in vehicle ownerships, we have also calculated accident rates per vehicle (Figure 1 right). Casualties have been slightly increased while fatalities have been decreasing. As driving conditions including the on road average speed and the number of traffic signals per road length have been almost constant since 1993, we assumed that the reduction of fatalities has been mainly caused by safety regulations [1].

Regulations have promoted R&D activities by the automobile industry and such R&D costs have been reflected ultimately in vehicle prices. The purpose of this study is to examine whether such vehicle regulations are cost effective or not. Vehicles themselves may have become safer. However, drivers may drive less carefully as they feel safer with better equipped cars. It is thus not obvious whether drivers and/or fellow passengers become safer or not. We should evaluate the cost effectiveness by actual results, not from the point of view of vehicle safety. Likewise, it should be noted that the installment of additional parts required by vehicle safety regulations caused increases in the weight of vehicles and it has negative impacts on fuel economy. We should also consider such negative impacts when we evaluate the cost-effectiveness of vehicle safety regulations.

This study is to examine the cost effectiveness of Japanese passive vehicle regulations since 1993. In the United States, the regulatory impact assessment is mandatory and NHTSA publishes information on costs and weights added by federal motor vehicle safety standards. In Japan, however, the decision making process for regulations is unclear and the cost effectiveness has not been publicly discussed.

In this study, we will discuss the following points to evaluate the cost effectiveness of regulations.

Q1. Timing of R&D caused by regulations

Q2. Parts and vehicle costs to comply with regulations

Q3. Costs and benefits of regulations

In order to examine questions above, in the next section, we will first explain the methodology. We will then show data for the analysis and its results respectively in sections 3 and 4, before we present our conclusion and further challenges.

1. Methodology

It is not easy to answer the above 3 questions. It is because, as we explained in the previous section, Japan has no system for the regulatory impact assessment unlike the U.S. and automobile makers are thus reluctant to release data on costs. Likewise, we should also consider following points.

* R&D: Makers invest in R&D even without regulations.

* Cost: Parts and vehicle costs are affected by material and other capital costs and they can fluctuate.

* Effectiveness: Drivers and driving conditions also have impacts on traffic accidents.

In this study, we assumed that among increases of parts costs, the ratio of the cost increase by safety regulations is proportional to the ratio of patents related to safety regulations. We are fully aware that this is a bold assumption and further researches will be required. Likewise, in order to control the cost fluctuation, we have estimated changes in costs with and without moving average (5 years). In estimating the reduction of traffic fatalities, we could not consider separately changes in drivers and driving conditions but we took the vehicle age effects and vehicle model year effects into consideration.

Therefore, following steps have been used in this study (Figure.2).

1. Data collection on the number of patents and vehicle safety regulations relating to patents

2. Estimation of the cost increase of parts and cars by safety regulations

3. Analysis of traffic accident data by vehicle type and by vehicle age

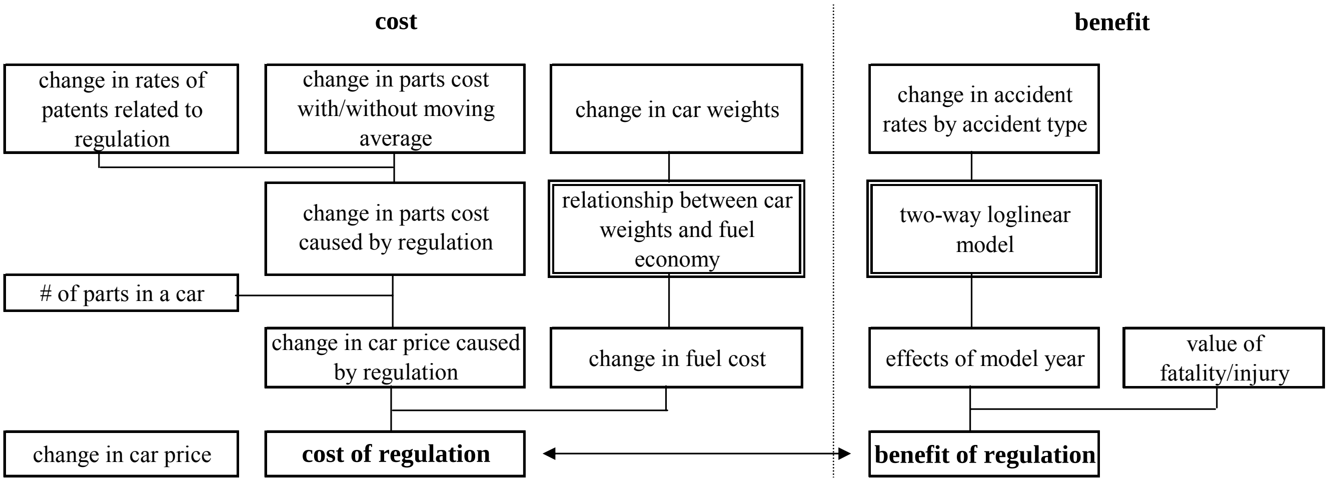


Figure 2: Estimation flow of costs and benefits by safety regulations

2. Data

The data we have collected is shown in Table 2. In this study, we have focused on costs of body, air-bags (including head restraints) and safety belts related to safety regulations. However, other instruments such as lamps, tires and etc. have been excluded as we could find almost no change in their costs. We have divided cars into two categories, which are compact cars (less than 2000cc) and larger cars (more than 2000cc). The definition of fatality is a death within 24 hours after the accident. Likewise, injuries have been divided into 2 groups; serious injury (procurement with more than 30 days) and other slight injuries.

Table 2: Data list

	Data	Source or Organization
Patents	Number of patents by type	Japan Patent Office
Costs, weight and fuel economy	Parts	Machinery statistics Shipment survey
	Vehicle	Japanese Motor Vehicle Guidebook Annual Report on the number of Automobile Registration
Traffic accidents	Number of vehicles by age	Vehicle registration statistics
	Number of fatalities and injuries	Institute for Traffic Accident Research and Data Analysis

3. Results

1) Regulations, Patents and Costs

First, we made interviews to staffs at Toyota Motor Corporation, who were in charge of regulations. All of them admitted that carmakers in Japan started R&D activities soon after they have noticed regulators' moves to introduce or reinforce regulations. By analyzing traffic accident data and investigating foreign treads on regulations, regulators tried to set or reinforce regulations. On the carmaker side, persons in charge regularly communicated with regulators and held several closed meetings with them. During this period, carmakers made R&D activities and developed new technologies to meet new standards. It is after such communications and R&D activities that regulators finally declared new standards. In short, R&D activities to meet regulations were conducted before the introduction of new standards. Therefore, in Japan, when new standards were announced, equipments of almost all new cars were already in accordance with new standards.

Therefore, we have collected not only patents data after the introduction of regulations but also that for the past 5 years before such introduction. Then, we have examined the relationship among regulations, patents and costs of parts (Figure 3).

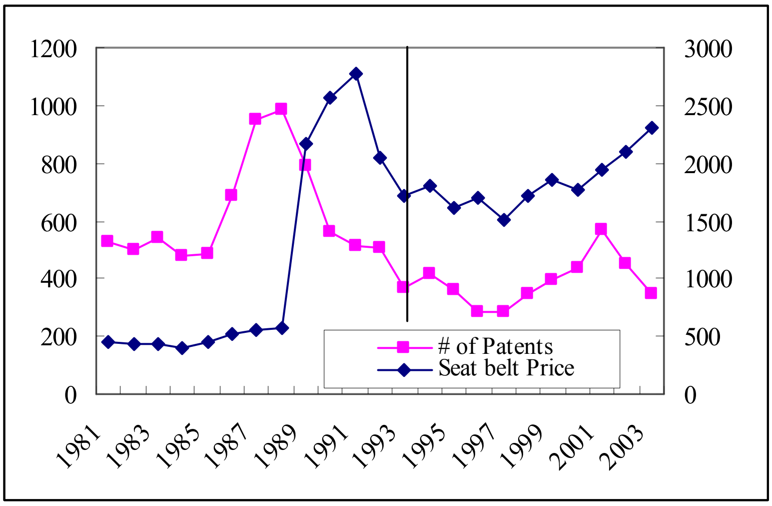


Figure 3: Number of patents and parts costs (safety belt)

Note: Vertical line shows the year where regulation started.

We can see a lag of about 2-3 years between the acquisition of patents and the change in costs of parts. Likewise, there is a lag of 2-3 years between changes in costs and regulations. After the installment of new technologies, parts and car makers try to reduce costs and/or to improve functions. Normally, costs of parts using same technologies will decrease over time. As this cost reduction is realized by efforts of parts makers and carmakers, there will be two definitions of cost. One includes this reduction in impacts of regulations and the other excludes this reduction from impacts of regulations as parts and car makers will make investigations to reduce costs even without regulations. Therefore, we calculate cost increases with/without including this reduction.

Furthermore, needless to say, carmakers always invest in R&D activities regardless of regulations in order to maximize profits, by ameliorating, for example, body designs, amenity equipments and etc. for sales promotion. Therefore, we have to survey not only the number of patents but also their contents. We have divided patents into two groups, which are patents regarding safety regulations and those by keywords of patents. Figure 4 shows changes of percentage of patents regarding safety regulations. Though they are fluctuating, almost 30% of patents were related to safety regulations. On average, 30% of patents were related to safety regulations. Through the analysis in this paper, we assumed that 30% of increases in costs and weights have been caused by regulations.

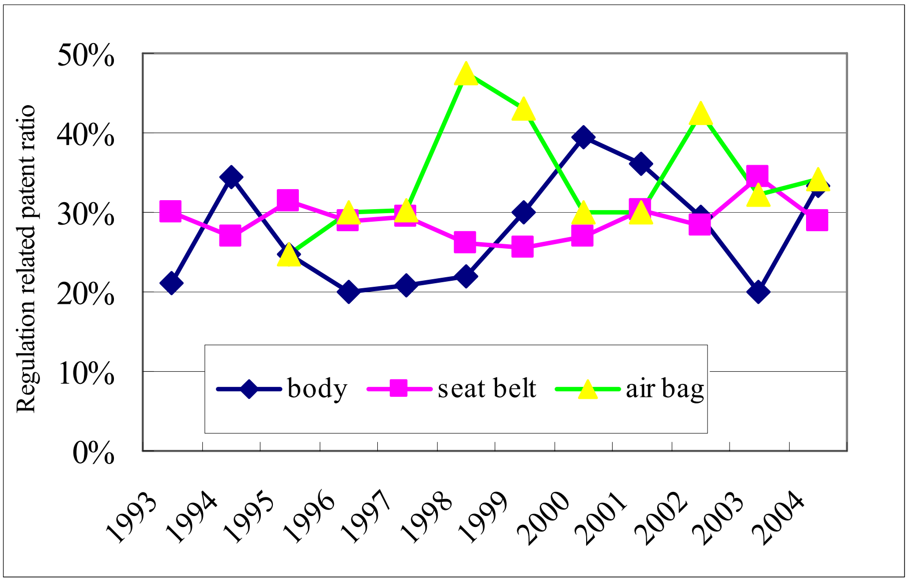


Figure 4: Changes in ratio of patents regarding safety regulations

2) Increases in car costs by safety regulations

As to increases in car costs by safety regulations, we have first calculated costs for safety belts and air-bags from the number of parts equipped in the vehicle and we have considered that 30% of such costs as the cost increased by regulations. Likewise, we consider that 30 % of increased body costs as the cost increase caused by safety regulations. By summing up these two amounts, we have determined increases in car costs by regulation (Figure. 5). In calculating body costs, we have considered the average weight increase caused heavier-ization from compact cars to larger cars.

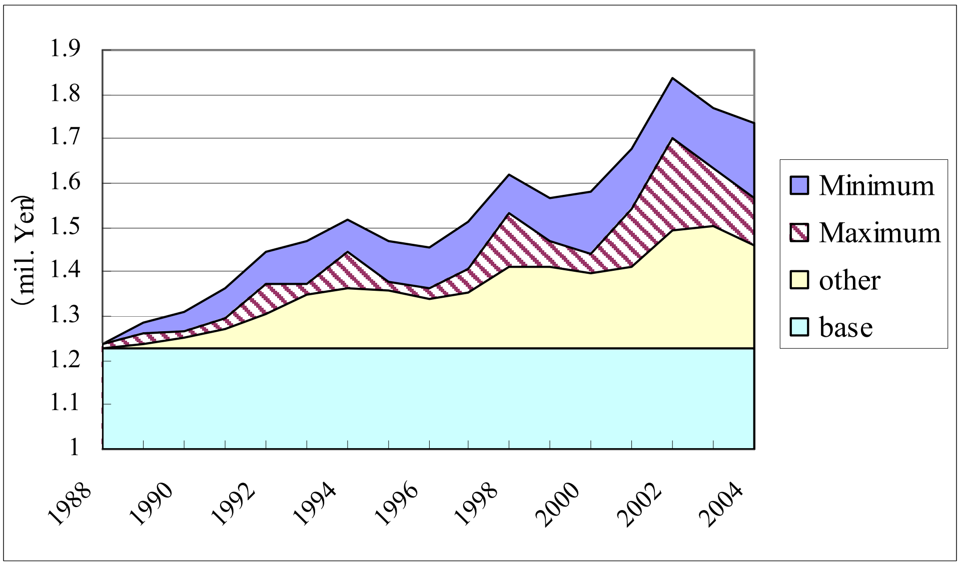


Figure 5: Increases in car costs by safety regulations

The average car price has increased by about 0.55 million yen. It is estimated that about 30% of the cost increase (0.14-0.26 mil. yen) was caused by safety regulations.

3) Changes in traffic accidents

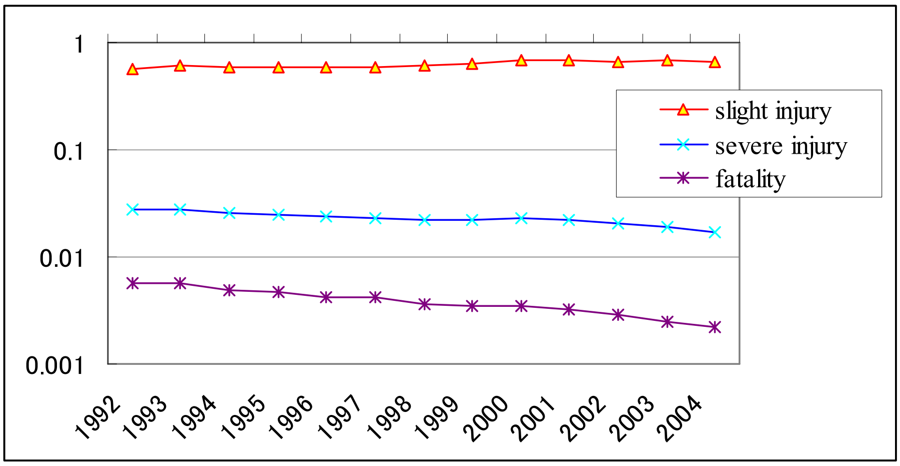


Figure 6: Changes in traffic accidents per vehicle (%) by accident types

Note: logarithm is used in vertical axis

Figure 6 shows changes in traffic accidents per car by accident types. Clearly, fatality and severe injury rates have decreased while the rate of slight injury tends to increase. However, these values may be incorrect because not only the model year but also the vehicle age may affect them simultaneously. To separate such effects, we assumed a two-way loglinear model (simple fixed effect model) and estimated parameters (β_i,γ_j).

$$\ln (Y_{ij}) = \alpha + \beta_i + \gamma_j + \varepsilon_{ij}$$

Here, Y_{ij}: accident rates by accident type (fatality, severe injury, slight injury) per 1 mil. registered cars, β_i: model year, γ_j: vehicle age, ε_{ij}: error term ~ $N(0, \sigma^2)$.

Table 3 shows ANOVA tables for larger cars. Compact cars showed almost same results. The model year has statistical significant effects on accident rates. The car age also showed statistically significant effects except for death rates.

Figure 7 shows fixed effects of model year and vehicle age. We can see the declining tendency in death and heavy injury rates since 1993. On the other hand, the rate of slight injury shows a tendency to rise. Interestingly, new cars are safer than used cars as car drivers drive carefully. In this analysis, we ignored impacts of changes in road conditions, drivers and travel distances as there were no outstanding changes in such factors compared with the increase in the number of cars. However, it will be necessary to closely examine such factors as well in the next step. Based on these fixed effects, we have estimated the number of traffic accidents reduction.

Table 3. ANOVA tables for larger cars

ANOVA table of death rate

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
year	25	511.69	20.47	3.445	1.25E-06
age	14	128.51	9.18	1.545	0.1013
Residuals	154	914.96	5.94		

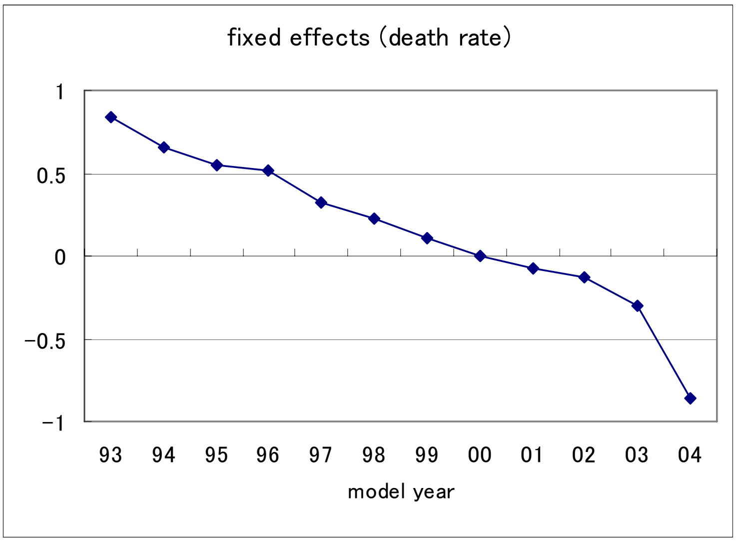
ANOVA table of heavy injury rate

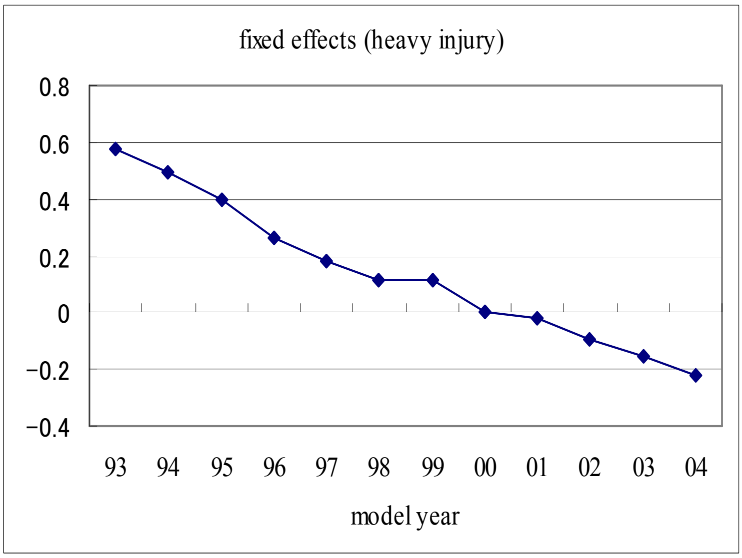
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
year	25	31.377	1.255	19.315	< 2.2e-16
age	14	14.791	1.057	16.260	< 2.2e-16
Residuals	154	10.007	0.065		

ANOVA table of slight injury rate

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
year	25	9.114	0.365	12.478	< 2.2e-16
age	14	11.972	0.855	29.268	< 2.2e-16
Residuals	154	4.499	0.029		

Figure 7: Fixed effects of safety improvement by model year and vehicle age





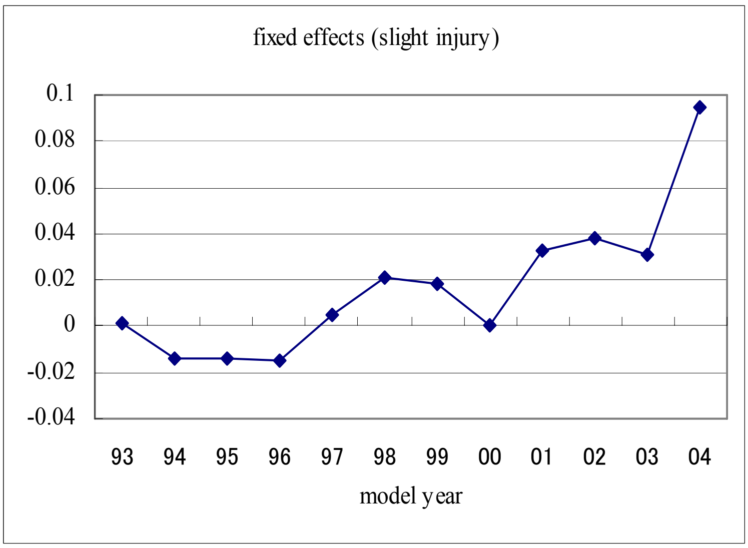
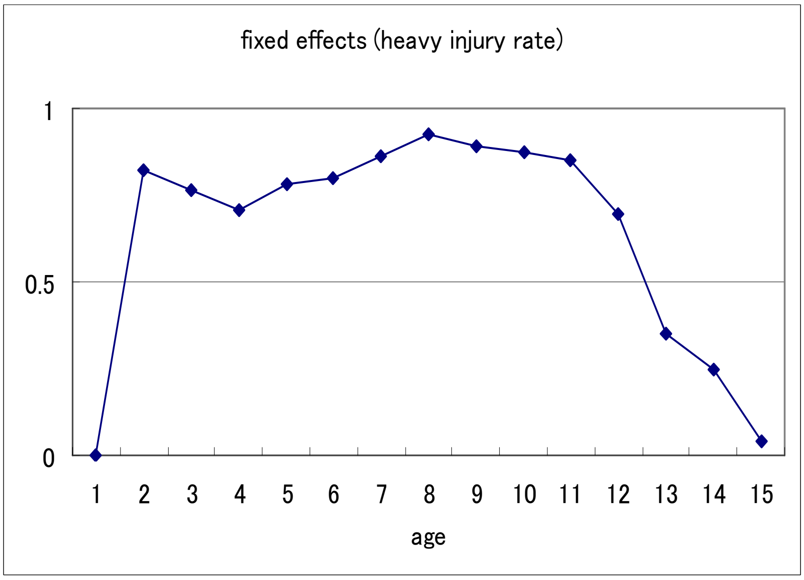


Figure 7: Fixed effects of safety improvement by model year and vehicle age (Continued)



With regards to values of traffic fatality prevention (VFP) and injury prevention (VIP), Japanese government indicated values for the cost benefit analysis of transport infrastructure improvement projects. However, these values are based on labor loss and they have little with willingness to pay for the reduction of probability of death/severe injury. In general, the hedonic wage or contingent valuation method is used to obtain the VSL. Blaeij et.al. (2003) showed the result of meta-analysis for VFP in road safety. On average, about 3.46 mil. (1996 US dollars) for Stated Preference (SP) studies and about 1.19 mil. (1996 US dollars) for Revealed Preference (RP) studies were obtained, though the range of estimates they reviewed varies from 392,000 to 30,838,000 (1996 US dollars). In Japan, Imanaga (2000) estimated VFP and value of severe injury via contingent valuation. In this study, we applied 300 mil.yen for VFP and 200 mil. yen for severe injuries. For slight injuries, we assumed 5 mil.yen per accidents as VIP.

Combining the change in β between 1993 and 2004 and VFP and VIP, we have estimated benefits of safety regulations. In this study, we assumed that all cars are used for 10 years. 10 years benefits are calculated based on 3% discount rate.

4) Changes in fuel economy

In general, the increase in vehicle weight makes fuel efficiency worse. The average vehicle weight has been increased approximately by 50kg since 1993. As we assumed that regulations affect 30%, that is 15kg, safety regulations make a vehicle about 1% heavier. In Japan, the fuel economy elasticity of vehicle weight is almost -1 (Figure 8). Therefore safety regulations increase fuel cost about 1%. As to other emissions such as NOx and PM, we omit them from the analysis because almost all Japanese cars are gasoline powered vehicles and it is the fuel quality, and not the weight of vehicle, that has a major impact on such emissions.

5) Cost effectiveness of safety regulations

Table 4 summarizes benefits and costs of safety regulations in Japan. We can not say that Japanese safety regulations are cost-effective, though it depends on VPF/VPI. In addition, if we overestimate the increase in vehicle costs due to miss-assumption, B/C will be improved.

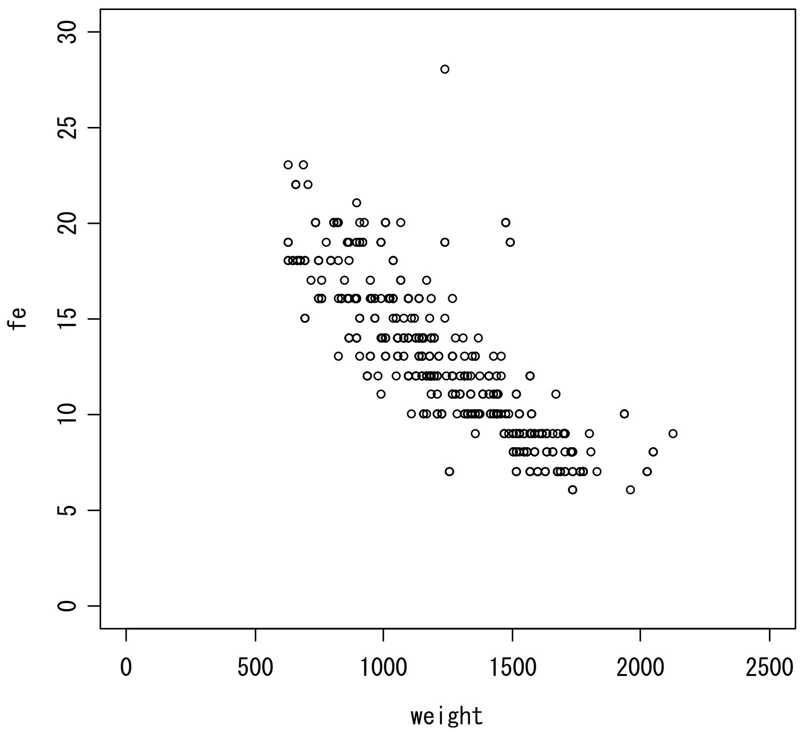


Figure 8: Relationship of vehicle weight (kg) and fuel economy (km/liter)

Note: One outlier point over 25 (km/liter) in fuel economy is Prius(Toyoya).

Simple regression result is as follows.

ln(fe)= 9.40 - 0.97 ln(weight) R2=0.71, # of sample=361

(40.43) (-29.75) (t-stats)

Table 4: Benefits and Costs of Safety Regulations in Japan

Benefit	Thou. Yen /10 years	Cost	Thou. Yen /10 years
Reduction of fatalities	90	Increase in vehicle cost	140-260
Reduction of severe injuries	120	Increase in fuel cost*	8.3
		Increase in slightly injury cost	15
Total	210	Total	163-283
B/C	0.74-1.29		

Note: travel distance 100,000 (km/year), fuel economy 12 (km/liter) gasoline price 100(yen/liter)

4. Conclusions

In this study, we have focused on Japanese vehicle passive safety regulations and estimated their cost-effectiveness based on patents resulted from R&D activities. Not only changes in traffic accidents but also changes in fuel economy were considered in the analysis. The following results were obtained.

- There is a lag of 2-3 years between the price change and the introduction of regulations and also almost same lag between the price change and R&D investments. Japanese regulations have been developed through negotiations between the car industry and the government. By the time regulations were enforced, related technologies have been almost established. Therefore, we should take this fact into account for the analysis of regulations. We considered 5 year lag for the cost.
- About 30% of increase in costs comes from regulation. This ratio is quite high compared with earlier studies (Sperling (2004) and Tarbet (2004)). This may be caused by our bold assumption that the cost increase related to regulations is proportional to the patent share related to regulations. We need further analysis for this point.
- The cost-benefit ratio seems to be almost 1 though it depends on the value of traffic fatality (injury) prevention and traffic fatality rates have been decreasing since 1993.

As we mentioned earlier, Japanese vehicle safety regulations are passive measures. At present, automobile makers have been developing active technologies such as lane keeping, brake-assist and caution systems to inform the approach of obstacles, pedestrians and fleets and so on. Not passive but these active accident prevention measures should be encouraged.

One remaining challenge is to examine whether further regulations are required to promote these active technologies or not. If consumers can obtain accurate information, we do not need regulations. In 1980's and 90's, automobile makers were reluctant to improve safety due to cost increase. However, at present, safety becomes one of the key issues for sales promotion. Therefore, we should also analyze the consumers' choosing behavior.

International comparison will be also very important. In doing so, comparisons of not only the cost effectiveness of regulations but also of their contents will be indispensable. In addition, as we showed in first chapter, in Japan, fatalities are decreasing while casualties are increasing. The cause of this growing gap should be also analyzed systematically. Finally, we believe that fuel economy and safety are not in opposition to one another (Ahmed and Greene (2004) and Wenzel and Marc (2005)). Vehicle design consistent with safety and fuel economy should be examined.

Note:

1. Of course, this gap may be caused by the improvement of emergency medical-care system. However, statistics of fire defense agency shows that the time required to carry casualties to the hospital after an ambulance received an emergency call has been increasing not only for traffic accidents but also for total ambulance activities ((FDMA (2005)). Therefore, we assume that safety regulations play a major role on fatality reduction after 1993.

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