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Miles, speed, and technology: Traffic safety under oligopolistic insurance

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ABSTRACT

We study road safety when insurance companies have market power, and can influence drivers' behavior via insurance premiums. We obtain first- and second-best premiums for different insurance market structures. The insurance program consists of an insurance premium, and marginal dependencies of that premium on speed and own safety technology choice of drivers. A private monopolist internalizes collision externalities up to the point where compensations to users' benefit matches the full (intangible) costs; in oligopolistic markets, insurers do not fully internalize collision externalities. Analytical results demonstrate how insurance firms' incentives to influence traffic safety coincide with or deviate from socially optimal incentives. Our results may be useful for design of pay-as-you-speed and alike insurances as well as policies related to driving safety.

1. Introduction

Collision externalities are among the most important external costs of road transport: Parry et al. (2007) estimate that the social costs of road crashes for the US correspond to around 4.3% of the GDP, Elvik (2000) concludes that "rough estimates of road accident costs amounting both to 2 and 1% of GNP can be defended as reasonable, depending on whether or not an economic valuation of lost quality of life is included in the accident costs", and Peden et al. (2004) provides in Chapter 2 a survey on the total annual costs of road crashes to high-, middle- and low-income countries. Both drivers' behavior (such as speeding, distance to the next car, attention paid towards the other road users) and technical characteristics (such as safety belts, advanced braking systems, windshields, lights, weight, etc.) of vehicles heavily influence the safety of the car driver and passengers, as well as of others on the road. This conclusion has been drawn from both empirical [1] and theoretical works.[2] Reanalysis (Aarts and van Schagen, 2006) of the data from Kloeden et al. (2001) revealed an exponential function between individual speed and the risk of being involved in a crash on urban roads. Also, on urban roads the accident rate increases more with increasing speed than on rural roads. Cohen and Einav (2003) state that seat belt usage enforcement greatly reduced traffic fatalities: "We estimate that a 1-percentage-point increase in usage saves 136 lives (using a linear specification), and a 1% increase in usage reduces occupant fatalities by about 0.13% (using a log-log specification)".

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[1] See, for example, Aarts and van Schagen (2006); Cohen and Einav (2003); Hultkrantz and Lindberg (2011); Hultkrantz et al. (2012); Lave (1985); Steimetz (2008).

[2] See, for instance, Jansson (1994); Nitzsche and Tscharaktschiew (2013); Verhoef and Rouwendal (2004); Wang (2013).

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Furthermore, Delhaye (2007); Rizzi (2008), and Hultkrantz et al. (2012), observe that incentives stemming from insurance can change drivers' behavior. However, the effect of insurance companies efforts and incentives to affect driver behavior remain under-investigated in the economic literature. For instance, based on Steimetz (2004), and Gossner and Picard (2005); Rizzi (2008) considers a rational driver who optimally chooses risk-reducing efforts (care), such as speed, distance between the cars etc., in a model where car insurance is available. Rizzi clearly shows that insurance influences drivers' efforts to drive safely. However, in his work insurance agents do not play an active role controlling drivers' choice, and only drivers' utility functions are maximized, that is, the insurance agents disregard the external costs the drivers impose.

The insurance model we consider is inspired by car tracking technologies, such as GPS. The latest developments allow tracking tools to be cheap and efficient, and nowadays many vehicle producers include such equipment in the default versions of their cars. Bigger insurance companies offer Pay-As-You-Drive (PAYD) and its extension Pay-As-You-Speed (PAYS) insurances in a few countries by now, among them the United Kingdom, Spain, Israel, and the Netherlands. In Japan, car sharing companies charge the rates according to their customers' driving behavior. The trial in Bolderdijk et al. (2011) shows that "PAYD resulted in modest, but significant reduction in speeding of young drivers". Lahrmann et al. (2012) studies combination of PAYS insurance providing economic incentive to drive within speed limits, with warning from intelligent speed adaptation system if speeding. The authors conclude that the decrease in speeding was statistically significant, although the effect decreased over time and had no educating effect. Hultkrantz and Lindberg (2011a) reported an economic field-experiment that also resulted in significant reduction of speed-limit violations made by participants compared to non-participants. The study suggested that economic incentive schemes may be an effective tool to increase road safety. Hultkrantz et al. (2012) build an analytical model of self-selected PAYS extension of a mandatory insurance and illustrate their findings using Swedish data. It was established that PAYS insurance makes up for the gap between external cost of speeding and expected revenue of speeding tickets. Insurances based on the actual vehicle use and intelligent tracking systems, are more actuarially accurate. This neutralizes asymmetric information in insurance market and may decrease social costs of driving and make road use safer.

Dementyeva et al. (2015) study the efficiency of regulated and unregulated insurance markets, taking into account the interactions between the markets for road trips and the market for traffic safety insurance. In that model, we assumed that road users' behavior involves just one margin: how much to drive. In this paper we extend the model, and insurance companies can now also influence road users' choices in terms of investments in private car safety for drivers, and speed. The latter may benefit the driver as well as a possible "partner" in a collision. A social regulator, in turn, has instruments to affect insurance providers, and thus indirectly also the drivers. We consider insurance to be mandatory.

Our model describes a two-stage game between obligatory car insurance providers and road users. First, insurance companies maximize their profit by optimizing aggregate kilometrage via insurance premium levels, and the choices of speed and technology via dependency of premiums on these choices, subject to equilibrium constraints. Then, each atomistic road user opts for a safety technology and speed, in order to minimize its generalized price per kilometer driven. (We assume drivers to be symmetric in terms of their travel cost functions.) Next, an aggregate kilometrage results from the inverse demand function for trips, given this optimized generalized price. This generalized price includes time costs, investments in own safety technology, insurance premiums, and a (possibly intangible) part of the expected collision costs in so far as it is not covered by insurance.

The crash cost per kilometer grows with aggregate kilometrage reflecting increasing chances of collisions, and thus the generalized price of driving depends on it. We furthermore assume that an individual's speed choice affects both one's own and other road users' safety, while the technology affects only the former. The technology chosen by a driver could in reality also influence the safety level of other road users, but distinguishing between a strictly internal safety measures (technology investment) and a combined internal-external safety measure (speed) is helpful for a clear interpretation of our results. In our terminology, 'own safety technologies' include, for example, air bags, interior head-impact protection, seat belts, child car seats, flammability of interior materials, etc. Advanced braking systems, tire-pressure monitoring system, high intensity lamps would rather be included into the other characteristics of driving, affecting also the safety of others. We refer to such characteristics as 'speed'. Because a higher investment in technology reduces the safety benefits of slowing down, our model reflects the well-known regularity that drivers may behave more recklessly when being better protected.[3]

Following and extending the reasoning provided in Verhoef and Rouwendal (2004) and Dementyeva et al. (2015), we obtain marginal conditions for the first- and second-best premiums, and their marginal dependencies of technology and speed.[4] In our model we thus acknowledge that companies influence drivers' behavior via insurance programs. We consider a social welfare-maximizing planner; a private profit-maximizing monopoly; and oligopolistic markets of firms playing Nash in a Cournot fashion assuming that firms choose their premiums and quantities [5] taking quantities (not premiums)

[3] Another important feature that could have been included into the model is the weight of vehicle: Heavier vehicles increase the damage suffered by other vehicles in the event of a collision between vehicles while being safer for its own driver. However, mathematical properties would stay similar, and no additional fundamental insights would be delivered.

[4] A social regulator can then impose taxes or subsidies on companies and/or road users, fines for speeding over a certain speed limit, and other regulations. For the sake of transparency, we do not explicitly consider speed limits or other speed policies.

[5] In this model, quantities refer to vehicle kilometers driven.