Endogenous Information and Privacy in Automobile Insurance Markets

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Abstract

This paper examines the implications of insurers' offering a voluntary monitoring technology to insureds in automobile insurance markets with adverse selection and without commitment. Under the consideration of the inherent costs related to the loss of privacy, the paper analyzes the incentives of insureds to reveal information, whereby they can decide how much or what quality of information to reveal. It is also allowed for the possibility that high risk individuals might mimic low risk individuals. The resulting market equilibria are characterized and it is shown, that it might be optimal for insureds to reject the monitoring technology, but also that under certain conditions, which are specified in the paper, it might be optimal for insureds to reveal complete information. Concerning the welfare effects of introducing voluntary monitoring of insureds, if low risk individuals reject it, there will be no change to either risk type. If they accept it, this will make them better off and high risks may either be made better off or worse off depending on the initial equilibrium before a monitoring technology is offered. Unless it is optimal for individuals to reveal either zero or complete information, an all-or-nothing nature of the monitoring technology will not be efficient.

Keywords: adverse selection, privacy, insurance, risk classification, endogenous information acquisition

JEL classification: D82, G22

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1 Introduction

More and more everyday objects are equipped with sensors, processing and communication technologies, which enable them to collect and exchange various types of data. The development of these networked technologies, often referred to as ubiquitous computing, will have important implications for economic transactions and in various markets. At this stage this statement is supported by the example of insurers using monitoring technologies in automobiles. Driving style and driving behaviour can be monitored with increasing precision and be used for the inference of individual risk.[1] Thus individual insurance premiums can be calculated with the effect that adverse selection and moral hazard are being alleviated.

This paper is concerned with the problem of adverse selection. Individual monitoring of the driver undoubtedly provides a better basis for the calculation of individual risk than the conventionally used personal and automobile-related data, which are declared by the insureds. Indeed, it is quite difficult to distinguish between pieces of information pertaining to the characteristics of a driver and those, which are associated with his behaviour. Nevertheless some kinds of data refer rather to characteristics than to behaviour, since drivers can hardly control them. Such are for example acceleration and braking in contrast to speed, adherence to traffic signs and regulation or usage of driving belts, which in turn are easier to be affected consciously.

A problem, which inevitably arises with the spread of monitoring technologies, is the loss of privacy. The growing scope and precision of collected data about the frequency and duration of trips and rests, the exact location and route of the vehicle, the time of the day and chronology of drives, or the number of people in cars, not only allows an improved calculation of individual risk, but also reveals information about the preferences of the drivers, their consumption behaviour, leisure activities etc. On the one hand individuals are often reluctant to reveal such data per se because of the inherent preference for privacy. On the other hand the problem is exacerbated by the improved storage capabilities and the growing network connectivity, which is implied by ubiquitous computing. Especially when privacy rights are not well defined, shared information, be it remunerated or not, can be combined with other data and entail the make-up of complete consumer profiles, the performance of more accurate price discrimination and the

[1] See Filipova/Welzel (2005) for a description of the parameters which can be monitored. An exemplary prototype of a monitoring technology is described at http://www.vs.inf.ethz.ch/publ/papers/ubicomp2005-tachograph-video.pdf.

misuse of data. Indeed, individuals buying insurance can opt for a monitoring technology in order to alleviate the negative impact of asymmetric information, but they have to trade it off against the costs of losing privacy.

In Filipova/Welzel (2005) it was shown that the availability of a black box contract in the market raises social welfare by reducing asymmetric information even in the case that some of the insureds have costs related to the loss of privacy. A crucial assumption for this result is that a black box contract is offered in addition to the conventional ones, so that insureds have the right of choice concerning the revelation of information. However, the nature of this choice is also assumed to be all-or-nothing, i.e. insureds may either choose a black box contract revealing perfect information about their risk type or a conventional contract without a black box. This all-or-nothing nature of the revelation quite well reflects the contract sets, which are presently being offered by insurers, who apply monitoring technologies, since the quality and duration of the collected data are invariably determined by the company.[2] However, in order to refine the analysis concerning privacy costs and get a better understanding of the effects of upcoming technologies, which will allow for an ever increasing precision and scope of the collected data, it is purposeful to put the question about what implications will result from individuals being able to choose the quantity and quality of information they reveal. Therefore some of the former assumptions are revoked and replaced by others which either better describe the real-life applications or better serve to approach the posed problem.

Specifically, the questions, which arise in the context of offering a voluntary monitoring technology with variable information to insureds, and which are examined in this paper, refer to the quantity (quality) of information, which individuals will reveal in equilibrium and to the factors which influence their decision; what contracts will result in equilibrium as a consequence of the revealed information; and also to the welfare effects of offering a monitoring technology to insureds. Another question concerns the efficiency compared to a situation with all-or-nothing revelation of information, for which it is necessary to find out the conditions, under which it is optimal for insureds to reveal no information or complete information, respectively.

The paper is organized as follows: section 2 contains some related literature, on which the paper draws. Section 3 presents the general setting of the model. In section 4 the resulting equilibria are examined: 4.1 concerns the case that before a monitoring tech-

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2 See Norwich Union http://www.payasyoudriveinsurance.co.uk/info.htm and Progressive https://tripsense.progressive.com/home.aspx.

nology is offered, a no-subsidy equilibrium persists; in 4.2 the equilibrium results are formally derived; 4.3 concerns the welfare implications of offering a monitoring technology; in 4.4 the procedure of the previous sections is repeated to analyze the case that the initial equilibrium is a cross-subsidizing one. The conclusions are presented in section 5 and finally some of the derivations and proofs are placed in the appendix.

2 Related Literature

The analysis relies heavily on Hoy (1982). He examines the welfare implications of imperfect risk categorization in insurance markets under adverse selection. Thereby he applies two separate equilibrium concepts for the case that a Rothschild/Stiglitz (1976) no-subsidy equilibrium does not exist. Unlike Hoy, who performs the analysis separately with the assumptions of the Wilson E2 Pooling equilibrium and of the Myazaki-Spence equilibrium, this paper focuses on the second equilibrium concept only. The reason for the author to omit the Wilson E2 Pooling equilibrium in this paper is, that the results are qualitatively very similar to those of the second equilibrium concept and hence no substantial additional insights can be derived. All theorems, which are derived for the second equilibrium concept, also hold for the Wilson E2 Pooling equilibrium. Since the Myazaki-Spence equilibrium also applies the assumption of Wilson foresight[3], further on it will be called Wilson-Myazaki-Spence (WMS) equilibrium[4]. As in the analysis by Hoy (1982), this paper examines the welfare effects of categorization only in a Pareto-sense. Similarly to Hoy (1982)'s results there will be situations, in which there are both winners as well as losers and therefore in those cases no Pareto-type improvement takes place.

There are other approaches to examine the welfare implications of categorization, which are not used here. In their analysis of the efficiency effects of categorization Crocker / Snow (1986) incorporate the possibility of hypothetical compensation of the losers by the winners. This approach implies the intervention by a regulator, who even if need not be better informed about insureds' types than the market agents, is though necessary in order to implement such compensation schemes. Naturally this analysis leads to results, which differ from those by Hoy (1982). Still, with this approach no inferences can be made about the efficiency of unregulated market equilibria.[5] Another approach of examining the welfare implications of categorization is used by Hoy/Lambert (2000) who

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[3] See Hoy (1982, 324).

[4] For instance Dionne/Doherty/Fombaron (2000) use this term.

[5] See Crocker/Snow (1986, 323).

consider the equity effects. The authors distinguish two components of "total discrimination" - horizontal discrimination, which occurs when individuals are misclassified, and vertical discrimination, which occurs when a particular group of individuals has to subsidize another group of individuals.[6] Hoy (2005) in turn assumes "fully interpersonally comparable and cardinal utility functions"[7] to measure social welfare. This paper corresponds to the approach by Hoy (2005) only to the extent that besides ex post also ex ante expected utility is calculated. As argued by Hoy (2005) the "maximization of utilitarian social welfare turns out to be the same problem as maximizing an individual's ex ante utility (i.e., ex ante to revelation of person-specific information)"[8]. But the author goes much further than is done in this paper and, in order to compare the welfare effects of different information regimes, he uses the Lorenz curves for the corresponding distributions of income, i.e. he incorporates the aspect of equality besides that of efficiency into the measurement of social welfare. As mentioned above, this paper performs no interpersonal comparisons.

A central aspect of the analysis in this paper are the incentives for individuals to accept a monitoring technology and thereby to reveal information to the insurer. In this respect there is a far reaching correspondence to the literature on the incentives of individuals to acquire additional information[9], most of which refers to the example of genetic testing in health insurance markets. Although the situation, described in this paper concerns the revelation and not the acquisition of additional information, as shall be seen below, both problems are very similar in the core, since both concern the value of information. The informational environment, described in this paper, presents a situation, in which individuals with prior hidden knowledge can acquire additional private information (at least concerning high risks), which they can possibly report to the insurer, but at the same time the information status of insureds is observable by insurers (insurers know, which individual installs a monitoring technology). A very similar scenario in the context of health testing is analyzed for instance by Doherty/Thistle (1996) in the case of "unreported negatives and verifiable positives"[10], particularly in the case of informed low risks and uninformed individuals. The authors find, that information in this scenario has a positive value for individuals, so that in equilibrium they will perform the health

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[6] See Hoy/Lambert (2000, 105-108).

[7] See Hoy (2005, 3).

[8] See Hoy (2005, 7).

[9] For a review of this literature see Crocker/Snow (2000) and Dionne/Doherty/Fombaron (2000).

[10] See Doherty/Thistle (1996, 92).

tests. There is a lot of other literature on the private and social value of information[11], but in contrast to it this paper allows for the quantity (quality) of information to be endogenous. A similar approach, which allows for the amount of information to be a continuous endogenous variable, is adopted by Taylor (2004). But the problem setting he studies is quite different from the one in this paper in that he analyzes a situation, in which firms decide how much information to gather about customers in a competitive product market. His research is motivated by the question how much privacy should be granted to consumers from a normative point of view in the context of internet-based consumer data. However unlike in this paper, in Taylor (2004) the consumer's taste for privacy is justified by the trade-off between an increasing price and a decreasing probability for trade to take place when the amount of information rises[12] and not "with the inherent preference for privacy on the part of individuals"[13].

The problem of privacy in the environment of advancing information technologies has not been studied extensively yet. The traditional articles related to this topic are by Hirshleifer (1980), Stigler (1980) and Posner (1981), Posner (1978). It is only in recent years, that the problem of privacy has become of interest to research. Papers, which bear a relationship to various aspects of privacy include Varian (1996), Acquisiti/Varian (2005), Calzolari/Pavan (2006), Taylor (2002) Dodds (2002), Hui/Png (2005), Hermaline/Katz (2005).

3 General Setting of the Model

Keeping in mind the purpose of the analysis, and in order to keep things as simple as possible, institutional characteristics of the automobile insurance market like minimum coverage level or compulsory insurance, which are considered to be irrelevant for the subject of matter, are neglected. Therefore the model is more suited to describe comprehensive insurance rather than third party liability insurance, which is quite more regulated. The market is assumed to be perfectly competitive and insurers, who are risk-neutral, set insurance premiums r and the indemnity d. The assumption, that insurers can ration the insurance coverage, reflects the restriction for individuals to buy insurance policies from only one insurer at a time and the fact that insurers offer different

[11] See for instance Doherty/Posey (1998), Crocker/Snow (1992). In contrast to the better part of the literature, which deals with adverse selection in perfectly competitive insurance markets, Buzzacchi/Valletti (2005) examine the incentives for firms to use classification variables as the result of strategic interaction in oligopolistic markets.

[12] See Taylor (2004, 5).

[13] See Taylor (2004, 16).

deductible[14] levels from which the individuals may choose. An insurance contract is thus described by the pair (d, r). As argued above, it is technologically feasible to collect information i about the style of driving. Thus insurers are able to offer both conventional contracts without monitoring and contracts, which include the monitoring technology (information contracts). For the purpose of simplicity it is assumed that the installation of this technology and the review of the data incur no costs. Unlike in the existing real-life examples it is additionally assumed, that the individuals can choose how much or what kind of information to reveal. This means, that individuals can choose the specific kind of information they reveal, e.g. location data, speed or distance traveled; or the precision of this information, e.g. if the maneuvers of the vehicle are tracked in the range of meters or centimeters; or the length of records, i.e. individuals may choose which particular time segments of the recorded driving activity to reveal to the insurer. The quantity or quality of information is normed $i \in [0,1]$, $i = 0$ meaning that although a monitoring technology is installed, no information is revealed afterwards, and $i = 1$ meaning either that the whole length or that the complete quality of record (100%) is submitted. This would also imply perfect information concerning the risk type. Values in between suggest both that individuals are able to cut out and withhold certain time segments of the records or / and that they can choose which kind of information to submit and thus affect the "accuracy" [15] of information. For the insurer this will result in a less precise calculation of risk. For example, an individual might "cut out" the segment containing a certain trip, by which the insurer will not know how fast he was driving in this period. Alternatively, the individual could submit the whole length of record, but withhold certain types of information, for instance the location data. However, the insurer will not know how often he was driving on highways or on country roads. In order to avoid unnecessarily burdensome formulations, in the following *quantity* of information, i.e. duration of the records, will be used also to refer to *quality* of information, i.e. scope or accuracy of the disclosed data.

The initial endowment of individuals is denoted by W. There are only two states of nature: either there is no accident (NA), or an accident (A) with a monetary loss denoted by L, ($L < W$) occurs. There are two types of individuals, which differ in the probabili-

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[14] When a fixed loss and only two states of nature are assumed, it makes no difference for the make-up of the model if talking about indemnities or deductibles.

[15] Intended reduction of the accuracy of data as a technical solution to the problem of losing privacy is proposed for instance by Jiang/Hong/Landay (2002). A more sophisticated concept for individuals to determine the quantity and quality of revealed data is described by Duri/Elliot et al. (2004, 698), who consider the allowance of different degrees of revelation of data in so called privacy policies.

ties of accident – low risks and high risks with a probability of loss $p^L \in (0,1)$ and $p^H \in (0,1)$ respectively, where $p^H > p^L$, and a proportion of the population q of low risks, and $(1-q)$ of high risks. Individuals know their own risk type with certainty and risk type is private information. All individuals have the identical concave utility function $V(w,i) = u(w) - g(i)$, which is common knowledge, $u(w)$ being the standard von Neumann-Morgenstern utility function of net wealth, with $u'(w) > 0$, $u''(w) < 0$, and $g(i)$, with $g(0) = 0$, the disutility from revealing private information, i.e. the inherent cost, related to the loss of privacy.[16] For the reasons explained above it is assumed that the disutility disproportionately increases in information, $g'(i) > 0$, $g''(i) > 0$ for $i > 0$; still, at $i = 1$ the marginal disutility is assumed to be finite ($g'(1) < \alpha$, $\alpha \in (0, \infty)$). Since individuals, who consider submitting the "first unit" out of the whole set of collected data, are likely to be able to select some information whose revelation does not affect privacy, it is further assumed that $g'(0) = 0$.

The time structure is as follows (see Figure 1). Starting from a situation, in which only conventional self-selecting contracts are offered, insurers may offer an optional information contract. An information contract prescribes that a monitoring technology is installed into the vehicle in the beginning of the data collection period. Insureds may either accept it or reject it. In both cases during the data collection period the original conventional contracts remain effective. During this period the device performs a non-stop and full quality record of data, which is however kept by the particular insured. In the end of this period insureds, who have installed the monitoring technology, i.e. who chose the information contract, may review and evaluate the collected data and then decide if and *how much* of it to disclose to the insurer. Based on this information, insurers update their beliefs about the risk type of the insureds and revise the contract set to be offered the next period. Unless they have perfect information about the risk type of individuals, the insurers will only be able to categorize them into risk groups, which, even though with improved proportions, still contain individuals of both low and high risk types.[17] To each risk group insurers then may offer a pair of self-selecting contracts. Properly the time lag, related to the collection of data, should be taken into account in a two-period model. But here no commitment on either side is assumed. Since insurers revise the whole contract set in each period, the consideration of the second period only is sufficient.

[16] As can be seen, the cost term in the utility function is independent of risk type. The reason is that it stems from the inherent preference for protection of privacy, which is assumed to be common for all individuals.

[17] See Hoy (1982) for an illustration of imperfect risk categorization.

Except for the freedom of insureds to determine the quantity or quality of information, this setup to a great extent reflects the contract structure of the US insurer Progressive. Besides conventional automobile insurance contracts Progressive also offers the so-called TripSense contract.[18] It stipulates the installation of a monitoring device into the car, which traces and stores the chronology and duration of drives, mileage, acceleration, braking and speed. Insureds are provided with various tools, with which they can afterwards evaluate their driving history and calculate the insurance premium corresponding to their individual risk. Depending on the performance during the particular period individuals can then decide if to upload the collected data to the insurer. Based on this information the insurer calculates the insurance premium and applies it to the next policy term.

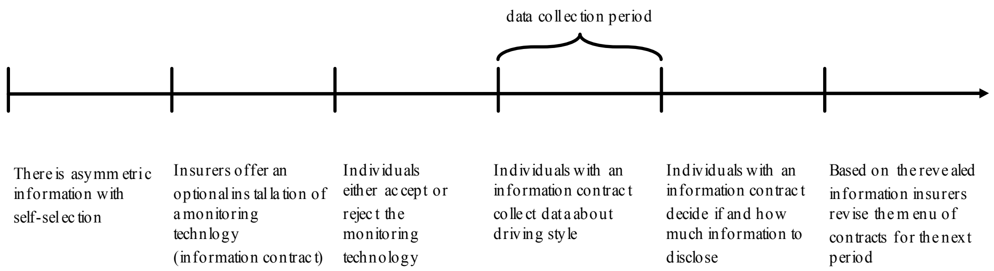

Figure 1: time structure

Low risks: In order to keep things as simple as possible, the strong assumption is made, that there is no classification risk for low risks, i.e. for any level of information, which is disclosed in equilibrium, low risks will be classified into a good risk group (G) with certainty. In this regard the assumption about the nature of information resembles the notion by Taylor (2004) of searching for “bad news” since the “probability of a false negative is zero”, i.e., the probability of a low risk driver, disclosing some information i, to be mistakenly taken for a high risk driver by the insurer and classified into a bad risk group (B) is zero. This is equivalent to the assumption that low risks’ driving style is careful and faultless all the time, so that for any i they reveal there will be no evidence which could make insurers suspect a high risk behind the insured.

High risks: As was mentioned above, all high risk individuals have an identical probability of loss p^H, i.e. their driving style is on average worse than that of low risks. Nevertheless, in a given period of time the driving experience of high risks may differ –

[18] See https://tripsense.progressive.com/home.aspx for further information.

not only concerning the realization of the loss state, but also their driving performance on the whole.

Unlike in the case of low risks it seems reasonable to assume that the detection of high risks' bad driving style and driving mistakes in their records is facilitated by an increasing temporal comprehensiveness, greater scope and precision of the collected data. Concerning the length of records this assumption is sustained by realizing that driving mistakes, which distinguish high risks from low risk, occur in specific situations and not all the time. Concerning the quality of information it is straightforward to assume that patterns of bad driving style become more distinct as the movement of the car or actions and reactions of the driver can be traced in more detail. It follows that the possibility for high risk insureds to choose the quantity or quality of information to reveal will allow them to mimic low risk driving to some extent. On the one hand high risks are able to cut out and conceal the time segments which testify for their bad driving style. Similarly, they can filter some segments of careful driving out of their records and disclose only these to the insurer. On the other hand they can reduce the precision of the data and thus blur the patterns of driving style. The more information is delivered in equilibrium, the more difficult it becomes for high risks to mimic low risks. Specifically it is assumed that for any given level of information i, which is to be disclosed in equilibrium, high risks will be able to mimic low risks only with a probability of $(1-i)$. Furthermore it is reasonable to assume that beforehand high risks do not know exactly how good the records of their driving performance will be in a particular spell of time. Thus, for a given level of information i in equilibrium, high risks, who take the information contract in the beginning of the period, do not know if they will be able to mimic low risks in the end of this period. So $(1-i)$ is also from the perspective of high risks the ex ante probability to be able to do so. But then, in the end of the data collection period, high risks can review their own driving performance and, for a given level of information i in equilibrium, check if they are able to mimic low risks.

4 Wilson-Myazaki-Spence Equilibrium

Unlike the Rothschild/Stiglitz (1976) (RS) separating equilibrium, which entails zero profits for every single contract, the Wilson-Myazaki-Spence (WMS) equilibrium (see Dionne/Doherty/Fombaron, 2000, 209-212) allows for cross-subsidization between risk types as long as on the whole insurers have nonnegative profits. With this concept there is an equilibrium even in those cases, in which the RS equilibrium does not exist.[19]

[19] See for instance Dionne/Doherty/Fombaron (2000, 209-212).

Contrary to the RS equilibrium, which assumes that firms follow pure Nash strategies when offering a menu of contracts[20], the WMS equilibrium is based on the assumption of anticipatory behavior, or that firms possess "Wilson foresight". It implies that a firm will offer a new set of policies "only if it makes positive profits after the other firms have made the anticipated adjustments in their policy offers"[21], i.e. after the other firms have withdrawn those of their policies which have become unprofitable. According to this anticipatory behavior, a contract set is an equilibrium, when "there is no portfolio outside the equilibrium set that, if offered, would earn a non-negative profit even after the unprofitable portfolios in the original set have been withdrawn"[22]. Which equilibrium will eventually result, depends on the particular proportions of risk types. If $(1-q)/q > \delta^{RS}$, where δ^{RS} is the critical value for the proportion of high risks for a RS separating equilibrium to exist, there will be such an equilibrium with actuarially fair insurance premiums for both risk types. However, this RS equilibrium will be second-best efficient, i.e. Pareto-optimal within the set of feasible allocations, only if $(1-q)/q > \delta^{WMS}$, where δ^{WMS} is itself larger than δ^{RS}.[23] Otherwise - even if a RS equilibrium exists, $\delta^{WMS} > (1-q)/q > \delta^{RS}$ - welfare can be improved with low risks subsidizing high risks, so that a WMS equilibrium will result[24]. Below different settings will be examined depending on the proportions of risk types before and after the offer of an information contract.

4.1 Initial RS equilibrium

Suppose that the proportion of high risks is sufficiently high, i.e. $(1-q)/q > \delta^{WMS} > \delta^{RS}$, so that, before the monitoring technology is offered, the initial equilibrium contracts are the RS no-subsidy separating contracts. In Figure 2 these contracts are depicted as C^{HK} for high risks and C^{LA} for low risks. The axes of the preference diagram represent the net wealth in both states of nature. Point N represents the wealth position without insurance, where $W-L$ (W) is the net wealth if an accident (no accident) occurs. As can be seen, both contracts lie on the respective zero-profits

[20] „Equilibrium […] is a set of policies which, if offered in the market, no firm has an incentive to change", Wilson (1977, 169).

[21] Wilson (1977, 169).

[22] Crocker/Snow (1985, 213), see also Wilson (1977, 189).

[23] See Dionne/Doherty/Fombaron (2000, p. 210, 211) and also Crocker/Snow (1985, 213).

[24] See for instance Crocker/Snow (1985, 213).

lines, where π^j has a slope of $-(1-p^j)/p^j$[25], $j \in \{L, H\}$. Thus both risk types pay actuarially fair premiums. But while high risks receive full insurance (C^{HK} lies on the certainty line), low risks get less than full coverage. Compared to a situation with symmetric information (C^{LK} in Figure 2), adverse selection makes low risks worse off .

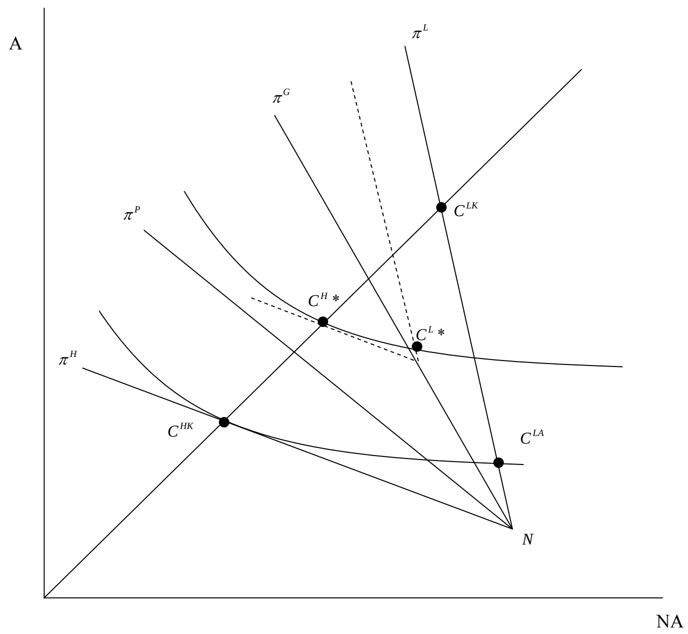

Figure 2: initial RS equilibrium

The acceptance of a monitoring technology will put low risks into the position to "signal" their type to the insurer. By assumption, their driving style is always careful, so that the more information they reveal, the more they will be able to distinguish from high risks, since the more difficult it becomes for high risks to mimic them. Hence, more information revealed will result in low risks approaching complete insurance coverage. Insofar information has a value in the sense that it Pareto-improves welfare[26]. However, if low risks accept an information contract, their decision about the quantity of information will be a trade-off between the positive effect of reducing information asymmetry and the negative effect of losing privacy. In an analogous manner, for high risks disclosing information the trade off will be between the chance of being able to

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[25] The slope of the iso-profit line is found by totally differentiating the expected profits $\bar{\pi} = p^j \cdot \pi(A) + (1-p^j)\pi(NA)$, by which $d\pi(A)/d\pi(NA) = -(1-p^j)/p^j$.

[26] According to Fagart/Fombaron (2003, 6) "information has some value if a contract based on the additional information dominates in a Pareto sense any contract ignoring [the] information".

mimic low risks and thus of getting more favorable contract conditions and, as with low risks, the costs of losing privacy.

For the time being it will be assumed that both low and high risks accept the information contract $EV^L(C(i),i) > EU^L(C^{LA})$ and $EV^H(C(i),i) > EU^H(C^{HK})$. This will be verified later.[27]

As was mentioned above, depending on the recorded driving performance during the collection of data, insureds who took the information contract, decide in the end of the period if and how much information to disclose.

Proposition 1: Suppose that both low risk and high risk individuals took an information contract and that in equilibrium low risks disclose $i^* > 0$. Then, (i) if high risks, who are able to mimic low risks at this level of information, reveal any information, they will also disclose $i^H = i^*$; (ii) and high risks who are not able to mimic low risks at this level of information, will not disclose any information, $i^H = 0$.

<u>Proof:</u> i) suppose that in the end of the data collection period a high risk individual is able to mimic the low risks at the equilibrium quantity of information i^* and $0 < i^H < i^*$. The insurer knows, that low risks disclose exactly i^* in equilibrium. For an individual disclosing less than i^*, the insurer will know that it is a high risk. But then the high risk can just as well withhold the information and save unnecessary privacy costs. For $i^H > i^*$, even if a high risk is able to mimic low risks at a higher level of information than the equilibrium one, it is useless to do so. Here too the insurer will know that a low risk reveals exactly i^* in equilibrium, so that an individual disclosing more than that will be identified as a high risk. So, if a high risk, which is able to mimic low risks, reveals any information, he will reveal $i^H = i^*$.

ii) suppose that a high risk individual is not able to mimic the low risks at the equilibrium information level i^* and $i^H < i^*$. By the same argument as before it is useless to reveal any information. For $i^H > i^*$ the argument applies even more so. Hence, a high risk, which is not able to mimic low risks, will not reveal any information $i^H = 0$. □

Corollary 1: There is no such scenario, that high risks disclose information, while at the same time low risks disclose no information.

[27] See proposition 4 for low risks and proposition 5 for high risks.

Proof: Suppose low risks reveal $i^* = 0$ in equilibrium. From the proof of proposition 1 it follows that high risks also reveal $i^H = 0$.

If no one reveals information, actually nothing will change compared to the to the initial equilibrium and the result would be the same as if both risk types had rejected the information contracts from the onset. The conditions for corner solutions $i^* = 0$ and $i^* = 1$ will be examined later, but first low risks revealing $0 < i^* < 1$ will be considered.

Thus, for any $i^* \in (0,1)$ submitted by low risks in equilibrium, high risks will either disclose $i^H = i^*$ or $i^H = 0$. Hence, from the viewpoint of the insurer, in the end of the data collection period, there will be two groups of insureds – one group disclosing information and the other group disclosing no information. Since low risks will be in the group disclosing information, it will be called the good risk group (G). The group of insureds who reveal no information, will be called the bad risk group (B) and as it has already been argued, it will contain no low risks, $q_B = 0$. In case that high risks never disclose information, no matter if they are ex post able to mimic low risks or not, the good risk group (G) will consist only of low risks, so that the insurer can offer to them the first-best contract with full insurance C^{LK}. As shall be seen later, this scenario will never occur.[28] In case that high risks, which are ex post able to mimic low risks at the equilibrium information level i^*, do reveal this quantity of information, from the viewpoint of the insurer the proportions of risk types in both risk groups will be as follows. The bad risk group (B) will consist only of high risks $(1 - q_B) = 1$, namely of those, whose records are unsuited to mimic low risks. The good risk group (G) will consist of all low risks and those of the high risks, which ex post discover their ability to mimic low risks. Hence, the proportions for this group will be $(1 - q_G^*) = [(1 - i^*) \cdot (1 - q)]/[(1 - i^*) \cdot (1 - q) + q]$ for high risks and $q_G^* = q/[(1 - i^*) \cdot (1 - q) + q]$ for low risks. The implications of this reasoning can be seen graphically in Figure 2. The pooling zero-profit line for the initial RS equilibrium is presented by π^P. It has a slope of $-(1 - p^P)/p^P$, where $p^P = (1 - q) \cdot p^H + q \cdot p^L$ is the average probability of accident of all individuals in the population. The pooling zero-profit line for the good risk group is denoted by π^G. It has a slope of $-[1 - p(i^*)]/p(i^*)$, where

$$p(i^*) = \frac{(1 - i^*) \cdot (1 - q)}{(1 - i^*) \cdot (1 - q) + q} \cdot p^H + \frac{q}{(1 - i^*) \cdot (1 - q) + q} \cdot p^L$$

[28] See proposition 5.

is the average probability of accident for the good risk group (G). As can be seen, it is steeper than the initial one, since the proportion of high risks in this group is smaller than the proportion of high risks in the population. At $i^*=0$ π^G coincides with π^P, so that the resulting information contracts coincide with the initial RS equilibrium contracts. At $i^*=1$ π^G coincides with π^L: the good risk group will contain low risks only, since by assumption the probability for high risks to mimic low risks, when complete information is revealed, is zero. In this case the resulting contract is the first-best for low risks C^{LK}. For $i^* \in (0,1)$ larger equilibrium quantity of information will imply a smaller proportion of high risks in this group, hence a steeper slope of π^G. For the equilibrium contracts in this group (G) it again depends on the proportions of risk types, which equilibrium will persist. Suppose that the quantity of information $i' \in (0,1)$ is chosen by low risks, such that the proportion of high risks in this group is still larger than the critical value δ^{WMS}, i.e. $(1-q_G')/q_G' = [(1-i')\cdot(1-q)]/q > \delta^{WMS}$. Then the RS equilibrium will still be second best efficient, so that, within this group (G), the optimal contracts will be again C^{HK} and C^{LA}. But individuals will anticipate this result when considering the revelation of information. If there is no change in the contract set after the revelation of data, it makes no use revealing any information at all. Hence, low risks will either disclose no information $i^*=0$, or they will disclose a level of information large enough $i^*>i'$ to promote a WMS equilibrium, where i^* is chosen such, that $(1-q_G^*)/q_G^* = [(1-i^*)\cdot(1-q)]/q < \delta^{WMS}$ holds. In this case, in equilibrium the WMS cross-subsidizing contracts will result, which are depicted in Figure 2 as C^{H*} for high risks and C^{L*} for low risks. A first reasonable conjecture is, that it might be optimal for low risks not to reveal any information $i^*=0$, when the proportion of high risks in the population is exorbitantly large and the amount of information, which would be necessary to entail a WMS-cross subsidizing equilibrium, would incur too much costs in order for that information to be worth revealing.

Proposition 2: Suppose that in equilibrium $i^*>0$. High risks, which do not disclose any information in equilibrium, will be offered C^{HK}.

Proof: This is a direct consequence of the fact that for the bad risk group (B) it holds that $(1-q_B)=1$, i.e. $(1-q_B)/q_B > \delta^{WMS}$, by which the initial RS equilibrium results. Since there are only high risks in this group, the only contract, which will be offered within this group will be C^{HK}. The intuition for this result is as follows. As shown by Rothschild/Stiglitz (1976) a contract for high risks with only partial insurance cannot be optimal.[29] Hence, the contract offered to individuals in the bad risk group must lie on

[29] In the case of a monopolistic market this is shown by Stiglitz (1977, 418-419).

the certainty line. Suppose that insurers offer a contract $C^{HK}{}'$ to the northeast of C^{HK}, having a loss with this particular contract. It will imply that, in order for the insurers to earn zero profits on the whole portfolio of contracts, the insureds in the good risk group have to subsidize insureds in the bad risk group. If this is an equilibrium, according to the definition of a WMS equilibrium, there must not exist another contract set outside this equilibrium, that if offered, would earn a non-negative profit even after the unprofitable portfolios in the original set have been withdrawn. But consider an insurer offering the menu C^{HK}, C^{H*}, C^{L*} for instance. Since with this menu, insureds in the good risk group (G) do not have to pay a subsidy, they will prefer it (remember, it was assumed that there is no commitment) and the insurers still offering $C^{HK}{}'$ will incur a loss and will have to withdraw it. Hence, $C^{HK}{}'$ cannot constitute an equilibrium. The same arguments apply to the case that a contract is offered to high risks, which lies to the southwest of C^{HK}. Only the menu of contracts C^{HK}, C^{H*}, C^{L*} satisfies the definition of a WMS equilibrium.

Now suppose, that high risks rejected the information contract from the outset. Given that low risks have accepted it and reveal $i^* > 0$ in equilibrium, the insurer will immediately recognize high risks as such. Since there is no commitment, he will offer in the second period C^{HK} to them. □

4.2 Optimization Problem

Formally the optimal contracts C^{H*}, C^{L*} in Figure 2 are found by maximizing the expected utility of low risks under the zero-profit constraint of the insurer and self-selection constraint for the good risk group G.[30]

$$(1) \qquad \max_{r^H, d^L, r^L, i} \quad p^L \cdot u(W - L - r^L + d^L) + (1 - p^L) \cdot u(W - r^L) - g(i)$$

The indemnity for high risks d^H as a choice variable has been omitted here, since it has already been shown, for instance by Crocker/Snow (1985, 210), that the contract resulting for high risks implies complete insurance, $d^H * = L$.[31] Besides that the program determines the equilibrium contracts $C^{L*} = (d^L*, r^L*)$ and $C^{H*} = (L, r^H*)$, low risks also decide, how much information to reveal in equilibrium. More information will increase the costs related to the loss of privacy. But it will also decrease the proportion of high risks in the good risk group and result in more insurance coverage for low risks. Still, as long as $i^* < 1$, insurers cannot distinguish high risks from low risks in the group reveal-

[30] See Crocker/Snow (1985) for a formal analysis of the WMS equilibrium.

[31] See also Spence (1978, 434).

ing information, so that a self-selection constraint is needed to assure that high risks choose the contract designed for them.

(2) $$u(W-r^H) \geq p^H \cdot u(W-L-r^L+d^L)+(1-p^H)\cdot u(W-r^L)$$

From Proposition 2 it follows that in equilibrium the insurers have to earn zero profits within each risk group. For group G this means that the zero-profit constraint

(3) $$\frac{(1-i)\cdot(1-q)}{(1-i)\cdot(1-q)+q}\cdot(r^H-p^H\cdot L)+\frac{q}{(1-i)\cdot(1-q)+q}\cdot(r^L-p^L\cdot d^L)\geq 0$$

must hold. Since by construction, $i \leq 1$, the optimization is also subject to

(4) $$1-i \geq 0$$

The solution to this problem can be found using the Kuhn-Tucker Conditions (see section A1 of the appendix).

For $i^* \in (0,1)$ it is straightforward to show, that both the self-selection constraint (2) as well as the zero-profit constraint (3) are active, and in addition two more equalities hold in the maximum:

(5) $$\frac{(1-q)(1-i^*)}{q}=\frac{u'(W-r^H*)\cdot\left[u'(W-L-r^L*+d^L*)-u'(W-r^L*)\right]}{u'(W-r^L*)\cdot u'(W-L-r^L*+d^L*)}\cdot\frac{(1-p^L)\cdot p^L}{(p^H-p^L)}$$

(6) $$g'(i^*)=\frac{(1-p^L)\cdot u'(W-r^L*)\cdot u'(W-r^H*)\cdot(1-q)\cdot(p^H\cdot L-r^H*)}{q\cdot(1-p^L)\cdot u'(W-r^H*)+(1-i^*)\cdot(1-q)\cdot(1-p^H)\cdot u'(W-r^L*)}$$

The first equality (5) is analogous to the usual optimality condition for a WMS equilibrium[32], except that here the proportion of high risks depends on the amount of information i^*, which is revealed in equilibrium. The second equality (6) states that the marginal disutility of revealing information must be equal to the marginal utility of doing so. From a normative point of view it is interesting to check the conditions, under which it is optimal for low risks, once they have accepted the information contract, to reveal complete information. In section A2 of the appendix it is shown that a sufficient condition for $i^*=1$ is

(7) $$g'(1)\leq\frac{(1-q)}{q}\cdot u'(W-p^L\cdot L)\cdot L\cdot(p^H-p^L).$$

[32] See Rothschild/Stiglitz (1976, 645).

As can be seen, the larger the right hand-side of this inequality, the more probable is it that it is satisfied. In other words, the higher the monetary value of the loss, which might occur, the larger the difference between the probabilities of accident of low risks compared to high risks, the larger the proportion of high risks in the population and the larger the marginal utility of net wealth, the more is it probable that low risks will disclose complete information in equilibrium.

A direct result of the Kuhn-Tucker Conditions, which is proved in section A3 of the appendix, is stated in

Proposition 3: For the good risk group (G) the RS no-subsidy equilibrium contracts, $r^i = p^i \cdot L$, $i \in \{H, L\}$, result if and only if $i^* = 0$.

This is a restatement of the above reasoning that, if expected utility of low risks is maximized by keeping the initial RS contracts, then it is no use revealing any information, and, the other way round, information is revealed only if it entails cross-subsidizing contracts that lead to some benefits to balance the disutility from losing privacy.

In order to get a better understanding of what factors determine the size of $i^* \in (0,1)$, it seems reasonable to use an alternative specification for the maximization problem (1)-(4). The optimal contracts C^{H*} and C^{L*} for group G can also be found by means of the optimal subsidy problem, which was first used by Rothschild/Stiglitz (1976, 644). In equilibrium high risks receive a subsidy s, so that the effective insurance premium for high risks is $r^H * = r^{HK} - s = p^H \cdot L - s$. Low risks pay a tax t in order to subsidize high risks, so that $r^L * = r^L + t = p^L \cdot d^L * + t$. In order for the zero-profit constraint to be satisfied, it must hold, that the tax paid by all low risks in the good risk group has to cover the subsidy paid to all high risks in this group,

(8) $$t = s \cdot \frac{(1-i^*)(1-q)}{q}, \; s \geq 0 .$$

The equilibrium contract set is found by choosing d^L, i, and s to maximize

(9) $$\max \; p^L \cdot u(A^L) + (1-p^L) \cdot u(NA^L) - g(i)$$

(10) s.t. $$u(W - p^H \cdot L + s) \geq p^H \cdot u(A^L) + (1-p^H) \cdot u(NA^L)$$

(11) $$1 - i \geq 0,$$

where $A^L = W - L + (1-p^L) \cdot d^L - t$ is the net wealth pertaining to contract C^{L*} in case that an accident occurs, and $NA^L = W - p^L \cdot d^L - t$ is the no-accident net wealth with this contract.

After solving it (see section A4 of the appendix), one gets, that the self-selection constraint (10) is binding and the following optimality conditions for $i^* > 0$:

$$(12) \qquad \frac{(1-i^*)\cdot(1-q)}{q} = \frac{u'(W-p^H\cdot L+s)\cdot[u'(A^L)-u'(NA^L)]}{u'(A^L)\cdot u'(NA^L)}\cdot\frac{p^L\cdot(1-p^L)}{p^H-p^L}$$

$$(13) \qquad g'(i^*) = s\cdot(p^H-p^L)\cdot\frac{(1-q)}{q}\cdot\frac{u'(A^L)\cdot u'(NA^L)}{p^H\cdot(1-p^L)\cdot u'(A^L)-(1-p^H)\cdot p^L\cdot u'(NA^L)}.$$

Equation (12) is identical to (5) and (13) provides an alternative way compared to (6) to specify the marginal utility of revealing information. Given that low risks prefer the information contract to the no-subsidy RS contract, the equilibrium quantity of information is likely to be larger, when the right hand side of (12) (of (13)) is smaller (larger). i^* is larger, when (i) the difference between the probabilities of accident of the risk types is large, (ii) the proportion of high risks in the population is large, (iii) the equilibrium subsidy per high risk is large, (iv) the risk-aversion of insureds is low, i.e. the difference $[u'(A^L)-u'(NA^L)]$ is small. These conditions are characterized by Rothschild/ Stiglitz (1976, 637) in their analysis of the non-existence of a RS no-subsidy equilibrium. According to the authors, the more these conditions apply, the higher are the "costs of pooling" and the lower are the "costs of separating" from the viewpoint of low risks, and hence, the more likely is it, that, as a result, a no-subsidy RS equilibrium will persist.[33] Particularly, they show that the sufficient condition for a RS equilibrium to be second-best efficient is

$\frac{(1-q)}{q} > \frac{u'(W-p^H\cdot L+s)\cdot[u'(A^L)-u'(NA^L)]}{u'(A^L)\cdot u'(NA^L)}\cdot\frac{p^L\cdot(1-p^L)}{p^H-p^L}$, where $s=0$. The right hand side of this inequality is equal to δ^{WMS}.[34]

From all said it follows, that once low risks find it optimal to reveal a positive level of information, the more likely it is for a RS no-subsidy equilibrium to result at a given level of information, the more it pays for low risks to reveal an even higher level of information and create a WMS cross-subsidizing equilibrium. The reasoning is as follows: when the proportion of high risks in the population is high, then the benefit of low risks from reducing the proportion of high risks in the good risk group (G) is also larger.

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[33] Higher costs of pooling arise, when there are many high risks to be subsidized (ii), or the subsidy per high risk is large (i), (iii). Separating costs are related to the risk-aversion (iv) of insureds and hence to the "individual's inability to obtain complete insurance", Rothschild/Stiglitz (1976, 637).

[34] See Rothschild/Stiglitz (1976, 645) and also Crocker/Snow (1985, 212-215).

Hoy (1982, 335) has shown that a decreasing proportion of high risks in a particular categorization group leads to an increase of the per capita subsidy in this group. So a higher equilibrium s in (13) corresponds to a smaller proportion of high risks in the good risk group (G) and hence, to a greater level of coverage for low risks. The smaller the proportion of high risks in the good risk group, which results from the revelation of information, the more advantageous it will be for low risks to disclose that information. With strongly differing probabilities of accident of both risk types, a RS no-subsidy equilibrium will entail less coverage for low risks than with weakly differing probabilities of accident[35]. Hence the benefit of low risks from "signaling" their risk type to the insurer by revealing information will be greater. The same argument applies to lower risk-aversion, which also entails less coverage in a RS no-subsidy equilibrium.

A question, which has not been answered yet, is, when the equilibrium level of information that low risks choose will be positive, i.e. when the monitoring technology will be accepted by insureds. Intuitively this will be the case, if the disutility from revealing information is not too large or, alternatively, if for a given disutility function the proportion of high risks is not too large. This is stated in

Proposition 4: Low risks will accept the information contract, i.e. $i^* > 0$, if and only if $\left.\frac{\partial EU^L(C^{L*})}{\partial i}\right|_{i^{WMS}} \geq g'(i)\big|_{i^{WMS}}$, where i^{WMS} is the minimum level of information necessary to trigger a WMS cross-subsidizing equilibrium.

Proof: As stated above, low risks will reveal information, if and only if thereby they can trigger a WMS cross-subsidizing equilibrium. For a set of parameters p^L, p^H, L, W and utility function $u(w)$, let δ^{WMS} be the critical ratio of high risk individuals to low risk individuals for a WMS cross-subsidizing equilibrium to be second-best efficient. Starting from an initial RS no-subsidy equilibrium is equivalent to $(1-q)/q > (1-q^{WMS})/q^{WMS} = \delta^{WMS}$. Let $i^{WMS} > 0$ be the minimum level of information, which is just necessary to trigger a WMS cross-subsidizing equilibrium, i.e. $(1-q)\cdot(1-i^{WMS})/q = \delta^{WMS}$. Only if at that level of information the marginal increase of contractual utility from reducing the proportion of high risks in the good risk group (G)

[35] Consider the self-selecting constraint (12), which is active in equilibrium. Holding everything else constant, a marginal increase of the probability accident of high risks $p^H{}' > p^H$ will cause the left hand side to decrease and the right hand side to increase. Hence, for the equation to hold with $p^H{}'$, it must be that the net wealth in the state of accident must decrease and the net wealth in the no-accident state must increase, which implies lower coverage.

is larger or equal to the marginal increase of the utility loss from the additional information,

i.e. $\left.\frac{\partial EU^L(C^{L*})}{\partial i}\right|_{i^{WMS}} \geq g'(i)\big|_{i^{WMS}}$, will low risks reveal $i^* \geq i^{WMS} > 0$. If the reverse is true,

$\left.\frac{\partial EU^L(C^{L*})}{\partial i}\right|_{i^{WMS}} < g'(i)\big|_{i^{WMS}}$, it will be optimal for low risks to reveal $i^* < i^{WMS}$, but in this case there will be no switch to a WMS cross-subsidizing equilibrium and as stated above (proposition 3), low risks will reject the information contract, $i^* = 0$.□

As can be seen, i^{WMS} is increasing in $(1-q)/q$. Due to the assumption that $g''(i) > 0$ for $i > 0$, $g'(i^{WMS})$ is increasing i^{WMS}, and hence it is increasing in $(1-q)/q$. This effect is amplified, if the size of $g''(i)$ for any i is large. Thus, the probability, that low risks will prefer revealing no information, $i^* = 0$, becomes larger.

Up to now it was taken for given, that high risks, who ex post discover the ability to mimic low risks, will do so and hence, that ex ante high risks will just as well accept the information contract. This assumption will now be proved in

Proposition 5: Given that it is optimal for low risks to reveal $i^* \in (0,1)$, then high risks (i) will also accept the information contract (ii) they will also reveal i^*, if they find out, that they are able to mimic low risks, (iii) they will also be better off choosing the information contract compared to the initial RS equilibrium.

Proof: Low risks choosing $i^* \in (0,1)$ implies that low risks prefer the information contract to the conventional RS contract, i.e. $EV^L(C^{L*}, i^*) > EV^L(C^{LA}, 0) \Leftrightarrow$

$$EU^L(C^{L*}) - g(i^*) > EU^L(C^{LA}) \Leftrightarrow$$

$$p^L \cdot u(W - L - r^L* + d^L*) + (1-p^L) \cdot u(W - r^L*) - g(i^*) >$$
$$p^L \cdot u(W - L - r^{LA} + d^{LA}) + (1-p^L) \cdot u(W - r^{LA})$$

$$\Leftrightarrow \quad p^L \cdot [u(W - L - r^L* + d^L*) - u(W - L - r^{LA} + d^{LA})] - g(i^*) >$$
$$(1-p^L) \cdot [u(W - r^{LA}) - u(W - r^L*)]$$

As $p^H > p^L$ and $(1-p^H) < (1-p^L)$, it follows that

$$p^H \cdot [u(W - L - r^L* + d^L*) - u(W - L - r^{LA} + d^{LA})] - g(i^*) >$$
$$(1-p^H) \cdot [u(W - r^{LA}) - u(W - r^L*)]$$

$\Leftrightarrow \quad EU^H(C^L*) - g(i*) > EU^H(C^{LA})$. But from the self-selection constraint (2), we know that $EU^H(C^H*) = EU^H(C^L*)$ and for the initial RS equilibrium it must also hold that $EU^H(C^{HK}) = EU^H(C^{LA})$. Hence

(14) $\quad EU^H(C^{H*}) - g(i*) > EU^H(C^{HK})$

This inequality states that, if high risks have accepted the information contract in the beginning of the data collection period and they find out in the end of that period, that they are able to mimic low risks with the equilibrium quantity of information $i*$, then their expected utility of doing so will be strictly larger than the expected utility of withholding the collected information (ii).

(i) For the decision, which contract to accept, high risks compare the ex ante expected utility of the information contract with the ex ante expected utility of the conventional contract C^{HK}. They will prefer the information contract, if

(15) $\quad (1-i*)\cdot EU^H(C^{H*}) + i*\cdot EU^H(C^{HK}) - (1-i*)\cdot g(i*) > EU^H(C^{HK})$

If they accept the information contract, high risks know, that in the end of the data collection period they will be able to mimic low risks only with a probability of $(1-i*)$. In this case they will incur the costs of losing privacy $g(i*)$ and get the contract C^H*. With probability $i*$ they will not be able to mimic low risks with the equilibrium quantity of information $i*$ and, as was shown, in this case they reveal no information (proposition 1) and get the contract C^{HK} (proposition 2). The other way round, keeping the conventional contract implies getting C^{HK} with certainty. After some transformation it can be seen, that inequality (15) is equivalent to inequality (14), which is always satisfied. Thus, given that it is optimal for low risks to disclose $i* \in (0,1)$, high risks will also accept the information contract.

(iii) the statement follows directly from (15) which is equivalent to $EV^H(C^{H*}, i*) - EV^H(C^{HK}, 0) > 0$.□

4.3 Welfare Effects

As shall be seen, especially in section 4.4, the assumption, that there is no commitment on either side will be crucial for the welfare effects.

In case that it is optimal for low risks not to reveal any information, $i* = 0$, which is equivalent to low risks' rejecting the information contract, there will be no change to either risk type compared to the initial equilibrium.

In case that it is optimal for low risks to reveal $i^* = 1$, high risks with certainty will not be able to mimic low risks at this quantity of information. Since they anticipate this result at the decision stage, they might just as well reject the information contract. In equilibrium the first-best contracts C^{HK} and C^{LK} will persist in the second period. For high risks nothing will have changed through the offer of a monitoring technology, low risks will get full insurance. Even though they suffer the costs of losing privacy $g(1)$, the fact that their expected utility is maximized at $i^* = 1$ implies that these costs are outweighed by the positive effect of the transition to full insurance. So, on the whole, the offer of the monitoring technology will lead to a Pareto-improvement of welfare.

In case that it is optimal for low risks to reveal $i^* \in (0,1)$, it was shown above, that high risks will also accept the information contract and reveal i^*, if they are able to mimic low risks at this quantity of information, and reveal no information in case that they are not able to mimic low risks. In the second period insurers will offer the contract menu C^{HK}, C^{H*} and C^{L*}. For high risks, which are categorized in the bad risk group (B), nothing will change compared to the initial contract. Considering only the contractual expected utility from the equilibrium information contracts (C^{H*}, C^{L*}) in the good risk group (G), both low risks and high risks, which are categorized in this group, are better off than with the former conventional contract set (C^{HK}, C^{LK})[36]: although low risks have to pay a subsidy to high risks, on the whole, because of the higher coverage, their expected utility increases compared to the initial contract C^{LA}. High risks with C^{H*} are better off, since they have to pay less than fair premium. For their decision problem, how much information to reveal, low risks consider also the costs of losing privacy, and the choice of an equilibrium level of information $i^* \in (0,1)$ implies that the costs are outweighed by the positive effect of revealing information also in this case. As was shown in proposition 4 (14), this also applies to high risks in the good risk group (G). Low risks get the contract C^{L*} with certainty, so that ex ante their expected utility from the information contract is larger than the expected utility from the former conventional contract C^{LA}. From an ex ante point of view high risks also have a larger expected utility from the information contract compared to the former conventional contract C^{HK} (see (15)). Therefore, the offer of a monitoring technology leads to a Pareto-type improvement of welfare both from an ex post as well as from an ex ante point of view.[37]

[36] See Hoy (1982, 331, 335).

[37] Recall, high risk,s who cannot mimic low risks, do not submit information and so do not incur any privacy costs.

It can be followed from the above results, that the all-or-nothing nature of the voluntary monitoring, which is currently offered by some insurers, can be efficient only in case that it is optimal for individuals to reveal no ($i^*=0$) or complete ($i^*=1$) information. Otherwise, offering insureds a monitoring technology with fixed quantity of information will not be efficient.

4.4 Initial WMS equilibrium

Now suppose that the proportion of high risks is smaller than the critical value for second-best efficiency of a RS equilibrium, $(1-q)/q<\delta^{WMS}$. Thus, before insurers offer a monitoring technology, a WMS cross-subsidizing equilibrium persists[38]. In Figure 3 the equilibrium conventional contracts are denoted by C^{HS} for high risks and C^{LS} for low risks. The argumentation is very similar to that in the last sections. Since propositions 1 to 3 were not related to the specific type of initial equilibrium, they apply also in this case. As shown below, proposition 4 is redundant for an initial WMS equilibrium. Proposition 5 also pertains to an initial RS equilibrium and has to be checked separately.

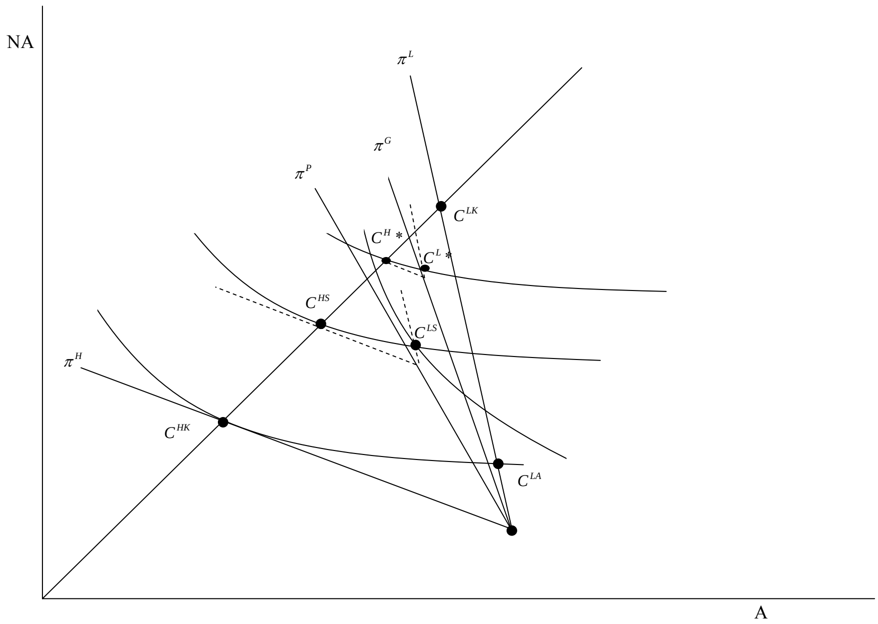

Figure 3: initial WMS cross-subsidizing equilibrium

[38] See Hoy (1982, 334).

By proposition 1, if the information contracts are accepted in equilibrium and information is disclosed at all, it will be $i*$ regardless of the risk type revealing that information. Again we will first assume that both low risks and high risks accept the information contract, and high risks who ex post discover that they are able to mimic low risks, indeed reveal the equilibrium information quantity $i*$. This will be verified in proposition 6. By proposition 1 high risks, who are not able to mimic low risks, will not reveal any information and by proposition 2 they will be recognized as high risks by insurers and will be offered C^{HK} for the second period. Hence, the reasoning is identical to the case of initial RS equilibrium and the optimal contracts for the good risk group can be found formally by solving the maximization problem (1) to (4). By proposition 3 the revealed information for low risks can be zero, if and only if the equilibrium premiums for both risk types are actuarially fair. This is the crucial point for the case of an initial WMS cross-subsidizing equilibrium. As it is characterized by $(1-q)/q < \delta^{WMS}$, actuarially fair premiums will never result in equilibrium, not even for $i*=0$. Hence, from proposition 3 it directly follows that

Corollary 2: If the initial equilibrium is the WMS cross-subsidizing one, low risks will always accept the information contract and the equilibrium quantity of information will always be positive $i*>0$.

Keeping in mind, that high risks, who accept the information contract, take the risk of getting C^{HK} instead of the initial subsidized contract C^{HS}, it is not as straightforward as in the last sections to see, that they will also accept the information contract. But this is proved in

Proposition 6: In case that it is optimal for low risks to reveal $i*<1$, high risks (i) will also accept the information contract and (ii) they will also reveal $i*$, if they find out ex post that they are able to mimic low risks.

The formal proof, which is analogous to the proof of proposition 5, is found in section A5 of the appendix. But the intuition is very simple and based on the assumption that there is no commitment on the part of the insurers. As soon as insurers update their beliefs concerning the risk type of the insureds, they adjust the contract set to be offered the next period. No matter if insureds have rejected the contract, or if they do not reveal any information after having accepted it, given that low risks reveal $i*>0$ in equilibrium, high risks, who do not reveal $i*$, will immediately be identified as such and will be offered C^{HK}. Since by accepting the information contract, high risks have the chance of being able to mimic low risks, they will do so.

Concerning the welfare effects of offering an optional information contract to insureds, the results differ from those in section 4.3. As was shown, with initial WMS equilibrium it is always optimal for low risks to reveal non-zero quantity of information, $i^* > 0$, and thus the information contracts will always be accepted. As in section 4.3, being categorized into the good risk group (G) makes low risks better off than with the former conventional contract C^{LS}.[39] Ex ante the contractual expected utility of low risks from the information contract is equivalent to getting C^{L*} with certainty, so that low risks are better off with the information contract than with the former conventional contract. High risks being categorized into the good risk group (and getting C^{H*}) are better off than with C^{HS} (see (A.13) in the appendix). But if they are ex post unable to mimic low risks, they get C^{HK}, which makes them worse off compared to the original contract. So, ex ante high risks face a lottery over the contracts C^{H*} and C^{HK}. The question, if the offer of a monitoring technology improves their welfare from an ex ante point of view, can be answered after comparing the ex ante expected utility from the lottery

(16) $$EV^H(C(i^*), i^*) = (1-i^*)\cdot EU^H(C^{H*}) + i^* \cdot EU^H(C^{HK}) - (1-i^*)\cdot g(i^*)$$

and the expected utility from the original contract $EU^H(C^{HS})$.

As is proved in section A6 of the appendix, it always holds that:

(17) $$EV^H(C(i^*), i^*) < EU^H(C^{HS})\text{, for all } i^* (0,1]$$

Hence, if the initial equilibrium is a WMS cross subsidizing one, high risks will be made worse off when a monitoring technology is offered. It is interesting to notice that, due to the assumption of no commitment, this result holds no matter if high risks accept or reject the information contract, i.e. the voluntary nature of the monitoring technology cannot prevent from making high risks worse off.

5 Conclusions

The development of sophisticated monitoring technologies in recent years has allowed some automobile insurers to offer to their customers voluntary observation of driving in order to calculate their individual risk and insurance premiums. Thereby the adverse effects of information asymmetries, i.e. incomplete insurance, can be reduced. However, a challenge, which naturally arises with monitoring, is the loss of privacy.

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[39] The welfare implications of categorization when the initial equilibrium is pooling, respectively cross-subsidizing are illustrated by Hoy (1982, 329, 335).

Focusing on the problem of adverse selection, this paper examines the implications of offering such monitoring technologies in a perfectly competitive insurance market without commitment. At the same time the analysis incorporates the inherent costs related to the loss of privacy. The possibility is examined, that insureds not only have the choice between conventional contracts and contracts with monitoring, but that they also have the freedom to choose the quantity or quality of information they reveal to the insurer. This assumption is justified by the current efforts of engineering research to find technological solutions, which allow individuals to determine the accuracy and scope of the revealed data. When individuals are able to determine how much or which kind of information to reveal to the insurer, it is straightforward to assume, that high risk individuals will select those pieces of information, by which they can mimic low risk individuals.

In this setting the incentives of individuals to reveal information, the factors which determine their decision, the resulting equilibria and welfare effects are analyzed. The analysis is performed both for the case, that before the offer of a monitoring technology the conventional contracts, which persist in equilibrium, are the Rothschild/Stiglitz no-subsidy contracts, and for the case that the initial contracts are the Wilson-Myazaki-Spence cross-subsidizing contracts. It was shown that with an initial RS equilibrium, the information contracts might be rejected and that with an initial WMS equilibrium individuals will always accept the monitoring technology. It was also found that, once the information contracts are accepted, more information will be revealed in equilibrium, when from the viewpoint of low risk individuals the costs of pooling are high and the costs of separating are low. This presumes strongly differing probabilities of accident between risk types, a large proportion of high risks in the population and low risk aversion of individuals. It was shown that, a larger quantity of information revealed in equilibrium entails a higher coverage for low risks, i.e. a better allocation of risk from an efficiency point of view. The conditions were derived, under which it will be optimal for individuals to reveal complete information. In this case the resulting contracts in equilibrium will be those, which would result under symmetric information, i.e. the first-best ones. As a consequence, the offer of all-or-nothing monitoring options will not be efficient unless it is optimal for individuals either to reject the monitoring technology or to reveal complete information. Another result was that the welfare effects depend on the type of the initial equilibrium contracts. If the initial equilibrium contracts are the Rothschild/Stiglitz no-subsidy ones, the offer of a monitoring technology, if it is accepted, Pareto-improves welfare. In this case, from an ex ante point of view, both low risk individuals and high risk individuals are made better off through the offer of voluntary monitoring. However, if the initial equilibrium contracts are Wilson-Myazaki-

Spence cross-subsidizing, the welfare implications are ambiguous. While low risks are still made better off both from an ex ante and from an ex post point of view, high risk individuals might be made better off from an ex post point of view with some probability, but they will be made worse off with certainty from an ex ante point of view. Hence, no Pareto-type improvement takes place in this case.

Appendix

A1 Optimal Contracts Problem (1)-(4)

Denoting by Z the Lagrangian, we get the following first-order conditions:

(A.1) $$\frac{\partial Z}{\partial r^H} = -\lambda_1 \cdot u'(W - r^H) + \lambda_2 \cdot (1-i) \cdot (1-q) = 0$$

(A.2) $$\frac{\partial Z}{\partial d^L} = p^L \cdot u'(W - L - r^L + d^L) - \lambda_1 \cdot p^H \cdot u'(W - L - r^L + d^L) - \lambda_2 \cdot q \cdot p^L = 0$$

(A.3) $$\frac{\partial Z}{\partial r^L} = -p^L \cdot u'(W - L - r^L + d^L) - (1 - p^L) \cdot u'(W - r^L)$$
$$+\lambda_1 \cdot [p^H \cdot u'(W - L - r^L + d^L) + (1 - p^H) \cdot u'(w - r^L)] + \lambda_2 \cdot q = 0$$

(A.4) $$\frac{\partial Z}{\partial i} = -g'(i) - \lambda_2 \cdot (1-q) \cdot (r^H - p^H \cdot L) - \mu \le 0 \,,\; i \ge 0 \,,\; \frac{\partial Z}{\partial i} \cdot i = 0$$

(A.5) $$\frac{\partial Z}{\partial \lambda_1} = u(W - r^H) - p^H \cdot u(W - L - r^L + d^L) - (1 - p^H) \cdot u(W - r^L) \ge 0 \,, \qquad \lambda_1 \ge 0 \,,$$
$$\frac{\partial Z}{\partial \lambda_1} \cdot \lambda_1 = 0$$

(A.6) $$\frac{\partial Z}{\partial \lambda_2} = (1-i) \cdot (1-q) \cdot (r^H - p^H \cdot L) + q \cdot (r^L - p^L \cdot d^L) \ge 0 \,,\; \lambda_2 \ge 0 \,,\; \frac{\partial Z}{\partial \lambda_2} \cdot \lambda_2 = 0$$

(A.7) $$\frac{\partial Z}{\partial \mu} = 1 - i \ge 0 \,,\; \mu \ge 0 \,,\; \frac{\partial Z}{\partial \mu} \cdot \mu = 0$$

After some transformation it can be shown that $\lambda_j > 0$, hence $\frac{\partial Z}{\partial \lambda_j} = 0$, $j = 1,2$. Specifically we get for the multipliers

$$\lambda_2 = \frac{(1 - p^L) \cdot u'(W - r^H) \cdot u'(W - r^L)}{[(1-i) \cdot (1-q) \cdot (1 - p^H) \cdot u'(W - r^L) + q \cdot (1 - p^L) \cdot u'(W - r^H)]} \text{ and}$$

$$\lambda_1 = \frac{(1-i) \cdot (1-q) \cdot (1 - p^L) \cdot u'(W - r^L)}{[(1-i) \cdot (1-q) \cdot (1 - p^H) \cdot u'(W - r^L) + q \cdot (1 - p^L) \cdot u'(W - r^H)]}.$$

After substituting the above terms into the first-order conditions, the optimality condition (5) is derived from (A.2). And the optimality condition (6) is derived from (A.4).

A2 Derivation of eq. (7)

Suppose $i^*=1$. From the first-order condition (A.6) it follows that $r^L{}^* = p^L \cdot d^L{}^*$, i.e. low risk premium is actuarially fair. In order for the optimality condition (5)

$$0 = \frac{u'(W-r^H{}^*)\cdot\left[u'(W-L-r^L{}^*+d^L{}^*)-u'(W-r^L{}^*)\right]}{u'(W-r^L{}^*)\cdot u'(W-L-r^L{}^*+d^L{}^*)}\cdot\frac{(1-p^L)\cdot p^L}{(p^H-p^L)}$$

to be satisfied, the right hand side of the equality must be zero, which is only possible when $d^L{}^* = L$ (complete insurance for low risks). Inserting these results into the first-order condition (A.4), we get

$g'(1)+\mu = \frac{(1-q)}{q}\cdot u'(W-p^L\cdot L)\cdot L\cdot(p^H-p^L)$, from which it follows

$$g'(1) \le \frac{(1-q)}{q}\cdot u'(W-p^L\cdot L)\cdot L\cdot(p^H-p^L).$$

A3 Proof of Proposition 3

$r^j{}^* = p^j\cdot d^j{}^*,\ j\in\{H,L\} \Leftrightarrow i^*=0$

- If

For $i^*=0$ it follows that $\frac{\partial Z}{\partial\mu} = 1-i^* > 0$ and hence $\mu=0$. After inserting $i^*=0$ into the first-order conditions, for (A.4) we get

$$g'(0) \ge \frac{(1-q)\cdot(1-p^L)\cdot u'(W-r^H)\cdot u'(W-r^L)}{[(1-q)\cdot(1-p^H)\cdot u'(W-r^L)+q\cdot(1-p^L)\cdot u'(W-r^H)]}\cdot(p^H\cdot L-r^H).$$

Since $g'(0)=0$ by construction, the condition can be satisfied only if $p^H\cdot L - r^H{}^* = 0$. But then, from (A.6) it follows that $r^L{}^* - p^L\cdot d^L{}^* = 0$. □

- Only if

Suppose in equilibrium $r^H{}^* = p^H\cdot L$. Then (A.4) is transformed to

$\frac{\partial Z}{\partial i} = -g'(i)-\mu \le 0$, $i\ge 0$, $\frac{\partial Z}{\partial i}\cdot i = 0$. Suppose now that $i^*>0$. For the first-order condition to be satisfied it follows that $\frac{\partial Z}{\partial i} = -g'(i^*)-\mu = 0$. But $\mu\ge 0$ and $g'(i)>0$ for

$i > 0$ by construction. Hence $i^* > 0$ cannot be a solution. Only for $i^* = 0$ the first-order condition $\frac{\partial Z}{\partial i} = -g'(0) \le 0$ is satisfied. □

Similarly it can be shown that $i^* > 0 \Leftrightarrow r^H{}^* < p^H \cdot L$ and $r^L{}^* > p^L \cdot d^L{}^*$.

A4 Optimal Subsidy Problem (9)-(11)

The solution is analogous to A1. The first-order conditions for the maximization problem are

(A.8) $$\frac{\partial Z}{\partial d^L} = p^L \cdot u'(A^L) \cdot (1-p^L) - (1-p^L) \cdot u'(NA^L) \cdot p^L$$
$$+\lambda \cdot [-p^H \cdot u'(A^L) \cdot (1-p^L) + (1-p^H) \cdot u'(NA^L) \cdot p^L] = 0$$

(A.9) $$\frac{\partial Z}{\partial s} = -p^L \cdot u'(A^L) \cdot \frac{(1-i)\cdot(1-q)}{q} - (1-p^L) \cdot u'(NA^L) \cdot \frac{(1-i)\cdot(1-q)}{q}$$
$$+\lambda \cdot [u'(W - p^H \cdot L + s) + p^H \cdot \frac{(1-i)\cdot(1-q)}{q} \cdot u'(A^L)$$
$$+(1-p^H) \cdot \frac{(1-i)\cdot(1-q)}{q} \cdot u'(NA^L)] \le 0,\ s \ge 0,\ \frac{\partial Z}{\partial s} \cdot s = 0$$

(A.10) $$\frac{\partial Z}{\partial i} = p^L \cdot u'(A^L) \cdot \frac{(1-q)}{q} \cdot s + (1-p^L) \cdot u'(NA^L) \cdot \frac{(1-q)}{q} \cdot s - g'(i)$$
$$-\lambda \cdot \frac{(1-q)}{q} \cdot s \cdot [p^H \cdot u'(A^L) - (1-p^H) \cdot u'(NA^L)] - \mu \le 0,\ i \ge 0,\ \frac{\partial Z}{\partial i} \cdot i = 0$$

(A.11) $$\frac{\partial Z}{\partial \lambda} = u(W - p^H \cdot L + s) - p^H \cdot u(A^L) - (1-p^H) \cdot u(NA^L) \ge 0,\ \lambda \ge 0,\ \frac{\partial Z}{\partial \lambda} \cdot \lambda = 0$$

(A.12) $$\frac{\partial Z}{\partial \mu} = 1 - i \ge 0,\ \mu \ge 0,\ \frac{\partial Z}{\partial \mu} \cdot \mu = 0$$

From (A.8) it follows that $\lambda = \frac{p^L(1-p^L) \cdot [u'(A^L) - u'(NA^L)]}{p^H \cdot (1-p^L) \cdot u'(A^L) - p^L \cdot (1-p^H) \cdot u'(NA^L)} > 0$ and hence $\frac{\partial Z}{\partial \lambda} = 0$. Similarly to section A1 it can be shown that $i^* = 0 \Leftrightarrow s = 0$. For $i^* > 0$ and $s > 0$ the optimality conditions (12) and (13) are derived.

A5 Proof of proposition 6

Since in equilibrium low risks reveal $i^* > 0$, they prefer the information contract C^{L*} to the conventional contract C^{LS}, i.e. $EV^L(C^L{}^*, i^*) > EV^L(C^{LS}, 0)$. $\Leftrightarrow$

$$p^L \cdot u(W - L - r^L*) + (1 - p^L) \cdot u(W - r^L*) - g(i*) >$$
$$p^L \cdot u(W - L - r^{LS}) + (1 - p^L) \cdot u(W - r^{LS})$$

$$\Leftrightarrow \quad p^L \cdot [u(W - L - r^L * + d^L*) - u(W - L - r^{LS} + d^{LS})] - g(i*) >$$
$$(1 - p^L) \cdot [u(W - r^{LS}) - u(W - r^L*)]$$

As $p^H > p^L$ and $(1 - p^H) < (1 - p^L)$, it follows that

$$p^H \cdot [u(W - L - r^L * + d^L*) - u(W - L - r^{LS} + d^{LS})] - g(i*) >$$
$$(1 - p^H) \cdot [u(W - r^{LS}) - u(W - r^L*)]$$

$\Leftrightarrow EU^H(C^{L*}) - g(i*) > EU^H(C^{LS})$. Due to the self-selection constraints for the initial WMS cross subsidizing equilibrium and for the optimal contracts in the good risk group, we have $EU^H(C^{HS}) = EU^H(C^{LS})$ and $EU^H(C^{H*}) = EU^H(C^{L*})$. Hence it holds that

(A.13) $EU^H(C^{H*}) - g(i*) > EU^H(C^{HS})$.

But it also holds that $EU^H(C^{HS}) > EU^H(C^{HK})$, since with C^{HS} while still getting full insurance, high risks have to pay less than fair premium. Hence we have that

(A.14) $EU^H(C^{H*}) - g(i*) > EU^H(C^{HK})$.

This inequality is identical to (14) and states that once high risks discover, that they are able to mimic low risks at $i*$, they will have a higher expected utility from doing so than from withholding the information.

From an ex ante point of view high risks will accept the information contract if the expected utility from doing so is larger than the expected utility from rejecting the information contract. Since low risks reveal a non-zero amount of information in equilibrium, individuals, who reject the information contract, will be recognized as high risks by insurers. Due to the assumption of no commitment, insurers will adjust the contract set for the next period and will offer C^{HK} to individuals who reveal no information. So, ex ante high risks anticipate that the former equilibrium contract C^{HS} will be withdrawn and replaced by C^{HK}. They will accept the information contract, if

(A.15) $(1 - i*) \cdot EU^H(C^{H*}) + i* \cdot EU^H(C^{HK}) - (1 - i*) \cdot g(i*) > EU^H(C^{HK})$

This is identical to (A.14) and, as was shown, will always hold.

A6 Proof of inequality (17)

By substituting $i^* = 1$ into (16) we get

(A.16) $EV^H(C(1),1) = EU^H(C^{HK}) < EU^H(C^{HS})$, i.e. for $i^* = 1$ inequality (17) holds.

It was argued, that i^* cannot be zero in the optimum, but we can check what the expected utility from the lottery is equal to, if the optimal quantity of information is near zero. It can be verified that that

(A.17) $\lim_{i^* \to 0} EV^H(C(i^*), i^*) = \lim_{i^* \to 0} EU^H(C^{H^*}) = EU^H(C^{HS})$.

The last equality is due to the fact that for $i \to 0$, $C^{H^*} \to C^{HS}$ (see Figure 3).

Having (A.16) and (A.17), if we show that $EV^H(C(i^*), i^*)$ is continuously decreasing for all $i^* \in (0,1)$, inequality (17) will be proved. Differentiating (16) with respect to the optimal quantity of information and relocating the terms yields

(A.18) $$\frac{dEV^H(C(i^*), i^*)}{di^*} = -[EU^H(C^{H^*}) - g(i^*)] + EU^H(C^{HK})$$

$$+(1-i^*) \cdot [\frac{dEU^H(C^{H^*})}{di^*} - g'(i^*)].$$

From (A.14) it follows that the first term on the right side of the equation is negative. The sign of the second term is determined as follows.

Low risks choose the optimal amount of information such that in the optimum marginal utility of the resulting contract is just equal to the marginal disutility of the revealed information. Thus, it must hold that

(A.19) $$\frac{dEU^L(C^{L^*})}{di^*} = g'(i^*).$$

As the self-selection constraint is binding for high risks in the optimum, we know that

(A.20) $EU^H(C^{H^*}) = EU^H(C^{L^*})$, and therefore $\frac{dEU^H(C^{H^*})}{di^*} = \frac{dEU^H(C^{L^*})}{di^*}$

where $EU^H(C^{L^*}) = p^H \cdot u(A^L) + (1-p^H) \cdot u(NA^L)$

and $EU^L(C^{L^*}) = p^L \cdot u(A^L) + (1-p^L) \cdot u(NA^L)$.

For $i^* < 1$ we know, that low risks get less than full insurance, i.e. $u(A^L) < u(NA^L)$. Combined with $p^H > p^L$ this implies that $EU^H(C^{L*}) < EU^L(C^{L*})$. Due to risk aversion it follows that

$$\text{(A.21)} \quad \frac{dEU^H(C^{L*})}{di^*} > \frac{dEU^L(C^{L*})}{di^*}$$

From (A.19) and (A.20) we have

$$\text{(A.22)} \quad \frac{dEU^H(C^{H*})}{di^*} > g'(i^*) .$$

Thus, the second term in (A.18) is positive and overall the sign of the right hand-side of the equation is not clear. But we can proceed in the same way and show, that

$$\text{(A.23)} \quad \left. \frac{dEV^H(C(i^*),i^*)}{di^*} \right|_{i^*=1} < 0$$

$$\text{(A.24)} \quad \lim_{i^*\to 0} \frac{dEV^H(C(i^*),i^*)}{di^*} = -\lim_{i^*\to 0} EU^H(C^{H*}) + \lim_{i^*\to 0} \frac{dEU^H(C^{H*})}{di^*} <$$

$$< -\lim_{i^*\to 0} EU^H(C^{H*}) + \lim_{i^*\to 0} \frac{dEU^L(C^{H*})}{di^*} = -EU^H(C^{HS}) < 0 ,$$

where the inequality of the last transformation is due to (A.20) and (A.21). Using (A.19) we get that $\lim_{i^*\to 0} \frac{dEU^L(C^{H*})}{di^*} = \lim_{i^*\to 0} g'(i^*) = 0$. We also know that $\lim_{i^*\to 0} EU^H(C^{H*}) = EU^H(C^{HS})$, whereby (A.24) is negative.

In order to show, that $\frac{dEV^H(C(i^*),i^*)}{di^*} < 0$ for all $i^* \in (0,1]$ we will argue as before and show, that it is continuously decreasing in i^* for all $i^* \in (1,0)$.

$$\text{(A.25)} \quad \frac{d^2EV^H(C(i^*),i^*)}{di^{*2}} = -2 \cdot [\frac{dEU^H(C^{H*})}{di^*} - g'(i^*)]$$

$$+(1-i^*) \cdot [\frac{d^2EU^H(C^{H*})}{di^{*2}} - g''(i^*)] < 0 ,$$

where the first term is negative due to (A.22) and in the second term due to risk aversion, $\frac{d^2EU^H(C^{H*})}{di^{*2}} < 0$.

Thus, from (A.23), (A.24) and (A.25) it follows that $\frac{dEV^H(C(i^*), i^*)}{di^*} < 0$ for all $i^* \in (0,1)$ which in combination with (A.16) and (A.17) proves inequality (17). □

References

Acquisiti, A. / Varian, H. (2005), Conditioning Prices on Purchase History, Marketing Science, 24(3), 367-381

Buzzacchi, L. / Valletti, T. M. (2005), Strategic price discrimination in compulsory insurance markets, The Geneva Risk and Insurance Review, Vol. 30(1), 71-97

Calzolari, G. / Pavan, A. (2006), On the Optimality of Privacy in Sequential Contracting, forthcoming, Journal of Economic Theory, 2006

Crocker, K. / Snow, A. (1992), The Social Value of Hidden Information in Adverse Selection Economies, Journal of Public Economics, Vol. 48, 317-347

Crocker, K. / Snow, A. (2000), The Theory of Risk Classification, in: Dionne (Edt.), Handbook of Insurance, Boston u.a., Kluwer Academic Publishers, 245-276

Crocker, K. J. / Snow, A. (1985), The Efficiency of Competitive Equilibria in Insurance Markets with Asymmetric Information, Journal of Public Economics 26, 207-219

Crocker, K. J. / Snow, A. (1986), The Efficiency Effects of Categorical Discrimination in the Insurance Industry, Journal of Political Economy, Vol. 94(2), 321-344

Dionne, G. / Doherty, N. / Fombaron, N. (2000), Adverse Selection in Insurance Markets, in: Dionne, G. (Edt.), Handbook of Insurance, Boston u.a., Kluwer Academic Publishers, 187-243

Dodds, S. (2002), Privacy and Endogenous Monitoring Choice When Private Information is a Public Good, Working Paper 1010, Queen's Institute for Economic Research, Queen's University, http://qed.econ.queensu.ca/pub/papers/abstracts/download/2002/1010.pdf

Doherty, N. / Posey, L. (1998), On the Value of a Checkup: Adverse Selection, Moral Hazard and the Value of Information, The Journal of Risk and Insurance, Vol. 65(2), 189-211

Doherty, N. / Thistle, P. (1996), Adverse Selection with Endogenous Information in Insurance Markets, Journal of Public Economics, Vol. 63, 83-102

Duri, S. / Elliot, J. et al. (2004), Data Protection and Data Sharing in Telematics, Mobile Networks and Applications, Vol. 9(6), 693-701

Fagart, M.-C. / Fombaron, N. (2003), Value of information and Prevention in Insurance Markets, http://www.aria.org/rts/rts2004/fagartfombaron.pdf

Filipova, L. / Welzel, P. (2005), Reducing Asymmetric Information in Insurance Markets: Cars with Black Boxes, Discussion Paper No. 270, Augsburg University

Hermalin, B. / Katz, M. (2005), Privacy, Property Rights and Efficiency: The Economics of Privacy and Secrecy, Haas School of Business, University of California at Berkeley, http://faculty.haas.berkeley.edu/katz/Privacy,%20Property%20Rights%20&%20Efficiency%20posted.pdf

Hirshleifer, J. (1980), Privacy, Its Origin, Function and Future, Journal of Legal Studies, Vol. 9, 649-666

Hoy, M. (1982), Categorizing Risks in the Insurance Industry, The Quarterly Journal of Economics, Vol. 97, 1982, 321-336

Hoy, M. (2005), Risk Classification and Social Welfare, Discussion Paper 2005-8, University of Guelph, http://www.economics.uoguelph.ca/econ/Research/DisPapers/2005_8.pdf

Hoy, M. / Lambert, P. (2000), Genetic Screening and Price Discrimination in Insurance Markets, The Geneva Papers on Risk and Insurance Theory, Vol. 25(2), 103-130

Hui, K.-L. / Png, I. P. L. (2005), The Economics of Privacy, Handbook of Information Systems and Economics, T. Hendershott, ed. Elsevier, 2005, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=786846

Jiang, X. / Hong, J. / Landay, J. (2002), Approximate Information Flows: Socially-Based Modeling of Privacy in Ubiquitous Computing, In: Proceedings of the 4th international conference on Ubiquitous Computing (2002), Göteborg, Sweden, p. 176-193, Springer-Verlag

Posner, R. A. (1978), Privacy, Secrecy, and Reputation, Working Paper No. 004, Center for the Study of the Economy and the State, University of Chicago,

Posner, R. A. (1981), The Economics of Privacy, American Economic Review, Vol. 71(2), 405-409

Rothschild, M. / Stiglitz, J. (1976), Equilibrium in Competitive Insurance Markets: An Essay on the Economics of Imperfect Information, The Quarterly Journal of Economics, Vol. 90, 629-649

Spence, A. M. (1978), Product Differentiation and Performance in Insurance Markets, Journal of Public Economics, Vol. 10., 427-447

Stigler, G. J. (1980), An Introduction to Privacy in Economics and Politics, Journal of Legal Studies, Vol. 9, 623-644

Stiglitz, J. (1977), Monopoly, Non-linear Pricing and Imperfect Information: The Insurance Market, Review of Economic Studies, Vol. 44(3), 407-430

Taylor, C. (2004), Privacy and Information Acquisition in Competitive Markets, Berkeley Program in Law & Economics, Working Paper Series, Paper 164, http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1165&context=blewp

Taylor, C. R. (2002), Private Demands and Demands for Privacy: Dynamic Pricing and the Market for Customer Information, Duke Economics Working Paper 02-02, Duke University, http://www.econ.duke.edu/Papers/Other/Taylor/private.pdf

Varian, H. (1996), Economic Aspects of Personal Privacy, in Privacy and Self-Regulation in the Information Age, National Telecommunikations and Information Administration: Washington, D.C., http://www.sims.berkeley.edu/~hal/Papers/privacy/

Wilson, C. (1977), A Model of Insurance Markets with Incomplete Information, Journal of Economic Theory, Vol. 16, No. 2, 167-207