



Analysis of the duration of compliance between recidivism of drunk driving and reinstatement of license after suspension or revocation



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ABSTRACT

The objective of this study was to examine the specific deterrence effect of administrative license suspension and revocation regarding the duration of compliance. This study tried to capture the effort of the reinstated offenders to increase the duration of their compliance in spite of their subsequent conviction for DUI. Specifically, the difference between the recidivism rate and the duration of compliance was examined and compared in terms of drivers' characteristics, including gender, the type of license, and age. Data from all drivers who have been newly licensed for five years from 2009 to 2014 in Korea were collected for analysis. The proportional hazard regression and logistic regression models were estimated for the drivers with suspended or revoked licenses, respectively. The former was for exploring the duration of compliance, and the latter was for analyzing the recidivism rate. The results of the analysis showed that license sanctions significantly increased the duration of compliance. The results indicated that the violation-prone groups included male drivers, those with regular and moped licenses, and those between the ages of 30 and 39. License suspension was more effective than license revocation, but this finding did not hold for regular licensed drivers. Drivers' groups that showed different results between compliance duration and recidivism rate also were identified and appropriate treatments should be implemented to improve their willingness to comply.

1. Introduction

Driving under the influence (DUI), also as known as driving while intoxicated, is one of the most hazardous traffic violations, and it is strongly associated with the occurrence of crashes (Kim et al., 2000; Eger, 2006). License suspension or revocation of driving privileges is the most extensively used administrative sanctions, e.g., Korea, France, Japan, Germany, the U.K., the U.S.A., and others, to prevent future DUI convictions. The purpose of these license sanctions is to improve traffic safety through incapacitation and deterrence. Specific deterrence pertains to the effect of legal punishment on offenders, while general deterrence refers to the effect due to the fear of punishment for potential offenders.

There have been a number of studies to confirm the effect of the specific deterrence of license suspension or revocation due to drunk driving. However, the validity of the results of most of the previous studies was threatened because they used a quasi-experiment with some

limitations, such as self-selection and non-random sampling, to investigate the difference in the recidivism rate between the experimental and control groups. In this study, the definition of recidivism rate is the rate of offenders for DUI whose licenses were reinstated after their license suspension or revocation. While the effectiveness of specific deterrence can be examined from the recidivism rate, the recidivism rate in itself may not capture the efforts of the drivers to avoid the subsequent conviction. Although drivers are reconvicted of DUI, some try to avoid drunk driving. As a result, some drivers show the longer duration until the recidivism of DUI than their former conviction for the DUI. In this study, the term 'compliance duration' is introduced, and it is defined as the length of time between the acquisition of a driver's license and the DUI conviction or the reinstatement of a driver's license and the DUI reconviction. Drivers who make an effort to increase the duration of their compliance can be separated from simple re-offenders, and different preventive measures should be applied.

The first objective of this study was to examine the specific

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deterrence effect of administrative license suspension and revocation regarding compliance duration. In this study, we tried to capture the effort of the reinstated offenders for increasing their compliance duration in spite of their subsequent conviction of DUI. To this end, the compliance duration was evaluated by using the proportional hazard model. All records of DUI conviction and license sanction for drivers who had either acquired or reacquired a driver license between 2009 and 2014 were collected to overcome the limitations of the quasi-experiment.

The second objective was to examine the difference between the recidivism rate and compliance duration in terms of driver's characteristics, including gender, the type of license, and age. To this end, adding to the proportional hazard model, the impact of license sanctions on the recidivism rate was evaluated with the logistic regression model. The regression models were developed using drivers' characteristics as independent variables, and violation-prone groups were identified. By comparing the effects of license sanctions on the duration of compliance and recidivism rate, it was possible to identify drivers who were trying to avoid drunk driving. The regression models were developed and compared for suspended and revoked drivers, respectively.

This study contributes to the literature in this field by suggesting the modeling framework to explore the deterrence effect of the license sanctions in the perspective of compliance duration associated with the driver's characteristics. This framework allows us to explore whether we have to analyze the deterrence effect by dividing the recidivism rate and compliance duration. By the results of the suggested framework, we can guess the effect of a policy that is a punishment according to the compliance duration. Although the punishment policy cannot be implemented differently depending on the driver's characteristics, we can identify the driver's characteristics of a target driver for preventing DUI-related education or care program. Moreover, this study used a large-scale tracing record rather than quasi-experiments for evaluating the effect of the exclusive sanction.

The remainder of this paper is divided into six sections, i.e., literature review, method, study data, model estimation, discussion, and conclusions. The literature review provides evidence of the effect of license sanctions regarding recidivism rate and clarifies the contributions of the study. The method section describes the proportional hazard regression for duration analysis. The logistic regression also was introduced for comparative purposes. In the study data section, the DUI policy in Korea is explained briefly, and the data collection and drivers' characteristics used for analysis are described in detail. The model estimation section provides the results of the proportional hazard regression and the logistic regression. Based on the results, new findings were discussed in the discussion section and compared with existing results in the literature. The paper concludes with a summary of the study and the identification of possible future studies.

2. Literature review

In earlier days, the suspension or revocation of drivers' licenses was a consequence of adjudication. Hagen (1977) examined the specific deterrence effect of the one-year suspension of licenses due to second DUI violations. Suspended drivers in the experimental group had significantly fewer subsequent DUIs than drivers in the reference group who had not had their licenses suspended because it was their first DUI conviction. Several studies examined the effect of license suspension on crashes and subsequent DUI convictions (Johns and Pascarella, 1971; Hagen et al., 1979; Salzberg et al., 1981; Popkin et al., 1983; Tashima and Peck, 1986; Tashima and Marelich, 1989; Sadler et al., 1991). The drawback of license suspensions or revocations as a result of adjudication is the time that elapses between the violation and the license sanctions. Quickly implemented punishments may improve the impact of license sanctions. As such, administrative license sanctions have been implemented extensively to hasten the speed of punishment.

"Per se" laws in DUI establish that once an individual is shown to have a blood-alcohol concentration (BAC) at or above a specific percent, that person will be considered intoxicated by law. Based on changes in 0.08 Minnesota's administrative per se law, Cleary and Rodgers (1986) reported that administrative suspension was more effective as general deterrence. Blomberg et al. (1987); Ross (1987); Lacey et al. (1990), and Rogers (1995) evaluated the general deterrence of the administrative per se law using interrupted time series analysis. These studies indicated that there was a significant decrease in alcohol-related crashes, night-time crashes, and crash fatalities. Rogers (1997) found that the administrative per se laws significantly reduced subsequent alcohol-related crashes and DUI convictions. Voas et al. (2000) and Wagenaar and Maldonado-Molina (2007) showed similar results. DeYoung (2011) summarized the previous literature and pointed out some limitations including the defect of the quasi-experiment approach. The author also posited that a comparison of effects among the alternatives is required and that license suspension has not been used independently since it is often integrated with an alcohol program or a mandatory jail sentence.

The research focus has been expanded regarding the implementation strategy or related drivers' characteristics. From the perspective of the specific deterrence of the administrative per se laws, DeYoung et al. (1997) found that combining an alcohol program with license suspension was more effective than either implemented alone, but they found no evidence that longer alcohol programs were more effective. Fell and Scherer (2017) found the effect of general deterrence of the suspension duration, and they recommended that the duration should exceed 91 days. In terms of driver's characteristics, Freeman et al. (2006) pointed out that the self-reported drunk-driving behaviors and alcohol consumption levels were identified as predictors of future intentions to drink and drive. Kim et al. (2011) showed that the suspension of drivers' licenses had a greater effect on reducing traffic violations and crashes than the revocation of their licenses.

3. Method

3.1. Proportional hazard model

The proportional hazard model is a kind of survival analysis of the duration of time until one or more events occur (Cox, 1972), such as a conviction of DUI as used in this study. The hazard function gives the instantaneous potential per unit time for an event to occur, given that an individual has survived up to time. The survival rate at time, $S(t)$, is formulated as shown in Eq. (1), where T is the time when an event occurred. The hazard function, $\lambda(t)$, which is also used in survival analysis, is the event rate at time t , conditional on survival until time t or later (Eq. (2)). The proportional hazard model is shown in Eq. (3), where the baseline hazard is denoted as $\lambda_0(t)$.

$$S(t) = \text{Probability}(T > t) \quad (1)$$

$$\lambda(t) = \lim_{dt \rightarrow 0} \frac{\text{Probability}(t \leq T < t + dt)}{dt \cdot S(t)} \quad (2)$$

$$\lambda(t|x) = \lambda_0(t) \cdot \exp(\beta'x) \quad (3)$$

The problem of data censoring occurs when a person does not experience a subsequent DUI conviction until the study ends (Kleinbaum and Klein, 1996). The observations over time for the occurrence of an event require both the beginning and the end points of the study. Data censoring occurs in two ways and is shown in Fig. 1. Left censoring occurs when the beginning point is missing, while right censoring occurs when the observation is closed without an event occurring. Left censoring occurs when a person acquired her or his license before the study began (Person 1). Right censoring occurs when a person is not convicted of DUI until the study had ended (Person 2). Person 3 was not censored, while person 4 was both left- and right-censored. There is no

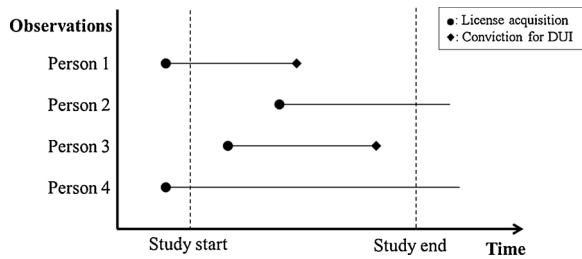


Fig. 1. Illustration of the data censoring.

left-censored data in this study since the data consisted of newly-licensed drivers. The duration model is less sensitive to changes in the endpoint of observation because the duration model uses the conditional information of the duration of survival.

An estimate of maximum likelihood (ML) is used to estimate the coefficients. The proportional hazard method requires no assumptions about the distribution, but it assumes that the odds ratio of hazard, $\lambda(tx)/\lambda_0$, is constant. Thus, the proportional hazard assumption should be checked. A statistically-significant p -value indicates that a coefficient in the regression model is not zero. It should be noted that a negative sign of β' indicates the reduction of the hazard, which can be interpreted that the compliance duration is increased in this study.

3.2. Logistic regression

In many previous studies, analysis of covariance has been used to compare groups of drivers whose licenses had been suspended and groups of drivers whose licenses had not been suspended. In this study, we used a logistic regression to examine the relationship between the independent variables and the recidivism rate. The dependent variable in a logistic regression is binary or dichotomous. The conditional mean of Y , given x , $\pi(x)$, is formulated as shown in Eq. (4), where β' is the model coefficient. The logit transformation of the $\pi(x)$ is the logistic function, $g(x)$, which is formulated as shown in Eq. (5).

$$E(Yx) = \pi(x) = \frac{\exp(\beta'x)}{1 + \exp(\beta'x)} \quad (4)$$

$$g(x) = \ln\left(\frac{\pi(x)}{1 - \pi(x)}\right) = \beta'x \quad (5)$$

Hosmer and Lemeshow (2013) summarized the three features of logistic regression. First, the conditional mean of the regression equation must be between zero and one. Second, the distribution of the error term is binomial, not normal. Third, the principles of linear regression apply for logistic regression. The logit $g(x)$ follows linear properties, and it is continuous from minus infinity to plus infinity. The independent variables can be categorical or continuous, or they can be a mixture of both. The ML estimation was used to estimate the model's coefficient rather than using the ordinary least squares estimation. A statistically-significant p -value indicated that a coefficient in the regression model was not zero. In this study, $Y = 1$ indicates the reconviction of a driver whose license has been suspended or revoked, while $Y = 0$ indicates a driver who has no subsequent conviction on her or his record. The plus sign associated with a coefficient indicates that the variable increases the DUI recidivism rate, while a minus sign indicates a reduction in the DUI recidivism rate.

4. Study data

In Korea, about 29.5 million people have a driver's license, which accounts for almost 60% of the population in 2014. The Korean National Police Agency (KNPA) is in charge of license acquisitions, suspensions, and revocations. There are six types of licenses in Korea, i.e., Class 1-heavy, Class 1-special, Class 1-regular, Class 2-regular,

Table 1

Types of Drivers' Licenses in Korea.

Class	Category	Description	Requirement		Test		
			Age	Experience	Written	Course	On-road
1	Heavy Special	Heavy vehicle	19	1year ^a	✓	✓	
		Trailer, tow truck	19	1year ^a	✓	✓	
	Regular	Passenger car, heavy vehicle ^b	18	–	✓	✓	✓
2	Regular	Passenger car	18	–	✓	✓	✓
	Small	Motorcycle	18	–	✓	✓	
	Moped	Moped, motorcycle (125 cc or less)	16	–	✓	✓	

^a One year of driving with a regular license.

^b Class 1-regular heavy vehicles are trucks that weigh less than 12 tons and buses with fewer than 15 seats.

Class 2-small, and Class 2-moped (Table 1). The Class 1-heavy and Class 1-special types of licenses are the most difficult to acquire because they require one year of driving experience with a Class 1- or a Class 2-regular license.

License suspension and revocation in Korea are implemented as administrative sanctions using both a demerit point system and the BAC. Drivers with a BAC of 0.05 to 0.10 will have their drivers' licenses suspended. The duration of the license suspension is at least 100 days, which may be reduced to 50 days if the driver attends an education program. Drivers with a BAC over 0.10 or a BAC of 0.05 to 0.10 with a crash occurrence receive a license revocation period of one to three years. Judicial sanctions are implemented separately in Korea.

The KNPA keeps the license-related records for five years for punishing the cumulative violations. For this study, we collected the license-related data and DUI violation data of newly-licensed drivers from October 2009 to September 2014. We traced the drivers who received their first DUI conviction, license suspension or revocation record, their subsequent DUI conviction, and the duration of their compliance. Among the 6,803,389 newly-licensed drivers in the observation period, 44,240 licenses were suspended (0.65%), and 119,483 licenses were revoked (1.8%) for DUI. The samples of drivers whose licenses were both suspended and revoked were eliminated.

The characteristics of the drivers who had their driver's licenses suspended and revoked in the collected data were arranged according to their gender, license type, and age (Table 2). The percentage of male drivers with suspended or revoked licenses was considerably higher than their percentage of the population of drivers.

5. Model estimation

5.1. Proportional hazard model

Among the 44,240 drivers whose licenses were suspended, 5,266 of them had a reconviction of drunk driving after the period of the suspension had ended. The maximum and minimum duration of suspensions were 140 and 50 days, respectively, and the average duration of the suspensions was 77.4 days. To develop the proportional hazard model, we traced the compliance duration twice, i.e., before and after the period of the license suspension. Among all of the cases, 45.5% was right censoring data which indicates the observation was closed without an event occurring. The independent variables included a prior experience of license suspension, gender, license type, and age. The groups with the lowest recidivism or the longest compliance duration in each of the nominal variables were selected as the reference groups, i.e., female, Class 1-heavy license type, and age 60 or older. The functional

Table 2
Characteristics of Drivers Who Received License Sanctions due to DUI Convictions.

Index	License suspension		License revocation		Total license (2014) Proportion
	Case	Proportion	Case	Proportion	
Gender					
Male	38,973	88.1	109,279	91.5	59.4
<i>Female^a</i>	5,267	11.9	10,204	8.5	40.6
License type					
<i>Class 1-heavy^a</i>	5,329	12.0	13,785	11.5	7.0
Class 1-special	581	1.3	843	0.7	0.01
Class 1-regular	24,962	56.4	66,378	55.6	57.6
Class 2-regular	11,555	26.1	34,159	28.6	34.0
Class 2-small	1,078	2.4	1,519	1.3	0.03
Class 2-moped	735	1.7	2,799	2.3	1.3
Age					
Younger than 30	14,199	32.1	28,280	23.7	Not available
30-39	13,760	31.1	35,180	29.4	
40-49	9,762	22.1	30,984	25.9	
50-59	5,275	11.9	20,475	17.1	
<i>60 years or older^a</i>	1,244	2.8	4,564	3.8	

^a Underlined italic variables indicate baselines in the estimated model.

form of the proportional hazard model is shown in Eq. (6):

$$\lambda(tx) = \lambda_0(t) \cdot \exp(\beta_1 x_{sus} + \beta_2 x_{male} + \beta_3 x_{1-spe} + \beta_4 x_{1-reg} + \beta_5 x_{2-reg} + \beta_6 x_{2-sma} + \beta_7 x_{2-mop} + \beta_8 x_{<30} + \beta_9 x_{30} + \beta_{10} x_{40} + \beta_{11} x_{50}) \quad (6)$$

where:

- x_{sus} : 1 if there is prior experience of license suspension; 0 otherwise
- x_{male} : 1 if gender is male; 0 otherwise
- x_{1-spe} : 1 if license type is Class 1-special; 0 otherwise
- x_{1-reg} : 1 if license type is Class 1-regular; 0 otherwise
- x_{2-reg} : 1 if license type is Class 2-regular; 0 otherwise
- x_{2-sma} : 1 if license type is Class 2-small; 0 otherwise
- x_{2-mop} : 1 if license type is Class 2-moped; 0 otherwise
- $x_{<30}$: 1 if age is less than 30; 0 otherwise
- x_{30} : 1 if age is between 30 and 39; 0 otherwise
- x_{40} : 1 if age is between 40 and 49; 0 otherwise
- x_{50} : 1 if age is between 50 and 59; 0 otherwise

The results of the model were statistically significant (Table 3), as compared to those of the constant-only model

Table 3
Estimation Result of Proportional Hazard Regression.

Variable	License suspension		License revocation	
	Coefficient	Standard error	Coefficient	Standard error
License sanction	−2.181**	.014	−2.167**	.020
Gender				
Male	.172**	.013	.117**	.011
License type				
Class 1-special	.038	.037	−.029	.036
Class 1-regular	.008	.013	.049**	.009
Class 2-regular	.195**	.014	.156**	.010
Class 2-small	.101**	.028	.108**	.027
Class 2-moped	.311**	.033	.272**	.022
Age				
Younger than 30	.077**	.026	−.029†	.016
30-39	.096**	.026	.078**	.016
40-49	.076**	.026	.030†	.016
50-59	.063†	.027	.048**	.017

† $p < .10$.

* $p < .05$.

** $p < .01$.

($\chi^2(11) = 41,161.7$, $p < .01$). The assumption of proportional hazard was checked with the log-minus-log survival plot. The assumption of proportional hazard is satisfied when the curves in the plot do not cross each other. Based on the log-minus-log survival plot, the developed model met the assumption of proportional hazard (Fig. 2).

Among 119,483 revoked licenses, 40,437 of the licenses had been reacquired once, and 250 of the licenses had been reacquired two or more times (248: twice; 2: three times). The proportional hazard model was developed, and 26.6% of the data were right-censored. The independent variables were a prior experience of license revocation, gender, license type, and age. The functional form of the proportional hazard model was similar to Eq. (6), except the variable x_{sus} was replaced by x_{rev} , which is a dummy variable for the prior experience of license revocation. The reference groups selected were the same as those in the proportional hazard model of suspension. The results of the model were statistically significant, as compared to those of the constant-only model ($\chi^2(11) = 24,730.8$, $p < .01$). The examination of the log-minus-log survival plot showed that the model satisfied the proportional hazard assumption (Fig. 3).

Based on the estimation results, the experience of a prior license suspension had the effect of increasing the compliance duration ($p < .01$). The revocation of licenses had the specific effects of increasing the compliance duration ($p < .01$) that indicated the driver made an effort to avoid a subsequent DUI conviction (Table 3). The driver's characteristics that affect the compliance duration is discussed in the next section.

5.2. Logistic regression

The logistic regression model was used to compare the difference between the recidivism rate and compliance duration. Among the 44,240 licenses that were suspended, data from 42,139 of those suspensions were used due to the minimum observation period of 6 month. The average observation period after the end of the suspension was 682 days. Of this total, 3165 licenses had a subsequent DUI conviction after the first suspension. The maximum likelihood method was used to estimate the model's coefficients. The functional form of the logistic regression model is shown in Eq. (7):

$$g(x) = \beta_0 + \beta_2 x_{male} + \beta_3 x_{1-spe} + \beta_4 x_{1-reg} + \beta_5 x_{2-reg} + \beta_6 x_{2-sma} + \beta_7 x_{2-mop} + \beta_8 x_{<30} + \beta_9 x_{30} + \beta_{10} x_{40} + \beta_{11} x_{50} \quad (7)$$

The estimation results of license suspension showed that male, Class 1-regular, and Class 2-regular drivers had a statistically significant coefficient ($p < .01$), which indicates a higher recidivism rate (Table 4). Drivers between 30 and 39 years had the highest recidivism rate ($p < .01$), followed by those younger than 30 ($p < .01$).

The logistic regression model was also developed for the effect of license revocation. The data from 30,494 drivers who were observed for more than six months after they reacquired their licenses were selected for the logistic regression. Males had a higher recidivism rate than females ($p < .01$). Drivers with the Class 2-moped license type had a higher recidivism rate than those with other types ($p < .01$). Drivers 60 or older ($p < .01$) had the lowest recidivism rate among all of the drivers (Table 4).

6. Discussion

Based on the results of the proportional hazard regression, license suspension or revocation increased the compliance duration of the drivers who reinstated their licenses. This indicates that the specific deterrence effect of license suspension or revocation was identified in the perspective of duration rather than the use of the recidivism rate of a certain period.

The regression results of compliance duration and the recidivism rate were compared for the expanded discussion of the specific

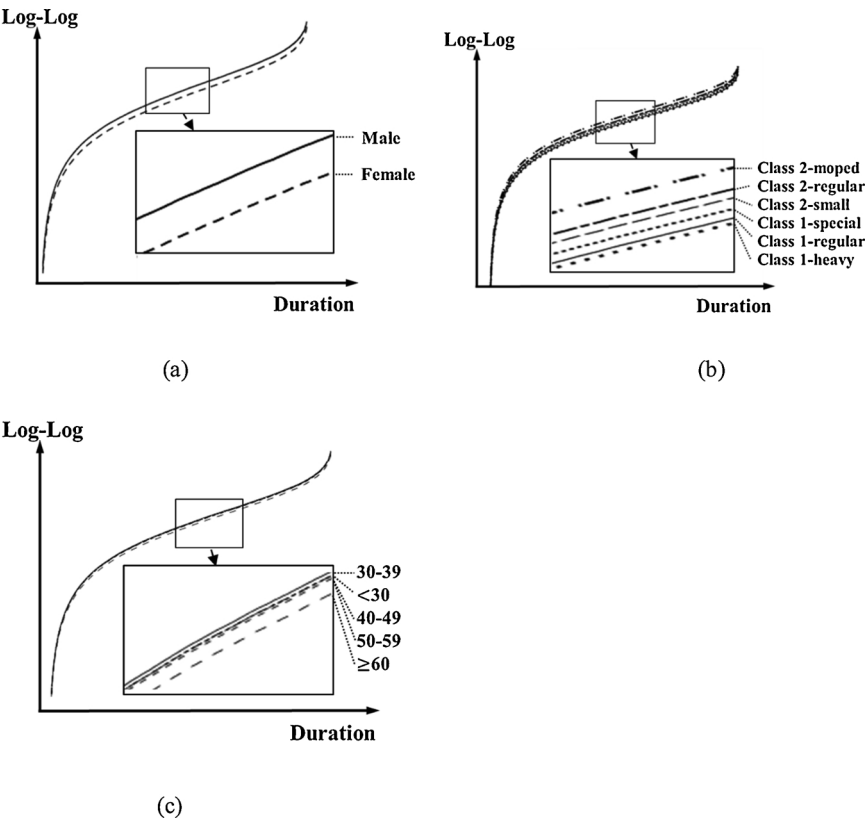


Fig. 2. Log-log survival plot of license suspension model: (a) gender; (b) license type; (c) age.

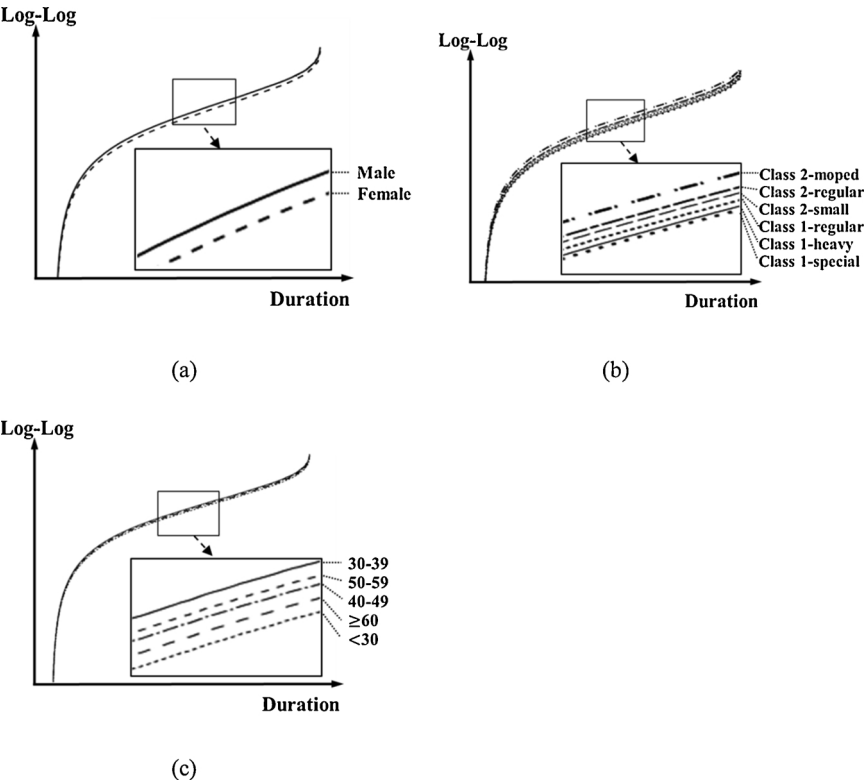


Fig. 3. Log-log survival plot of license revocation model: (a) gender; (b) license type; (c) age.

Table 4
Estimation Result of Logistic Regression.

Variable	License suspension		License revocation	
	Coefficient	Standard error	Coefficient	Standard error
Constant	−3.408**	.126	−3.369**	.176
Gender				
Male	.714**	.057	.575**	.094
License type				
Class 1-special	.007	.151	.644	.543
Class 1-regular	.347**	.052	.101	.077
Class 2-regular	.572**	.056	.130	.080
Class 2-small	.150	.110	−.954	1.019
Class 2-moped	.225†	.131	.483**	.175
Age				
Younger than 30	.455**	.103	.340*	.134
30-39	.463**	.104	.353**	.132
40-49	.365**	.106	.259†	.134
50-59	.250†	.110	.368**	.137

† $p < .10$.

* $p < .05$.

** $p < .01$.

Table 5
Comparison of the Exponential Coefficients in the Models.

Index	Proportional hazard model		Logistic regression	
	Suspension	Revocation	Suspension	Revocation
License sanction	0.113	0.115	–	–
Gender				
Male	1.188	1.124	2.042	1.777
Female	1	1	1	1
License type				
Class 1-heavy	1	1	1	1
Class 1-special	1	1	1	1
Class 1-regular	1	1.050	1.415	1
Class 2-regular	1.215	1.169	1.772	1
Class 2-small	1.106	1.114	1	1
Class 2-moped	1.365	1.313	1.252	1.621
Age				
Younger than 30	1.080	.971	1.576	1.405
30-39	1.101	1.081	1.589	1.423
40-49	1.079	1.030	1.441	1.296
50-59	1.065	1.049	1.284	1.445
60 years or older	1	1	1	1

Note: The value “1” indicates the reference group or an insignificant coefficient.

deterrence effect. The effect of driver's characteristics was compared in the model and between sanctions. The exponential values of β , $\exp(\beta)$, were calculated and compared (Table 5).

Based on the similarities of the regression results, the violation-prone groups were identified as male drivers, those with Class 2 (regular, small, and moped) licenses, and those between the ages of 30 and 39. However, females, those with Class 1-heavy and -special licenses, and drivers who are 60 or older had the lowest recidivism rates. There are several implications of these findings of the identified violation-prone groups. First, license sanctions are more effective for the types of licenses that are more difficult to acquire. Due to their age restrictions and experience requirements, Class 1-heavy and -special licenses are more difficult to acquire than other types of licenses (Table 1). In addition, these groups of drivers have a greater proportion of job-related driving, and, thus, the license sanctions could result in their losing their jobs. Therefore, it can be implied that drivers with Class 1-heavy and -special licenses are more cautious drivers who would try to avoid a subsequent DUI conviction to maintain their jobs and who recognize the barriers to reacquiring these types of licenses. A study by DeYoung et al. (1997) produced similar results. Second, the highest recidivism rate and the shortest compliance duration were observed in drivers

nearing middle age, i.e., drivers whose ages were between 30 and 39. This finding is similar to that of Kim et al. (2000), who showed a peaking trend using the square-term of age. This means that the recidivism problem of DUI occurs in both young and novice drivers and middle-aged groups. Third, license sanctions are more effective with females, which is consistent with Robertson et al.'s (2009) report that females had a lower recidivism rate than males.

There are differences in the effects of license suspension and revocation. First, the license suspension provides a greater deterrence effect than revocation. An asymptotic t -test was conducted to examine the statistical significance of this difference. The test statistic was calculated using Eq. (8):

$$\frac{\hat{\beta}_i^k + \hat{\beta}_j^k}{\sqrt{\text{var}(\hat{\beta}_i^k) + \text{var}(\hat{\beta}_j^k)}} \quad (8)$$

The coefficient of license suspension was -2.181, and the standard error was 0.014. The coefficient of license revocation was -2.167, and the standard error was 0.02 (Table 3). These parameters and the test statistic showed that the difference of the coefficients between the license sanctions was statistically significant ($t = 21.7$, $p < .01$). This can be interpreted that drivers who have had their licenses suspended are more careful thereafter because a subsequent DUI conviction would result in the revocation of their licenses. A similar result was found by Kim et al. (2011). However, revoking licenses was more effective for drivers who had a regular license. Second, although all of the models indicated that the effect of license sanctions on females was greater than on males, the difference between males and females was higher for suspension than revocation, such as $\exp(\beta)$ of hazard (1.188 > 1.124, respectively) and recidivism (2.042 > 1.777, respectively). Although the license suspension showed the better result to increase the compliance duration than license revocation, some groups showed a different result. As seen in Figs. 2 and 3, the results are similar between license sanctions in terms of gender and license type, but it showed slightly different the regarding the age. Drivers younger than 30 whose licenses were revoked showed a longer compliance duration than the license suspension, and the drivers' age between 40 and 49 showed similar results. These results are associated with the relative financial values; the fine is constant while the income and expenditure are changed by their life cycle. The amount of the fine of DUI is the result of the judicial sanction, and it is up to 3 million Korean won for suspension, and up to 10 million Korean won for revocation. Typically, wages in Korea increase with age until retirement. Thus, the drivers under 30 are more sensitive to the amount of their fine than other age groups. A driver age between 40 and 49 showed a similar result because they have increased economic stress for family supporting, e.g., education fee for their children. This result supports that imposing differential fines according to income levels could be an effective countermeasure.

Some driver groups showed conflicting behavior between compliance duration and recidivism rate. Drivers younger than 30 who had experienced revocation and Class 1-regular drivers who had experienced suspension showed higher recidivism rates, but longer compliance duration, than others. We can interpret these findings to mean that these drivers try to increase the duration of their compliance, but, eventually, they tend to be convicted for a subsequent DUI offense. These driver groups may have a willingness not to be reconvicted for DUI for a long time, but it has weakened over time. This implies that either the merit for long compliance duration or the demerit for short compliance duration can be an effective countermeasure for specific deterrence.

Based on the results, there are several policy implications of license suspension and revocation. Increasing fines for some types of licenses (i.e., Class 2-regular, small, and moped) can improve the specific deterrence effect. Determining the value of fines according to their income can improve the deterrence effect for high-income drivers, e.g., age

between 50 and 59. Considering some conflicting results between the compliance duration and recidivism rate, a countermeasure that prevents further DUI of the drivers who have a long compliance duration can be effective. Benefits for long compliance duration or additional penalties for shorter duration can also be an alternative. While some implications can be generalized, such as fines based on income levels and the demerit for a short compliance duration, the policy target groups or violation-prone groups depend on the data of the analyzed area.

7. Conclusions

This study used a proportional hazard model to examine the specific deterrence effect of the suspension and revocation of drivers' licenses in Korea. This approach can handle censored data and evaluate their effect from the perspective of the duration of compliance. Five years of DUI conviction records were used to overcome the limitations of the quasi-experimental methods of previous studies. Based on the regression results, both the suspension and revocation of driver's licenses had a significant effect in increasing the duration of compliance, indicating that drivers who had experienced prior license sanction had longer durations of compliance without drunk driving.

In this study, we also examined and compared the relationships between the effects of license sanctions and driver's characteristics on the recidivism rate and the duration of compliance. To this end, the proportional hazard regression model and the logistic regression model were used with the drivers' characteristics as the independent variables for drivers who had suspended and revoked licenses. The results were compared between suspension and revocation and among drivers' characteristics. Based on the results and comparisons, male drivers, those holding Class 2 (regular, small, moped) licenses, and drivers between the ages of 30 and 39 were identified as violation-prone groups. In terms of sanctions, license suspension was more effective than license revocation. However, license revocation was more effective for drivers who had regular licenses. Also, license sanctions had a greater effect on drivers who had licenses that were more difficult to obtain, i.e., licenses that require a higher age, experience driving with other types of licenses, and additional testing. This indicates that more rigorous licensing requirements can enhance the effects of license sanctions. The drivers' groups that showed different results between compliance duration and recidivism rate were also identified and appropriate treatments should be implemented to improve their willingness to comply.

This study can be improved through additional research. The analysis in this study was performed based on the drivers who have recently acquired a new license during a five-year period. Therefore, it has the limitation of not controlling the effects of some influential factors, such as driving experience, drinking habits, and restricted duration, on the estimation results. If additional data on drivers and license sanctions for a longer period were available, the ability of the model to explain the data could be enhanced. The effects of treatment programs and multiple license sanctions also could be estimated by using a long-term tracing survey.

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