Does Adverse Selection Matter?
- Evidence from a Natural Experiment*

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Abstract

The empirical evidence of adverse selection in insurance markets is mixed. The problem in assessing the extent of adverse selection is that private information, on which agents act, is generally unobservable to the researcher, which makes it difficult to distinguish between adverse selection and moral hazard. Unique micro data, from a dental insurance natural experiment, is here used to provide a direct test of selection. All agents in a population were stratified into different risk classes, and were unexpectedly given the opportunity to insure their dental care costs. The setup of the insurance makes it possible to observe a proxy for private information. Interestingly, results differ across risk classes. Within high-risk classes, there is evidence of adverse selection and within low-risk classes, the results, surprisingly, indicate an advantageous selection. This dual selection can explain the limited empirical evidence for adverse selection in insurance markets in the literature: the two effects may balance out on the aggregate level. The paper also presents a model of insurance choice that can harbor both adverse and advantageous selection. The pattern in the data is explained by differences in the effectiveness of prevention across high and low risk classes.

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1 Introduction

Economists typically regard insurance markets to be inhibited by asymmetric information when the insured part is better informed about risks than the insurer. Akerlof (1970) showed that asymmetric information is a potent source of market failure. High risks may drive out low risks, resulting in an adverse selection death spiral. Rothschild and Stiglitz (1976), in turn, pointed out that markets can mitigate this type of asymmetric information, but at the price of low risks being under-insured.

Adverse selection in insurance markets has been given considerable theoretical attention. The question is, however, how large the problem is in practice; that is, do people have private information on risk and do they act on it? The empirical evidence of adverse selection as a source of market failure in insurance markets is still limited, see Chiappori and Salanié (2003). In part, this is due to problems measuring private information available to the policy holder, but not to the insurer, making it difficult to distinguish adverse selection from moral hazard in the analysis. An observed relation between health insurance coverage and health care expenditures need not be the result of adverse selection, but might just as well be due the higher demand for services, that follows with more extensive coverage. To separate adverse selection from moral hazard, health risks need to be exogenous to insurance status. Apart from the methodological problems, the lack of clear evidence in the literature is also due to inconclusive empirical results; this is also true for markets where health risks are insured.[1]

This study provides a direct test of selection using unique data from a dental insurance natural experiment. In 1999, the National Dental Service in Värmland, Sweden, gave a population of dental patients the possibility to sign a full-coverage dental insurance. Prior to 1999, no voluntary dental insurance was available to this population, and the introduction of the insurance scheme was unexpected from the patients' perspective. Dental health was therefore exogenous to the introduction of the insurance,

[1]For example, Cutler and Reber (1998), Thomasson (2002), Finkelstein and Poterba (2002), and Godfried, Oosterbeek and Tulder (2001) find evidence of adverse selection, while Cameron and Trivedi (1991), Cawley and Philipson (1999), Cardon and Hendel (2001), Buchmueller and DiNardo (2002), Finkelstein and McGarry (2003), and Pauly et al. (2003) do not find any, or only limited, evidence of adverse selection.

constituting a natural experiment. The setup of the insurance and the recurrent characteristic of dental problems make it possible to observe a proxy for private information. Interestingly, the results differ across risk classes and there is direct evidence of both adverse and advantageous selection, the latter implying that agents with low risk are more inclined to buy insurance. Some evidence consistent with advantageous selection is also found by Finkelstein and McGarry (2003) and Cawley and Philipson (1999).

The lack of conclusive empirical evidence in the literature has led to arguments for why adverse selection may not be a major problem in insurance markets. de Meza and Webb (2001) model a situation where the propensity to take precaution increases with the degree of risk aversion, resulting in low risks buying extensive coverage, albeit at an actuarially unfair premium, while high risks go under-insured, i.e. advantageous selection. Their analysis is, here, extended by letting the effectiveness of prevention vary. The theoretical model presented in this paper is cast in a setting that mimics the dental insurance in Värmland, and can simultaneously harbor both adverse and advantageous selection; that is, advantageous selection in low risk classes and adverse selection in high risk classes, just as observed in the data.

This dual selection observed in the data, and captured by the model, may explain the limited empirical evidence of adverse selection in insurance markets, as the two effects balance out on the aggregate level. The next section describes the voluntary dental insurance in Värmland, and the setting where it is cast. Section three presents a theoretical framework of the decision to purchase insurance. Data, econometric framework, and estimations are presented in section four. In the final section, the results are discussed and related to the theoretical framework.

2 A dental insurance natural experiment

Dental care in Sweden is covered by a public dental insurance, providing coverage from the year a patient turns 20.[2] Dental care is provided both by private, mainly self-employed, dentists and by the National Dental Service. Both private and public dentists are affiliated to the public dental insurance. Within the National Dental

[2] Up to the age of 19, patients are provided with free dental services.

Service, dentists are employed with a fixed salary, and have therefore no direct private economic gain from increasing revenues or reducing cost.

The public dental insurance was originally designed as a progressive subsidy, where the level of the subsidy was increasing with higher treatment costs. Over time, both the progressiveness and the level of subsidy has gradually been reduced. In 1999, the public dental insurance was reformed, and a linear subsidy providing a coverage of 30 percent was introduced (Olsson, 1999). So, individuals have, over time, become more exposed to the risk of high dental care costs.

In order to reduce this risk exposure, the National Dental Service in the county of Värmland, Sweden, introduced a voluntary private dental insurance in January 1999, supplementing the public insurance. All their patients were offered to subscribe to dental care; that is, at a fixed annual fee, a subscription contract provides free dental services during a two-year contract period. The dental care subscription is, in effect, a full-coverage voluntary dental insurance provided by a public monopolist.

An interesting feature with this insurance is that it was offered to a whole population of patients, who previously had not been able to buy a supplementary insurance. Dental health, at the time the insurance was launched, would therefore be exogenous to the insurance choice. The potential for moral hazard in anticipation of the insurance was negligible, as the introduction was unexpected from the patients' perspective: it only reached the general public from August 1998. Moreover, officials at the National Dental Service in Värmland state that the option of voluntary insurance was mainly brought to patients' attention by their dentist after January 1st 1999, and the possibility of moral hazard, ex-ante, is even further reduced by the fact that agents did not know their would-be premium before January 1999. With dental health being exogenous to the insurance choice, the introduction of the voluntary dental insurance constitutes a natural experiment, and any systematic difference between purchasers and non-purchasers would be due to selection.

The price of a subscription contract is based on the patient's dental risk and is set after an oral examination of the patient. The oral examination evaluates dental risk in four dimensions (general risk, technical risk, caries risk, and parodental risk) and for each dimension there are 6 to 8 risk indicators, where each indicator is rated on a four-graded scale. Based on the sum of these scores, patients are clustered into one of 16 risk classes. Contracts are priced according to risk class, with the annual prices in 1999 ranging from 295 SEK (32 EURO) for the lowest risk class to 11 000 SEK (1 200 EURO) for the highest. The dental service in Värmland only uses these risk indicators when assessing risk, and does not take explicit account of realized dental costs.

Risk classes are also used by the dental service in Värmland to assess the dental status of the population.[3] Roughly 60 percent of all registered patients had a valid risk classification in 1999, and where thus offered to purchase insurance. Around 23 percent of these patients, 6 888 individuals, bought a dental subscription in 1999. Within each risk class, it is therefore possible to compare individuals purchasing insurance, with those who did not. Note also that dentists within the National Dental Service do not have any direct private economic interest in the insurance, as they are employed with a fixed salary.

The main dental problem, caries, can be characterized as a life-long infectious disease. Caries arises when bacteria on the teeth produce acid, gradually dissolving the enamel on the surface of the teeth. Eventually, this may result in a cavity; that is, the bacteria will penetrate the tooth and make the pulp inflamed. Every time we eat something, the harmful acid is produced and will be active for around half an hour. Caries is a relatively slow process and with preventive activities, it can be stopped or even reversed at an early stage, e.g. with tooth brushing, dental flossing and fluoride rinsing.

If a person has a history of prior caries, he has a higher probability of getting new problems. Bacteria will easily grow if the enamel has been coarsened by prior caries, or grow in the seam between a prior filling and the tooth. Further, a filled tooth will need future maintenance or replacement, and is also more fragile. Consequently, dental care utilization has been observed to have a high correlation over time (see, for example, Powell 1998). Past dental consumption would therefore be a good measure of dental care risk and future dental care consumption.

If agents have private information about their dental risk, this could be proxied

[3]The ambition is that all patients should be classified, but this is a slow process as patients come for check-up visits annually or every second year.

with past dental care consumption, since the National Dental Service in Värmland does not explicitly use past dental care utilization in their risk assessment. Now, even if patients are clustered into 16 risk classes, there is still heterogeneity among patients within each risk class, and since prior use of dental care is a predictor of future use, it would capture the intra-group variation in risk. More specifically, dental costs 1996 to 1998 are used as a proxy for private information, i.e. utilization the three years preceding the insurance. Hence, the impact of asymmetric information in the decision to purchase insurance can be directly observed.

An important question at this stage is whether past dental consumption contains any private information on dental risk. It would be natural to think that the oral examinations would exhaust all information contained in past utilization. To this end, the validity of past dental costs, as a proxy for private information, is assessed by regressing dental costs during the three years 1999 to 2001 on dummy variables for each of the 16 risk classes and on dental costs during the three preceding years, i.e. 1996 to 1998. If the proxy does contain private information, past dental costs should explain future costs in excess of the risk classification.[4]

[Table 1 about here]

Table 1 reports that past dental costs, 1996 to 1998, alone explain 12 percent of the variation in future costs, whereas the risk classification system alone explains 17 percent. The risk classes are better predictors of future dental costs, and contain more information on dental risk, than do past costs. When both past dental costs and risk classes are used as regressors, 21 percent of the variation in costs 1999 to 2001 are explained. Hence, a large part, but not all, of the information contained in past dental consumption is also captured by the risk classification system. There is still scope for private information to act on. Past dental consumption captures an additional 20 percent (3.5 percentage points) of the variation in future dental costs not captured by the risk classification system.

[4] The validity test is conducted on the group of patients who did not purchase insurance during the period 1996 to 2001, 36 241 individuals. The reason for only using non-policyholders is that dental care within the insurance may be influenced by clinical guidelines related to specific risk classes, generating a spurious relation.

3 A model of dental insurance choice

A standard asymmetric information argument would state that high-risk individuals are more inclined to purchase insurance, but this need not be true if agents differ in risk aversion and there is a positive correlation between risk aversion and preventive activities. In this section, insurance choice is analyzed in a model with asymmetric information, accounting not only for differences in risk aversion but also the characteristics of the dental insurance launched in Värmland. The set-up is close to de Meza and Webb (2001), but extended by letting the effectiveness of prevention to vary.

3.1 Prevention and risk aversion

It is easy to find anecdotal evidence consistent with low-risk individuals being more likely to purchase insurance. Hemenway (1990), for example, reports that people with a motor vehicle liability coverage are less likely than others to drink-and-drive, and that members of the American Automobile Association, with on-site car service assistance, have better cars than the average American. Apart from anecdotal evidence, the hypothesis of a positive relation between risk aversion and health precaution is empirically supported by Barsky, Justin, Kimball and Shapiro (1997). From a psychological perspective, the relation between risk aversion and precaution could be due to concordance in agents' underlying preferences, i.e. that some agents are generally averse to risks in life, financial as well as other risks, as argued by Keinan, Meir and Gome-Nemirovsky (1984). However, there is no unambiguous evidence of risk-taking being an overall personality trait; for example, Slovic (1972) argues that the "*majority of evidence argues against the existence of risk-taking propensity as a generalized characteristic of individuals*".

Without the argument of risk-taking being a personality trait, the relation between risk aversion and precaution would be the result of equilibrium behavior in a risky world, as analyzed by Dionne and Eeckhoudt (1985), and Briys and Schlesinger (1990). The general conclusion is that precautionary activity that reduces the potential loss in a bad state, *self-insurance*, is enhanced by risk aversion. For *self-protection*, precautionary activity reducing the probability of the bad state, the relation is not as clear cut. A higher risk aversion does not necessarily imply more self-protection.

In a dental context, precautionary activities can mainly be seen as self-protection; that is, prevention reduces the probability of caries by reducing the likelihood of bacteria penetrating the enamel of a tooth. Once this has occurred, preventive activities do not affect the progress of the cavity.[5] Still, a higher risk aversion will result in more dental prevention. Suppose that agents have a utility function $U(W, F)$, where they obtain utility from general consumption, W, and disutility from precautionary activities, F. Self-prevention is assumed not to enter the agents' budget constraint, as it has a negligible monetary effect on general consumption in a dental context. Instead, the disutility of prevention enters directly as a separate argument in the utility function. The disutility comes from the unpleasantness of preventive activities, for instance it hurts to floss, or that preventive activities may crowd-out more pleasant activities. A second assumption is that the marginal disutility of prevention is unaffected by the level of income, $U''_{12} = 0$. This would imply that prevention like dental flossing is equally painful regardless of income. Under these two assumptions, agents with higher risk aversion unequivocally perform more self-protection.[6]

To see this effect, assume that agents face a financial loss L with probability $1 - P$. The probability is not predetermined, but can be reduced if agents make a precautionary effort; that is, $P = P(F)$, where $P'(F) > 0$ and $P''(F) < 0$. The loss is viewed as a pure financial cost. In the case of a health risk, the loss can be seen as the cost of treatment necessary to regain health, or as the repairing cost necessary to restore teeth to be fit for use. Agents are also assumed to have constant relative risk aversion, i.e. higher wealth reduces the degree of risk aversion. By letting $U(.)$ be a CRRA function, risk aversion can be modelled with an individual-specific taste-parameter, α_i. This parameter is added to the wealth component of the utility function, $U(\alpha_i + W, F_i)$, so

[5] The distinction between self-insurance and self-protection is not razor-sharp, as dental prevention naturally has some self-insurance as well. For example, by reducing the extent of potential tooth loosening, the loss in the bad state is reduced.

[6] With some restrictions on how prevention affects the marginal utility of income, the result would still hold in a more general formulation, see Appendix A.1. Moreover, Dachraoui, Dionne, Eeckhoudt and Godfroid (2003) shows for a general class of utility functions, mixed risk aversion, that even if prevention has a monetary cost, a higher risk aversion does increase the level of self-protection given that the probability of loss is less than one-half.

with a higher α_i, the agent behaves as if he were wealthier. Hence, a higher α_i implies a lower level of risk aversion.

The expected utility for the agent becomes

$$EU_i = P(F_i)U(\alpha_i + W, F_i) + (1 - P(F_i))\, U(\alpha_i + W - L, F_i). \tag{1}$$

Prevention raises the expected utility as it increases the probability of the healthy state, but comes at a cost as prevention induces disutility. From the assumption of marginal disutility of prevention being unaffected by income, $U''_{12} = 0$, there exists an interior maximum optimizing the level of prevention.[7]. By differentiating the first-order condition with respect to F_i and α_i, the marginal effect of risk aversion on precautionary activities is obtained as

$$\frac{\partial F_i}{\partial \alpha_i} = -\frac{P'(F_i)\,[U'_1(\alpha_i + W, F_i) - U'_1(\alpha_i + W - L, F_i)]}{S.O.C.} < 0. \tag{2}$$

This effect is negative, which implies that precautionary effort, F, will increase with the degree of risk aversion. Hence, in equilibrium, prevention is a function of risk aversion, $F_i = F(\alpha_i)$, and more risk averse agents have a higher probability of ending up in the good state than have less risk averse agents.

3.2 Who purchases insurance

Suppose that a voluntary full-coverage insurance is introduced, giving agents the opportunity to avoid risk exposure and smooth out consumption. An agent's risk level is determined by his prior prevention. A problem, however, is that the insurer cannot distinguish between high-risk and low-risk agents, so the premium will be based on the average probability $\Theta = \sum n_k P_k$, where n_k is the number of agents with probability P_k in the population. An actuarially fair full-coverage insurance would give the agent an assured wealth level $Z = \Theta W + (1 - \Theta)(W - L)$ in both states, which will yield him a utility level of $U(\alpha_i + Z, 0)$. Note that the second argument is 0, since the agent will not perform any precautionary activity once he is fully insured.

[7] There can still be an optimal level of prevention if the disutility of prevention increases with the level income or if prevention has a monetary cost, see Appendix A.1.

The certainty equivalence—the certain income level that takes the agent to the same utility level as in the risky world—is defined as

$$\begin{aligned} & U(\alpha_i + C(L, \alpha_i, P_i), 0) && (3) \\ = \; & U(\alpha_i + \tilde{C}(L, \alpha_i, P_i), F(\alpha_i)) \\ = \; & P(\alpha_i) U(\alpha_i + W, F(\alpha_i)) + [1 - P(\alpha_i)] \, U(\alpha_i + W - L, F(\alpha_i)), \end{aligned}$$

where $C(L, \alpha_i, P_i)$ is the certainty equivalence for an agent with loss L, risk aversion α_i, probability P_i, and $F_i = 0$;[8] that is, for an assured wealth of at least $C(L, \alpha_i, P_i)$, the agent is willing to relinquish the higher expected returns of a risky world. Let there also be a loading factor Γ in the insurance, so that the insurance yields $Z - \Gamma$ in both states.[9] The agent will buy the insurance if the wealth, assured from insurance, is higher than the certainty equivalence, $C(L, \alpha_i, P_i) < Z - \Gamma$.

At a given level of risk, the certainty equivalence is lower for an agent with a high degree of risk aversion, than for a peer with lower aversion, as follows directly from the definition of risk aversion. At different levels of risk, but with the same degree of risk aversion, the agent with the highest risk has the lowest certainty equivalent; as can be seen when taking the total differential of equation (3) w.r.t. $C(L, \alpha_i, P_i)$ and P

$$\frac{\partial C(L, \alpha_i, P_i)}{\partial P} = \frac{U(\alpha_i + W, F(\alpha_i)) - U(\alpha_i + W - L, F(\alpha_i))}{U_1'(\alpha_i + C(L, \alpha_i, P_i), 0)} > 0. \qquad (4)$$

Hence, for the same level of risk, more risk-averse agents have a higher demand for insurance than less risk-averse agents. However, agents with higher risk aversion engage in more prevention and will, in effect, face a lower risk, which reduces their demand for insurance.

Lemma 1 *Suppose there are two types of agents; where prudent agents are more risk averse than reckless agents,* $\alpha_R > \alpha_P$*, then for a given difference in risk aversion,* $\alpha_R - \alpha_P = c$*, it follows that:*

[8]Note that $\tilde{C}(L, \alpha_i, P_i)$ is defined at the current level of prevention and $C(L, \alpha_i, P_i)$ is defined at no prevention, and therefore $C(L, \alpha_i, P_i) < \tilde{C}(L, \alpha_i, P_i)$.

[9]The loading factor is interpreted as fixed administration costs in the insurance, e.g. the oral examination, but there may also be loading due to slack in the organization or even mark-up. Another explanation of perceived loading from the agents' perspective can be systematic over-confidence toward dental risks; that is, agents underestimate their dental risks in a systematic way.

i. (Advantageous selection) if the difference in the probability of ending up in the good state is sufficiently small and there is a sufficiently large, but not too large, loading factor, only prudent agents will buy the insurance, i.e. $C(L, \alpha_P, P_P) < Z - \Gamma < C(L, \alpha_R, P_R)$,

ii. (Adverse selection) if the difference in the probability of ending up in the good state is sufficiently large and there is an adequate, possibly infinitely small, loading factor, only reckless agents buy the insurance, i.e. $C(L, \alpha_R, P_R) < Z - \Gamma < C(L, \alpha_P, P_P)$.

Proof. From the definition of risk aversion, it follows that the certainty equivalence is decreasing with risk aversion, and from equation (4), it follows that the certainty equivalence is increasing with the probability of ending up in the good state. So, for a given difference in risk aversion $\alpha_R - \alpha_P = c$, there exists a d such that $C(L, \alpha_P, P_P) < C(L, \alpha_R, P_R)$ for $P_p - P_R < d$, and $C(L, \alpha_R, P_R) < C(L, \alpha_P, P_P)$ for $P_p - P_R > d$.

i. Since $P_R < \theta$, it follows that $Z_R < Z$ where $Z_R = P_R W + (1 - P_R)(W - L)$. Given that reckless agents have at least some risk aversion, it follows from the definition of risk aversion that the certainty equivalence of reckless agents is lower than their expected wealth, i.e. $C(L, \alpha_R, P_R) < Z_R$. Hence, for $P_p - P_R < d$, there exists a loading factor Γ such that $C(L, \alpha_P, P_P) < Z - \Gamma < C(L, \alpha_R, P_R)$.

ii. Since $P_P > \theta$, it follows that $Z < Z_P$ and $C(L, \alpha_P, P_P) < Z_P$ (analogously to i). Hence, for $P_p - P_R > d$ and $C(L, \alpha_P, P_P) < Z$, there exists a loading factor Γ such that $C(L, \alpha_R, P_R) < Z - \Gamma < C(L, \alpha_P, P_P)$. Also, if $P_p - P_R > d$ and $Z < C(L, \alpha_P)$, there exists a loading factor Γ such that $C(L, \alpha_R, P_R) < Z - \Gamma < C(L, \alpha_P, P_P)$, though this factor may be infinitely small. ■

There are four more potential cases not covered in the proposition. These cases are not interesting, since they do not involve a separation between different types of agents; either all or no agents purchase the insurance.[10]

The case with advantageous selection is described in figure 1, where there are only two types of agents; the prudent and the reckless. They differ with respect to risk aversion and the level of risk they face. Here, prudent and reckless agents have the

[10] All agents will buy insurance when $C(L, \alpha_P, P_P) < C(L, \alpha_R, P_R) < Z - \Gamma$, or when $C(L, \alpha_R, P_R) < C(L, \alpha_P, P_P) < Z - \Gamma$. No agent buys insurance if $Z - \Gamma < C(L, \alpha_P, P_P) < C(L, \alpha_R, P_R)$ or if $Z - \Gamma < C(L, \alpha_R, P_R) < C(L, \alpha_P, P_P)$.

same utility level both in the good and the bad state. The concave segment AB, i.e. U, is the utility function of a risk-averse prudent agent. For expositional simplicity, reckless agents are assumed to be risk neutral, so that the linear segment AB, i.e. V, is their utility function. The difference in risk is sufficiently small, given the difference in risk aversion, for prudent agents to have a lower certainty equivalence than reckless agents, $C_P < C_R$. The certainty equivalence of prudent agents is also smaller than the income assured with insurance, $C_P < Z - \Gamma$, so the insurance is worth purchasing, $U^I > U^{NI}$. For the reckless, on the other hand, the insurance is not worth its price, $V^I < V^{NI}$, as their certainty equivalence is larger than the assured insurance income, $Z - \Gamma < C_R$. The loading factor is crucial for obtaining a separation, because a reckless agent will always accept an actuarially fair premium in an insurance market with asymmetric information.

[Figure 1 about here]

The insurance selection effect may be altered for larger differences in risk. In figure 2, there is a larger dispersion in probability, as compared to figure 1, which generates adverse, instead of advantageous, selection, given an adequate loading factor. Due to the larger dispersion in probability, the certainty equivalence of prudent agents is larger than for reckless peers, and even larger than the assured insurance income, $Z - \Gamma < C_P$. Prudent agents will therefore not find the insurance worth buying, $U^I < U^{NI}$. The certainty equivalence of reckless agents, on the other hand, is lower than the insurance income, $C_R < Z - \Gamma$, and they will therefore purchase the insurance, $V^I > V^{NI}$.

[Figure 2 about here]

For a given difference in risk aversion, the difference in risk is not exogenous, but depends on how effective preventive activities are in reducing the probability of loss. More effective prevention will generate a larger difference in probability

$$\frac{\partial P}{\partial \alpha} = \frac{\partial P}{\partial F}\frac{\partial F}{\partial \alpha} = -P'(F)\frac{P'(F)\left[U_1'(\alpha + W, F) - U_1'(\alpha + W - L, F)\right]}{SOC} < 0. \qquad (5)$$

This comes from two sources. First, a more effective prevention has a direct positive effect. Second, with more effective prevention agents with higher risk aversion will increase their preventive effort more, as they have more to gain. Hence, if prevention were totally ineffective, there would be no differences in risk across agents. This means that disparities in prevention would not affect the probability of ending up in the good state, $P'(F) = 0$, and that it would be optimal to not perform any prevention as it would only incur a utility cost, $F'(\alpha) = 0$.

Proposition 1 *For any given difference in risk aversion between prudent and reckless agents,* $\alpha_R - \alpha_P = c$*, it follows that:*
i. (Advantageous selection) if prevention is effective, but not too effective, in increasing the probability of ending up in the good state, there exists a loading factor such that only prudent agents will purchase the insurance, i.e. $C(L, \alpha_P) < Z - \Gamma < C(L, \alpha_R)$*,*
ii. (Adverse selection) if prevention is sufficiently effective in increasing the probability of ending up in the good state, there exists a loading factor such that only reckless agents will purchase the insurance, i.e. $C(L, \alpha_R) < Z - \Gamma < C(L, \alpha_P)$*.*

Proof. Follows from Lemma 1 and equation (5) ■

The general conclusion will essentially hold, even if there are exogenous differences in risk. The exact implication of the exogenous factor will, however, depend on how it is allocated across agents, see Appendix A.2.

So far the analysis is dealing with selection within a given risk class. Now suppose that the insurer has some discriminatory power across risks and can allocate individuals into a high-risk and a low-risk class, and offer them separate insurance contracts. Within each risk class there is still heterogeneity in risk, so there are agents within each risk class who are relatively prudent and relatively reckless, i.e. α_P^i, α_R^i for $i = L, H$. As all variation in risk is driven by differences in precautionary activities, it follows that agents in the low-risk class have invested more in prevention than have their friends in the high risk class. The assumption that marginal productivity of prevention is decreasing, $P''(F) < 0$, therefore implies that prevention is more effective in the high risk class than in the low. From proposition 1 a corollary therefore follows.

Corollary 1 *Let there be two risk classes—low and high—with heterogeneity in risk within each risk class. Then, given (a) any difference in risk aversion within the low-risk class and the high-risk class,* $\alpha_R^L - \alpha_P^L = \alpha_R^H - \alpha_P^H = c$*, and given that (b) prevention*

is effective, but not too effective, in the low-risk class, $C(L, \alpha_P^L) < C(L, \alpha_R^L)$*, and that (c) prevention is sufficiently effective in the high-risk class,* $C(L, \alpha_R^H) < C(L, \alpha_P^H)$*, there exists a loading factor,* Γ*, such that there is;*
(i) advantageous selection in the low-risk class and,
(ii) adverse selection in the high-risk class.

Proof. Follows from proposition 1, equation (2) and decreasing marginal productivity of prevention, $P''(F) < 0$. ■

The corollary tells us that advantageous selection is more likely in the low risk class than the high, while the opposite applies for adverse selection. Also, if there is both adverse and advantageous selection in the insurance scheme, the latter would be found within the low risk class.

4 Data and estimations

4.1 Data

Data comes from an administrative database over dental consumption. The sample consists of risk-classified dental patients aged 22 or older registered with the National Dental Service in Värmland for the period 1996 to 1999, and who had at least one dental visit in 1999. These patients had the opportunity to purchase a contract in 1999. The insurance was mainly brought to the patients' attention by their dentist, so patients without a visit in 1999 may not have taken any active decision on whether to insure and are therefore excluded from the analysis. Patients also need to have been registered with the National Dental Service from 1996, so that their dental care can be tracked through 1996 to 1998.

[Table 2 about here]

Patients are mainly clustered in the low and middle risk classes, and the share of policyholders varies across risk classes, see table 2. None of the policyholders belong to any of the three top risk classes, 14 to 16, and they are therefore excluded from the analysis. The potential sample consists of 49 617 patients, but around 40 percent were not given an offer to buy dental insurance.[11] The final sample therefore consists of 29 544 patients who were directly offered to subscribe to dental care, 6 888—23 percent—of whom signed up for a contract.

Private information on dental risk is proxied with previous dental costs. This variable includes all dental costs from the years 1996 to 1998. Table 2 shows that previous costs rise with higher risk classes and that there is a large variability within each risk class. Descriptive statistics of the variables are reported in table B.1 in Appendix B.

4.2 Econometric model

An agent will purchase insurance if the utility from being insured exceeds the expected utility from being uninsured, $U^I > U^{NI}$. To study if adverse selection is a problem for the dental insurance in Värmland, the model of insurance choice can be characterized as a reduced-form random utility model

$$Prob(y_i = 1) = Prob(U^I > U^{NI}) = Prob(u_i > -\boldsymbol{\beta}'\mathbf{I}_i), \tag{6}$$

where $y_i = 1$ if the agent purchases the insurance. $I = (X, P)$ is the information on dental risk, where X is the public information on which the insurer prices the insurance contracts, and P is private information on risk available to the agent only. The model of insurance choice gives clear reduced-form predictions. In the case of adverse selection, agents with high private dental risk, P, conditional on the insurer's information, X, will buy insurance. With advantageous selection, it is agents with low dental risk, P, conditional on X, who purchase insurance coverage.

Demand for insurance is affected by risk aversion. Now, the mechanism generating advantageous selection is the negative correlation between risk aversion and dental risk, and by controlling for risk aversion, only behavior consistent with adverse selection will be observable, not whether this is balanced out with systematic differences in risk

[11] This is either directly noted by the dentist, or indicated by patients having no risk classification, or the risk assessment being made before 1998. Patients without, or without a valid up-to-date, risk classification are regarded as not having had the opportunity to buy insurance, since they do not know how a potential contract would be priced.

aversion. A problem with adding variables to control for heterogeneity is therefore that they may be related to risk aversion. Variables like gender and age are therefore problematic, since they have a reported relation with risk aversion, see Barsky, Justin, Kimball and Shapiro (1997), and Guiso and Paiella (2003).

There are also other reasons why age and gender are problematic; they may pick up private information not captured by the risk-classification system. The empirical strategy is to analyze the effect of private information, P, conditional on public information, X, in the decision to buy insurance. Adding age and gender to the analysis would, in an econometric sense, be the same as conditioning on more information than contained in X. Unless P is unrelated to age and gender, the estimated effect of P would be biased downwards, as these variables will pick up effects generated by asymmetric information. In fact, table B.2 in Appendix B shows that age and gender is related to past dental costs after controlling for the risk classes. Age and gender is therefore not included in the analysis.

The propensity to purchase insurance varies across dental clinics and dentists, indicating that the attitudes of dentists influence the decision to insure dental risks. Certain clinics may try to influence profitable patients to sign up. Note that dentists do not have any direct economic interest in cream skimming as they are paid a fixed salary. It is possible that, for compassionate reasons, individual dentists try to influence patients with particularly high risks. Either way, it is important to take account of the effect from individual clinics and dentists. To this end, a dummy variable D_c for each clinic c=2,3,...,43 is used. The differences in attitudes across individual dentists are captured through each *Dentist's share* of patients having insurance.

To capture the risk assessed by the National Dental Service, X, a dummy variable D_r is included for each risk class r=2,3,...,13. The effect of private risk, P, is measured by past dental cost, and to observe if the effect of asymmetric information is stable across different levels of risk, an interaction variable $D_g * cost_i$ for class g=1,2,...,13. is used

$$\boldsymbol{\beta}'\mathbf{I}_i = \alpha + \sum_{r=2}^{R} D_r + \sum_{g=1}^{G} \beta_g (D_g * cost_i) + \sum_{c=1}^{C} D_c + \beta_d Dent.share_i. \tag{7}$$

Another issue is whether the sample is random. Not all patients were directly offered to subscribe to dental care by their dentist, which raises the question of whether the sample may be non-random due to sample selection. Suppose dentists would offer the insurance selectively to profitable patients, or selectively to high-risk patients. This would then lead to biased estimates in equation (6), if the selected patients are more inclined to purchase the insurance, than those not selected. To take account of potential sample selection bias a bivariate probit model is estimated, as suggested by Greene (1997)

$$\begin{aligned} Prob(y_{1i} &= 1) = Prob(u_i > -\boldsymbol{\beta}'\mathbf{I}_i), \\ Prob(y_{2i} &= 1) = Prob(v_i > -\boldsymbol{\delta}'\mathbf{Z}_i). \end{aligned} \tag{8}$$

The first line is the random utility model from equation (6) and the second line is a sample selection equation where y_1 is observed only if $y_2 = 1$. The sample selection problem implies that the error terms in the two lines of equation (8) is related, $\rho = cov(u, v) \neq 0$. By estimating the insurance choice and sample selection equations as a bivariate system allowing for u_i and v_i to be bivariate normal distributed with a covariance ρ and independent of I, unbiased estimates of the insurance choice is obtained. In order to identify ρ there has to be an exclusionary restriction in the selection equation; that is, an instrument that is a good predictor of y_{2i} but is independent of the error in the insurance choice equation $E(u|I, Z) = E(u|I)$ (Heckman, Lalonde and Smith, 1999 p. 1957). The observation that the share of patients that were given an offer varies across dentists is used as an exclusionary restriction. As patients with the National Dental Service essentially are allocated randomly to their dentist, and with few patients changing dentist unless they move, any variation in the share of offers across dentists must reflect differences in attitudes and not characteristics of patients. Hence, the dentist's *Share of offers* would not have any direct effect on the insurance purchase, making it a valid instrument. Other covariates used in the sample selection equation are age, gender, dental cost and dummy variables for each clinic.

4.3 Estimations

The results differ across risk classes. In low-risk classes, past dental costs are higher for patients not purchasing insurance. The pattern for high-risk classes is the opposite; insurance purchasers have a higher past dental cost. For intermediate risk classes, the difference in cost is small and the pattern is unclear. Thus, there is evidence of both adverse and advantageous selection in the sample, as displayed in figure 3.

[Figure 3 about here]

Estimates of the insurance choice are reported in table 3. In the simplest model, only dummy variables for the risk classes and a joint cost variable are used to explain insurance choice. The coefficient for the cost variable is positive and significant, indicating adverse selection on the aggregate level. Agents with higher dental costs, in the past, are more likely to purchase dental insurance. When the *dentist's share* of policyholders and a fixed effects for each clinic are added to the analysis, dental cost does not affect the probability of purchasing insurance. This finding, that the cost variable is insignificant when the influence of dentists and clinics is taken into account, may be interpreted as if some dentists actively influence agents with high risk, relative to peers in the same risk class, to buy insurance. Alternatively, there may be patient heterogeneity across clinics not captured by the risk classification.

[Table 3 about here]

When interaction terms are allowed the cost coefficient is negative and significant for the five lowest risk classes, insignificant for risk classes 6 and 7, and then positive and significant for risk classes 8 to 12. In risk class 13, however, the coefficient is negative but insignificant. For agents in the lowest risk classes, the probability of purchasing insurance increases with lower dental costs. For the highest risk classes, the probability of subscribing to dental care increases with the dental costs. Risk class 13 does not fit into the rest of the pattern, but can be explained by the fact that this risk class consists of 332 patients, only 9 of whom have chosen to insure their dental risks. Chance thus has a larger scope.

When the influence of dentists and clinics again is added to the analysis, the results are slightly changed. The cost coefficients are now negative and significant for classes 1 to 7, and positive and at least marginally significant for risk classes 8 to 12. The estimated effect of adverse selection diminishes somewhat, and the effect of advantageous selection increases, when the influence of clinics and dentists is accounted for. It seems as if dentists strengthen the adverse selection effect by influencing patients with a relatively high risk to purchase insurance.

The marginal effects show a stable and systematic pattern, from negative to positive. For low-risk classes, the results are consistent with advantageous selection. For the highest risk classes, on the other hand, the results are consistent with adverse selection.

[Table 4 about here]

To get an impression of the economic significance of the estimated effects in model 4, the probability of buying insurance is first evaluated at the mean cost for each risk class, and then compared to the probability when dental cost is doubled, see table 4.[12] For risk class 2, the probability of purchasing the insurance is reduced by more than a third—from 0.40 to 0.25—when dental cost is doubled from its mean value, while for risk group 11, the probability of insurance purchase is increased with 51 percent—from 0.025 to 0.037.

[Table 5 about here]

Table 5 reports the bivariate probit estimates, when controlling for sample selection bias. In both models, the error covariance, ρ, indicates that sample selection may be a problem, i.e. $\rho = 0$ is rejected. In model 5, the insurance decision is explained with an intercept term and a slope for each risk class, but no controls for dentist or clinic effects. The results are similar to model 3, but for some of the high-risk classes the adverse selection effect no longer reach significance. When the influence of dentists and clinics are added (model 6), the pattern remains almost unchanged.

Correcting for sample selection has little impact on the results. The pattern with advantageous selection in low risk classes and adverse selection in high risk classes is still clear, though the evidence for adverse selection becomes slightly weaker.

5 Discussion

In the face of the mixed empirical evidence of adverse selection in insurance markets, extended mechanisms for selection are called for. de Meza and Webb (2001) present

[12] For each risk class, the mean value of dental cost is roughly the same as the standard deviation.

an argument reversing the conclusion that low risks are under-insured in competitive insurance markets with asymmetric information. Advantageous selection is generated by differences in risk aversion and a causal relation between risk aversion and risk.

The theoretical model presented here extended the analysis by showing that the more (less) effective is prevention, the higher is the likelihood of adverse (advantageous) selection. The analysis was cast in a setting mimicking the dental insurance in Värmland, Sweden.

The overall evidence from the dental insurance natural experiment in Värmland suggests that adverse selection may not be a problem at the aggregate level. The estimated adverse selection is concentrated to high risk classes. In lower risk classes, however, there is evidence consistent with advantageous selection. Here, the probability of purchasing dental coverage is increasing with lower dental risk, measured as past dental care consumption. This latter evidence is consistent with findings of Cawley and Philipson (1999) and Finkelstein and McGarry (2003).

The interesting feature with the present results, though, is the behavioral differences across the sample. The pattern can be contained within the theoretical model, where heterogeneity in risk was generated only through differences in risk aversion. Low risk classes would therefore contain agents with a high degree of risk aversion, whereas high risk classes have less risk averse agents. With a lower preventive effort in high risk classes and a decreasing marginal productivity of prevention, the effectiveness of prevention would be greater in high risk classes. This implies a higher likelihood of adverse selection in high, than in low, risk classes, as follows from corollary 1. Correspondingly, advantageous selection would be more probable in low risk classes than in high.

In practice, however, dental status and dental risk are also influenced by genetic factors, e.g. the quality of saliva. Preventive activities are more effective for agents who are genetically predisposed to caries, as they have more to gain from prevention. The average genetic predisposition to caries would also be worse in high-risk than in low-risk classes, so, on average, the effectiveness of prevention would thus be further reinforced in high-risk classes. This implies that the prediction of adverse selection in high-risk classes, and advantageous selection in low risk classes, is strengthened when genetic factors are taken into account.

Entities such as risk aversion and utility functions cannot be explicitly observed in the data, and therefore it is not possible to directly test the theoretical model. However, the empirical results show evidence of advantageous selection in low risk classes, and adverse selection in high risk classes. These findings can still be reconciled with the predictions of the theoretical framework. The dual selection may explain the limited empirical evidence of adverse selection in insurance markets, as the two effects balance out on the aggregate level.

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Figures

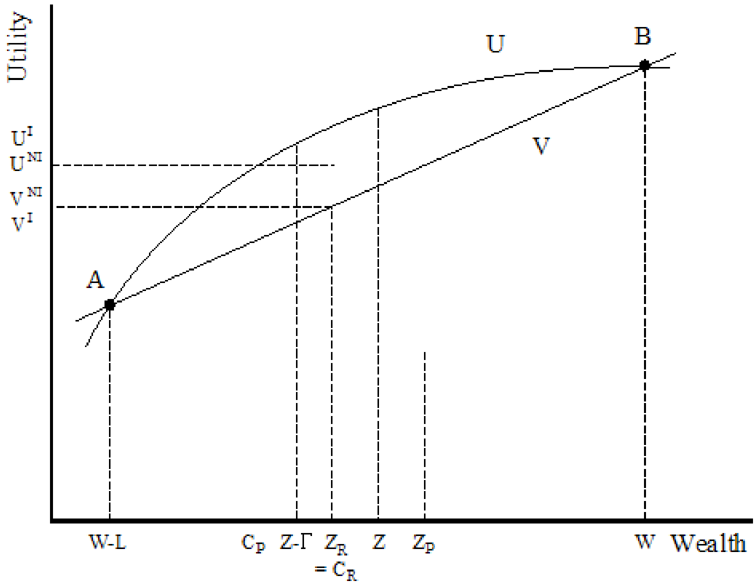

Figure 1: Advantageous Selection

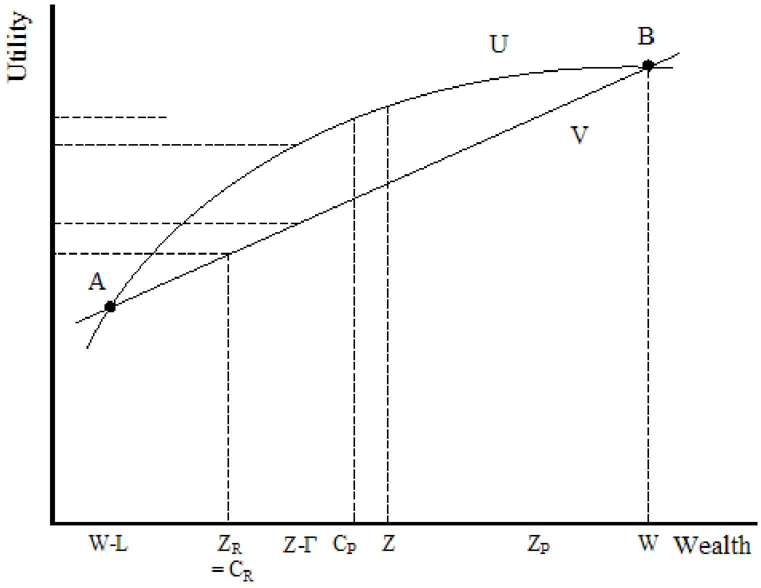

Figure 2: Adverse Selection

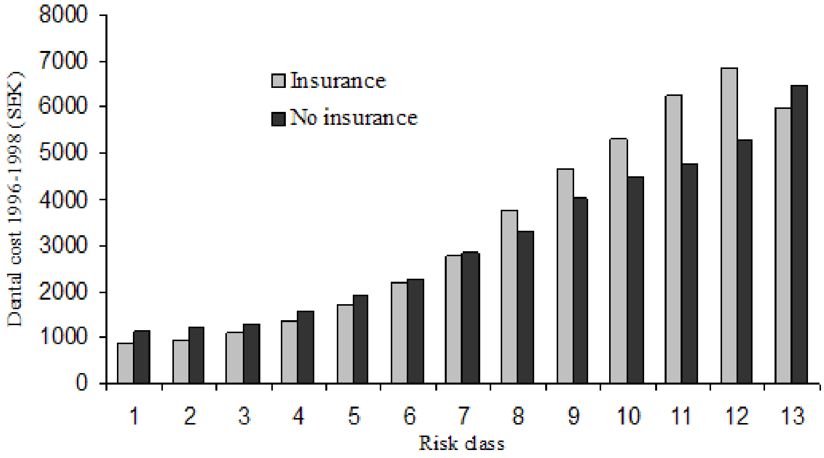

Figure 3: Dental Cost 1996-1998 (SEK) by Insurance Choice and Risk Class

Tables

Table 1: Regression of Dental Costs 1999-2001

	Model 1		Model 2		Model 3	
	Coef	t-value	Coef	t-value	Coef	t-value
Cost 99-01						
Cons.	2042	96.8	979	8.66	751	6.78
Cost 96-98	0.360	68.8			0.217	39.9
D gr2			142	1.02	124	0.91
D gr3			321	2.38	288	2.18
D gr4			581	4.74	488	4.07
D gr5			966	7.95	804	6.76
D gr6			1373	11.4	1143	9.68
D gr7			1941	16.2	1583	13.5
D gr8			2446	20.7	1983	17.0
D gr9			3154	26.1	2565	21.5
D gr10			3500	28.2	2798	22.8
D gr11			3978	31.0	3216	25.3
D gr12			4717	32.8	3845	27.0
D gr13			5222	30.3	4166	24.4
D gr14			5074	21.2	4018	17.0
D gr15			4317	10.6	3331	8.32
D gr16			927	1.11	-11.2	-0.01
N	36241		36241		36241	
Adj R^2	0.116		0.173		0.208	

Note: The sample consists of patient who did not purchase a dental insurance contract during the period 1996 to 2001.

Table 2: Insurance Choice and Dental Cost 1996-1998 by Risk Class

Risk class	Number of observations	*Insurance*	*No ins.*	Av. Cost	Stdv.	Min	Max
All	29544	*6888*	*22656*	2936	2997	0	88451
1	370	*139*	*231*	1023	931	0	6826
2	976	*439*	*537*	1090	753	0	6446
3	1245	*509*	*736*	1213	788	0	6611
4	2718	*959*	*1759*	1484	1176	0	19259
5	3380	*1055*	*2325*	1834	2011	0	88451
6	3772	*1089*	*2683*	2248	1957	0	46902
7	4206	*1042*	*3164*	2820	2339	0	36785
8	4879	*895*	*3984*	3405	2938	0	66675
9	3300	*433*	*2867*	4089	3445	0	42975
10	2178	*218*	*1960*	4585	4374	0	60597
11	1459	*63*	*1396*	4836	3933	0	44779
12	729	*38*	*691*	5359	3933	0	26713
13	332	*9*	*323*	6458	4623	0	29377

Table 3: Probit Estimates of the Insurance Choice

	Model 1		Model 2		Model 3		Model 4	
	Coef.	p-value	Coef.	p-value	Coef.	p-value	Coef.	p-value
Insurance								
Cons.	-0.32	0.000	-1.26	0.000	-0.12	0.266	-1.04	0.000
D gr2	0.190	0.014	0.130	0.120	0.337	0.008	0.313	0.025
D gr3	0.085	0.261	0.035	0.668	0.118	0.343	0.069	0.608
D gr4	-0.064	0.364	-0.087	0.258	-0.117	0.295	-0.126	0.301
D gr5	-0.179	0.011	-0.192	0.011	-0.274	0.013	-0.261	0.031
D gr6	-0.250	0.000	-0.293	0.000	-0.407	0.000	-0.438	0.000
D gr7	-0.378	0.000	-0.431	0.000	-0.546	0.000	-0.585	0.000
D gr8	-0.604	0.000	-0.677	0.000	-0.872	0.000	-0.938	0.000
D gr9	-0.83	0.000	-0.92	0.000	-1.11	0.000	-1.18	0.000
D gr10	-0.99	0.000	-1.09	0.000	-1.26	0.000	-1.36	0.000
D gr11	-1.43	0.000	-1.55	0.000	-1.78	0.000	-1.97	0.000
D gr12	-1.34	0.000	-1.48	0.000	-1.72	0.000	-1.86	0.000
D gr13	-1.65	0.000	-1.81	0.000	-1.74	0.000	-1.91	0.000
Cost	7.48E-06	0.020	-2.02E-06	0.572				
Cost gr1					-2.04E-04	0.015	-2.07E-04	0.023
Cost gr2					-3.25E-04	0.000	-3.66E-04	0.000
Cost gr3					-1.94E-04	0.000	-2.02E-04	0.000
Cost gr4					-9.95E-05	0.000	-1.15E-04	0.000
Cost gr5					-5.58E-05	0.001	-7.61E-05	0.000
Cost gr6					-1.55E-05	0.156	-2.74E-05	0.017
Cost gr7					-6.91E-06	0.452	-1.88E-05	0.057
Cost gr8					2.45E-05	0.000	1.52E-05	0.036
Cost gr9					2.51E-05	0.001	1.31E-05	0.106
Cost gr10					1.92E-05	0.009	1.23E-05	0.113
Cost gr11					3.43E-05	0.004	3.79E-05	0.004
Cost gr12					3.67E-05	0.033	2.77E-05	0.129
Cost gr13					-1.16E-05	0.736	-1.94E-05	0.652
Dent. Share			3.31	0.000			3.33	0.000
FE clinics	No		Yes		No		Yes	
N	29544		29544		29544		29544	
Log L	-15007		-12758		-14943		-12696	
LRI	0.065		0.205		0.069		0.209	

Table 4: Impact of the Selection Effects

Risk class	Prob. at mean	Prob at 2*mean	Change	Perc. Change
1	0.345	0.270	-0.075	-21.5
2	0.396	0.260	-0.142	-36.0
3	0.368	0.282	-0.087	-24.2
4	0.324	0.270	-0.058	-18.3
5	0.286	0.240	-0.045	-16.1
6	0.253	0.232	-0.019	-7.7
7	0.209	0.193	-0.015	-7.2
8	0.146	0.157	0.012	8.4
9	0.096	0.106	0.009	9.9
10	0.069	0.077	0.008	11.3
11	0.024	0.036	0.013	51.4
12	0.028	0.041	0.011	38.9
13	0.014	0.010	-0.004	-28.0

Note: The probability are calculated using the estimates in model 4, table 3, and evaluated (i) at the mean cost and (ii) at two times the mean cost in each risk class. *Change* indicate the change in probability as the mean cost is doubled

Table 5: Bivariate Probit Estimates of the Insurance Choice

		Model 5		Model 6	
		Coef.	p-value	Coef.	p-value
Insurance	Cons.	0.30	0.000	-0.98	0.000
	D gr2	0.247	0.013	0.305	0.020
	D gr3	0.090	0.349	0.065	0.611
	D gr4	-0.091	0.290	-0.120	0.295
	D gr5	-0.200	0.020	-0.244	0.032
	D gr6	-0.287	0.001	-0.405	0.000
	D gr7	-0.365	0.000	-0.537	0.000
	D gr8	-0.574	0.000	-0.854	0.000
	D gr9	-0.72	0.000	-1.08	0.000
	D gr10	-0.80	0.000	-1.23	0.000
	D gr11	-1.16	0.000	-1.79	0.000
	D gr12	-1.08	0.000	-1.68	0.000
	D gr13	-1.04	0.000	-1.71	0.000
	Cost gr1	-1.42E-04	0.025	-1.86E-04	0.031
	Cost gr2	-2.54E-04	0.000	-3.47E-04	0.000
	Cost gr3	-1.42E-04	0.000	-1.83E-04	0.000
	Cost gr4	-6.96E-05	0.000	-1.04E-04	0.000
	Cost gr5	-4.09E-05	0.002	-6.90E-05	0.000
	Cost gr6	-9.82E-06	0.196	-2.37E-05	0.028
	Cost gr7	-7.45E-06	0.280	-1.60E-05	0.085
	Cost gr8	1.30E-05	0.011	1.48E-05	0.030
	Cost gr9	1.36E-05	0.015	1.29E-05	0.091
	Cost gr10	1.03E-05	0.071	1.17E-05	0.111
	Cost gr11	2.34E-05	0.007	3.49E-05	0.005
	Cost gr12	1.75E-05	0.154	2.40E-05	0.163
	Cost gr13	-2.93E-05	0.332	-2.29E-05	0.581
	Dent. Share			2.92	0.000
	FE clinics	No		Yes	
Offer	Cons.	-1.018	0.000	-1.000	0.000
	Age	0.006	0.005	0.006	0.004
	Age2	-1.33E-04	0.000	-1.27E-04	0.000
	Gender	7.41E-03	0.484	1.61E-02	0.177
	Cost	-1.49E-06	0.464	-1.88E-06	0.363
	Share of offers	2.09	0.000	2.22	0.000
	FE clinics	Yes		Yes	
	N	49617		49617	
	N cens.	20073		20073	
	N uncens.	29544		29544	
	Log L	-43633		-42135	
	Rho	-0.862	0.000	-0.476	0.000

Appendix A

A.1 A general formulation of the model

In a more general formulation of the model in section 3, prevention enters the agents' utility function both in terms of monetary cost and direct disutility, $U(W-F,F)$ where $U_1' > 0$, $U_{11}'' < 0$, $U_2' < 0$, $U_{22}'' < 0$. Further, the direct disutility from prevention is assumed to be affected by the level of income, $U_{FW} \neq 0$. With probability $1-P(F)$, the agents suffers a monetary loss L, and the expected utility is

$$EU = P(F)U(W-F,F) + [1-P(F)]\,U(W-F-L,F) \tag{A.9}$$

F.O.C. w.r.t. F;

$$\begin{aligned}
&P'(F)\,[U(W-F,F) - U(W-F-L,F)] \\
&+P(F)\,[U_1'(W-F-L,F) - U_1'(W-F,F)] \\
&+P(F)\,[U_2'(W-F,F) - U_2'(W-F-L,F)] \\
&-U_1'(W-F-L,F) \\
&+U_2'(W-F-L,F)
\end{aligned} \tag{A.10}$$

S.O.C

$$\begin{aligned}
&P''(F)\,[U(W-F,F) - U(W-F-L,F)] \\
&+P(F)U_{11}''(W-F,F) + [1-P(F)]\,U_{11}''(W-F-L,F) \\
&+P(F)U_{22}''(W-F,F) + [1-P(F)]\,U_{22}''(W-F-L,F) \\
&+2P'(F)\,[U_1'(W-F-L,F) - U_1'(W-F,F)] \\
&+2P'(F)\,[U_2'(W-F,F) - U_2'(W-F-L,F)] \\
&-2P(F)U_{12}''(W-F,F) - 2\,[1-P(F)]\,U_{12}''(W-F-L,F).
\end{aligned} \tag{A.11}$$

The first, second and third lines are negative. They capture the trade-off between a higher probability for the good state and the utility cost of prevention in both states. The fourth line is positive and captures the fact that the monetary cost of prevention gives rise to a larger utility reduction in the bad than in the good state, as follows from the concavity of the utility function. This means that prevention worsens the consequences of the bad state, relative to the good state. If $U''_{12} > 0$ ($U''_{12} < 0$), the fifth line is positive (negative); that is, if the direct disutility of prevention is decreasing (increasing) with income, the utility reduction is larger (smaller) in the bad than in the good state. The sixth line is positive (negative) if $U''_{12} < 0$ ($U''_{12} > 0$), and captures the indirect effect reducing (strengthening) the utility loss in both states. This effect follows because the lower net income following from a larger purchase of prevention (first argument) reduces the direct utility loss of prevention (second argument). In the same way, a larger direct utility loss following from more extensive prevention (second argument) reduces the utility loss following from a higher monetary cost of prevention (first argument).

For the S.O.C to be negative, the positive terms need to be sufficiently small; that is, (i) the monetary cost of prevention needs to constitute a sufficiently small part of the agents' total budget or the concavity of utility w.r.t. income needs to be sufficiently mild and (iia), if $U''_{12} > 0$ the increased direct disutility of prevention following from lower income needs to be sufficiently small, or (iib) if $U''_{12} < 0$, the indirect utility increasing effect needs to be sufficiently small. The intuition behind (i) and (iia) is that a higher level of prevention increases the expected utility as it increases the probabilityof the good state, but prevention will also cause a larger utility reduction in the bad than in the good state. Therefore, it is not certain whether the utility enhancing effect or the utility reducing effect dominates.

Risk aversion can be modelled with an individual-specific taste-parameter α being added to the first argument of the utility function, assuming constant relative risk aversion. A higher α implies a lower level of risk aversion. The marginal effect of risk aversion on precautionary activities is obtained by differentiating the first-order condition with respect to F_i and α_i, as

$$\frac{\partial F_i}{\partial \alpha} = -\frac{1}{S.O.C.}\left[\begin{array}{c} P'(F_i)\left[U'_1(\alpha_i + W, F_i) - U'_1(\alpha_i + W - L, F_i)\right] \\ -P(F_i)U''_{11}(\alpha_i + W, F_i) - \left[1 - P(F_i)\right]U''_{11}(\alpha_i + W - L, F_i) \\ +P(F_i)U''_{12}(\alpha_i + W, F_i) + \left[1 - P(F)\right]U''_{12}(\alpha_i + W - L, F_i) \end{array}\right]. \tag{A.12}$$

The result that a higher degree of risk aversion results in more extensive prevention may still hold under less restrictive assumptions; that is, when (i) preventive activities have a monetary cost and (ii) $U''_{12} \neq 0$, equation (A.12) may still be negative if the second-order condition is negative and the second term is negative. The first line in the second term is negative. The second line is positive and must be sufficiently small. The third line is negative if $U''_{12} < 0$, and positive if $U''_{12} > 0$. In the latter case, the cross derivative must be sufficiently small.

A.2 Exogenous differences in risk

In section 3, the differences in the probability of loss are purely generated through differences in the level of prevention. Now, suppose that there is an exogenous source influencing the probability of loss, e.g. a genetic factor. Let G be the exogenous factor, where higher levels of G imply a higher probability of avoiding loss, $P'_2(F,G) > 0$. The impact of the genetic factor on the theoretical results depends on how G is distributed across types. For simplicity, let there be only two levels of G, $G_H > G_L$, and only two agents, a reckless and a prudent one. Furthermore, the following notational conventions are used $C(L, \alpha_j, P(F(\alpha_j), G_i)) = C_j(G_i)$ and $P(F(\alpha_j), G_i) = P(\alpha_j, G_i)$ for $i = L, H$.

Consider first the case where, for some exogenous reason, e.g. better genetics, the prudent agent has a higher probability of avoiding loss than the reckless agent. So even if prevention is completely ineffective $P(\alpha_P, G_H) > P(\alpha_R, G_L)$, and if the exogenous influence is sufficiently mild, we may have that

$$C_P(G_H) < C_R(G_L). \tag{A.13}$$

With an adequate loading factor, only the prudent agent buys insurance. In other words, there may be an advantageous selection. As prevention becomes more effective the difference in probability—between the prudent and the reckless agent—will increase and eventually

$$C_R(G_L) < C_P(G_H). \tag{A.14}$$

Given an adequate loading factor, only the reckless agent will buy insurance, and there will be adverse selection. If the exogenous influence is sufficiently large, the difference in probability may generate adverse selection, even if prevention is completely inefficient.

The second case to consider is that when the reckless agent is exogenously allocated with a higher probability of avoiding loss. Hence, if prevention is completely ineffective, then $P(\alpha_P, G_L) < P(\alpha_R, G_H)$, and

$$C_P(G_L) < C_R(G_H). \tag{A.15}$$

With an adequate loading factor, only the prudent agent purchases insurance. Since he also has a lower probability of avoiding loss, this means adverse selection. When prevention becomes more effective $P(\alpha_P, G_H) > P(\alpha_R, G_L)$, while equation (A.15) still holds. Hence, still only the prudent agent will purchase insurance, but since he has a higher probability of avoiding loss, there will now be advantageous selection given an adequate loading factor. As prevention becomes even more effective, the difference in probability will increase and eventually

$$C_R(G_H) < C_P(G_L). \tag{A.16}$$

Now, only the reckless agent purchases insurance, given an adequate loading factor, and since he has a lower probability of avoiding loss, this implies adverse selection.

The general results from section 3 will still hold when there is an exogenous source to risk, i.e. with prevention being highly effective, adverse selection may exist, while there may be advantageous selection if prevention is less effective.

Appendix B

Table B.1: Descriptive Statistics

	N	Mean	Stdv.	Min	Max
Insurance	29544	0.233	0.423	0	1
Dent. Share	29544	0.163	0.138	0	0.621
Offer	49617	0.595	0.491	0	1
Age	49617	47.6	16.6	22	98
Gender	49617	0.494	0.500	0	1
Cost	49617	2990	3100	0	88451
Share of offers	49617	0.592	0.183	0	1

Table B.2: Regression of Dental Cost 1996-1998 on Risk Classes and Socio-Demographics

	Coef.	t-value
Cost 96-98		
Cons.	-764	-3.94
D gr2	19.8	0.12
D gr3	90.6	0.56
D gr4	255	1.69
D gr5	549	3.65
D gr6	870	5.79
D gr7	1336	8.86
D gr8	1840	12.16
D gr9	2499	16.17
D gr10	2964	18.63
D gr11	3219	19.51
D gr12	3755	20.86
D gr3	4851	22.97
Age	87.5	13.78
Age^2	-0.74	-12.20
Gender	-164	-5.16
N	29466	
R^2	0.177	
Adj R^2	0.177	