Essays on Asymmetric Information in the Automobile Insurance Market
Sara Arvidsson

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Abstract


This thesis is concerned with the consequences of private information on risky traffic behavior from the perspective of the insurer, the society and the individual. The overall objective is to extend the knowledge of the consequences of private information on the demand for insurance coverage and contract outcome by conducting empirical research on Swedish data. Another aim is to establish if it is possible to identify and price risky traffic behavior such that the accident externality from speeding is reduced.

Essay 1 establishes whether private information about traffic violations has any effect on the choice of coverage and ex post risk in the contract. Essay 2 investigates if traffic violations indicate whether the policyholder is a one period or a loyal customer. Essay 3 empirically investigates the relationship between risky behavior and characteristics of the vehicle owner and the vehicle. Essay 4 illustrates how insurance companies can combine contract theory and available and emerging technologies to identify risky traffic behavior. Essay 5 illustrates how the accident externality imposed on society can be reduced. Alternative policies are analyzed to implement optimal speed control.

Keywords: Asymmetric information, Adverse selection, Moral hazard, Propitious selection, Risky behaviour, Automobile insurance, Insurance data, Positive correlation test, Private information.

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**List of Essays:**

1. Does private information affect the insurance risk? – Evidence from the automobile insurance market.

2. Predictors of customer loyalty in automobile insurance: the role of private information in risky driving behavior and claim history.

3. Traffic violations and insurance data: a note on the role of age, gender, annual mileage and vehicle brand.

4. Reducing asymmetric information with usage based automobile insurance.

5. Voluntary internalization of speeding externalities.
1. Introduction

This thesis consists of five separate and self contained essays, the common theme being the consequences of private information of risky traffic behavior. This information asymmetry is analyzed in the Swedish automobile insurance market from the perspective of the insurer, the society and the individual. The first three essays empirically investigate the effect of private information about traffic violations, while the last two provide theoretical analyses of how to approach first best.

More precisely, essay 1: *Does private information affect the insurance risk? – Evidence from the automobile insurance market* establishes whether private information about traffic violations has any effect on the choice of coverage and ex post risk in the contract. Essay 2: *Predictors of customer loyalty in automobile insurance: the role of private information in risky driving behavior and claim history* investigates if traffic violations and claims indicate whether the policyholder is a one period or a loyal customer. Essay 3: *Traffic violations and insurance data: a note on the role of age, gender, annual mileage and vehicle brand* empirically investigates the relationship between risky behavior and characteristics of the vehicle owner and the vehicle. Essay 4: *Reducing asymmetric information with usage based automobile insurance* illustrates how insurance companies can combine contract theory and available and emerging technologies to identify risky traffic behavior. Essay 5: *Voluntary internalization of speeding externalities* illustrates how the accident externality imposed on society can be reduced. Alternative policies are analyzed to implement optimal speed control.

The overall objective of this thesis is to extend our knowledge of the implications of private information on the demand for insurance coverage and
contract outcome by conducting empirical research on Swedish data. We also want to establish if it is possible to identify and price risky traffic behavior such that the accident externality from speeding is reduced. Extending and refining methods to study and identify information asymmetries have important policy implications which can be beneficial in other areas as well. The thesis contributes to the empirical risk-coverage literature in that it provides a potentially viable alternative to the test for information asymmetries in the automobile insurance market. This alternative approach involves studying the effect of policyholders’ private information about risky driving behavior. This implies that we can directly observe how risky behavior affect the choice of coverage and the outcome (claim or not). The theoretical analysis illustrate that the accident externality from driving arises from information asymmetry, and that it is possible to separate risks and reduce this externality by introducing Usage-Based-Insurance (UBI).

The following sections provide a unifying framework and a summary of the papers. Section two starts with the theoretical scope of the thesis and provides an overview of the asymmetrical information problem in an insurance context. This section further describes the data and standard econometric method used in the literature. We also highlight the fact that this data raises new methodological issues. Section three describes the accident externality and the motivation for the theoretical analysis. This unifying section also discusses UBI, which provides a potential alleviation of the private information problem and accident externality caused by driving behavior. Section four contains a summary of the papers, while section 5 considers the lessons learned.
2. The theoretical scope of the thesis

Since the early 1970s the topic of information asymmetries has permeated many areas and there exists a vast literature in leading journals of, for instance, finance and law. Several researchers have been rewarded with the Nobel Memorial Prize in economics for their theoretical contributions. Despite this progress there are only a few standard notations and findings in microeconomic textbooks. Much of the existing literature only serves as an introduction to this area even though more recent work has tried to fill this gap (Bolton and Dewatripont; 2005 and Salanié; 2005). One reason for this gap is that the empirical research is lagging behind. Even though the potential importance of asymmetric information has been established, the empirical relevance of asymmetries has not. The Nobel committee, when rewarding pioneering theoretical work, noted that empirical evidence of asymmetric information in insurance markets was ambiguous (Bank of Sweden 2001). The potential effects of information asymmetries have important implications for decision makers, and the efficiency and even existence of markets. This section provides a brief summary of this extensive field in an insurance context, with focus on adverse selection, propitious selection and moral hazard.

2.1 The classical prediction: adverse selection

Asymmetric information is always present since at least one party, if not all, to a transaction has information that is not observable to the other(s). A seller, for instance, does not have full information about the buyers’ preferences. Similarly, a buyer has in general limited information about the sellers’ production function and cost structure. However, asymmetric information does not have to be synonymous with inefficiencies since in many transactions and situations this asymmetry is irrelevant. For asym-
metric information to be contract relevant, the outcome of the contract must be affected. In an insurance market context this implies, for instance, that the insurer’s profit depends on the risk in the contract, and usually the level of risk is the policyholders’ private information, at least ex ante. During the early seventies theoretical research exhibited cases in which asymmetric information was indeed relevant. Among others, Akerlof (1970) and Rotschild and Stiglitz (1976) showed that information asymmetries in some situations had important consequences for the existence and the efficiency of competitive equilibrium. Over time it has become common to assume that asymmetric information causes inefficiencies in the insurance market where the insured have some ex ante private (hidden) information that is important for the contract but unknown to the insurer. The classical prediction is that the informational advantage of the policyholder leads to an adverse selection where bad risks are the most eager to buy insurance coverage. This means that individuals more exposed to risk show a higher demand for insurance compared to individuals less exposed to risk. Although substantial work has been done on adverse selection outside insurance markets, the term itself originated in the insurance market context (see for instance Chiappori and Salanié (2003) for a review).

To reduce the asymmetries, the insurer tries to screen information about type via the risk classification (Stiglitz; 1975, Rothschild and Stiglitz; 1976). Here the uninformed part (insurer) tries to approximate information about the informed party (policyholder). To obtain an efficient risk classification, the insurer uses observable, and accessible, information that is correlated with ex post risk. In life insurance, individuals with diseases are generally viewed as higher risks, and young male drivers are generally considered risky to insure in the automobile insurance market.
The purpose of the risk classification is thus to create homogenous groups of risks that share the stochastic risk of a loss within each group. More specifically, the risk classification in the Swedish automobile insurance is based on individual, vehicle and residential area characteristics. Ever since the mid-1990s Swedish insurers have been free to develop their own formula for pricing the premium; that is, their own risk classification.

In addition to dividing similar risks into separate groups, another attempt to reduce information asymmetries about type is signaling, which means that the informed party reveals information about his/her type to the uninformed party. The party with superior information, in this case the policyholder, signals his or her type. Spence (1973) laid the foundation of the signaling theory with a model of the job market. The idea is that one party (the worker) sends a signal in order to reveal relevant information about his or her ability to the uninformed party (the employer). One basic assumption is that the employer is willing to pay a higher wage for high ability workers and that the employer cannot distinguish between high and low ability workers. The worker therefore sends a signal of ability via her education level. High ability workers are assumed to have a certain amount of education while low ability workers do not invest in education. The employer is then able to interpret the signal and adjust the contract accordingly.

In the insurance market, however, the opportunities to signal risk type are generally limited. One possible signal is the choice of deductible, a higher deductible implying a lower premium and vice versa. Low risk individuals are likely to choose a higher deductible since they know that their probability of being involved in an accident is low (Rees and Wambach; 2008). At the same time, if low risk individuals are associated with high risk aversion, it is reasonable to choose a lower deductible since a larger part of the
economic risk is then transferred to the insurer. Recent research has shown that both high and low risks show a high demand for coverage (Finkelstein and McGarry; 2006), which suggests that both types have incentives to choose the lower deductible. It may therefore not be possible, ex ante, to make inferences from the choice of deductible. From a customer perspective it means that low risk individuals have limited opportunities to signal their low risk type when they buy an insurance policy. Eventually, however, the insurer learn their customers’ type since they observe their outcome (claim or not) over time. The disadvantage is that this learning takes several periods and can be costly for both insurers and low risk individuals. Another consequence is that it may be costly for a low risk type to switch insurer. The reason is that there is a new learning period for the new insurer.

2.2. Moral hazard

Another often debated consequence of information asymmetry is that the insured may take actions that affect the risk in the contract. This is referred to moral hazard and implies that a policyholder reduces the preventive effort and becomes riskier after having purchased insurance. The reason is that the majority of the economic risk is transferred to the insurer. To reduce the problems of moral hazard, the insurer can increase monitoring, which is difficult and costly, or provide incentives so that the policyholder increases preventive efforts such as reducing the accident risk.

The terms adverse selection and moral hazard are often treated separately, but are closely related since the individual acts upon information that is unknown to outsiders. Still, the two terms imply different kinds of inefficiencies, since the risk ex ante and ex post when signing the contract may differ. If risk classification is used to separate risk types ex ante, the ad-
verse selection problem is dealt with. If moral hazard makes policyholders change behavior ex post, other instruments are needed to maintain homogenous groups.¹

In the context of traffic behavior it is not likely that an individual will change his or her (risky) behavior after purchasing automobile insurance. The moral hazard effect is likely more related to vehicle maintenance. If the insurance covers, for instance, vehicle flaws, the incentive for preventive maintenance may decrease, which increases the probability of a claim. Furthermore, type and action presumably coincide in the context of traffic behavior; i.e. if a policyholder speeds (action), s/he is a speeder (type), and vice versa.² This does not rule out the severity of the information asymmetry, since some individuals enhance larger risks and some behaviors are more difficult to affect than others, but it implies that the inefficiencies of both sources of information can be diminished by reducing either one or the other.

2.3 Propitious selection

An alternative hypothesis was suggested in the early 1990s, possibly as a response to the ambiguous empirical confirmation of information asymmetries. Instead of assuming that informational advantage results in adverse selection (or moral hazard), several studies suggested the opposite. This theory is called propitious (favorable) selection and was first introduced by Hemenway (1990). Examples of other contributions include DeMeza and

¹ Note that low risk types may become higher risks with insurance since the risk is transferred to the insurance company.

² One example where type and action do not coincide when studying behavior is the health insurance market, where moral hazard can be affected by providing incentives to have a healthy lifestyle. These preventive efforts may not reduce the risk of inheritable diseases though.

A propitious selection of policyholders poses a lower economic risk to themselves and their insurer, at least ex ante. The reason is that they have a high level of risk aversion and perform preventive efforts in line with this. As with high risk types, risk-averse individuals have a higher taste for insurance coverage, but, in contrast to the adverse selection prediction, propitious selection predicts that risk and coverage are negatively correlated.³ DeDonder and Hindriks (2009) nevertheless show that, under some mild regularity conditions, a negative correlation is not achieved, the reason being that risk-averse individuals may become riskier after purchasing insurance.

A note of caution is that the economic literature defines risk aversion narrowly. The strict economic definition of risk aversion is that the marginal utility of wealth decreases as wealth increases. A propitious selection story requires that risk aversion is stable across contexts, which implies, in terms of risky behavior, that individuals with financial risk aversion are also averse to physical risk. The stability of risk preferences across different contexts has received considerable attention in the economic literature, with ambiguous empirical findings (See for instance Barsky et al.; 1997, Lowenstein et al.; 2001 and Einav et al.; 2010). Risk aversion is not the only explanation for a negative correlation between risk and coverage. Since there may exist other characteristics that are negatively correlated with risk and positively correlated with coverage we should not rule out propitious selection on the basis of the above mentioned ambiguity of risk aversion.

³ Cohen and Einav (2007) however argue that risk and risk aversion may be positively correlated in the automobile insurance context.
2.4 Empirical testing of the positive correlation prediction

This section provides a brief overview of empirical findings of the adverse selection and moral hazard prediction. Although much work has been devoted to adverse selection and moral hazard outside the insurance market, we focus on related studies in the insurance context. The basic prediction of adverse selection and moral hazard concerns the correlation between risk and coverage. The intuition is that if different insurance contracts are sold to observationally identical agents, then the frequency of claims among the policyholders should increase with coverage. Hence, we expect to find a positive correlation between coverage and risk. The positive correlation prediction has been the major focus of empirical work in insurance markets.

Early surveys of important contributions are provided by Dionne and Doherty (1992), Chiappori (1999, 2000) and Chiappori and Salanié (2003). They conclude that contract econometrics is a promising field and highlights the use of insurance data when testing theories of information asymmetries. One reason is that insurance data is fairly standardized and comes in large data sets. Nonetheless insurance companies have been reluctant to open their data files to researchers, which may explain why empirical testing lags behind theory. Some of the early work, for instance Puelz and Snow (1994), indicated the presence of information asymmetry suggesting empirical evidence of adverse selection or moral hazard, but the results were later criticized for being biased (Dionne et al.; 2001). Several studies, especially in the automobile insurance market, provide no

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4 Hitherto there are no established method to disentangle adverse selection and moral hazard. Furthermore, with insurance data it is often difficult to establish if the observed information asymmetry was present ex ante or emerged ex post signing the insurance policy.
evidence of adverse selection or moral hazard. The interpretation of previous is that the insurer (or other principal) seems to be successful in dealing with information asymmetries.

Still, there are reasons to believe that the inefficiencies exist due to information asymmetries. In Essay 4 we analyze the consequences of the presence of asymmetric information and argue that insurers are not able to distinguish between high and low risk customers who belong to the same risk class on the basis of their observable characteristics. Availability of information determines how efficient the insurer is in distinguishing risks and this availability can be restricted by laws and regulations. Market characteristics, such as available information, differ across countries. It is therefore important to consider market heterogeneity when comparing results from different markets. One example of available information differing is previous claims with other insurers. In Sweden insurers do not share information about previous claims, while in Italy the policyholder needs a certificate of claim history from the previous insurer when switching insurance company (Ceccarini; 2007). Cohen (2005, 2008) considers the underlying market characteristics and finds, in contrast to previous studies using automobile insurance data, evidence of the prediction of adverse selection and moral hazard. The results suggest that policyholders under-report previous claims when switching insurer, if claim history with other insurers is the policyholder’s private information. The reason is that high risk types can mimic low risk types by reporting untruthfully about previous claims. In Essay 4 we further illustrate that it is possible for a new policyholder to report untruthfully about his or her type to receive a lower premium. This is because several of the Swedish risk classification variables are based on self-reports and that claim history is not shared between insurers.
While theory often uses oversimplified frameworks and assumes one dimension of risk, real practice is more complex. Finkelstein and McGarry (2006) conclude that multiple dimensions of private information increase demand for insurance. They consider private information about risk in the health care insurance market by adding the policyholders’ beliefs of ending up in a nursing home to their proprietary insurance data. Policyholders’ private beliefs are not observed by the insurer. Finkelstein and McGarry suggest that two types purchase insurance, individuals with private information that they are high risks, and individuals with a strong taste for insurance. Ex post the former implies a higher risk to the insurer, while the latter imposes a lower risk. In aggregate, those with more insurance are not higher risks.

The Finkelstein and McGarry finding may be one explanation for the ambiguous empirical findings in the automobile insurance market. If both low and high risk individuals demand insurance, then the adverse selection, or moral hazard, prediction may not describe the entire insurance demand. The empirical prediction based on adverse selection or moral hazard is that risk and coverage are positively correlated. If, on the other hand, low risk individuals demand extensive insurance, then risk and coverage may be negatively correlated. Hence, if both high and low risk individuals demand extensive coverage, the correlation effects may cancel out. This implies that the correlation structure looks very different from what we expect according to the classical theoretical prediction. Cohen and Einav (2010) survey the risk-coverage correlation literature and conclude that the empirical results differ across markets. They further emphasize the importance of taking the context into consideration when studying information asymmetries, since this may affect the outcome.
Still, the results in Finkelstein and McGarry are a bit puzzling since no significant correlation between actual risk and coverage is found; a correlation only exists for the perceived risk and coverage. Koufopoulos (2009) uses a theoretical model to provide an explanation for this puzzle. It is assumed that all agents maximize their expected utility given their beliefs, and that an optimistic agent underestimates the true probability of a loss, while the realistic agent correctly estimates the probability of a loss. If optimism discourages precautionary effort, there will exist a separating equilibrium that exhibits the observed empirical patterns of negative or zero correlation. Overestimating ability is often mentioned when it comes to driving. According to Svenson (1981) 90 percent of the automobile drivers in Sweden consider themselves “above average”. Similar results are reported by Rutter, Quine and Alberry (1998) for British motorcyclists. On average motorcyclists perceive themselves as less risky than other motorcyclists and they underestimate their absolute accident probability. This may explain why often no correlation is found between risk and coverage in the automobile insurance market; if people overestimate their skills and underestimate risk, it is not rational to buy extensive coverage.

Furthermore, in related research based on actuarial science, Thomas (2007) claims that motor insurance is a well recognized example of propitious selection; this viewpoint is not explicitly mentioned as propitious selection in economic literature since traditionally propitious selection requires risk aversion. Thomas argues that uninsured drivers are likely exhibit risky driving behaviors. An uninsured driver is nine times more likely to be convicted of a serious driving offence, and approximately five times more likely than insured drivers to suffer a car-crash injury. In the same vein, Guppy (1993) finds that convicted individuals generally perceive themselves as less likely to have an accident compared to individuals with no convictions. The implication is that the highest risks select themselves from
extensive coverage, suggesting that the insurer is left with less risky policy-holders. This is interpreted as propitious selection. In Essay 1 we confirm that individuals with previous convictions for traffic violations are less likely to have more insurance at the same time as being more likely to cause an at-fault accident. This result helps to explain why there generally is no evidence of adverse selection or moral hazard in the automobile insurance market. If high risk individuals do not purchase extensive insurance coverage, there will be no positive correlation between extensive coverage and risk. However, the market may still suffer from information asymmetries.

2.5 The standard risk-coverage correlation test

Much of the work on testing information asymmetries has been devoted to the positive correlation test first introduced by Chiappori and Salanié (2000). It provides an indicator of the existence of residual asymmetric information, and was developed to test the prediction that more insurance is associated with higher risks. However, the correlation test is not strong enough to separate adverse selection and moral hazard. A significant correlation between risk and coverage only implies that there exists residual asymmetric information. In terms of the adverse selection prediction, the correlation arises from high risk agents being more willing to pay for additional coverage. Similarly, in terms of moral hazard, a positive correlation is predicted since an agent with extensive coverage makes less preventive effort after signing an insurance contract and therefore becomes riskier. Disentangling adverse selection and moral hazard is probably the most significant and difficult challenge that empirical work on information asymmetries faces and is outside the scope of this thesis (for a discussion see Cohen and Siegelman, 2010).
One reason why the empirical literature has focused on the positive correlation test is its wide applicability. It is, so far, the most robust test available when testing for information asymmetries. The correlation test of the residuals is based on the following equations, where equation (1) represents the choice of coverage and equation (2) the outcome (risk) (Cohen and Siegelman; 2010 and Rowell; 2010):

\[
\begin{align*}
\text{Coverage}_i & = f(X_i) + \varepsilon_i \quad (1) \\
\text{Risk}_i & = g(X_i) + \eta_i \quad (2)
\end{align*}
\]

\( (i = \text{contract}) \)

The dependent variable of equation (1) takes the value one if the policyholder has a specified coverage. The dependent variable in equation (2) takes the value one if the policyholder has reported a claim. It is important to consider what risks the insurance coverage includes and what claims are relevant when performing this test. If not, there may be a spurious correlation, which provides us with the wrong conclusions. \( X \) represents a vector of all the characteristics in the contract and \( \varepsilon_i \) and \( \eta_i \) are the error terms. Previous studies stress the importance of including all information that the insurer uses in classifying applicants and setting the premium when conducting the risk-coverage test. If there are characteristics that are observable to the insurer, but unobservable to the researcher, the results may be biased (see Chiappori et al; 2006, Cohen and Siegelman; 2010, Rowell; 2010).

The equations are estimated simultaneously or sequentially by a bivariate probit model or separate probit models. If the correlation between the residuals is statistically different from zero, the equations are estimated simultaneously. If there is no significant correlation, then the equations
may be estimated separately. Finding a significant correlation between the residuals is consistent with a coverage risk correlation, while an insignificant correlation generally is interpreted as symmetric information.

Furthermore, the definition of risk calls for a remark since the insurance literature generally distinguishes between accidents and claims. The reason is that not all accidents/losses lead to a submission of a claim. The probability of a claim may be lower than the accident risk, especially if there are many uninsured drivers. This is one reason why the literature highlights the effect of preventive actions. A practical example of reducing the insurance risk is deductibles and higher premiums \( t \) periods after a reported claim. Whether or not this actually increases preventive efforts such that the accident risk is reduced is disputed: as long as the deductible and increased future premiums are higher than the accident cost there are no incentives to report a claim. This further implies that it is possible to decrease the risk to the insurer even though the risk classification may not fully capture the accident risk. In this thesis we therefore distinguish the accident risk from the insurance risk (risk for a claim).

### 2.6 The data and methodological issues

In Sweden the vehicle owner is the owner of the automobile insurance policy. The vehicle, the driver and the passengers are insured, and the insurance industry views the policy as property insurance. Most studies on information asymmetries use proprietary insurance data that is collected, and thus observed, by the insurers themselves. To establish the effect of policyholders’ private information on risk, we therefore combine proprietary insurance data with data on the number of traffic violations associated
with the policyholder. This information is inaccessible, and thus unobservable, to Swedish insurers.

Data on traffic violations consist of both on-the-spot-fines and convictions, which implies that data covers different degrees of sanctions. Convictions are legally viewed as a more serious sanction compared to on-the-spot fines. Data on convictions comes from the Swedish National Council for Crime Prevention (BRÅ) and data of on-the-spot fines comes from the Swedish police. BRÅ adds data on traffic violations to the insurance data and de-identifies the data set. We finally merge data on insurance policies and claims with the insurers’ risk classification regarding vehicle and residential area risk; we also clean the data.

We have access to all information the insurers have when setting premiums. In total there are 565,836 females and 930,573 males in the data, which sum up to about 1.5 million individuals (policyholders or vehicle owners). There are furthermore approximately 2.4 million contract-ids and when including a contract-id with a new time period, that is a repeated contract, we have a total of 9,274,116. Each observation includes all the information that the insurer has about the policyholder’s characteristics and contracts. The empirical essays provide a detailed list of information in each observation.

The complexity of insurance data calls for a remark. To the best of our knowledge previous literature identifies the insurance policy-id and the time period for the contract, which implies that it is possible to treat data as a panel, at least if each contract appears as one observation per time unit. Most statistical software requires one panel id and one observation

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5 In Sweden an ethical vetting is necessary to apply for access to this kind of data. Thereafter each authority performs a confidentiality review before providing the data.
per time unit. Previous studies generally present data as a panel but do not consider this in the analysis. Cohen (2005), for instance, considers only the first year and the majority of contracts are one-year policies, suggesting that data used in the empirical analysis is no longer a panel.

Similarly Finkelstein and McGarry (2006) use a panel of survey data but in their econometric analysis they do not consider their data as a panel. The two dimensions of policy-id and time period are also reflected in the papers in that the index $i$ of the probit models is referred to as both the contract and the policyholder, even though these should be treated separately. This is because an individual can have several contracts, which makes it better to consider the contract rather than the individual.

In our data, however, we are able to identify not only two, but four dimensions; individual-id, contract-id, vehicle-id and time period. The complexity with many dimensions implies that it is problematic to treat data as a panel: first an individual may own several vehicles (vehicle-id) where several vehicles owned by the same individual can have the same or different contract-ids. Generally all vehicles should have their own contract-id, even if they are owned by the same individual. This makes it problematic to create a panel-id that is consistent. Second, even if a unique panel-id was to be created in a consistent matter, this panel-id would appear as more than one observation during the same time period. Such observations are often treated as duplicate observations by statistical software. With insurance data two observations that appear identical to the software can occur if two or more accidents are reported during the time period. Since these are separate accidents, they should not be interpreted as duplicate observations.

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6 They analyze their data with Stata and the bivariate probit command, where it is not possible to set data as a panel.
The number of observations of an individual further depends on how many periods the policyholder has been a customer of the insurer, how many vehicles he or she owns and how many changes are made in the contract. Examples of changes in the contract are: changing deductible, moving, registering or de-registering the vehicle. This is equivalent to a change in risk that requires an updated contract. For every change that is made, the contract receives a new time period (a repeated contract) and appears as a new observation. Hence, if an individual owns several vehicles and makes several changes in the contract he or she will appear as many observations.

Finding an econometric approach that fits the data best is beyond the scope of this thesis. In each separate essay we specify more clearly how data is treated and analyzed. The approach depends on the context, that is, if we take on an insurer approach by applying the assumptions the insurer uses when dealing with data, such as in Essay 1 and 2. Or, if we use data for other purposes, where we do not apply the insurers’ assumptions, such as in Essay 3, where we study traffic violations within the insurer population.
3. Risky behavior – a social externality

This section provides a unifying framework for the theoretical analysis in the thesis. The aim is to analyze private information of policyholders from an insurer and social welfare perspective. Risky driving behavior is highly policy relevant since it contributes to the extensive traffic accident costs. The insurer can always try to reduce the probability of a claim by means of terms in the contract, that is, by making it more expensive to report a claim by using deductibles. Providing incentives to report fewer claims have an ambiguous effect on the number of accidents, at least those with an economic value lower than the deductible. Since minor accidents are far more common than serious accidents, a large share of the accident costs is likely caused by minor accidents. The cost is then divided by the individual and the society. The individual is likely to pay for expenditures such as repairing the vehicle, while society bears the costs that are not dealt with by the insurer. The theoretical analysis in this thesis focuses in particular on the inefficiencies that arise from information asymmetries regarding risky traffic behavior, and they can be reduced in order to receive first best.

Currently, road traffic accidents are known to be a major public health problem causing 1.2 million fatalities and 50 million injuries worldwide annually (World Health Organization; 2004). The associated costs are large, for the US alone the cost was estimated to be $433 billion in the 2000, which corresponds to approximately 4 percent of GDP (Parry and Small 2005). For the European Union the costs are estimated to be $216 billion, which corresponds to about 2 percent of GDP (Scadplus; 2007).7

These costs are larger if an economic value of grief and suffering is included. Arvidsson and Nilsson (2006) argue that the accident costs in Swe-

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7 Note 160 billion euro corresponds to $216 billion at an exchange rate of 1.35.
den, when including an economic value for grief and suffering, can be larger than SEK 50 billion ($6.25 billion). To reduce these costs the number and the consequences of accidents need to be mitigated. The theoretical analysis of this thesis is devoted to the accident externality of speeding. It is known that risky driving contributes to the number and outcome of accidents, but it is difficult to affect this behavior since it is largely unobservable. In order to reduce the accident externality, we first need to identify those drivers that contribute the most to it. Essay 4 illustrates how this can be done by Usage-Based-Insurance, while the purpose of Essay 5 is to establish how to reduce the social accident externality with different policy instruments. Even though the analysis is based on the Swedish market structure the general policy conclusions are also applicable to other contexts.

3.1 The Swedish accident externality

Traffic behavior obviously affects own safety as well that of others. One of the main difficulties is that behavior is difficult to price ex ante since it is unobservable. This section informally derives the Swedish accident externality of speeding based on Lindberg (2006), the purpose being to illustrate how the costs are allocated among the society, the insurer and the vehicle owner.

The expected accident costs associated with speeding can be written as $C = p(s_i)A(c_1 + c_2 + c_3)$. The accident probability, $p(s_i)$, depends on individual $i$’s speed $(s_i)$ and $A$ represents the number of accidents. A high risk driver has a higher probability of causing an accident compared to a low risk driver. The cost components of an accident can be denoted $(c_1 + c_2 + c_3)$, and consist of material costs and driver and passenger injuries that is covered by the privately owned insurance $(c_1)$. Costs for hospital care and produc-
tion/income loss is denoted \((c_2)\), while the third cost \((c_3)\) represents warm-blooded costs due to an accident.

Vehicle owners can insure themselves against economic risk via the compulsory and privately owned Traffic Insurance. This implies that the individual pays some share of the cost if an accident occurs \((\delta c_1)\). Since the traffic insurance is designed as a complement to the social insurances, only a small part of the accident costs is included in the compulsory third part liability insurance. The Swedish social insurance system covers the main part of the costs associated with hospital care and income and production loss which we denote as \((1- \sigma c_2)\), where \(\sigma c_2\) is the share borne by the individual. The private marginal cost of an accident with increasing speed is then: 

\[
MC_p = p(s_i)A(\delta c_1 + \sigma c_2 + c_3).
\]

By definition the marginal cost of the insurer is: 

\[
MC_i = p(s_i)A(1-\delta c_1).
\]

The social cost of an accident also includes the increased risk an individual impose on others in their choice of speed, \(c_4\). This implies that the social marginal cost of an accident with respect to speed can be defined as: 

\[
MC_s = p(s_i)A[(1- \sigma c_2) + c_4].
\]

The social externality of speeding is high if there are many speeders and high cost components. Because the cost for hospital care and production/income loss is not covered by private insurance a large part of the accident costs fall on the society, especially if \(\sigma\), the share borne by the individual, is small. The individual cannot be reimbursed by neither the private, nor the social insurances for the warm blooded costs, \(c_3\). All in all, there is a large part of the accident costs that falls outside the automobile insurance, which can be referred to as an accident externality.
3.2 Accident cost allocation in Sweden

Although the Swedish Road Administration has been estimating the economic cost of traffic accidents since the 1960s an accident cost analysis is complex for two main reasons. First, it is complicated to estimate the magnitude of the accident costs and, second, the cost allocation is complex, which obstructs the identification of cost units. A reason for the difficulties is that the official accident statistics only report road traffic injuries with physical injury, not property damage. In addition there are unknown cases that are never reported to the police. It is also difficult to estimate the costs, since there are issues related to method and measurement when estimating individuals’ willingness to pay for reduced risks (Hultkrantz et al; 2006). Due to the Swedish insurance market structure, a large share of the accident costs is carried by the society. One reason is that the insurance companies takes the social insurance system as given when offering the compulsory third part liability insurance, implying that it mainly functions as a complementary insurance. Furthermore the Swedish social security system has no possibilities of regressing costs due to traffic accidents from the Traffic Insurance.8

We identify four main economic agents that affect the Swedish accidents costs in either way. First, the government spends large amounts on safety investments in terms of safer roads and roadsides etc. These actions are financed via taxes and aim at reducing the number of accidents and alleviating the consequences of accidents. The government also handles a large share of the associated to an accident costs via the social insurance system, which is also financed via taxes. Second, the private insurance industry insures a part of the financial risk of an accident. Third, the vehicle indus-

8 According to Strömbäck (2003) regress is a basic principle in many countries and when this principle applies the compulsory insurance premiums are much higher.
try develops safer vehicles such as instruments supporting the driver, e.g. air-bags, anti breaking systems, etc. This is ultimately paid for by the vehicle owners. Fourth, the road user has a large impact on the accident costs. According to Lonero et al (1995), 85 percent of all accidents are due to road-user mistakes. In addition, motorists are known adjust their behavior to compensate for increased safety investments (as performed by the government and vehicle industry) by taking greater risks (Peltzman; 1975). Road users may not take the safety among other road users into account. Lindberg and Jonsson (2009) argue that a vehicle driver generally has an incentive to increase the vehicle mass since it increases own safety. On the other hand, an increased vehicle mass reduces the safety of others.

It is evident that risky driving behavior is an important contributor to the accident externality in aggregate. How to internalize externalities has been on the top of the transportation agenda for a long time. The theoretical part of the thesis focuses on the externality of speeding and the possibility of developing instruments to implement optimal speed control. The next section presents a potentially viable policy that increases monitoring, without the high costs often associated with increased monitoring.

### 3.3 Usage-Based-Insurance – a way to price the externality

Technological progress in the vehicle industry has provided the majority of new automobiles with navigation systems and digital maps, at least as options. The insurance industry continuously adjusts its pricing schemes and promotes safer vehicles. Examples are premium reductions for vehicles with safety equipments. An extension of this pricing is to let the premium vary by usage and behaviors; these types of policies are commonly known as Usage-Based-Insurance (UBI). The interest in these policies has increased
rapidly among vehicle insurers ever since the end of 1990s (Arvidsson et al; 2007). A central focus of UBI is to internalize the externality generated by driven distance. Vickrey (1968) was the first to introduce a partial solution to problems of unaffordable insurance, uninsured driving, premium unfairness and inefficiencies by proposing a usage-based car insurance. Vickrey explains the accident externality with the difference between the marginal and average cost of driving. He provides an example where he considers two vehicles that collide and suggests that the accident would not occur if either driver took the subway instead of driving. Strictly speaking both cause the accident in full, even though only one party may be negligent. The average accident cost is the damage to the two vehicles divided by the two vehicles, but the marginal cost exceeds this. It is the damage to the two vehicles, that is, the marginal cost is twice the average cost. The proposed solution by Vickrey was to sell distance-based insurance with tires or gasoline known as Pay-At-The Pump auto insurance.

Several insurance companies have adopted Vickrey’s idea in the form of Pay As You Drive (PAYD) automobile insurance. Another common term for these policies is Vehicle-Mile-Insurance, in which the insurers charge the vehicle owner per mile instead of a fixed number or interval of miles. There are various techniques for collecting information about actual behavior, ranging from annual vehicle inspections to advanced GPS-techniques with continuous reporting of driving records. Compared to a fixed annual charge, PAYD gives the driver an (economic) incentive to reduce the mileage, which in turn affects accident risk exposure since reduced mileage implies reduced exposure. This pricing has similarities to a green tax in that it is believed to reduce driving. Another embranchment, which can be referred to as Pay-As-You-Speed (PAYS), focuses on the externality caused by speeding. The purpose of PAYS is to affect the average speed, by letting the drivers pay according to speeding frequency and level.
This means that a more frequent speeder will pay a higher insurance premium compared to a driver who complies with speed restrictions. Thus, UBI opens up for the possibility of reducing the private information of traffic behavior and pricing the externality imposed on society.

The next section provides a summary of the papers. The first three study the presence and implications of private information about risky behavior empirically, while the last two provide a theoretical analysis how to deal with this information asymmetry problem.
4. Results – summary of the papers

**Essay 1.** Does private information affect the insurance risk? – Evidence from the automobile insurance market.

In the first paper we empirically investigate the effect of policyholders’ private information about (risky) traffic behavior on insurance coverage and ex post risk. We study information asymmetries, using a rich data set from the automobile insurance market, in two ways. First we use the correlation test of Chiappori and Salanié (2000) on a sample of new policyholders, which we use since the information asymmetry between the insurer and policyholder are likely largest in the first period. In contrast to much of the previous work, we find a positive significant correlation for three of the ten groups of policyholders. These results are consistent with the adverse selection and moral hazard prediction that high risks are associated with extensive coverage.

We also test the effect of private information explicitly by adding data on on-the-spot-fines and convictions for traffic violations. This information is inaccessible and thus unobservable to the insurer. Furthermore, previous claims are not observable since this information is not shared between insurers and since we use a sample of new policyholders the insurer has no previous observations of these individuals. The added information compared to the positive correlation test described in section 2 is PI, which represents the private information on traffic violations (risky driving behavior):

\[
\text{Coverage}_i = f(X_i) + \text{PI} + \epsilon_i \quad (1)
\]
\[
\text{Risk}_i = g(X_i) + \text{PI} + \eta_i \quad (2)
\]
It is demonstrated that being unable to reject the null of zero correlation is not necessarily consistent with the fact the insurer efficiently handles the information asymmetry. Further it is established that policyholders with private information about risky traffic behavior are more likely to be involved in at-fault claims. In contrast to the theoretical prediction that risky individuals have extensive coverage, our findings suggest that risky drivers are both more and less likely to own extensive insurance coverage. More precisely young individuals and speeders show a higher demand while individuals with other traffic offences, such as running red lights etc, and individuals with convictions are less likely to have extensive coverage. This suggests that individuals with private information about risky behavior differ in their demand for insurance. Our conclusion is that the ambiguity of previous research on automobile insurance data may be explained by high risks showing different demand for extensive insurance coverage.

**Essay 2: Predictors of customer loyalty in automobile insurance: the role of private information in risky driving behavior and claim history.**

Contract-relevant information asymmetries are known to cause inefficiencies in markets, at least if it is contract relevant. The information asymmetry is largest in the beginning of the customer-insurer relationship and reduces over time; the longer a policyholder stays with the insurer the more the insurer learns about the policyholder’s risk. This implies that it is reasonable to expect that if there are problems with information asymmetries they will eventually be dealt with. But, two important characteristics of the market suggest that the information asymmetry may not be reduced for all policyholders. First, insurers do not have access to traffic violations, which are predictors of risk since policyholders with traffic violations are more likely to report a claim. Second, the insurers do not share information, such as previous claims, which means that the policyholder can flee a poor
claim record by switching insurer. Due to the market characteristics, there may exist a selection of high risk customers that switch insurer more often, such that the information in this group is never reduced.

To study this hypothesis we compare information asymmetries in two groups of policyholders; new customers that stay with the insurer for a period or less (short term) and long-term customers who stay with the insurer for several periods (loyal). We define loyalty in terms of periods (years) that the policyholder has been a customer. Two probit models are used. In the first we estimate loyalty and condition on all the insurers’ observables, whether or not the policyholder had at-fault claims in the proceeding periods, if s/he was claim-free and whether or not s/he committed traffic violations. In the second we use short-term policyholders that depart, while controlling for observables and previous at fault-claims with the insurer, if s/he was free from claims and if s/he committed any traffic violations.

All in all our findings suggests that short-term customers constitute an adverse selection of risks and are more likely to commit traffic violations and report claims. Loyal customers, on the other hand, constitute a propitious (favorable) selection of risks, and are less likely to commit traffic violations and report claims. Another indicator of loyalty is that they are more likely to be claim-free during their time as a customer with the insurer. The results support the fact that the market suffers from opportunistic behavior since short-term departure customers are disproportionately ones with claims; once a claim is reported there are incentives to switch company.

Risky behavior, such as violations of existing driving regulations, is one of the best predictors of accident risk (Parker et al.; 1995, Forward; 2006, 2008). Traffic violations also increase the probability that the vehicle owner will report an at-fault accident to the insurance company (Arvidsson; 2010). It is therefore policy relevant to establish the characteristics that are associated with risky driving behavior. There is a huge literature addressing this issue, much of it using survey data on self-reported accidents and traffic violations or data on individuals involved in accidents; moreover, the data analysis is often based on small samples. The drawback of only using individuals involved in accidents is that it obstructs inference since we lack information of traffic violations on the population at large, that is, also about individuals who have not been involved in an accident. The disadvantage of self-reported violations and accidents is that individuals, consciously or unconsciously, under-report accident history and traffic violations.

The contribution of this paper is to set out and explore a rich data set when studying traffic violations, including both accident involved and accident free individuals. The data set comprises all insurance policies from Sweden’s largest automobile insurance company covering several years, in total 9.3 million observations, as well as information about fines and convictions for traffic violations. The data consists of insurance contracts that contain information such as characteristics of the vehicle, the vehicle owner, annual mileage and if the policyholder has received fines or convictions for traffic violations. This implies that the methodological issues associated with self-reported violations and only accident-involved individuals are disused. The first purpose is to establish the role of age and gender in traffic violations. The second purpose is to provide a first attempt to
establish if vehicle owners of status brands are more likely to commit traffic violations. Three probit models of observed traffic violations are estimated, and we separate fines and convictions since they represent different degrees of sanctions, social acceptability and economic cost.

Our main findings confirm previous results in the accident literature in that males have a higher share of fines and convictions, compared to women. Furthermore, young individuals, especially males, have a higher share of fines, compared to older individuals. This result holds also when controlling for self-reported annual mileage, suggesting that males, and especially young males, are more inclined to take risks than females. The results also indicate that owners of status vehicle brands are more likely to get on-the-spot-fines, especially for speeding, while owners of family orientated vehicle brands are less likely to commit traffic violations.

The main conclusion is that, due to its nature, insurance data provides a viable option when studying behavior, but also raises new methodological issues that have not previously been discussed.

**Essay 4. Reducing asymmetric information with usage-based automobile insurance**

The fourth paper establishes the consequences of information asymmetries in the vehicle insurance market as it is organized today and how this affects the pricing of risk. We argue that with the current risk classification it is possible for the high risk type to mimic a low risk type. We introduce a previously unavailable opportunity to refine the risk classification via emerging techniques for collecting information about driving behavior. This implies that insurers can link the pricing scheme to actual mileage
and/or driving behavior, a solution called Usage-Based-Insurance (UBI). In this way it is possible to reward safe(er) driving.

We suggest that the insurer should offer UBI as an additional contract where the UBI contract offers a low premium on condition that an in-vehicle device to register the driving behavior is installed in the car. Data can be collected with the aid of Global Positioning Systems (GPS) and a digital map over current speed limits etc. to match how, where, when and at what speed the motorists drives. This data is transferred to the insurer and reduces the asymmetrical information about driving patterns and makes it possible to adjust a more individual-based premium.

The choice between a UBI and a regular non-monitoring insurance policy creates equilibrium where low risk drivers self-select by installing an in-vehicle device. Low risk drivers therefore constitute propitious (favorable) selection of risks. The non-monitoring contracts, on the other hand, will consist of high risk drivers who create an adverse (bad) selection of risks. Both risk types receive full coverage at their respective actuarially fair premiums, a result generally not achieved under asymmetric information. According to the standard result, only the high risk agents receive full coverage, while the low risk agents receive partial coverage at the actuarially fair premium. Our main conclusion is that introducing UBI as an additional contract in the automobile insurance market reduces the information asymmetry and the possibility for the high risk driver to mimic the low risk driver.
**Essay 5. Voluntary Internalization of Speeding Externalities**

The internalization of the external cost of transport has been high on the transport agenda for a long time. Both economists and policymakers acknowledge that there is a need for more differentiated prices or other instruments to handle this externality. Our work in Essay 5 differs in one major way from the previous literature in that the analysis is devoted to the internalization of external accident costs associated with speeding.

Using a modal choice model we develop a framework to analyze alternative instruments that encourage drivers to drive according to the speed limits. We also consider a given number of daily commuters who have a choice between a car and a reference travel mod such as a bike. Motorists choose between speed limit compliance (slow car) and non-compliance (fast car). Hence, the model comprises three modes distinguished by the time to get to a destination, speed and accident risk. We start with the current situation with a vehicle tax and fines for speeding in a competitive insurer setting. We show that drivers speed under the existing policy and consider an alternative policy to approach first best. In particular we consider an insurance policy conditioned on speed (or speeding) where accident costs are borne by the insurance industry.

We first demonstrate how today’s vehicle taxes and speeding fines works relative to a policy to implement first best. Secondly, we demonstrate how pay-as-you-speed (PAYS) insurance, in combination with regress of costs for hospital care etc. against the insurance industry, and a tax on traffic insurance can be used to target speeding externalities. Using PAYS the insurer can price risky behavior by differentiating the premiums proportionally to the accident risk, a possibility that is not available to the government. Our analysis suggests that a pay-as-you-speed (PAYS) policy can
be a helpful instrument where the insurer can differentiate the premium in order to achieve an optimum.
5. Concluding remarks

Competitive models of asymmetric information predict a positive relationship between coverage and risk. In contrast most recent empirical studies find no correlation. Nonetheless, this unifying part has established that asymmetric information is always present, takes different forms and varies across markets. This suggests that we should consider market-specific properties when testing for information asymmetries. Early studies took a broad approach when empirically investigating the positive correlation prediction, by using a large pool of policyholders. The main motive was to explore and provide a first step towards testing for information asymmetries. It was and still is believed that, if insurers handle the potential information asymmetry efficiently, the most robust result is that no residual asymmetric information is left. This is generally interpreted as insurers being successful in handling both adverse selection and moral hazard. Since reducing inefficiencies associated with information asymmetries lies in the industry’s best interest, the absence of evidence of adverse selection or moral hazard is not very surprising.

However, in recent years we have learned that the correlation between risk and coverage may be answered differently across markets, countries and subsets of policyholders. Cohen and Siegelman (2010) suggest that empirical researchers in this area should not think of themselves as participating in resolving, once and for all, the question of whether or not a coverage-risk correlation exists. It is reasonable to expect that a correlation can be found in some markets and some policy pools, but not in others. For this reason one should not interpret studies that find “contradicting” evidence, that is, a positive correlation, a negative correlation, or a zero risk-coverage correlation in conflict with each other, since this difference may be a result of market heterogeneity. A more important question is under which market characteristics we can expect to find empirical support for
adverse or propitious selection, moral hazard or preventive behavior. Since empirical research finds that information asymmetries may take different forms from what the classical theory predicts, there are reasons to look beyond the positive correlation prediction of adverse selection and moral hazard prediction. We therefore need to be prudent in the prediction and interpretation of information asymmetries, since it may not always be synonymous with adverse selection or moral hazard, but still contract relevant.

Another explanation for the puzzling empirical results is proposed by Koufopoulos (2009) in terms of heterogeneity in risk perceptions. The model introduces two types of individuals; the first is the optimistic individuals who underestimate their true accident probability, and the realistic individuals who accurately estimate their true loss probability. According to theory we expect a positive relationship between risk and extensive coverage. But, if optimism discourages precautionary efforts, and leads to these individuals purchasing less insurance, there will be a zero or a negative correlation between risk and extensive coverage. The reason is that riskier types do not purchase more coverage as expected, this theoretical prediction is also supported by the results in Essay 1.

In this thesis we analyze the Swedish automobile insurance market to conclude whether it suffers from information asymmetries. Instead of limiting the test to a risk-coverage correlation within the entire set of policies available, we conduct the test on subsets of contracts. The reason is that the absence of a correlation in a universe of policies does not rule out a significant correlation within subsets of policies. Considering the Swedish market conditions we show that the correlation structure indeed looks different among different subsets of policyholders. One explanation is that several risk classification variables are based on self-reports. With information
asymmetries it is possible for the high risk type to mimic the low risk type. A potential caveat with the correlation test is that the insurers’ information set must be included as control variables. This implies that no matter how accurate the econometrician is, there may be some characteristics that are observable to the insurer but not to the econometrician. This may bias the correlation test. A more robust test, at least according to Finkelstein and McGarry (2006) is to include some other characteristics that are not observable to the insurer, but to the econometrician. When adding private information about risky behavior we see that high risk individuals show a different demand for insurance. We also conclude that driving behavior is an indicator of loyalty in the Swedish automobile insurance market. Individuals who leave the insurer after a short period are more likely to be fined or convicted for traffic violations, while loyal customers tend to be less likely to be fined or convicted.

It is well known in the literature that traffic violations and accidents are highly correlated. This implies that insurers likely capture risky behavior since it is correlated with at-fault claims, at least ex post. Since (at-fault) claims regarding new policyholders are unobservable to Swedish insurers, it is ex ante difficult to predict the probability of a claim. Since the current risk classification enables type H to mimic type L, we expect that the market may be unfair, at least in the compulsory insurance policy. The reason is that individuals cannot drop out of the market as the general results suggest, because dropping out implies driving uninsured, which is illegal. A potential consequence is therefore that unfair pricing increases the number of uninsured vehicle owners. Another consequence is that there can be a selection of risks, where some individuals tend to systematically switch insurers to hide their risk type. This implies that the insurers do not fully learn the type of these individuals.
A conclusion is that the information asymmetry associated with new policyholders in the Swedish market, and any market with similar characteristics, would reduce if insurers have access to information about previous claims. The Swedish insurance industry has shared a register of previous claims since the beginning of the year 2000, which implies that accessing information about previous claims are approachable. But, the claim register is not used in risk classification; the aim is rather to detect frauds.

Secondly, accessing information about traffic violations is another alternative to reducing the information asymmetry, but such information-sharing between authorities and insurers would likely require amendments. Some countries apply a point-record system where the driving license is suspended after \( x \) violations. Lobbying groups argue the need for a similar record in Sweden, but have hitherto faced resistance. Some countries apply this point record system in their risk classification, implying a premium increase for observed violations. A comparative study, where traffic violations are observable to the insurer, or where previous claims are shared between insurers, would likely not produce the results observed in this thesis.

A third option, which is potentially the most efficient, is Usage-Based-Insurance (UBI). As with the other two options, UBI does not only identify high risk individuals. A major advantage is that a voluntary UBI-contract provides the low risk driver with the opportunity to signal their good risk to the insurer. Insurance policies based on actual behavior, rather than proxies, open up for a more differentiated pricing of risk, which is often on the policy agenda when discussing accident externalities. Another main advantage of UBI is the possibility of using economic incentives to increase preventive efforts to reduce both the insurer risk (probability of a claim) and the accident risk. The reason is that reducing the actual number of
traffic accidents by safer traffic behavior affects both the insurers’ risk and the accident risk. Hence, a UBI-solution would potentially reduce one of our largest public health care problems, and its associated costs.
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