# Propitious selection in the vehicle insurance market

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**Abstract**

By combining Contract Theory and vehicle positioning techniques, insurance companies can replace some of the proxies for risk by actual traffic behavior when pricing the premium. A mechanism design model is used to illustrate that Usage Based Insurance (UBI) can separate risks in terms of driving behavior. This makes it possible to reward safe driving habits since the pricing scheme better reflects the accident risk. The conclusion is that UBI provides an actuarially fair premium for the insuree. It is further an efficient instrument to separate risks for the insurer since it reduces the information asymmetries highlighted in this paper.

**Keywords**: Contract Theory, UBI, PAYD, PAYS,*Selection, Incentives, Insurance, Traffic Safety, Mechanism Design.

JEL: D82, D86

# 1 Introduction

With full information an insurer can set insurance premiums according to actual behavior. In reality much of this information is however unknown. When it comes to vehicle insurance driver risk is rather determined by proxies based on observable characteristics which are correlated with claims.

The purpose of this paper is to show that today's insurance industry has a previously unavailable opportunity to more efficiently separate risk types and to reduce the costs from opportunistic behavior. The number of accidents, and their associated costs, are likely to be reduced if the driver's risk type is identified and priced in a more accurate way than presently. This further makes it possible to reward safe(r) driving, even when the private information about accident probabilities is large. Examples of groups where the private information is large are young drivers and new customers of whom the insurer has no previous driving records. By making use of emerging techniques for collecting information about actual behavior, insurers can link the premium pricing scheme to actual mileage and/or driving behavior. This type of contracting is called Usage Based Insurance (UBI) and the interest in its usefulness has increased rapidly among vehicle insurers during the last decade, see Nilsson, Arvidsson and Bagdadi (2007).

Since the underlying problem is asymmetrical information about risk, one main issue when designing the contracts is to know which risk types are more prone buying insurance. To illustrate the motives for a separation of risks a basic mechanism design model is applied on the Swedish compulsory Traffic Insurance. The idea here is that the insurer should offer two versions of the compulsory contracts: The first, the UBI contract, combines a low premium with an in-vehicle device which registers driving. Data can be collected with the aid of Global Positioning Techniques (GPS) and a digital map of current speed limits, etc. to match how, where, when and at what speed the car user drives. This data is transferred to the insurer and reduces the asymmetrical information about driving patterns and makes it possible to charge a more individually based premium. The other contract is a regular Traffic Insurance with a higher insurance premium. Driving habits in this contract is unobservable by the insurer since no device is installed.

The choice between an UBI and a regular non-monitoring Traffic Insurance policy creates an equilibrium where safe (precautious) drivers self-select by installing an in-vehicle device. The selection of precautious drivers will therefore constitute a propitious (favorable) selection of risks. The non-monitoring contract will on the other hand constitute of more risk taking (reckless) drivers which creates an adverse selection of risks. The conclusion is that the premium to a greater extend corresponds to the expected cost to insure with a choice of UBI in a compulsory insurance, that is, the premium becomes more actuarially fair.

The reminder of this paper is as follows: Section Two reviews the Swedish automobile insurance market: it also outlines UBI and provides a short overview of the concept of asymmetrical information in this context. This section further draws attention to current information asymmetries which may affect the actuarially fairness. Section Three illustrates how insurance risks can be separated when the insurer introduces an UBI-option. The final section provides concluding remarks.

# 2 Insurance, the information gap and consequences for policy pricing

This section begins with a summary of the current position of asymmetric information in the vehicle insurance market. Thereafter a description of the Swedish automobile insurance market is given as well as how the policies are priced. It is argued that it is possible for opportunistic behavior due to the information gap between the insurer and the insuree. As a consequence the premium will not be actuarially fair. The section ends with an overview of the potential solution to this problem; UBI.

## 2.1 Insurance and asymmetrical information

It is theoretically known that asymmetric information is a fundamental problem in most insurance markets. Ever since the 1970s the theoretical research regarding asymmetrical information has developed at a quick pace. The general idea is that the insurees are heterogenous in risk and this is *private (hidden) information* that is important for the contract but unknown for the insurer. According to the standard interpretation this informational advantage results in the situation where the highest risks buy insurance. This implies that those with insurance constitute an adverse (bad) selection of risks (see for example Akerlof 1970; Bolton & Dewatripont 2005; Salanié 2005). In addition the insured may undertake *private (hidden) actions* that affect the risk and thereby the contract. The individual with insurance is then less cautious when having insurance since s/he does not fully carry the financial risk of an accident. This is known as moral hazard.

It has become standard in theory that private information results in adverse selection. It may however be a reason to reevaluate the concept of private information, the reason being that several studies have suggested that private information can also lead to propitious (favorable) selection (Hemenway 1990; DeMeza & Webb 2001; Finkelstein & McGarry 2006; Karagyozova & Siegelman 2006; Fang & Silverman 2006; DeDonder & Hindriks 2009). According to DeDonder and Hindriks (2009) the assumption of propitious selection implies that the insurees may be heterogenous not only in their probability of loss (as in the adverse selection model) but also in their aversion to risk. Along the same line of reasoning the agent performs preventive actions that reduces the risk in the contract. These individuals have a high demand for insurance and are good risks ex post. From the perspective of the insurance company these types thus represent a propitious selection of risks. There might therefore be reasons to believe that the selection, either adverse or propitious, arise from the contract formation. This kind of separating equilibrium is illustrated in section three.

The empirical research regarding asymmetrical information has lagged behind and did not significantly evolve until the 1990s. According to the critics this has resulted in advanced models which may, in some cases, have ambiguous empirical grounds. Finkelstein and McGarry (2006) find evidence for multiple dimensions of private information in the Long-Term-Care insurance. They conclude that both those with private information about high preferences for insurance (low risk ex post) and those with private information that they are high risk individuals (high risk ex post) buy more insurance. The empirical results regarding the vehicle insurance market are however mainly inconclusive, for a review see Chiappori and Salanié (2003). One exception is a more recent study by Cohen (2005) who finds evidence for adverse selection on the Israeli automobile insurance industry among new customers with more than three years of driving experience. For more references regarding empirical conclusions on information asymmetries see Cohen and Einav (2007), Cawley and Philipson (1999) and Chiappori and Salanié (1997).

## 2.2 The Swedish Automobile Insurance Market

Traffic injuries are considered to be a serious public health problem in many countries and the associated direct and indirect costs have been estimated to be 160 million euro.[1] According to SCADplus (2007) these costs correspond to 2

[1] The Swedish accident costs are estimated to be approximately 5,9 billion euro. These also include costs for grief and suffering which explains the higher numbers. According to the Swedish Insurance Federation the premium payments was 9,7 billions for the Traffic Insurance and 10,9 billions for the voluntary Motor Vehicle Insurances during 2003. Not all premium payments refer to traffic accidents (according to the Road Administration approximately 60 percent of the Motor Vehicle Insurance regards traffic accidents and 55 percent of the Traffic Insurance regards indemnity for bodily injuries.)

percent of the EU's GNP (2005). In Sweden, as in most countries, automobile insurance is divided into compulsory and voluntary insurance. The compulsory part, *Traffic Insurance*, is often referred to as a "no-fault" insurance since bodily injuries are compensated for both for the vehicle at fault and the innocent parties. The no-fault principle does not, however, include property damage for the vehicle at fault. The complementary voluntary insurance is divided into *Partial Insurance*, covering theft, break-in, glass and fire etc. and *Full Insurance* also including collision damage and other vehicle damages.[2]

The Swedish government has realized that the full accident costs are not covered by the compulsory policy. One reason is that much of the cost for medical care, rehabilitation and early retirement etc. are paid by social insurance, not the Traffic Insurance.[3] Sweden differs in comparison to other countries regarding regulations and the possibility to get loss indemnity. The social insurances provide an extensive cover and the compulsory Traffic Insurance mainly works as a complement to these insurances. In many other countries the only chance to be reimbursed is payments from the compulsory insurance. Generally no-fault insurance is applied in countries where the social insurance and other system of regulations do not provide enough cover.[4] The Swedish social security system has no possibilities to regress costs due to traffic accidents from the Traffic Insurance. According to Strömbäck (2003) regress is a basic principle in many countries and when this principle applies the compulsory insurance premiums are much higher.

[2] In addition it is possible to sign complementary policies that for instance cover costs such as replacement cars etc. If an accident is caused by, or occurs with, an uninsured vehicle, or if there is a hit and run, an accident fund is used for compensation. The principle is that all bodily injuries in traffic accidents will be covered, even for the uninsured driver and passengers. The fund is financed through a fee included in the Traffic Insurance premium and individuals that drive uninsured are heavily fined if they are detected. About one percent of all motor vehicles are uninsured in Sweden.

[3] Moreover the non-financial costs for grief and suffering due to accidents are thought to be much higher than the out-of-pocket costs.

[4] The commercial insurance industry handles compulsory and non-compulsory insurances, and the government's National Insurance Office handles the social insurances. Private policies are mainly voluntary and operate as a complement to the social insurances which are financed through taxes and fees.

Currently traffic accidents are costly for the Swedish governmental budget and to decrease this externality a uniform tax on the compulsory Traffic Insurance was recently introduced. Since this tax affects vehicle owners by the same percentage no matter what risk they constitute, this may not provide an actuarially fair insurance premium.

A resolution of the Swedish insurance regulation mechanisms, and how to reduce the accident costs imposed on society, is beyond the scope for this paper. The aim is rather to illustrate that the insurer can, by separating risks in terms of traffic behavior, identify those who constitute the larger share of the accident costs and thereby adjust the premium according to this information.

## 2.3 Current Premium Pricing

This section and those following point out information asymmetries in insurance data. These problems affects the actuarially fairness of the premium, it is also worth noting that these problems may affect any empirical analysis on automobile insurance data. Most studies consider insurance data as the ideal for testing contract theory. Since the results regarding automobile insurance seem rather inconclusive the general option is that there is minor or no problems with asymmetrical information in insurance markets. This conclusion may be incorrect when the data is adjusted for the information asymmetries presented in this section. The empirical difficulties are outside the scope of this paper and regarded as an area for future work.

As in most countries Swedish insurers typically price their policies by observable characteristics based on the vehicle owner, the vehicle itself and national registration address of the vehicle owner. Available data, and the possibilities to collect data, set the limit on the variables the insurer can use in the pricing scheme. The information collected by insurers differs between companies but is essentially the same.[5] Each insurer collects data and creates its own database and common proxies for driver risk are age, gender, number of years with driving licence has been held and past claim history. Vehicle characteristics are divided into vehicle model, age, vehicle performance, etc. The geographical characteristics are mainly represented by the residential area code which provides information on where the vehicle is mainly used. The insurers use proxies for the neighborhood risk and number of days per year with icy roads, etc.

All contracts that share the same observable variables, $x$, are considered to be homogenous in risk and are divided into the same premium cell, or equivalently, the same risk group. The ambition is to create groups where the differences in risks are larger between groups than within each group. The pricing scheme is then based on the assumption of homogeneity implying that the insurer does not consider any further heterogeneity other than the observable characteristics described above.[6]

An important and, for the insurers, unknown parameter that affects the expected cost of insurance is traffic behavior. In some countries traffic offences are known and used in the pricing scheme while in others, such as in Sweden, this is classified information for the insurer. This obstructs the pricing and the design of insurance contracts which encourage safe driving.

## 2.4 Shortcomings with the current pricing scheme

A first difficulty is the *claims* $\neq$ *accident* problem, see Chiappori and Salanié (2003). Note that the assumption *claims* $\neq$ *accidents* is likely to be larger for minor accidents since there is no point in reporting an accident where the

[5] Insurers argue that the differences in pricing variables and hence in the premium prices are due to the fact that they focus on different client groups such as individuals and vehicles on the countryside or in cities.

[6] The Swedish Financial Supervisory Authority functions as a controller of the insurers so that they maintain the competition among the industry. The pricing scheme was previously regulated according to a principle of fairness. The price should match the expected cost of the policy. Nowadays the authorities only monitor the competition.

deductible is larger than the cost of damage. It implies that a reduced risk for the insurer (claims) does not necessarily imply a reduced risk for the society (accidents and the associated costs). If the number of claims decrease due to increased preventive efforts of the insuree the *accident risk* is reduced. If a higher deductible only reduces the incentive to report a claim the *claim risk* is reduced but the accident risk is not affected. Cohen (2005) found that higher deductibles decrease the number of claims and vice versa.

An extension of the above problem is the potential problem of a weak correlation between observable characteristics, $x$, and accident risk, $\theta$; two people with the same car, age and other observable characteristics, $x$, might behave differently in the traffic which results in different accident probabilities, $p(\theta_i)$. A low correlation between accident probability, $p(\theta_i)$, and probability of a claim, $p(x_i)$, implies that there exists unobserved heterogeneity beyond observable characteristics that might affect the outcome. Under a voluntary insurance approach the good risks would, according to the theory, drop out of the market. With a compulsory approach, as in the current paper, this heterogeneity not accounted for result in an equity problem since the premiums are not actuarially fair.[7] As a result good types subsidies bad types. Appendix A provides a more detailed illustration of this problem.

A third issue is that some of the pricing variables are based on the drivers' self-reports, such as claim history and home district. Since insurers do not share claim history for pricing purposes, information about previous claims is based on the insuree's honesty. Cohen (2005) found that self reporting on previous claims caused adverse selection among new customers with a certain degree of driving experience.[8]

[7] Thus, an actuarially fair pricing scheme based on proxies requires a strong correlation between $x$ and $\theta$.

[8] There is, however, a moot theoretical discussion about future risk based on previous claims. The question is if individuals that report a claim always are more accident prone or if an accident works as a preventive effect of future accidents in that an individual becomes more cautious.

Residential area, the proxy for home district, is collected from Statistics Sweden and is based on the national registration. This implies that the insuree might live in a certain area such as a large city with a lot of risk exposure and be registered in a small town for instance with a considered low risk. In this case the insurers price the policy as if the vehicle is used in a less risky environment when actually the vehicle, and driver, are exposed to higher risk. Self-reporting variables may give bad risks the incentive to pretend to be better risks, when applying for insurance. The reason is that a poor claim history and a risky home district both increase the premium. Cohen (2005) provides empirical evidence showing that drivers tend to underreport their past claims if this variable is based on truthful self-reports. It is obviously a disadvantage if the insurers do not share past claims, and when it is possible for a new customer to self-report on damage, since previous claims provide a strong signal of actual behavior. Cohen (2008) shows that the higher risk insuree has incentives to change insurer when a claim occurs. Cohen also provides empirical evidence which shows that the insurer makes a lower profit on these customers and a higher profit on long-term customers who tend to be good risks.

A fourth problem is the possibility that inexperienced and young drivers let parents with better benefits own the car, the purpose being to lower the insurance premium. With most policy schemes the owner has to be the main user and must report if someone below the age of 25 is going to use the car regularly. Whether or not an insuree tells the truth about the main user and owner is difficult for the insurer to check. Untruthful reports on the main user may however affect compensation in a claim if the fraud is detected.

A fifth drawback with current pricing is that an individual has few possibilities to affect the premium size by behaving in a safe way. Currently there is no evident connection between safe driving behavior and the premium. It takes several years for a good driver to signal his or her type in order to receive a more accurate premium. Since the information asymmetries are larger among inexperienced drivers the problems with accurate pricing are especially large within this group. In contrast it is possible to correct for a higher risk instantaneously (ex post). If a claim occurs the premium will increase immediately after the insurer has regulated the claim.

## 2.5 Usage Based Insurance

The difficulties reviewed above are a result of the present pricing scheme used in the vehicle insurance market. A consequence of the private information among insurers is that the good type is not rewarded enough and the bad type can pretend to be good. This review highlights a need for a more individually based insurance premium since drivers may be heterogenous in more than observable characteristics. As yet it has not been any alternative approach for the insurance industry to efficiently collect information on individual driving behavior. Observability should however reduce the private driver heterogeneity and decrease the degree of risk approximation. An insurance premium that reduces the possibility to report untruthfully and rewards safe driving results in a more accurate pricing and it further provides incentives for safer driving.[9]

By making use of the technological revolution in the electronic industry it is possible to create insurance policies based on traffic behavior which would reduce the need for proxies. Usage Based Insurance (UBI) can be seen as part of what is referred to as Intelligent Transport Systems (ITS). The foundation is that the insuree has an in-vehicle computer with a digital map containing current speed limits (similar to existing GPS navigation systems available in the market). The computer registers the driving patterns i.e. where, how and what time of the day the vehicle is driven and a mobile communication unit transfers this driver-data to the insurer.

Several insurance companies worldwide are involved in UBI pilot projects and some usage based policies are already available in the vehicle insurance

[9] A more individual based insurance premium will require changes in the law since the insurers need information from different registers.

market. There are various techniques for collecting information about driving habits, such as mileage and/or driving behavior, ranging from annual vehicle inspections to advanced GPS techniques with continuous reporting of driving records, see Nilsson et al (2007). A common way to make regular insurance policies more usage based is to let the premium vary with mileage. This is referred to as Pay-As-You-Drive (PAYD). Compared to a fixed annual charge PAYD gives the driver an (financial) incentive to reduce their mileage, which in turn affects accident risk exposure. With PAYD it is also possible to differentiate road sections according to their risk and the hours of the day.[10]

Another version of UBI is referred to Pay-As-You-Speed (PAYS), the purpose being to create incentives to reduce the average speed. This implies that a more frequent speeder will pay a higher Traffic Insurance premium compared to a driver who obeys the speed restrictions. The speed level is an important aspect of traffic safety since the exposure to risk and the consequences of accidents and the accident costs increase progressively with speed. Moreover, an increase in the average level of speed brings with it external effects since it affects both the driver's own safety and the safety of other road users.

## 3 Theoretical analysis

This section provides a theoretical model which separates types by a voluntary choice of UBI when buying Traffic Insurance. Since all vehicle owners are obliged by law to purchase this policy there is an exogenous matching of drivers and policies. Hence the insurance buyers consist of both high and low risks. The first best scenario is compared with the second best for both current Traffic Insurance and when introducing an UBI option.

[10] Roads with higher traffic flows can be set to higher tariffs for instance. The tariffs may also differ between hours depending on congestion or time of day.

## 3.1 The Model

Driver behavior, such as speeding and other traffic offences, is used as the drivers' private information. Generally private information about type and action are treated separately, but not in this setting. To see the distinction between type and action in different insurance markets consider the following example: in health insurance it is not possible to let type and action coincide since creating incentives for a healthy lifestyle (actions) may not affect the risk of inheritable diseases (type). This implies that the risk in the contract is not reduced simply by affecting the actions since $type \neq action$. In vehicle insurance on the other hand, private information about type to a large extent coincides with the behavior in traffic. If a driver has a high preference for speeding (type) s/he is likely to speed (action). By providing incentives to act in a certain manner the type will be affected and the risk is reduced since $type = action$. This difference between markets is an important implication for the contract formation.[11]

Assume that there are two types in the driver population. The first type is the safe road user who primarily drives within speed limits, keeps a safe distance from the car in front and takes other road users into consideration etc. This type is referred to as the precautious low risk driver, denoted $\theta_p$. The other type tends to be less careful towards other road users and drives more aggressively; a higher frequency of abrupt brakings, rapid acceleration and at higher speed levels. This type is referred to as the reckless high risk driver and is denoted $\theta_r$. The game that will be considered consists of an informed agent (a car driver) and an uninformed principal (the insurance company). The insurer proposes a take-it-or-leave it contract to the car driver and the contract will last for one period that corresponds to a year.

The probability of an accident is denoted $P(\theta_i)$, a stochastic term that is affected by the driver's individual accident risk. The probability of being involved

[11] Incentives provided in the contract are more efficient if $type = action$. If $type \neq action$ the incentives might affect both but this is not certain.

in an accident is higher for the reckless type compared to the precautious type, $P(\theta_r) > P(\theta_p)$. The drivers are separated by their individual risk and are thus divided into homogenous risk according to behavior. Each group shares their stochastic risk of an accident.

The utility of the mandatory insurance for a driver is denoted as:

$$U_i = P(\theta_i)C - Z_i - P(\theta_i)\overline{\delta} \geq 0 \qquad i = r, p$$

The first term on the right hand side represents the utility of avoiding an accident cost. The accident cost, $C$, is constant and its size is independent of type. The expected cost is however higher, since it is more frequent, for a reckless type who tends to be more accident-prone.

The insurance premium is denoted, $Z_i$, and $P(\theta_i)\overline{\delta}$ is the deductible the insuree has to pay if s/he has a claim, that is, the portion of a claim that is not covered by the insurance provider. In the following analysis the coverage will be equal in all contracts, this is denoted as $\overline{\delta}$.[12] In this setting the driver does not have to choose the optimal deductible level and hence selection effects that occurs due to different deductibles are excluded from the analysis.

Since no other means of transportation is considered the outside option can be set to zero. Driving uninsured is not an option and hence without insurance it is not possible to drive. To be willing to participate in the game the driver's total utility (i.e. consumer surplus) must be at least larger than zero.

The insurer, who is a monopolist, insures risks $0 < P(\theta_i) < 1$ at an expected cost of providing insurance, $E(c) = P(\theta_i)(C - \overline{\delta})$, with $(C - \overline{\delta})$ being the insurance coverage. The insurer diversifies the risks such that the drivers, or contracts, are divided into homogenous groups according to $\theta_i$. Since the insurance is mandatory the number of policies sold is determined by the number

[12] With most Swedish insurers it is possible to choose to include a deductible or not in the compulsory part i.e. the option is generally to choose between 0 or €110. If no deductible is chosen the premium is higher and vice versa.

of car owners. The profit of the insurer is the difference between the insurance premium and the cost to insure:

$$\max_{Z_i} \pi = \sum_{j=1}^{N} \left[Z_i - P(\theta_i)(C - \overline{\delta})_j\right] \qquad (i = r, p \; and \; j = number \; of \; car \; owners)$$

The insurer optimizes over the premium alone since the number of car drivers is exogenously given.

## 3.2 The full information solution

With full information the insurer maximizes the premium subject to the individual rationality constraint:

$$\max_{Z_i} \pi = \sum_{j=1}^{N} \left[Z_i - P(\theta_i)(C - \overline{\delta})_j\right] \qquad (i = r, p \; and \; j = number \; of \; car \; owners)$$

$$st.$$

$$P(\theta_p)\left[C - \overline{\delta}\right] - Z_p \geq 0 \qquad (IR_p)$$

$$P(\theta_r)\left[C - \overline{\delta}\right] - Z_r \geq 0 \qquad (IR_r)$$

The individual rationality constraint ($IR_i$) will be binding for both types. This indicates that the value of avoiding the cost associated with an accident exactly matches the premium. It is straightforward to see that the solution for each type of car driver becomes:

$$Z_p = P(\theta_p)\left[C - \overline{\delta}\right]$$

$$Z_r = P(\theta_r)\left[C - \overline{\delta}\right]$$

The premium is thus a function of driver type, probability of an accident, the accident cost and the deductible, $Z_i = Z_i[P(\theta_i), C, \overline{\delta}]$. With full information it is possible for the insurer to price the premium by these parameters which implies that reckless types will pay a higher premium compared to precautious types, $Z_r > Z_p$.

The full information solution leads to a complete separation of risk types and there is no need for proxy variables since all relevant information about the insurees' accident risk is available.

## 3.3 Hidden Information: a pooling solution

With hidden information the insurer at best knows the fraction of each type in the population. Assuming that the share of precautious drivers in the car insurance market is $(1-\lambda)$ and the share of reckless drivers is $\lambda$. This implies that a driver is reckless, $\theta_r$, with probability $\lambda \in [0,1]$ and precautious, $\theta_p$, with probability $(1-\lambda)$.

Since there is hidden information about the probability of a claim, the insurer is forced to offer an average contract that is based on proxy variables. A vehicle insurance contract can be described by $\{Z_{pool}, (C-\overline{\delta}); 0\}$ It is known that in first best, where the agent's type is known, there exists an efficient solution for both types. This outcome is not incentive compatible when $\theta$ is private information because the reckless type would prefer the contract offered to the precautious type, $\{Z_p, (1-\overline{\delta})\}$, rather than her own first best allocation due to the lower premium price. The reckless type would deviate and earn a positive surplus of $(Z_r - Z_p)$ by pretending to be precautious. This situation illustrates the current situation in the Swedish automobile market.

$$P(\theta_r)\left[C-\overline{\delta}\right] - Z_p > P(\theta_r)\left[C-\overline{\delta}\right] - Z_r = 0.$$

Both types would under hidden information prefer the contract intended for the precautious type and there is no longer a separation. The contract fails in rewarding the precautious driver since both types get the low premium and end up in the same policy group, even though they may turn out to be different risks (ex post).With a compulsory insurance this implies that eventually the precautious (reckless) types pay a higher (lower) premium than the actuarially fair. See Appendix A.

## 3.4 Hidden information: separating the risk types

In order to separate the drivers the insurer offers two contracts. One contract is an UBI-policy which provides a low premium if an in-vehicle device is installed in the car. The premium will stay low if the driver acts safely and drives within the speed limits, if not there will be a premium increase. The in-vehicle computer records the driving behavior and may warn the driver if the speed is too high compared to the speed restriction on the road the insured is travelling on. If the driver continues to drive too fast the premium will increase progressively with speed (see Schmidt-Nielsen & Lahrman (2004); Lindberg, Hultkrantz, Nilsson & Fridtjof(2005) for field experiments)The other contract is a regular traffic insurance with no monitoring. The premium in this contract will, as in first best, be higher compared to the other contract. The precautious type signs the UBI-contract since this policy makes it possible to signal his or her good type to the insurer. The reckless driver chooses the regular Traffic Insurance contract with no monitoring. To distinguish the insurance products the monitored Traffic Insurance coverage is denoted $(C-\overline{\delta})^M$ and the non-monitored Traffic Insurance coverage is denoted $(C-\overline{\delta})$.

### 3.4.1 The optimization problem

To find the best (welfare maximizing) pair of contracts that separate the types we set up a maximization program where the insurer maximizes the profit under the restrictions that both drivers get enough utility to participate and that no one deviates and chooses the wrong contract. To find a sustainable equilibrium, where the types choose to be separated, both must reveal their true type.

The problem can be reduced to the pair of optimal choices made by the two agents $\{[Z_P,(C-\overline{\delta})^M]$ and $[Z_R,(C-\overline{\delta})]\}$. This simplifies the incentive compatibility constraints and the insurers problem can be written as:

$$\max_{Z_p,Z_r}\{(1-\lambda)[\sum_{j=1}^{N}(Z_{jp}-P(\theta_p)(C-\overline{\delta})_j^M)]+\lambda[\sum_{j=1}^{N}(Z_{jr}-P(\theta_p)(C-\overline{\delta})_j)]\}$$

$(i=r,p$ and $j=number\ of\ car\ owners)$

subject to:

$$(IR_r)\ \ P(\theta_r)\left[C-\overline{\delta}\right]-Z_r\geq 0$$

$(IR_p)$ $P(\theta_p)\left[C-\overline{\delta}\right]^M - Z_p \geq 0$

$(IC_r)$ $P(\theta_r)\left[C-\overline{\delta}\right] - Z_r \leq P(\theta_r)\left[C-\overline{\delta}\right]^M - Z_p$

$(IC_p)$ $P(\theta_p)\left[C-\overline{\delta}\right]^M - Z_p \geq P(\theta_p)\left[C-\overline{\delta}\right] - Z_r$

The individual rationality constraints are the same as in first best. The agents incentive compatibility constraints, $(IC)$, show which conditions that need to be fulfilled for the car driver to sign the contract that is designed for him or her. In optimum the following will hold:

1. $IR$ will be binding for both types, $P(\theta_i)\left[C-\overline{\delta}\right] - Z_i = 0$ where $(i = r, p)$.
2. $IC_P$ will not be binding $P(\theta_p)\left[C-\overline{\delta}\right]^M - Z_p > P(\theta_p)\left[C-\overline{\delta}\right] - Z_r$. The precautious type strictly prefers their own contract and will not deviate since, $Z_p < Z_r$. There is no reason why this type would prefer to pay a high premium compared to the low premium. This constraint can thus be neglected.
3. $IC_r$ may not bind $P(\theta_r)\left[C-\overline{\delta}\right] - Z_r < P(\theta_r)\left[C-\overline{\delta}\right]^M - Z_p$. The reckless type might prefer to deviate and choose to be monitored as long as s/he benefits from doing so, i.e. as long as $Z_r - Z_p \geq 0$. In spite of this, a potential deviation is not associated with an efficiency loss since the insurer have full observability in the contract the reckless type is tempted to deviate to. If the reckless type deviates s/he must act cautiously in order to receive the lower premium, $Z_p$. Otherwise the insurer readjusts the premium such that the reckless type get the higher premium, $Z_r$. Hence there is no possibility to benefit from telling lies about the true type in the monitoring contract. This implies that the $IC_r$ can be neglected as well. As a result the insurer optimizes over the same problem as in first best.

## 3.5 Summary

This analysis illustrates the possibilities created by making it feasible to observe driving. Hence insurance policies can be priced according to actual behavior rather than using observable driver characteristics such as proxies for driver risk. This benefits the good road user and reduces the possibility for opportunistic behavior. As a result the information gap associated with the current pricing practice diminishes.

To be able to find an equilibrium that separates the drivers, the premium must be dependent on driver behavior in the UBI-contract. This is because the reckless type has an incentive to deviate if the reward in terms of a low premium is independent of behavior. It is illustrated that with a premium that is behavior dependent the first best contracts can be offered.

One drawback is that we do not have full information about the reckless type who chooses to be non-monitored. The reckless driver may still not be reporting truthfully, for instance, about residential area, etc. The benefit of doing so may however be smaller since the non-monitored group will constitute higher risk drivers and this is, unlike today, common knowledge to the insurer. Hence a larger share of accident costs can be allocated to the pool of higher risks who contribute to the larger share of it.

There might further be the probability, which has been ignored in the theoretical analysis, where the worst risks drop out of the market and tend to drive uninsured if the premium increases markedly in the non-monitoring Traffic Insurance. The threat of an increase of uninsured vehicle owners is commonly debated against premium increases. It is however important to see the distinction between an UBI-contract and a uniform tax (or similar). Unlike a uniform premium increase an UBI-option provides the possibility for the insuree to affect the premium size by acting as a safe driver, which potentially prevents market drop-outs.

This approach does not create incentives for reckless drivers to become precautious, it only illustrates how it is possible to separate types and increase the actuarially fairness. Since a compulsory insurance and a monopoly insurer are used in the analysis the immediate alternative is to make the UBI-insurance mandatory as well. In this way it would be possible to increase the premium for reckless drivers to prevent risk taking. A compulsory UBI-insurance may however be resisted, not least for integrity reasons. The possibilities to create incentives to prevent risk taking, in terms of speeding, with UBI is however an area for future research.

## 4 Conclusions

The UBI-platform does not only provide additional scope for use of traffic safety equipment, such as breath alcohol ignition devices when pricing the policy. It also provides an opportunity to study risky behavior in a way that may be unique for an insurance market. Learning more about risks decreases the information gap since UBI-data makes it possible to study the relationship between risk types and accidents. This may not only affect future pricing variables, it further creates the potential to evolve contract formation such that incentives to prevent accidents, not only claims, are provided. Accidents are known to be costly to society, thereto large sums of money are invested in safer traffic environments. These investments might be insufficient if drivers take compensating in terms of a riskier behavior on increased road safety and safer cars etc. It is obvious that traffic safety has a potential gain from providing the individual incentives to act in a safer manner.

UBI has a particular potential to reduce private information about young drivers. This is an accident-prone group with no previous driving record which makes the asymmetric information problem potentially larger than for other groups. Young male drivers are on average thought to represent a much higher risk that to a large extent reflects in a very risky driving. However there are young male drivers who drive according to the rules. As a consequence cautious young drivers are discriminated by an expensive premium due to the asymmetric information regarding risk taking.

There is a crucial distinction between a compulsory and, as in this paper, a voluntary approach. A voluntary approach is valuable since it reduces the information gap about driving between the insurer and insuree. This separate risktypes but may not affect the aggregate behavior. A compulsory UBI approach may however affect the aggregate average speed since it is possible to internalise fines if speeding. It is clear that the efficiency of UBI is a concern for future theoretical and empirical work.

Currently there are no strong incentive compatibility constraints that separate risks since it is possible to behave opportunistically. The weak constraints violate the homogeneity assumption i.e. the beliefs that insurers efficiently divide risk into homogenous groups. By adding the fact that there might be further heterogeneity not accounted for, such as traffic behavior, there might be reasons to reconsider the quality of the automobile insurance data. This does not imply that this data is unusable for testing contract theory but it might be useful to consider the potential flaws in the data. Neither does it imply that insurers misjudge their insurance risks, they simply estimate their risks according to the currently available information. The resulting consequence however is a premium that is not actuarially fair.

Despite the potential gains of UBI the insurance industry hesitates in implementing these systems. The introduction of voluntary UBI might however work as a business concept for a start-up insurance company since it targets careful drivers.

## References

[1] Akerlof, G., 1970. The market for lemons: quality uncertainty and the market mechanism. *Quarterly Journal of Economics*, 84(3), pp. 488-500.

[2] Bolton, P. & Dewatripont, M., 2005. *Contract theory.* Cambridge: Cambridge Mass: MIT Press.

[3] Cawley, J. & Philipson, T., 1999. An empirical examination of information barriers to trade insurance. *American Economic Review*, 89(4), pp. 827-846.´

[4] Chiappori P-A and B Salanié (1997) "Empirical contract theory: the case of insurance data", *European Economic Review*, 41(3-5), pp 943-950.

[5] Chiappori, P.A. and B. Salanié (2003), "Testing contract theory: a survey of some recent work", in M. Dewatripont, Hansen l. &. Turnovsky, s., eds. *Advances in economics and econometrics,* Cambridge university press,Cambridge.

[6] Cohen, A., 2005. Asymmetric information and learning: evidence from the automobile insurance market *The Review of Economics and Statistics*, 87, pp 197-207.

[7] Cohen, A., 2008. Asymmetric learning in repeated contracting: an empirical study. NBER Working Paper No. 13752.

[8] Cohen, A. & Einav, L., 2007. Estimating risk preferences from deductible choice. *American Economic Review*, 97(3), pp 745-788.

[9] DeDonder, P. & Hindriks J., 2009. Adverse selection, moral hazard and propitious selection. *Journal of Risk and Uncertainty*, 38(1), pp 73-86.

[10] DeMeza D. & Webb, D., 2001. Advantageous selection in insurance markets. *RAND Journal of Economics,* 32(2), pp 249-262.

[11] Fang, H., Keane, M. & Silverman, D., 2006. Sources of advantageous selection: evidence from the medigap insurance market. Working Paper no 12289, Department of Economics, Yale University.

[12] Finkelstein, A. & McGarry, K., 2006. Multiple dimensions of private information: evidence from the long-term care insurance market. *American Economic Review*, 96(4), pp 938-958.

[13] Hemenway, D., 1990. Propitious selection. *Quarterly Journal of Economics*, 105(4), pp 1063-1070.

[14] Karagyozova, P..& Siegelman, P., 2006. Is there propitious selection in insurance markets?. Working Paper no 2006-20. Department of Economics University of Connecticut.

[15] Lindberg, G., Hultkrantz, L., Nilsson, J.E. & Thomas, F., 2005. Pay-as-You-Speed, two field experiments on controlling adverse selection and moral hazard in traffic insurance. The Field Experiments Website [Online]. Available at: http://ideas.repec.org/p/feb/framed/0037.html [Accessed 18 May 2009]

[16] Nilsson, J.E., Arvidsson, S. & Bagdadi, O., 2007. Intelligenta försäkringar för person- och lastbilar .[Intelligent insurance policies for cars and trucks] VTI-Report No.R561. [Online] Available at: http://www.vti.se/templates/Report____2796.aspx?reportid=6421 [Accessed 18 May 2009].

[17] Salanié, B., 2005. *The Economics of Contracts: a primer*. Cambridge: Cambridge Mass MIT Press.

[18] Salanié, B., 2003. Testing Contract Theory. *CESifo Economic Studies*, 49(3), pp 461-477.

[19] Schmidt-Nielsen, B. & Lahrman, H., 2004. Traffic Safe Young Drivers, Experiments with Intelligent Speed Adaption. TRG, University of Aalborg.

[20] SCADPlus, 2007. Road safety action programme 2003-2010. [Online] Available at: http://europa.eu/scadplus/ [Accessed 1 May 2009]

[21] Strömbäck, E., 2003. *Trafikskadelagen – ersättning vid trafikskada*, [Traffic injury law-reimbursement at traffic injury]. Stockholm: Norstedts juridik AB.

# 5 Appendix A

Assume that the share of precautious drivers in the car insurance market is $(1-\lambda)$ and the share of reckless drivers is $\lambda$. This implies that a driver is reckless, $\theta_r$, with probability $\lambda \in [0,1]$ and precautious, $\theta_p$, with probability $(1-\lambda)$. Suppose that the drivers share the same driver, vehicle and geographical characteristics, $x$. These individuals are thus considered to be homogenous with no further heterogeneity other than observable characteristics. The insurer offers a premium based on the observable characteristics that correspond to the expected cost to insure, or equivalently, the expected *claim rate*, $C(x)$ :

$$Z(x) = E\left[P(x)C(x)\right].$$

$P(x)$ is the expected probability of reporting a claim based on observable characteristics. If there are deviations in driving behavior, and thus accident risk, within a group then $x$ is a weak proxy for $\theta$. This implies that the premium will not be actuarially fair. To see this assume that $\lambda$ is the share of reckless drivers and $(1-\lambda)$ is the share of precautious drivers:

$$Z(x) = \lambda Z_r + (1-\lambda)Z_p$$

If the share of reckless drivers, $\lambda$, is larger than zero then $Z(x)$ is higher than the fair premium for the precautious type, $Z_p$. In the same way the premium $Z(x)$ is lower than the fair premium for the reckless type, $Z_r$. This implies that the premium $Z(x)$ functions as a pooling premium within each risk group. The more accurate the observable characteristics, $x$, correlate with risk, $\theta$, the more likely this pricing scheme provides an actuarially fair premium. Even if the proxies for risk, $x$, constitute a fair premium in terms of risk there are still possibilities of opportunistic behavior as discussed in section two, for an empirical analysis of the opportunistic effect on the premium size, see Cohen (2008).