Developing ERP in Indonesia: Investigating Social Interaction on Driver's Decisions in Electronic Road Pricing

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Abstract

Road pricing is one of important policy in regulating road usage in urban area. Road pricing have been using cost of production, externalities, and optimization scheme to construct appropriate price to nudge driver's travel behavior. Social interaction in transportation argued have influence the behavior of decision maker, especially in route choice. This research aimed to inference social interaction in travel behavior in Indonesia using ERP as study context. Experimental economics was employed to mimic driver's state of preference when they commute. Result showed that social interaction on interdependence level significantly drive driver's route choice to use ERP

Keywords: *road pricing; social interaction; experimental economics; route choice*

Introduction

Pricing of transportation facility such as road fundamentally using cost-benefit analysis based on cost of production and its maintenance cost, which was calculated to be self-sustained and meet investment rate of return (citation). Furthermore, optimization approach were implemented which compute idealistic price incorporate externalities (Tsekeris & Voß, 2009).This approach assumed road is a product to accommodate demand of road usage. On the other hand, from policy perspective, road pricing was an instrument which used as an apparatus to imply incentive or punishment. This kind of policy used macroscopic (Vrtic, Schuessler, Erath, & Axhausen, 2010) and microscopic (Steg & Schuitema, 2007) view of the system to design determine appropriate level of price to achieve its goals.

Road pricing and ERP

Road pricing basic rationale argue that congested occur in effect of increasing number traveller which used private transportation mode, instead of public transport. This growing number of private mode traveller outgrow road length and width development. On account of land use competition with sustainable development, building new roads become insufficient. Therefore, road pricing policy aimed to reduce road usage in the targeted area.

Policy makers and researchers believed that road users decision are directly affected from the policy they have developed. Thus, similar policy can be replicated to other region as long as the characteristics is relatively similar. Successful case such as Electronic Road Pricing in Singapore is widely studied and examine with purpose to replicate to other region. This external validity holds an important role in disseminating good policy. Few tunes and adjustment further needed to conform for each contextual cases (Vonk Noordegraaf, Annema, & van Wee, 2014). Some successfully implemented congestion charges or Electronic Road Pricing (ERP) along with providing adequate public transport system are road pricing systems in countries such as Singapore, London, New York, and Stockholm (Olszewski & Xie, 2005).

Social interaction in transportation

Complex scheme of road pricing induced the difficulty of decision maker to decide (Francke & Kaniok, 2013). Simpler model of road pricing was called upon more impactful road pricing policy. Social interaction of the drivers was proposed in this research to construct simpler road pricing scheme (Gaker, Zheng, & Walker, 2010).

Whenever an individual is in an interdependence situation that involves other individuals a social interaction is most likely to happen. Social interaction may contributes to the changes of environment (Sunitiyoso, 2016; Wilton et.al, 2011). The change towards environment will depend on the size of the group (or society). In a smaller scale (e.g. group), actions of a group member will receive higher influence than those in population, since there exists a feeling of belonging and responsibility as a group member. While in population, those feelings may not strongly exist as for an individual may expect others take the action, so that she/he does not need to do anything.

According to Sunitiyoso (2016), there are three levels of social interaction. First, level of social interaction is due to an interdependent situation where none of individuals who engaged in a collective action can be excluded from enjoying the benefits/ costs of their decisions (e.g. a social dilemma of public road users, where the decision of each user affects not only themselves but also the state of the system, hence affect other users). Second, level of social interaction occur when travellers learn vicariously from other people's experiences (observation) of other travellers' choices without involving processes of communication. The last level is through communication between travellers regarding their travel choices.

The Mechanism of Social Interaction

Travellers' choice making and behavior can be considered as dynamic processes, since individuals can do change their behavior over time. The understanding of how travelers learn, develop and change behavior over time is important in order to predict traffic congestion. A traveler's decision may be due to new information gained from their (i) own experience, (ii) information and influence from the experience and behavior of others through social networking, and (iii) official information from the authorities.

While others tried to use different approaches to change traveler's behavior through the implementation of toll roads, or in the case of Indonesia, 3-in-1 scheme in certain hours and providing bus way as alternate public transportation. The of 3-in-1 scheme was partially working but it created negative consequence with the mushrooming problem of 3-in-1 "jockeys". Now the 3-in-1 policy has been eliminated and replaced by odd-and-even number plate scheme, while more proven scheme of ERP is in the pilot stage prior to its implementation.

Thus, this research tries to identify the influence of external information on drivers' through several objectives: (i) to analyze the drivers' decision towards various scheme of variable road pricing, (ii) analyze the influence of external information through various settings of information distribution on drivers' decisions..

Literature Review

Road pricing first initiated by Arthur Pigou using two-road model in which strengthen by Frank Knight by incorporating context in that model. Since then, the discipline of road pricing expanded into mathematics, psychology, economics, management, and engineering (Vanoutrive, 2016). Road pricing could influences road users' choice for transportation method. After the increase of toll charge in Singapore on August 2013, significant increase in bus ridership was recorded especially in the morning and evening hours (Agarwal & Koo, 2016).

Policies related to public transportation services always been viewed as one way to overcome traffic congestion problems. On the other hand, the success of the policy to deal with such problem depends on the support of the users; on this case are the road users. From the study conducted in three major cities in Indonesia, public transportation users support for policy related to improving the public transportation system was significantly determined by users' dissatisfaction, trip-making, negative experience, and last but not least, service importance (Joewono, Tarigan, & Susilo, 2016).

Internal validity enables researchers to gain a complete comprehension of behavioral shifts and changes in aggregate behaviour and what cause them (V.Dixit, Ortmann, Rutstrom, & Ukkusuri, 2017). The use of incentives from Experimental Economics methods would improve the ways of researchers, or experimenters, to gain a more complete understanding about the underlying reason which influences the behaviour of participants to further inform policies alongside with contextual realism through laboratory (V.Dixit, Ortmann, Rutstrom, & Ukkusuri, 2017)

Methodology

To see how drivers respond to ERP implementation and how social interactions contributes to their decision in their road using behaviour, an experiment was conducted which adapts the principle of experimental economics where the experiment participants will receive rewards for their participation and for how they perform in the said experiment. Before the experiment, participants were given a pre-experiment survey regarding their travel habit, and after the experiment ends, they were also given a post experiment survey to capture their point of view about the experience they had while doing the experiment.

There are 4 different treatments that were applied in the experiment. The first treatment is the baseline treatment; second treatment is the Social Interaction treatment; the third and fourth treatment were the Official Information treatment where on the third treatment the information was regarding the route capacity and route cost respectively. The experiment treatments will be explained further in the 'Experiment Design' section. From the 4 different experimental treatments, it can be seen that there were 3 hypotheses that the experiment was trying to prove:

- *H1: There are difference in drivers' decision between baseline and treatment with Social interaction*
- *H2: There are difference in drivers' decision between baseline and treatment with Official Information regarding capacity*
- *H3: There are difference in drivers' decision between baseline and treatment with Official Information regarding cost*

Experimental Design

Dixit et al stated that there are 3 main needs driven behavioral experiment in transportation, technology testing, theory testing and exploring relationship between key characteristics of context or participant (V.Dixit, Ortmann, Rutstrom, & Ukkusuri, 2017). This research focus on how theory and fundamental assumption based on social interaction of road driver. Social interaction proposed to construct road pricing scheme.

The main experiment was developed using z-tree software (Fischbacher, 2007). Basically, in this experiment, the participants were requested to choose the route between pricing applied (ERP) and non-pricing applied (alternative route). A total of 40 respondents from various backgrounds (undergraduate students, master students, employees, and housewives) participated in this experiment. They were all divided into 4 different sessions of experiment which were held in 2 different days, 2 sessions each day. On each session, 10 participants were engaged in the experiment that consists of 4 periods of ten rounds decision-making play. All participants were asked to imagine themselves as car drivers which wanted to go from a hypothetical same starting point to a same destination where there are 2 available routes they can choose, the ERP route and alternative route, in order to reach their same destination.

Each route has different capacity and price. The ERP route will cost each participant 30,000 rupiah if they choose to use it, while the alternative route will cost them nothing. The capacity of the ERP route is 7 cars and the alternative route was limited to only 3 cars. If the capacity of each route were exceeded, it will automatically cost a penalty of 10,000 rupiah per car over the initially stated capacity. The accumulation of total number of cars exceeding the capacity of a route on each round will become the total penalty cost for that said round and will be implied to all drivers which chose that over-occupied route. The formula for the total cost for each driver on each round can be seen below:

$$Total\ cost = fix\ route\ cost + \{(number\ of\ cars\ exceed\ route\ capacity\ ) * 10.000\}$$

All of the participants made the decision regarding the route they will choose simultaneously, and after the decisions of each participant were tallied, the final cost, including the total penalty cost, resulted from their decision will be subjected to all participants accordingly.

Table.1 Experimental design

	Previous round performance	Previous round overall result	Capacity official information	Cost official information
Treatment 1	X			
Treatment 2		X		
Treatment 3	X		X	
Treatment 4	X			X

Throughout the experiment, there are four treatments given to the participants. Every treatment consists of ten rounds. These treatments are related to the information that each participant can use to make their decisions on the next round. The information given to each participant in each corresponding treatment are: (Treatment 1) participant's performance on previous rounds and his/her selected choices, (Treatment 2) participant's performance on previous rounds, and overall players' decisions and costs plus penalty/over capacity cost on previous rounds, (Treatment 3) participant's performance on previous rounds and official information related to the available capacity of route, and (Treatment 4) participant's performance on previous rounds and official information related to the price changes of route. Those settings are applied to both sessions to study the influence of social interaction through various information distribution settings.

Besides the treatment, the experiment also wanted to see if there are any influence resulted from the sequence of the treatments implied to the experiment participants. Therefore, the treatment sequences were differentiated between experiment sessions in day 1 and day 2. This was conducted as a control point to check whether there are factors outside of the treatments that also cause the difference in the responses of the participants. The sequences of the treatments can be seen in the table on the '*Results and Findings'* section.

On the beginning of every treatment, each participant was given a 400,000 rupiah of hypothetical transportation budget. This amount of transportation budget, with regards to the price of ERP route and over capacity penalty cost, was a representation of real life situation derived from the approximate ratio between the fraction of a household's income that is being used for transportation and the average daily transportation cost in Indonesia; especially in cities like Jakarta, Surabaya, and Bandung. Furthermore, in the end of the experiment, the average money that each participant able to saves was added to their fix participating fee and was given to them in real money as a reward for their participation in the experiment. This was conducted to stimulate an incentive for the participants to save their money being used for transportation as close to their own real life situation as possible

Results and Findings

The analysis is using percentage of alternative route chosen by all drivers in each period and treatment. This was intended to simplify the analysis. The averages and variations from the percentages of alternative route chosen were presented in the table 2 below.

Table 2. Mean and average of alternative route choice proportion

Group	Treatment Sequence	Treatment 1		Treatment 2		Treatment 3		Treatment 4	
		Mean	Var	Mean	Var	Mean	Var	Mean	Var
A	1-2-3-4	0.57	0.01122222	0.54	0.011556	0.52	0.030667	0.38	0.021778
B	1-2-3-4	0.53	0.02233333	0.6	0.02	0.58	0.010667	0.42	0.012889
C	1-2-4-3	0.54	0.04488889	0.46	0.018222	0.44	0.022667	0.53	0.015667
D	1-2-4-3	0.57	0.01122222	0.61	0.027667	0.57	0.013444	0.47	0.020111

Proportion between treatments showed that treatment 1, 2, and 3 not have difference especially in group A. This could indicate that treatment 4 which intervene drivers using official information could impacted driver's decision in route choice. Furthermore, more detailed analysis we will using ANOVA in group and treatment difference in route choice.

There were four treatments given to four groups in the experiment. The mean for treatment 1 across all groups is quite similar with the highest mean is 0.57 with variance of 0.01, while the lowest mean is 0.53 with variance of 0.022. The treatment 2 have various mean from 0.46 as the lowest mean from group C with variance of 0.018 and the highest mean of 0.61 with variance of 0.0277. While in treatment 3, the lowest mean showed for group C with 0.44 with variance of 0.023 and the highest mean of 0.58 with variance of 0.011. In treatment 4, group A gain the lowest mean with 0.38 with variance of 0.022 and group C with the highest mean, 0.53, with variance of 0.0157 (see Table 2 for detail)

```
                 Df Sum Sq Mean Sq F value  Pr(>F)   
group             3 0.0977 0.03256   1.654 0.17964   
treatment         3 0.2827 0.09423   4.786 0.00329 **
group:treatment   9 0.3066 0.03406   1.730 0.08717 . 
Residuals       144 2.8350 0.01969                   
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

. Fig. 1. (a) Group and treatment ANOVA result

Even though the treatment order for group A-B and C-D are different, but the effect of the treatment order is not significant (*F-value* 1.654, *p-value* 0.17964), means that the order of the treatment do not affect the travel decision toward route choice (see Fig 1 for detail).

```
             Df Sum Sq Mean Sq F value  Pr(>F)   
treatment     3  0.283 0.09423   4.538 0.00444 **
Residuals   156  3.239 0.02076                   
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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Fig. 2. (a) Treatment ANOVA result

Comparing all treatments, there were significant difference among all treatment (*F-value* 4.538, *p-value* 0.0044). The most significant different treatment was between group 1 and 4 (*p-value* 0.0094916), and between group 2 and 4 (*p-value* 0.0094916). The other pairs of treatments showed no significant difference for their p-value were larger than 0.05 (see the Tukey-Kramer table for details)

```
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = percentage ~ treatment)

$treatment
             diff         lwr          upr     p adj
2-1  1.110223e-16 -0.08367711  0.083677106 1.0000000
3-1 -2.500000e-02 -0.10867711  0.058677106 0.8652668
4-1 -1.025000e-01 -0.18617711 -0.018822894 0.0094916
3-2 -2.500000e-02 -0.10867711  0.058677106 0.8652668
4-2 -1.025000e-01 -0.18617711 -0.018822894 0.0094916
4-3 -7.750000e-02 -0.16117711  0.006177106 0.0802680
```

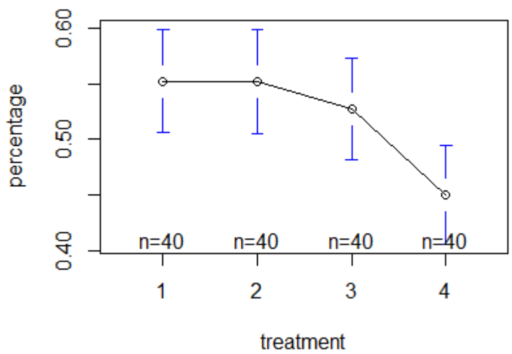

Fig. 1. (a) Tukey-Kramer result; (b) Tukey-Kramer graphics

The graphical average comparison between treatments shown in the figure below corroborates further the results of the Tukey-Kramer analysis. It can be seen that the average alternative route chosen in treatment 4 is far lower than in treatment 1 and 2.Thus this conclude that treatment 4 result on most significant route choice difference with the base treatment.

From the results of Tukey-Kramer analysis, the first two hypotheses (hypothesis 1 and 2) were failed to be proven where the results of the experiment only responded to treatment 4 (hypothesis 3). Social interaction in interdependent level which diffusing cost information of the route caused changes in driver's decision to use ERP. This result may have been effect of price elasticity of each driver. Each driver was incentivized by balance remaining on the end of experiment treatment. This was also confirmed by the responses of most participants in their post-experiment survey where they admitted that they feel worried if they lose money by the end of the experiment.

Conclusion

This research indicates that social interaction holds important role in developing road pricing policy. Furthermore, constructing road pricing using social interaction could help policy maker to build simpler and more impactful policy. This notion supported by our experiment that present official information on route cost significantly drive respondent to choose ERP route. The interdependent level of social interaction shows the most promising result compared to observation level. Our post questionnaire supported this result by showing that they more concern about the remaining balance that they will be obtain in the end of the experiment. The competitiveness of the respondent must studied more closely to dissect that this phenomenon is the byproduct of experimental economics or basic human instinct to compete with the others.

Social interaction contributes to the versatility of road pricing development process. But on the other hand, these prices must reflect additional and intangible effect from road usage. if the ERP is still in the early stage of development, whereas ERP in Indonesia is still on the discourse stage, it would require extensive study. For further study, communication must be taken into account in the experiment, and combination of interdependent and observation level may take more impactful effect. Our study expects to provide development ERP in Indonesia with important insight to travel behavior.

The results of the experiment show that there are significant differences among treatments for each session, thus showing the effects of difference information distribution settings. It also indicates that drivers significantly influenced by social interaction in the form of official information regarding price changes.

Road pricing generally can be constructed from social interaction point of view. In order to form a road pricing policy that can meet the fundamental objective of the policy itself, which is to solve the road congestion issues, social interaction point of view can complement the traditional economic point of view in developing electronic road pricing policy. A complete understanding on how road users, in this case vehicle drivers, respond to road pricing policy with the addition of how social interaction also influence their behaviour can hopefully help policy maker to design an effective and efficient road pricing policy for the betterment of the future.

Further research and exploration on other level of social interaction and different demographic of Indonesian citizen as experiment participant, and also survey respondent, are needed to further improve the understanding of how social interaction would help in developing road pricing policy in Indonesia.

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