THE HOSPITAL COSTS OF TRAFFIC ACCIDENTS INVOLVING THE ELDERLY IN TAIWAN

Jou, Rong-Chang

Professor, Department of Civil Engineering, National Chi Nan International University, Taiwan (address: No. 1, University Road, Puli, NanTou County, Taiwan 545, tel: +886-49-2910960 ext. 4956, fax: +886-49-2918679, E-mail: rcjou@ncnu.edu.tw)

Chen, Tzu-Ying

PhD Candidate, Department of Civil Engineering, National Chi Nan International University, Taiwan (address: No. 1, University Road, Puli, NanTou County, Taiwan 545, tel: +886-49-2910960 ext. 4944, fax: +886-49-2918679, E-mail: s97322903@ncnu.edu.tw)

Chao, Ming-Che

PhD Candidate, Department of Civil Engineering, National Chi Nan International University, Taiwan (address: No. 1, University Road, Puli, NanTou County, Taiwan 545, tel: +886-49-2910960 ext. 4944, fax: +886-49-2918679, E-mail: dreame79.tw@yahoo.com.tw)

ABSTRACT

The purpose of this paper is to examine the relationship between medical treatment costs and length of hospital stay resulting from traffic accidents involving the elderly. The World Health Organization defines “elderly” as people more than 65 years old. The sample for this study consisted of data for the year 2007 collected by the Bureau of National Health Insurance (BNHI), Taiwan. BNHI data used in this study included all cases coded as E810-E819 and E826 using the ICD-9-CM system. This study attempts to develop a model predicting hospital costs based on diagnosis, hospital type and travel mode. The Seemingly Unrelated Regression Equations (SURE) method was applied first to investigate the relationship between medical costs and length of hospital stay. The SURE method shows that the type of injury (for example, Head injury) is statistically significant and has positive effects on medical costs for both car and motorcycle accidents. Due to the insignificance of the dependency between medical costs and length of hospital stay, two separate simple linear regression models are used. The linear regression model shows that in car accidents medical costs for patients 65-69 were lowest, while patients over 80 had the longest hospital stays. In motorcycle accidents, patients over 80 had the highest medical costs. These results suggest that it is economically and medically important for the transportation authorities to focus on preventing certain types of injuries which are particularly serious and costly in the Taiwan elderly.

Keywords: traffic accidents, elderly, medical costs, length of hospital stay, SURE.

1. INTRODUCTION

In developing countries such as Taiwan, traffic accident rates are high and the medical costs of these accidents very expensive. According to Mohan(2002), low-income countries (gross domestic product (GDP) less than $US10,000 per capita) have more vulnerable road users: pedestrians, bicyclists and motorcycle riders who experience more fatalities and injuries when compared to high-income countries (GDP more than US$20,000). Nowadays, in developed countries the traffic accident fatalities are decreasing. This is also true in Taiwan (Li et al., 2008). Organization for Economic Co-operation and Development (OECD) health data from 2009 shows that national health expenditure (NHE) per capita has a strong positive correlation with GDP. The NHE/GDP ratio in Taiwan for 2007 was 6.0% and relatively lower than the OECD average rate. In 2007, Taiwan spent 24% of its NHE on in-patient care. This is also lower than the OECD average rate. If we analyze NHE by categories, injury and poisoning make up 6.27% of Taiwan 2007 NHE. Around $NT43.6 billion ($US1.33 billion in 2007) were spent on health care for injury and poisoning. From 1998 to 2008, traffic accidents were the leading cause of injury and poisoning deaths in Taiwan. The median age of injury and poisoning fatalities increased from 42 years to 53 years during this period.

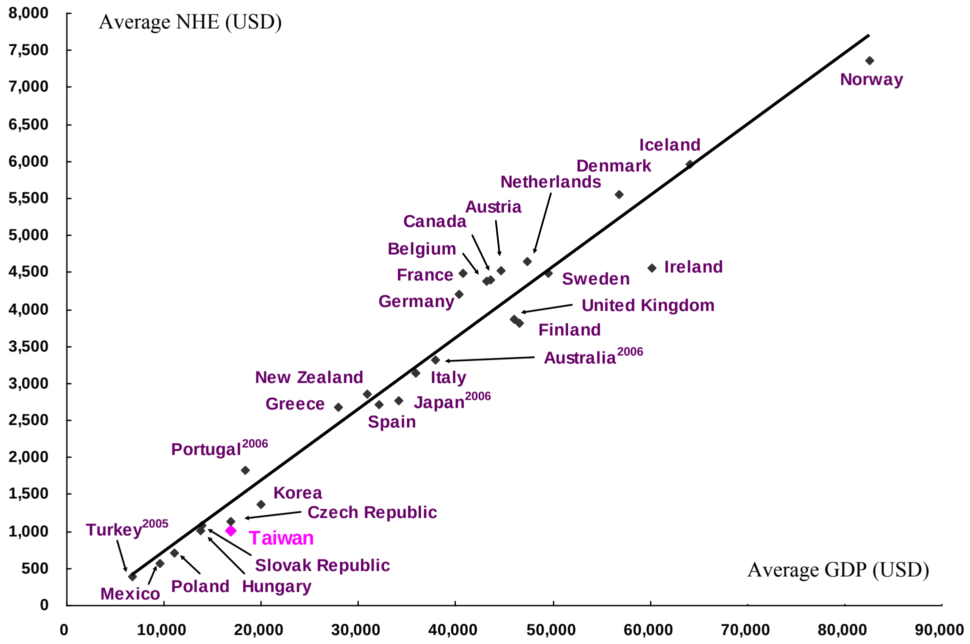


Figure 1: the location distribution of different countries in NHE/GDP domain in 2007 from OECD Health Data 2009

In 1993, Taiwan officially became an "aging society" (7% of population > 65 years). By 2006, the figure had risen to 10%, and Council of Economic Planning and Development estimated that Taiwan will become an "aged society" (14% of population > 65 years) by 2017. Although the Taiwan's population is still relatively "younger" than the member countries of the OECD, it is actually aging at a faster rate.

In aged societies the elderly involved in traffic accidents often have higher fatality rate than younger. Comparing the years 1980 and 1989, motor vehicle accident rates declined 8.4% for the overall population but increased 43% for drivers aged over 65 in United States (Barr RA, 1991). Older drivers were judged around 1.5 times more likely to have crashes than middle-aged drivers (Langford et al., 2006). Over a 20-year period, the American elderly trip patterns have changed by an increasing use of private vehicles, a reduction in the use of public transportation and some reduction in walking. Older people rely more on their own vehicles for transportation (Eberhard John, 2008).

Using inpatient costs from one hospital, Begg et al. (1994) estimated that the total cost of motorcycle accident injuries in New Zealand was $13,485,628 NZD and Langley et al. (1994) examined 2,623 motorcycle crash victims hospitalized in 1988. The most common injuries in hospitalized victims were lower limb injuries (43%) and head injuries(24%). In the Netherlands, total health care costs due to injuries of all kinds in 1999 were €1.15 billion, or 3.7% of the total health care budget. Meerding et al. (2006) found costs per patient go up linearly as patients age until they reach 60 and then rise exponentially. Traffic injuries made up in 19% of all injury costs.

2. RESEARCH METHODS

Based on the previous research, the preliminary analysis explores available socioeconomic factors influencing traffic accidents involving the Taiwan elderly. By using the data of National Health Insurance, we focus on two major medical expenditures: time and money, i.e., the length of hospital stays and medical costs. The length of hospital stays and medical costs are assumed to have a positive relationship and to commonly share unobserved factors. The properties mentioned above indicate the appropriate application of seemingly unrelated regression equations (SURE) model (Washington et al., 2003; Zellner, 1962) that can analyze the possibility of relationship between the length of hospital stays and medical costs.

Seemingly Unrelated Regression Equations (SURE) model

In order to investigate the medical expenditure of motor vehicle traffic injury admitted to hospitals of different levels, we employ SURE models to estimate the relationship. The system has the following general form:

$$\mathrm{Y}_m = \beta'_m \mathrm{X}_m + \varepsilon_m \ , \quad m = 1,\ 2 \qquad (1)$$

Y1 and Y2 are the hospital stays and medical cost, respectively. Each equation is expected to satisfy the assumptions of the Classical Linear Regression model (CLRM).

However, if the regression disturbances in the different equations are mutually correlated then we have that: $E\left[\varepsilon_i, \varepsilon'_j\right] = \sigma_{ij} I_N; i, j = 1,2$; N= sample number. The covariance of the disturbances of the first and second equations is σ_{ij}, which is assumed to be constant over all observations, and is the only link between the first and second equations. The variance-covariance matrix ($\Omega = \mathrm{E}\left[\varepsilon_i, \varepsilon'_j\right]$) can be defined as:

$$\Omega = \begin{bmatrix} \mathrm{E}\left[\varepsilon_1, \varepsilon'_1\right] & \mathrm{E}\left[\varepsilon_2, \varepsilon'_1\right] \\ \mathrm{E}\left[\varepsilon_2, \varepsilon'_1\right] & \mathrm{E}\left[\varepsilon_2, \varepsilon'_2\right] \end{bmatrix} = \begin{bmatrix} \sigma_{11} I_N & \sigma_{21} I_N \\ \sigma_{21} I_N & \sigma_{22} I_N \end{bmatrix} \tag{2}$$

Ordinary linear squares (OLS) will yield unbiased and consistent estimates for each separate equation. However, because the approach ignores the correlation of the disturbances the estimates will not be efficient. Therefore, we should estimate via general linear squares (GLS) that yields:

$$\tilde{\beta} = (X'\Omega^{-1}X)^{-1}(X'\Omega^{-1}Y) \tag{3}$$

The inclusion of Ω^{-1} improves the efficiency of the estimates, especially when the disturbances are highly correlated, but the independent variables are not.

3. DATA ANALYSIS

3.1 Data sources

Taiwan launched a single-payer National Health Insurance program on March 1, 1995. In 2007, 22.60 million out of 22.96 million Taiwanese populations were enrolled in this program. The database of this program contains registration files and original claim data for reimbursement. Large computerized databases derived from this system by the Taiwan Bureau of National Health Insurance (BNHI) and maintained by the National Health Research Institutes are provided to the public for research purposes.

We enrolled three kinds of data banks: Inpatient expenditures by inpatient (DD), Registry for contracted medical facilities (HOSB), and Registry for catastrophic illness patients (HV). Hospital discharge records in Taiwan were coded using International Classification of Diseases (ICD)-9 codes and external cause coding (E). Focusing on the elderly injury of motor vehicles, only those data aged over 65 were included.

(1) Data selection

In the data bank of inpatient expenditures by inpatient (DD) from 2007, we considered ICD-9-CM external cause coding E810.0-E819.9 as traffic accident cases. The discharged diagnosis mainly contained up to five disease items and we selected those items limited from ICD-9 800 to 955. That prevents us from analyzing those traffic injuries which may be due to chronic diseases.

(2) Data linkage

By analyzing the variable of hospital ID we could link DD, HOSB, and HV data banks to obtain the admitted hospital status. And by hospital stays we linked DD and HOSB to obtain the hospital where the patients were sent to.

(3) Setting new variables

To get more information from the data, the following variables are defined:

1. Age groups: 65-69, 70-74, 75-79 and those over 80 years old
2. Road user types: car driver, car passenger, motorcycle driver, motorcycle passenger.
3. Hospital levels: medical center, regional hospital and local hospital
4. Injury numbers: how many injury types are involved.
5. Injury types：Head injury, Internal Organ injury, Fracture and Dislocation, General Trauma and Spinal Cord injury. The relations of injury types and ICD-9 codes are shown in table 1.

Table 1 the injury type definition

Injury type	**ICD9 diagnosis code**
Head injury	850-854
Internal Organ injury	860-869
Fracture & Dislocation	800-839 except 806
General Trauma	840-957 except 850-854,860-869,952
Spinal Cord injury	806&952

Because every Injury patient may be coded with one or up to five diagnoses, there may be 31 injury diagnosis combinations. But there are only 25 combinations in our data banks. We listed available combinations in table 2 and showed whether it happened in car or motorcycle accidents. For further analysis, an A is added to mean total occurrence of that injury and thus HA indicates all head injury and combinations of other injuries.

Table 2. Car and motorcycle accident injury type code

injury type	Car	Motor	code	HA	IA	FA	TA	SA
Head	☆	☆	H	●				
Internal	☆	☆	I		●			
Fracture	☆	☆	F			●		
Trauma	☆	☆	T				●	
Spine	☆	☆	S					●
Head _ Internal	☆	☆	H_I	●	●			
Head _ Fracture	☆	☆	H_F	●		●		
Head _ Trauma	☆	☆	H_T	●			●	
Head _ Spine		☆	H_S	●				●
Internal _ Fracture	☆	☆	I_F		●	●		
Internal _ Trauma	☆	☆	I_T		●		●	
Internal _ Spine	☆	☆	I_S		●			●
Fracture _ Trauma		☆	F_T			●	●	
Fracture _ Spine	☆	☆	F_S			●		●
Trauma _ Spine		☆	T_S				●	●
Head _ Internal _ Fracture	☆	☆	H_I_F	●	●	●		
Head _ Internal _ Trauma	☆	☆	H_I_T	●	●		●	
Head _ Internal _ Spine		☆	H_I_S	●	●			●
Head _ Fracture _ Trauma	☆	☆	H_F_T	●		●	●	
Head _ Fracture _ Spine		☆	H_F_S	●		●		●
Internal _ Fracture _ Spine		☆	I_F_T		●	●	●	
Internal _ Fracture _Trauma		☆	I_F_S		●	●		●
Head _ Internal _ Fracture _ Trauma	☆	☆	H_I_F_T	●	●	●	●	
Head _ Internal _ Fracture _ Spine	☆	☆	H_I_F_S	●	●	●		●
Internal _ Fracture _ Trauma _ Spine		☆	I_F_T_S		●	●	●	●

3.2 Statistic analysis

Inpatient medical costs is the major variable in this study, and we will first analyze its characteristics by descriptive statistics and cost distributions. Then we try to figure out the difference between genders, ages, hospital stays, hospital status and so on. As shown in Table 3, of total 4,697 cases, 412 are car occupants survivors, 4,257 are motorcycle riders survivors and 28 are fatalities in motorcycle accidents. The average cost per case is 50.1 USD, standard deviation is 104.3 USD and the cost median is 16.5 USD. The cost distribution is therefore not normal but positively skewed.

Table 3. Motor vehicle traffic accident inpatient medical expenditure

Expenditure	Car		Motorcycle		Fatalities	
Parameter	Days(D)	Cost(C)	Days(D)	Cost(C)	Days(D)	Cost(C)
Number(N)	412		4,257		28	
Average	7.1	961.3	7.7	960.6	9.1	3,462.4
Standard deviation(SD)	6.7	866.8	8.0	1,238.0	6.9	2,694.1
Median	5	748.2	5	705.5	8	2,875.3
Mode	2	52.5	3	374.9	3	43.3
Min	1	41.6	0	4.2	1	43.3
Max	47	6,920.7	91	29,988.4	26	9,450.5
Sum	2,909	396,052.0	32,754	4,089,366.7	255	96,948.4

Note：The unit of medical costs is「USD」and 1 USD=32.84 NTD；The unit of hospital stays is「day」.

Table 4 presents the statistical data of elderly injuries and fatalities both in car and motorcycle accidents. Due to our data inclusion criteria, elderly fatalities can be found only in motorcycle accidents. As shown in Table 4, more than 60% of elderly injuries and fatalities are female in both car and motorcycle accidents. Older females are major motor vehicle traffic accidents victims in our study and that is a unique pattern compared to WHO World report on road traffic injury prevention (Peden, 2004).

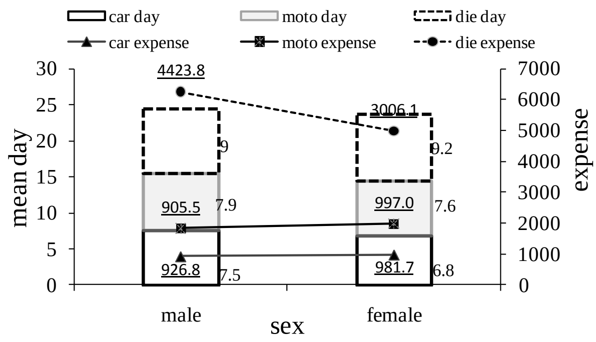
The average age of those survivors in car accidents was 73.8 and the average age of those survivors in motorcycle accidents was 72.4. The average age of fatalities in the sample was 71 years old in motorcycle accidents. The cases decrease as the age increases, and over 30% of elderly injuries and fatalities are 65-69 years old in both car and motorcycle accidents. We think it is the real situation since aged people do drive less as they become older and they seldom speed. It is interesting to note that most elderly injuries (70%) are passengers in car accidents, while 95% of elderly injuries are drivers in motorcycle accidents. But 100% of elderly dead in motorcycle accidents are drivers. We suggest elder people may ride their motorcycles (highly availability in Taiwan) for daily activity even in inappropriate condition. And they are frail as car passengers since they behave much carefully as car drivers.

As for the types of injury, over 68% of elderly injuries have head injury in car or motorcycle accidents, followed by internal organ injury and fracture. Most elderly injuries are sent to regional or local hospitals whereas most elderly fatalities are sent to regional hospitals or medical centres. It means under the National Health Insurance program our emergency medical technicians (EMT) do their good job. Finally, most elderly injuries have one injury type in both car and motorcycle accidents while most elderly fatalities have two injury types in motorcycle accidents.

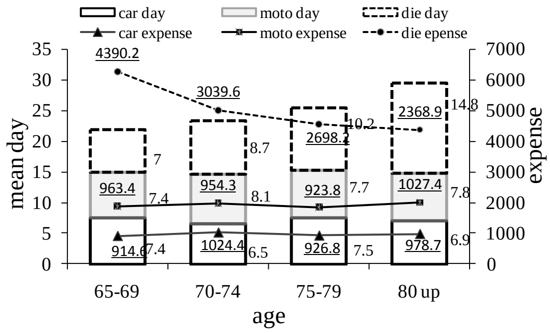
Table 4. Inpatient medical expenditure of motor vehicle accident

		Car		Motorcycle		Fatalities		cases
		cases	%	cases	%	cases	%	
Sex	Male	149	36.2	1,703	40.0	9	32.1	1,861
	Female	263	63.8	2,554	60.0	19	67.9	2,836
Age	65-69	132	32.0	1,602	37.6	12	42.9	1,746
	70-74	120	29.1	1,214	28.5	7	25.0	1,341
	75-79	78	18.9	879	20.6	5	17.9	962
	Over 80	82	19.9	562	13.2	4	14.3	648
Average Age & SD		73.8 & 6.6		72.4 & 5.7		71.0 & 5.4		—
Role	Driver	124	30.1	4,038	94.9	28	100.0	4,190
	Passenger	288	69.9	219	5.1	0	0.0	507
injury type II	HA	284	68.9	2,918	68.5	17	60.7	3,202
	IA	244	59.2	2,475	58.1	16	57.1	2,719
	FA	97	23.5	1,175	27.6	17	60.7	1,272
	TA	23	5.6	229	5.4	7	25.0	252
	SA	8	1.9	57	1.3	0	0.0	65
Hospital status	Center	90	21.8	871	20.5	12	42.9	973
	Regional	200	48.5	2,106	49.5	14	50.0	2,320
	Local	122	29.6	1,280	30.1	2	7.1	1,404
injury type number	1	208	50.5	2,056	48.3	6	21.4	2,270
	2	166	40.3	1,829	43.0	16	57.1	2,011
	3	36	8.7	348	8.2	5	17.9	389
	4	2	0.5	24	0.6	1	3.6	27
Total number		412		4,257		28		4,697

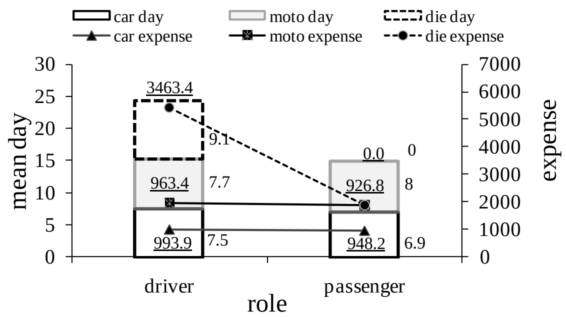
The medical costs and length of hospital stays can be plotted in the following figures according to items (gender, age, etc.) listed in Table 4. The y-axis in the left represents the length of hospital stays while in the right represents medical costs in both car and motorcycle accidents. The values with underlines are medical costs and those without underlines are hospital stays. For example, in Figure 2(a), the length of hospital stays between male and female are no significant difference, but the medical costs of male fatalities are much higher than those of female. It suggests males may ride in riskier behaviours and have more severe fatal injury. In Figure 2(b), we find the length of hospital stays increases as the age increases, especially in fatalities.



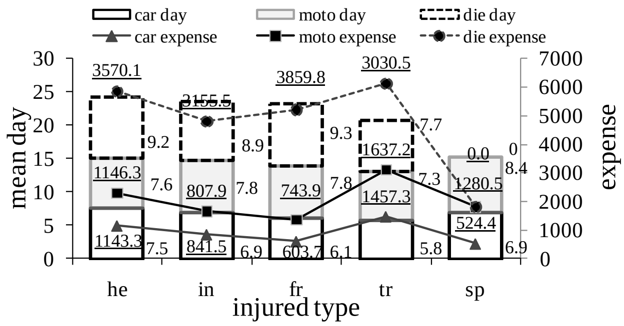
(a) Sex



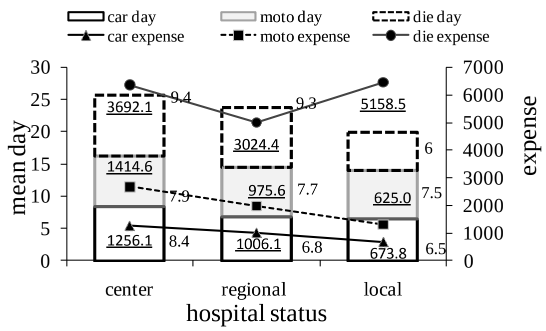
(b) age



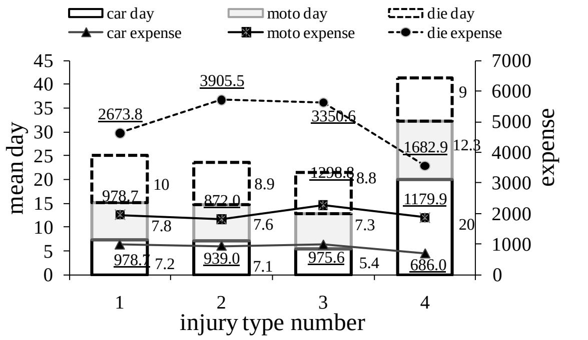
(c) role



(d) injury type



(e) hospital status



(f) injury type number

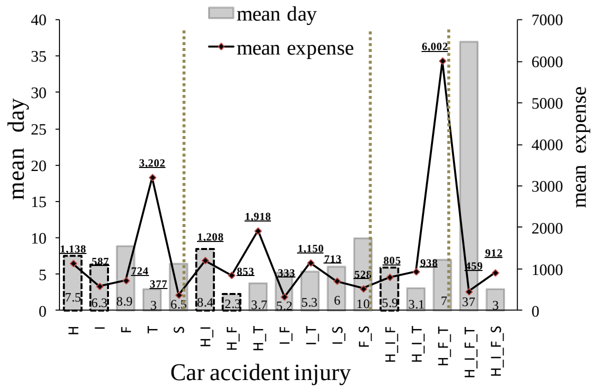
Figure 2. Inpatient medical expenditure of elder motor vehicle accidents

(1) Injury type distribution in car accidents

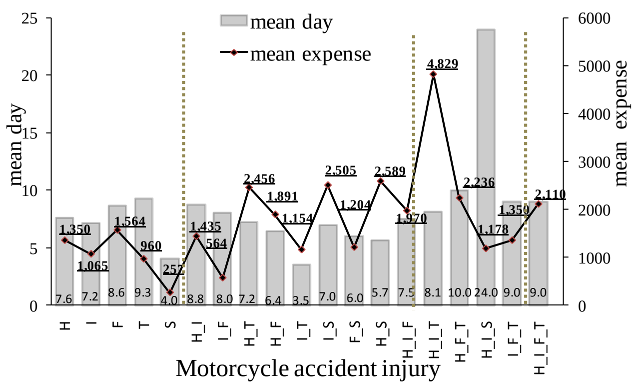
Figure3(a) shows 17 injury types due to car accidents including combinations of injuries. The most expensive injuries are Head _Fracture _ Trauma (H_F_T) injuries and is US$6,002.3. The second most expensive type of injury is simple Trauma (T). Its mean cost per patient is US$3,202.2. The third most expensive injury type is Head _ Trauma (H_T) and is US$1,917.6. As far as average inpatient days are concerned, Head _ Internal _ Fracture _ Trauma (H_I_F_T) has the longest hospital stay with 37 days. That is significantly more than any other injury combinations. The second longest type of injuries are Fracture _ Spine (F_S) and is 10 days. The third longest injury type is simple Fracture (F); the mean length of hospital stay is 8.9 days.

(2) Injury distribution in motorcycle accident

The medical expenditure of those motorcycle accident injuries is shown in figure 3(b)。Comparing those 25 combinations, the Internal _ Fracture _ Trauma _ Spine (I_F_T_S) injury type has the longest average hospital stay of 23.0 days. The second longest injuries are Head _ Internal _ Spine (H_I_S) and spend 14.4 days. The third longest injuries are H_I_F_T and the mean of hospital stay is 13.8 days. The average medical costs are higher in the Trauma _ Spine (T_S) and H_F_T groups. The former is US$8,684.0 and the latter is US$3,103.9.



Car accident injury



Motorcycle accident injury

Figure 3. Injury types and medical costs in car and motorcycle accidents

According to the statistics, the most frequent injury types both in the car and motorcycle accidents are the Head (H), Head_ Internal (H_I), Internal Organ (I), Internal _Fracture (I_F) and Head_ Internal _ Fracture (H_I_F) (bar charts with dashed lines in Figures 2a and 2b)。In consideration of few but extreme data we chose the top 5 injury combinations for further analysis to prevent bias.

Figure 4 showed the top 5 injury types of car and motorcycle traffic accidents with their medical cost and hospital stays. The mean costs is shown using line chart with underlined values. Overall H_I injury type has the longest average hospital stays which is 16.1 days. The second is the H and the mean is 15.1 days. The third is I with 14.5 days. As we separate the car and motorcycle accidents we find there is little difference between those motorcycle accidents hospital stays; the longest belongs to the I injury type which is 8.2 days. In the car accidents the H_I injury type has the longest average hospital stay and the next is the H injury type. The former is 8.4 days and the latter is 7.5 days. Regarding the average medical cost of both car and motorcycle accidents, those with head injury including H, H_I, H_I_F spend much more than those without Head injury including I and I_F. Besides, we found the I, I_F and H_I_F injuries in motorcycle accidents have longer hospital stay and more medical costs than those in car accidents.

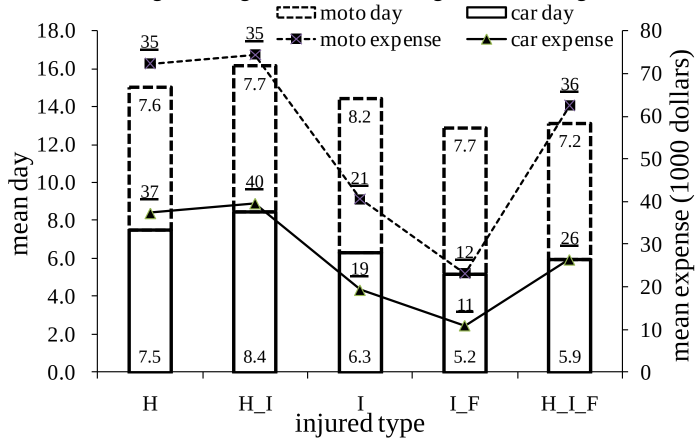


Figure 4. Top 5 injury types in motor vehicle traffic accident

3.3 injury numbers and their medical expenditure analysis

(1) car accidents

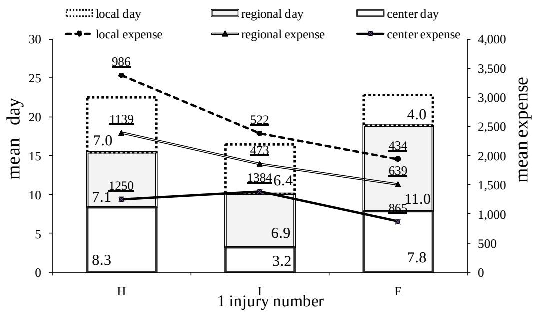
In this section,we analyze the medical expenditure of car accidents according to different injury type numbers. The table 5 shows the sample size is largest in the H type and the second is in the H_I type. The former has 142 cases and the latter 97 cases. These two together are over 50% of total samples. 359 samples contain only one or two injury numbers and are over 85% of total samples. We also know those with Head injury including H, H_I, and H_I_F have longer hospital stays and spend more medical costs comparing with those of the same injury number. The length of hospital stay in the H was 7.5 days and the average medical costs was US$1,137.2. The length of hospital stay in the H_I was 8.4 days and the average medical costs was US$1,207.3. The length of hospital stay in the H_I_F was 5.9 days and the average medical costs was US$804.9. In the group of one injury type the F has the longest hospital stay and the next is the H. As far as average medical cost is concerned the H costs most and the F least. In the group of two injury types most samples are within the H_I, I_F and I_T types。

Because table 5 shows there are only 2 samples in these car accidents with 4 injury numbers, we do the following injury numbers and hospital status analysis focusing on these with 1-3 injury numbers. The result is shown below. In respect to these with 1 injury number the H type costs most and stays longest as admitted to the medical center and decreases as admitted to hospitals of lower status. As for the I type, the average hospital stays is longest in the regional hospital and shortest in the medical center. But the average cost is still higher in the medical center. In the F type the average hospital stays is longest in the regional hospital and shortest in the local hospital. The average cost of this injury type decreases as admitted to hospitals of lower status. As we analyze the 2 injury numbers group we find：(1) the H_I injury has longer hospital stay and increased cost especially in the medical center. (2) the I_F injury seems to cost less. In these with 3 injury numbers group the H_I_F injury has longer hospital stay than the H_I_T type.

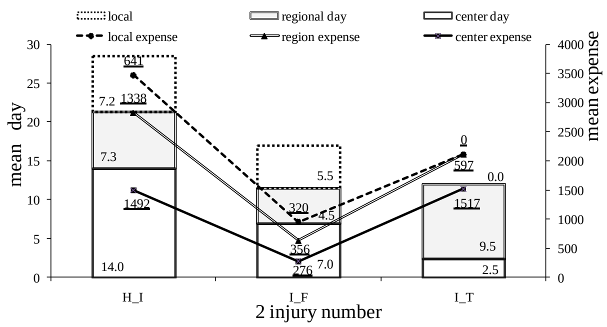
Table 5. injury numbers in car accidents analysis

injury number	injury type	sample	(%)	Accumulated(%)	Hospital days*	Medical cost(USD)*
1	H	142	68.3	68.3	7.5	1,137.2
	I	50	24.0	92.3	6.3	588.4
	F	11	5.3	97.6	8.9	722.6
2	H_I	97	59.5	59.5	8.4	1,207.3
	I_F	49	30.1	89.6	5.2	332.3
	I_T	10	6.1	95.7	5.3	1,149.4
3	H_I_F	28	77.8	77.8	5.9	804.9
	H_I_T	7	19.4	97.2	3.1	939.0
	H_F_T	1	2.8	100	7.0	6,003.0
4	H_I_F_T	1	50.0	50.0	37.0	460.4
	H_I_F_S	1	50.0	100.0	3.0	911.6

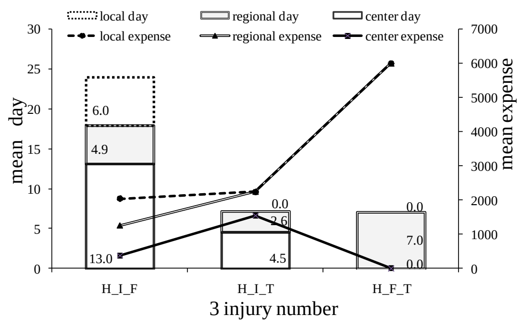
Note：「*」means average



(a) 1 injury number



(b) 2 injury numbers



(c) 3 injury numbers

Figure 5. injury numbers and medical expenditure of car accidents in different hospitals

(1) motorcycle accidents injury

The table 6 tells us the type numbers distribution of motorcycle accidents, and the graph further presents the injury type numbers and medical cost of motorcycle accidents in different hospitals. As for simplification, we list only top 5 injury combinations of each injury type number group. The table shows there are most victims in the H type which made up over 30% of total elder motorcycle injury. The second are H_I with 923 victims and the third are I_F with 695 victims. In respect to these with one injury number, F, T, and I injury type have longer average hospital stay. F spends 8.9 days, T spends 8.5 days and I spends 8.2 days. In the other hand, the I, H and S types have more average medical cost.

In the group of two injury numbers types we find the H_F type has longest hospital stay and the H_T type costs most. However, some interesting results can be found for the same type of injury and listed as follows: (1) for those elderly with head injury, the average hospital stays would be longer if they also have internal organ injury or fracture Injury than if they also have trauma, (2) for those elderly with internal organ injury, the average hospital stays would be longer if they also have head injury or fracture injury than if they also have trauma, (3) for those with fracture Injury, the average hospital stays are longer and medical costs are higher when head Injury is involved than internal organ injury.

As for those with 3 Injury numbers group, the I_F_S type stays longest and the H_F_T type costs most.

Table 6. Injury numbers analysis in motorcycle accidents

Injury number	Injury type	sample	(%)	Accumulated(%)	Hospital days*	Medical cost(USD)*
1	H	1491	72.5	72.5	7.6	1067.1
	I	454	22.1	94.6	8.2	649.4
	F	82	4.0	98.6	8.9	1219.5
	T	23	1.1	99.7	8.5	893.3
	S	6	0.3	100.0	5.7	954.3
2	H_I	923	50.5	50.5	7.7	1061.0
	I_F	695	38.0	88.5	7.7	372.0
	H_F	86	4.7	93.2	7.9	1844.5
	H_T	63	3.4	96.6	6.4	2070.1
	I_T	38	2.1	98.7	6.4	643.3
3	H_I_F	242	69.5	69.5	7.2	1100.6
	H_I_T	57	16.4	85.9	6.5	2015.2
	I_F_T	15	4.3	90.2	8.0	747.0
	H_F_T	13	3.7	94.0	6.4	3106.7
	I_F_S	12	3.4	97.4	9.0	329.3
4	H_I_F_T	16	66.7	66.7	13.8	1341.5
	H_I_F_S	7	29.2	95.8	7.4	896.3
	I_F_T_S	1	4.2	100.0	23.0	542.7

Note：「*」means average

4. MODEL ESTIMATION RESULTS

This study applies the framework of SURE to investigate the relationship between medical costs and hospital stays caused by traffic accidents for the elderly in Taiwan. Two SURE models, for car accidents and motorcycle accidents, are estimated to distinguish the effects of explanatory variables on the medical inpatient expenditure caused by different transportation modes for Taiwanese elderly.

4.1 Definition of variables

We use LIMDEP software (Greene, 2002) for the estimation of SURE models. Variables, including two dependent variables and explanatory variables, are presented in Table 7.

Table 7. Definitions of variables used in SURE models

	abbre. of variables	variable types	ranges of variables	
			car	Motorcycle
Dependent variable				
costs		Inpatient medical cost(USD)		
Day		hospital stays (days)		
Independent variable				
General medical costs (USD)	Gen_exp	continuous	0.1~3,825.6	0.0~19,277.4
Operation costs (USD)	Ope_exp	continuous	0.0~596.1	0.0~1,149.8
Average daily costs (USD)	Day_exp	continuous	0.0~378.0	0.0~1,990.9
Over average daily costs (USD)	O_day_exp	continuous	96.7~692.1	0.9~1,990.9
Under average daily costs (USD)	U_day_exp	continuous	0.0~94.5	0~0.8
hospital stays≦7 days	Day_No.≦7	continuous	1~7	0~7
7d＜hospital stays≦14d	7＜Day_No.≦14	continuous	8~14	8~14
hospital stays＞14d	Day_No.＞14	continuous	15~91	15~91
Injury number	Injur_No	continuous	1~5	
Diagnosis number	Dia_No	continuous	1~5	
Sex	Male	dummy	1 (0)	
Age type	Age_6569	dummy	1 (0)	
	Age_7074		1 (0)	
	Age_7579		1 (0)	
	Over_80		1 (0)	
Injury I	25 combinations(table 2)	dummy	1 (0)	
Injury II	HA	dummy	1 (0)	
	IA		1 (0)	
	FA		1 (0)	
	TA		1 (0)	
	SA		1 (0)	

Table 7. Definitions of variables used in SURE models--continued

	abbre. of variables	variable types	ranges of variables	
			car	Motorcycle
Hospital status	Center	dummy	1 (0)	
	Regional		1 (0)	
	Local		1 (0)	
User type	Driver	dummy	1 (0)	
Hospital stay	Day≦7	dummy	1 (0)	
	7＜Day≦14		1 (0)	
	Day＞14		1 (0)	
Under mean costs	U_mean_exp	dummy	1 (0)	
Under daily costs	U_dayexp	dummy	1 (0)	
Injury I _ Hospital	ex. H_center, I_local	dummy	1 (0)	
Injury II _ Hospital	ex. HA_center	dummy	1 (0)	
Injury I _ ID type	ex. H_driver, I_passenger	dummy	1 (0)	
Injury II _ ID type	ex. HA_driver	dummy	1 (0)	

4.2 SURE model_car

Table 8 presents the estimation results of SURE model for the elderly injury in car accidents. Variables included in both equations all reveal the right directions and statistically significance (t values). In the equation of medical costs, H, H_I, and H_I_F are all significant (at 5% significant level) indicating that these three types of injuries greatly contribute to the medical costs caused by injured elderly occurred in car accidents. The injuries with simple trauma(TA), medical centers, regional hospital and diagnosis numbers all have positive effects on the medical costs caused by injured elderly occurred in car accidents. Since the medical center and regional hospital are the highest and second highest in the level of hospitalization system in Taiwan, the magnitudes of both coefficients are reasonable and intuitively make sense. However, the number of injury has a negative influence which indicates that the medical costs do not increase as the number of injuries increases. It is consistent with the results obtained from the preliminary analysis.

Table 8. Estimation results of SURE model_car

medical costs				
variables	Variable definition		coefficients	t-value
Constant	Constant value		17.0	2.657
H	Head		19.0	4.935
H_I	Head _ Internal Organ		24.7	6.064
H_I_F	Head _ Internal Organ _ Fracture		20.0	2.532
Center	Center		12.8	3.403
Regional	Regional hospital		7.2	2.389
TA	Injury II_TA		32.2	4.593
Injur_No	Injury number		-10.4	-2.461
Dia_No	Diagnosis number		3.7	2.859
Hospital stay				
Constant	Constant value		8.3	9.471
H_I	Head _ Internal Organ		2.6	3.314
H_I_F_T	Head _ Internal Organ _ Fracture _ Trauma		33.9	5.137
dia_No	Diagnosis number		-1.2	-2.293
explanation		**medical costs**	**Hospital stay**	
R^2		0.24	0.08	
F[9, 402] F[3, 408]		13.87(0.000)	12.3(0.000)	
LS conditional variance	medical costs	6.6×10^9	-2110.46	
	hospital stay	-2110.46	41.91	
LM test		0.11		
Sample size		412		

$\chi^2_{(1,\ 0.95)} = 3.84$

As for the equation of hospital stays, significant variables are H_I, H_I_F_T, and the number of diagnosis (all at 5% significant level). Comparing the two equations, H_I and number of diagnosis are two variables both significant in the two equations. However, the signs of number of diagnosis are opposite. The results indicate H_I will have a positive impact on both medical costs and hospital stays. On the other hand, as the number of diagnosis increases, the medical costs will increase whereas the hospital stays will decrease. It shall be noted that R-squares of both equations in this model are not statistically high enough which may suggest the joint estimation of these two equations are questionable.

4.3 SURE model_ motorcycle

Table 9 presents the estimation results of SURE model for the elderly injured in motorcycle accidents. The directions of variables included in both equations are reasonable and the t-values are all statistically significant. In the equation of medical costs, H, F, H_I, H_F, H_T, H_I_F and H_F_T are all significant (at 5% significant level) indicating that these seven types of injuries positively influence the medical costs caused by injured elderly occurred in motorcycle accidents. It is noted that H_F and H_T have higher medical costs (the coefficients are 44.7 and 26.7, respectively). In addition, the injuries with trauma, those aged over 80 years old, and with more number of diagnosis all have the effects on the medical costs caused by injured elderly occurred in motorcycle accidents. Meanwhile, the only variable significant in the equation of hospital stays is H_I_F_T.

We find those over 80 years old spend more medical costs but they don't stay longer. Their wounds maybe severe but as soon as possible they want to be discharged. Again, the R-squares of both equations in this model are not statistically satisfactory which indicates the necessity of separately estimating the two equations.

Table 9. Estimation results of SURE model_ motorcycle

Medical costs				
variable	Variable definition		coefficient	t-value
Constant	Constant value		-3.1	-1.447
H	Head		29.9	16.307**
F	Fracture		34.7	7.686**
H_I	Head _ Internal Organ		17.7	10.540**
H_F	Head _ Fracture		44.7	10.419**
H_T	Head _ Trauma		26.7	4.630**
H_I_F	Head _ Internal Organ _ Fracture		11.8	4.225**
H_F_T	Head _ Internal Organ _ Trauma		53.2	4.780**
Over_80	Age over 80		2.9	1.685*
TA	These with trauma		23.6	7.131**
dia_No	Diagnosis number		6.3	10.892**
hospital stay				
Constant	Constant value		7.7	61.781**
H_I_F_T	Head _ Internal Organ _ Fracture _ General Trauma		6.2	3.098**
explanation		**Medical costs**	**hospital stay**	
R^2		0.11	0.002	
F[13, 4234] F[1, 4255]		39.03 (0.0000)	10.57 (.0012)	
GLS conditional variance	Medical cost	1.48×10^9	-3264.83	
	hospital stays	-3264.83	63.3	
LM test		0.79		
Sample size		4257		

"*" and "**" indicate the statistical significance at 10% and 5% respectively. $\chi^2_{(1,\ 0.95)} = 3.84$

Taking another look at the GLS conditional covariance listed in Tables 8 and 9, the negative values between medical costs and hospital stays (off-diagonal) indicated a substitution relationship between the two factors. However, the LM test values are low (0.11 and 0.79, respectively) in both models. As a result, the hypothesis of zero covariance between medical costs and hospital stays cannot be rejected. That is, the substitution relationship is not statistically strong enough. Therefore, it suggests linear regression models might be adequate and appropriate in this case.

4.4 Linear regression models of medical costs in car and motorcycle accidents

Table 10 presents the estimation results of medical costs in both car and motorcycle accidents. The R-squares are 73.3% and 41.6% respectively in car and motorcycle models. The results show that the significant variables influencing medical costs both in car and motorcycle accidents are injury numbers, diagnosis numbers, and the driver with Fracture. The injury numbers also have the same influence on medical costs in SURE models of both vehicles. That is, the more Injury type numbers are, the less medical costs are. This may suggest that, both in car and motorcycle accidents, when the injury types are down to only one or two, the elders are more severely hurt. Consequently, the medical costs are higher. On the other hand, it is intuitively reasonable that the medical costs increase as the number of diagnosis increases. If the elderly in car accidents with fracture injury are sent to medical centers, they usually spend less medical costs. If the elderly in motorcycle accidents with trauma injury are admitted to medical centers, on the other hand, they spend more medical cost. Finally, those elderly aged 65-69 have less medical costs in the car accidents and these aged over 80 do cost more in the motorcycle accidents.

Table 10 : Estimation results of medical costs in linear regression models

variable	Variable definition	Car			Motorcycle		
		coefficient	T value	VIF	coefficient	T value	VIF
Constant	Constant value	0.8	0.461	—	16.4	1.286	—
Age_6569	Age between 65-69	-1.8	-2.866**	1.27	—	—	—
Over_80	Age over 80	—	—	—	38.5	3.450**	1.16
Injur_No	Injury number	-2.5	-2.320**	5.93	-37.4	-3.757**	2.87
Dia_No	Diagnosis number	2.6	4.390**	6.33	20.2	4.162**	3.09
7＜day≦14	7< hospital stay<14	0.3	1.749**	1.22	—	—	—
Day_no.＞14	hospital stay > 14	—	—	—	0.5	2.049**	1.08
FA_center	With fracture admitted to center	-7.0	-5.561**	3.36	—	—	—
TA_center	With trauma admitted to center	—	—	—	26.6	1.734*	1.18
FA_driver	Driver with Fracture	5.4	2.774**	1.88	25.1	2.809**	1.06
Sample size		412			4257		
R^2		0.733			0.416		

ps. "*" and "**" indicate the statistical significance at 10% and 5% respectively.

4.5 Linear regression models of hospital stays in car and motorcycle accidents

The estimation results of hospital stays in car and motorcycle accidents are depicted in Table 11. The R-squares are 87.5% in car and 54.0% in motorcycle models. Since the total medical costs are not significant in both models, four types of medical costs are further defined and included in the models. They are general, operational, blood transfer, and psychiatric costs. The results indicate that, both in car and motorcycle accidents, the injured elderly stay longer in the hospitals as the general and operational costs increase. Nevertheless, those with less average daily costs stay shorter in the hospitals. It reveals that higher costs occur in the beginning of hospitalization. The elderly in car accidents sent to medical centers with head or internal organ injury stay longer in hospitals, but those in motorcycle accidents sent to medical centers with general trauma have shorter stays. Finally, the elder motorcycle riders injured with the head, internal organ and spinal cord injuries have a longer hospital stays (coefficient: 12.7 days).

Table 11: Estimation results of linear regression models of hospital stays in cars and motorcycles

Variable	Variable definition	Car accidents injury			Motorcycle		
		coefficient	T value	VIF	coefficient	T value	VIF
Constant	Constant value	6.6	4.430^{**}	1.02	0.1	0.362	–
Over_80	Age over 80	3.4	2.675^{**}	1.65	–	–	–
Injur_No	Injury number	–	–	–	0.9	1.730^{*}	1.23
Gen_exp	General medical cost	4.3	8.707^{**}	1.23	0.3	8.279^{**}	1.27
Ope_exp	Operation cost	3.2	10.387^{**}	1.18	0.3	12.493^{**}	1.32
U_dayexp	Under daily costs	–	–	–	-4.4	-4.132^{**}	1.26
U_day_exp	Under average daily costs	-2.9	13.444^{**}	1.47	-3.2	22.356^{**}	1.30
HA_center	With Head trauma admitted to center	2.8	2.214^{**}	1.11	–	–	–
IA_center	With Internal Organ trauma admitted to center	2.0	2.217^{**}	1.02	–	–	–
TA_center	With Trauma admitted to center	–	–	–	-2.7	-2.085^{**}	1.14
Driver_H_I_S	Driver with Head _ Internal Organ _ Spinal Cord injury	–	–	–	12.7	3.250^{**}	1.05
Sample size		412			4257		
R^2		0.875			0.540		

ps. "*" and "**" indicate the statistical significance at 10% and 5% respectively.

The effects of age on both medical costs and hospital stays shown in Tables 10 and 11 indicate the aging process and functional decline. As results, the "younger" injured elderly (65-70 years old) spent less medical costs than other elderly in car accidents. However, the "older" injured elderly (>80) stayed hospitals longer in car accidents and spent more medical costs in motorcycle accidents.

On the other hand, victims sent to the medical centers in motorcycle accidents did spend more but stay shorter. The result is consistent with the policy of health insurance system in Taiwan. that is, patients hospitalized in centers pay more and shorten their stays due to the high medical costs. It may also suggest the high turnover rate of beds or high quality of trauma team care in medical centers.

5. CONCLUDING COMMENTS

Aging is a part of our future. We use motor vehicles for better quality of life but get hurt in traffic accidents. When we're injured in an old age, hospitalization for trauma care may be necessary. This preliminary study use data banks of Taiwan's National Health Insurance to explore the hospital costs of traffic accidents involving the elderly.

In this paper, we analyzed the relationship (substitution or complementary) between medical costs and hospital stays in motorbike and car accidents by using SURE and multiple linear regression models. Some concluding comments from this study can be obtained and presented as follows.

The estimation results from SURE models indicated that the substitution relationship between medical costs and hospital stays was insignificant both in car and motorcycle SURE models. However, the common variables influencing medical costs in car and motorcycle SURE models included H, H_I, H_I_F, TA and the diagnosis number. As for hospital stays, the only common variable significant was H_I_F_T in car and motorcycle SURE models.

Linear regression models were then employed because the substitution relationship did not exist between medical costs and hospital stays in SURE models. The estimation results of regression models performed better than the SURE models in terms of goodness of fit (R-squares). In medical costs models, the same significant factors in both car and motorcycle linear regression models were drivers with fracture injury, the number of diagnosis and the number of injury types. Other variables, such as age, hospital stays and hospital levels, all influenced medical costs statistically significantly in either car or motorcycle accidents. In hospital stays models, the common variables in both car and motorcycle models were general medical cost, operational cost and daily medical cost under average. Again, the interaction term of injury types and hospital levels (especially medical centers) had significant effects on the hospital stays in both linear regression models.

There is room for improvements. First, we only use the data from 2007 and the result is not concrete. Maybe using panel data in time series analysis improves the result. Second, the NHI data are coded in incomplete transportation information by paramedics. It's hard to drop the data precisely. Bhalla et al. (2008) also suggests hospitals need to incorporate accurate external cause coding in routine record keeping.

After all, as a developing country, Taiwan set up a world wide known national health insurance system and had numerous traffic accident medical record. What we need is more time to tell the world our story.

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