Endogenous Information and Adverse Selection under Loss Prevention

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January 2, 2013

Abstract

We examine the endogenous value of information in an insurance market where there is heterogeneity in prevention technology and adverse selection along the efficiency dimension of prevention. Prior research on the value of information in adverse selection economies suggests that it has zero social value and negative private value leading consumers to rationally stay ignorant. We show that by introducing observable preventive effort into the picture this harsh conclusion is alleviated. If people can adjust their behavior in terms of prevention to the information acquired, information might still be valuable.

The possibility of loss prevention preserves the ordering of the values of information with respect to assumptions on the observability of informational status and risk type compared to a situation without prevention opportunities. However, a first-best efficient risk allocation does not necessarily deter information acquisition which has important public policy implications for the areas of genetic testing, HIV testing and product liability.

Keywords: information, information value, loss prevention, adverse selection, insurance

JEL-Classification: D11, D82, G22, G28

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1 Introduction

Consider an individual who can undertake a genetic test or an HIV test. Alternatively, we can imagine a firm who reflects about whether and how much to invest in better understanding the exact product liability risks attached to a new product. Under which conditions will information about risk type be acquired? In both examples, the specific insurance possibilities essentially impact the value of information, i.e., the question of whether and to what extent insurance companies should be allowed to utilize the level of information of potential costumers is crucial. What has been neglected so far is, however, that individuals do not only passively obtain information, but may adjust their behavior in terms of risk mitigation techniques to the information acquired, which in turn has implications for insurance pricing again. Put differently, the nature of the health and liability risks under consideration is not only determined by individuals’ risk types, but also by environmental factors over which, to some extent at least, individuals might have some control.

Milgrom and Stokey (1982) show that if ex-ante efficient contracts are negotiated in a complete market set-up, the social value of subsequently generated information is zero, as it cannot create new investment opportunities. The question then arises why individuals should decide to become informed at all. Crocker and Snow (1992) demonstrate that if insurers can observe whether individuals are informed or not and if consumers do not have prior private information, then the private value of information is negative meaning that information will not be obtained. Hence, insurance deters diagnostic testing. Tabarrok (1994) discusses the potential threat of uninsurability through genetic testing, because insurance coverage for high risk types might be too expensive. He introduces genetic insurance as a possible solution. Also in the context of health insurance, Strohmenger and Wambach (2000) model an insurance market with state-dependent consumer preferences and treatment costs exceeding the individual’s willingness to pay. They find that additional risk classification can be welfare enhancing under symmetric information, but there is the threat of complete market failure under asymmetric information about risk types. Doherty and Thistle (1996) re-analyze the private value of information and find that it is non-negative only if insurers are unable to observe the informational status of the consumers or if individuals are able to conceal their informational status. This demonstrates the crucial role of the regulator when it comes to the question of how to handle information from genetic tests or from risk classification devices in general for the purposes of insurance purchasing. In Doherty and Posey (1998) the value of a treatment option for tested high risks is examined which is a first step.
towards the consideration of prevention opportunities. However, when thinking about health related risks or liability risks, it seems obvious that also uninformed costumers or low risks will invest in risk mitigation, and therefore a more general model is required.

The above stream of literature focuses mainly on the canonical Rothschild and Stiglitz (1976) model that studies heterogeneity in individual risk type by allowing for different loss probabilities. However, not only heterogeneity of types, but also individual measures of prevention\(^1\) seem to matter a lot. Especially in the contexts of health risks and liability risks this is an important dimension. For instance, for HIV the medical treatment has made important improvements during the last 15 to 20 years and hence it is a reasonable assumption that individuals who obtain a positive test result will adjust their lifestyle to the recommendations given by doctors. Although there is still no cure for an HIV infection, the treatment consisting of the so-called highly active antiretroviral therapy (HAART) has been highly beneficial to HIV-infected people since its introduction in 1996, see for instance Palella Jr et al. (1998). They find a reduction of mortality rates of more than 20 percentage points on average regardless of sex, race and age. Said more generally, the interplay between risk type and environmental factors that can at least partially be controlled by consumers shapes the risk to be insured.

Another example is breast cancer which can be linked to genetic testing. A mutation of the genes BRCA1 and BRCA2 is known to be associated with a higher risk for breast or ovarian cancer (Thompson et al. (2002)). However, since the 1970s some strong medical progress has been made regarding potential therapies for breast cancer especially when detected early, as has been documented by Goldhirsch et al. (2007) for instance. It seems to be a reasonable assumption that once information is obtained for a BRCA1 or BRCA2 mutation the individual prevention behavior in terms of the frequency of seeing a doctor to detect indication of breast cancer as early as possible will change. But also for individuals who might not know their genetic make-up or those who have tested negative, the interplay between risk relevant factors and risk type determines their final probability of disease. To this extent many of the risks to be considered in the area of genetic testing are multifactorial. Again, one can recognize that individuals do not only passively acquire information, but adjust their risk-relevant behavior to the information obtained.

For the case of liability risks it also seems to be natural to think that once the specific

\(^1\)In their seminal work, Ehrlich and Becker (1972) distinguish between self-protection, i.e., investments to reduce the probability of loss, and self-insurance, i.e., investments to reduce the size of a loss. Common in the insurance literature is also the terminology loss prevention for the former and loss reduction for the latter risk management device. In this paper we focus on loss prevention.
dangers for a new product category have been identified, preventive action in terms of monitoring the production process or R&D will be directed towards these threats. In the context of product liability this issue makes a lot of sense for highly innovative production technologies where there is up to date little knowledge and little experience about potential risks to costumers. To give an example, products involving nanotechnologies are highly on the rise. However, there is still pretty poor overall knowledge about long-term health risks due to respiration of nanoparticles, due to contact with skin, or via gastrointestinal absorption. Warheit et al. (2008) mention in their survey that in the area of nanotechnology research on health and environmental effects lags behind technological progress, but there can be serious problems. They report evidence that lung exposure to nanoparticles can be associated with adverse inflammatory responses, an observation reminiscent of the behavior of asbestos fibers. From the perspective of a firm selling nanoproducts two questions arise: How much should be spent on identifying risks, maybe even beyond regulatory thresholds, and how can the risk management process be adjusted to the information obtained?

All in all, these examples demonstrate that a mere focus on an exogenously given distribution of risks in the population seems to be insufficient to judge the incentives to obtain information in an adverse selection framework. There are plenty of situations where individuals react to the information acquired and adjust their behavior in terms of prevention expenditures, as soon as they have a clearer idea of their individual risk situation. Therefore, the goal of the paper is to analyze the impact of the possibility of loss prevention on the endogenous value of information in adverse selection economies.

To give a short preview on our results, we find that by introducing loss prevention into the picture the ordering of endogenous values of information with respect to assumptions on observability of informational status and risk type is the same as compared to a situation without loss prevention. However, the “reference point” changes, i.e., the endogenous value of information in the complete observability benchmark case can be negative or positive, whereas without prevention opportunities it is unambiguously negative. Hence, the well established result that a first-best efficient insurance market in terms of risk allocation deprives consumers of any incentive to obtain information about risks is no longer valid. If loss prevention is possible, we may have situations with full insurance at a fair price for all groups of costumers, but still sufficient incentives to make the acquisition of information worthwhile, especially if high risk individuals

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2Some internet databases suggest annual average growth rates of 40% from 2006 to 2011, see for instance http://www.nanotechproject.org/inventories/consumer/analysis_draft/.
are endowed with the more efficient prevention technology, i.e., if high risk types can improve a lot on their loss propensity.

This demonstrates that from an incentive perspective it might no longer be necessary to improve on the endogenous value of information by allowing individuals to conceal their informational status when purchasing insurance coverage. The trade-off between efficient risk allocation and information production can also be alleviated by enhancing risk mitigation opportunities for the high risk individuals. This gives rise to very strong public policy implications to be derived from this analysis. Regulatory responses to genetic testing, e.g., the Genetic Information Nondiscrimination Act (GINA) in the US and the Gene Diagnostics Law in Germany, can be judged from the viewpoint of informational incentives and allocative efficiency within our analysis. Put shortly, if individuals have sufficient control over environmental factors they can adjust to information acquired it might not be necessary to sacrifice allocative efficiency to restore informational incentives. Hence, whether banning the use of genetic information for rate-making purposes is desirable depends a lot on the specific kind of genetic information itself.

The paper proceeds as follows. The next section outlines the basic model and introduces prevention opportunities and prevention heterogeneity. Section 3 introduces adverse selection by allowing for different assumptions on the observability of informational status and risk type of customers. Section 4 offers public policy implications and concludes.

## 2 The Basic Model

### 2.1 General Assumptions

Following the classical literature in the analysis of insurance demand, we consider risk-averse individuals equipped with utility of final wealth \( u \), which is assumed to be monotonic and concave \( (u' > 0, u'' < 0) \). Let \( w > 0 \) be initial wealth which is subject to incurring a loss of \( l \) with probability \( p \). Individuals may choose to spend \( x \) on prevention which reduces the probability of loss\(^3\) and comes at costs of \( c(x) \), which rise convexly in the extent of prevention \( (c' > 0, c'' > 0) \). Also note that we assume costs to be separable.\(^4\)

\(^3\)Adopting the terminology of Ehrlich and Becker (1972) we consider self-protection only. An analysis of the value of genetic information if consumers may choose a self-insurance action can be found in Barigozzi and Henriët (2011).

\(^4\)We abstract from heterogeneity in the dimension of prevention cost. Rogerson (1985) and Jewitt (1988) discuss potential problems of the first-order approach in principal-agent problems, which is related
As said before, we employ a more flexible view on preventive action. Specifically, we assume that the probability of disease consists of a component that is exogenous and of a component over which the individual has some control and is in that sense endogenous. For instance the probability of developing breast cancer depends on the genetic make-up, i.e., on whether one carries a BRCA1 or BRCA2 mutation or not, and on behavior regarding other risk relevant factors, e.g., nutrition, smoking and drinking habits, or lifestyle in general. In this respect, we mean by preventive action all sort of behavior conducted by the individual that might decrease the probability of illness, irrespective of the genetic disposition.

Therefore, individuals are identical except for loss probability, such that a fraction $\theta_H$ of the population is considered high-risk and a fraction $\theta_L$ is considered low-risk: For any given level of effort, high-risks face a higher loss probability than low-risks, formally $p_H(x) > p_L(x) \forall x$. Furthermore, every individual is either high- or low-risk, and therefore $\theta_H + \theta_L = 1$ in the population. However, individuals might not (yet) know to which risk class they belong and hence assume an average loss probability of $p_U = \theta_H p_H + \theta_L p_L$ due to rational expectations.\(^5\) Subscript $U$ denotes the uninformed individual.

To account for the possibility of prevention technology heterogeneity we introduce the positive difference function $\delta(x) := p_H(x) - p_L(x)$ as in Hoy (1989). Following his terminology we distinguish between the three cases of constant difference (CD) for which $\delta'(x) = 0$, decreasing difference (DD) for which $\delta'(x) < 0$, and increasing difference (ID) for which $\delta'(x) > 0$. DD corresponds to a situation where H-types are more efficient at loss prevention than L-types, meaning that there is a promising treatment option available that might lower the probability of a severe break-out of the disease drastically. This might correspond to the current situation regarding HIV treatment. CD resembles a situation where H-types are equally efficient at prevention as L-types and therefore there is no effective treatment available and the detection of a genetic mutation simply means enhanced likelihood of the breakout of a specific disease. In the case of ID, H-types are even less efficient than L-types in prevention meaning that the genetic mutation not only carries with it an elevated probability of the breakout of the disease, moreover means of preventing the breakout are no longer efficient compared to the fact that effort levels identified by the first-order condition might not necessarily represent utility-maximizing effort choices. This problem can be circumvented by using a specification with separable cost as we do.

\(^5\)We abstract from concerns of ambiguity aversion here. Formally, being uninformed corresponds to having a lottery between either the high-risk or the low-risk probability, which is disliked by ambiguity averse decision makers. For a study of effort choices under ambiguity aversion refer to Snow (2011) and Alary et al. (2010).
healthy people without the mutation. Lastly, we assume prevention technologies to be convex, $p_i'' > 0$ for $i \in \{H, L\}$. Let us make an important clarifying remark regarding terminology. We speak of risk type in order to distinguish high-risks with prevention technology $p_H$ from low-risks with prevention technology $p_L$. We speak of informational status to distinguish uninformed individuals with prevention technology $p_U$ from informed individuals with prevention technology $p_i, i \in \{H, L\}$.

2.2 No Insurance

In the absence of insurance the objective function is given by

$$V_i(x) = p_i(x)u(w - l) + (1 - p_i(x))u(w) - c(x), \quad i \in \{H, L, U\},$$

with first-order condition

$$V_i'(x) = p_i'(x)(u(w - l) - u(w)) - c'(x) = 0.$$ (1)

Optimal prevention is chosen such that it balances marginal benefit from prevention and marginal cost. Let $x^*_i$ denote optimal prevention for a type $i$ individual. It is straightforward to show that

- under CD $x^*_H = x^*_U = x^*_L$,
- under DD $x^*_H > x^*_U > x^*_L$,
- and under ID $x^*_H < x^*_U < x^*_L$.

This is intuitively plausible as the marginal cost of prevention do not depend on type. Therefore, in case of CD where marginal benefit from prevention is equal among types everybody choses the same amount of effort. Under DD H-types are more efficient on prevention which makes them spend more on prevention. Said differently, at the optimal level of prevention for L-types marginal benefit of H-types from prevention is still too low which induces them to further raise it beyond $x^*_L$. In case of ID the argument is simply reversed.

Concerning the (endogenous) value of information we obtain

$$I = \theta_H V_H(x^*_H) + \theta_L V_L(x^*_L) - V_U(x^*_U),$$ (2)

\[\delta' < 0 \implies p'_H(x) < p'_L(x) \forall x \] and therefore $p_H$ decreases more sharply as effort increases.
which is zero in case of CD. For the other two cases, let us observe that

\[ I > \theta_H V_H(x^*_U) + \theta_L V_L(x^*_U) - V_U(x^*_U) = 0, \]

where the inequality holds due to optimality of \( x^*_H \) and \( x^*_L \) and the last expression is zero as it corresponds to a situation in the absence of prevention opportunities.\(^7\) We learn that self-protection generates positive private value in the cases ID and DD, as the additional information of how exactly prevention technology heterogeneity looks like can be exploited to adjust effort appropriately. Using Savage (1954)'s terminology, the individual is free to ignore the information and hence it cannot be disadvantageous.

Already in this simple case without an insurance market we learn that the possibility of loss prevention gives rise to a broader set of possibilities, as individuals do not only passively obtain information, but can adjust their risk management in terms of loss prevention to the information acquired.\(^8\)

### 2.3 Fair Insurance Coverage

Now assume the availability of insurance coverage in a perfectly competitive market set-up. Therefore, prices are assumed to be actuarially fair. Let us first abstract from informational asymmetries, i.e., the insurer is able to observe both informational status and risk type. Throughout the whole analysis we focus on the adverse selection component of the market and therefore assume that the insurer is able to observe individual investments in loss prevention.\(^9\)

Coming back to our example for health risks this corresponds to a situation where the insurer must be informed about whether a genetic test or an HIV test has been conducted and if so what the results were, i.e., there is a disclosure duty regime. This

\(^{7}\)In that case we would obtain

\[
I = \theta_H V_H + \theta_L V_L - V_U \\
= (\theta_H p_H + \theta_L p_L - p_U)u(w - l) + (\theta_H (1 - p_H) + \theta_L (1 - p_L) - (1 - p_U))u(w) = 0.
\]

\(^{8}\)In the appendix we provide an example where we parametrize the structural heterogeneity in prevention technologies and illustrate the value of information for that special case.

\(^{9}\)It would be interesting to see how the value of information is affected by the presence of unobservable or not completely observable self-protection expenditures by the individuals. Papers dealing with the simultaneous existence of adverse selection and moral hazard in insurance are for instance Dionne and Lasserre (1985), Hoy (1989), Bond and Crocker (1991), Stewart (1994) and Ligon and Thistle (1996). However, research on endogenous information under adverse selection and full moral hazard has to the best of our knowledge not yet been conducted.
could occur if the insurance company paid for the test, perhaps as a part of more general medical examination. In this case it seems particularly reasonable that the insurance company has some information on average precautionary measures taken by an average individual, a low risk individual and a high risk individual, and therefore considerations of moral hazard can be neglected. Looking at the liability example this situation corresponds to the case where the insurance company wants to have detailed information about how much is spent on risk identification and about the results of this part of the risk management process. Furthermore, observability of the level of prevention resembles the fact that the insurance company is concerned with how much the firm invests in managing threats of product liability which again seems to be plausible.

Under these assumptions, insuring a proportion $\alpha$ of the loss $l$ comes at a premium of $\alpha p_i(x)l$ for a type $i$ individual. We know from classical insurance demand theory that full insurance coverage will be obtained, see for instance Mossin (1968).\footnote{Of course, Mossin abstracts from precaution and considers a fixed premium only, but in case prevention expenditures are observed optimality of full insurance coverage still holds.} The objective of a type $i$ individual is therefore to maximize

$$
V_i(x) = u(w - p_i(x)l) - c(x),
$$

which yields the first-order conditions

$$
V_i'(x) = -p_i'(x)lu'(w - p_i(x)l) - c'(x) = 0.
$$

Note that the second-order conditions hold.\footnote{They are given by

$$
V_i''(x) = -p_i''(x)lu'(w - p_i(x)l) + (p_i'(x)l)^2 u''(w - p_i(x)l) - c''(x) < 0.
$$
}

Here the marginal benefit of increasing expenditures on prevention is the reduction in insurance premium. Let $\hat{x}_i$ denote the optimal amount of effort for a type $i$ individual, i.e., the $\hat{x}_i$ are first-best effort levels. We find the following relationship:

- In case of CD and DD, $\hat{x}_H > \hat{x}_U > \hat{x}_L$,

- in case of ID, the levels of effort cannot be unambiguously ordered.

For CD H-types and L-types are equally efficient with loss prevention and therefore with premium reduction. However, H-types pay a higher premium as they have a higher premium rate and therefore they will spend more on prevention to reduce premium
further. In case of DD H-types are even more efficient at loss prevention than L-types, hence again they will spend more on prevention than L-types. In a situation with ID where L-types are more efficient in terms of their loss prevention technology the reverse could occur, i.e., they could be so efficient that in absolute terms they spend more on prevention than H-types. Notice that for ID the two effects countervail each other: H-types have a higher premium rate which induces them to spend more on prevention than L-types. However, they are less efficient at loss prevention and this induces them to spend less on prevention. Therefore, the overall effect depends on the relative strength of these two aspects.

Observe that in the case of DD both in a situation without insurance and in a situation with full insurance at the fair rate H-types will spend more on prevention than L-types. The value of information is here given by

\[
I_1 = \theta_H V_H(\hat{x}_H) + \theta_L V_L(\hat{x}_L) - V_U(\hat{x}_U)
\]

\[
= \theta_H u(w - p_H(\hat{x}_H)l) + \theta_L u(w - p_L(\hat{x}_L)l) - u(w - p_U(\hat{x}_U)l)
- (\theta_H c(\hat{x}_H) + \theta_L c(\hat{x}_L) - c(\hat{x}_U))
\]

\[
= u(w - (\theta_H p_H(\hat{x}_H) + \theta_L p_L(\hat{x}_L))l - \rho) - u(w - p_U(\hat{x}_U)l)
- (c(\theta_H \hat{x}_H + \theta_L \hat{x}_L + \sigma) - c(\hat{x}_U)),
\]

for constants $\rho, \sigma > 0$. Again, we can confirm that the existence of prevention opportunities increases the value of information, because

\[
I_1 > \theta_H V_H(\hat{x}_U) + \theta_L V_L(\hat{x}_U) - V_U(\hat{x}_U)
\]

due to the optimality of $\hat{x}_H$ and $\hat{x}_L$. However, the last expression is negative\(^\text{12}\) and we cannot unambiguously sign $I_1$. We conclude that the following two conditions are sufficient for positivity of the value of information,

\[
p_U(\hat{x}_U)l > (\theta_H p_H(\hat{x}_H) + \theta_L p_L(\hat{x}_L))l + \rho,
\]

\[
\hat{x}_U > \theta_H \hat{x}_H + \theta_L \hat{x}_L + \sigma.
\]

(3)

If the insurance premium when uninformed exceeds the expected insurance premium when informed plus a constant accounting for the aversion to premium risk, and if average expenditures on prevention are sufficiently below expenditures when uninformed,

\(^{12}\)In the absence of prevention, the private value of information with full insurance is given by

\[
I_1 = \theta_H u(w - p_H l) + \theta_L u(w - p_L l) - u(w - p_U l).
\]

\[
= u(w - p_U l - \rho) - u(w - p_U l),
\]

for a positive risk premium $\rho > 0$, and is therefore negative.
an uninformed individual will decide to become informed and learn about his or her type.

**Proposition 1.** *Let informational status and risk type be observable. The value of information can be positive or negative. The inequalities in (3) are sufficient for the value of information to be positive. That is, the value of information is positive if the premium for the uninformed is sufficiently above the average premium and prevention expenditures of the uninformed are sufficiently above the average spendings on prevention.*

In the appendix we again parametrize the heterogeneity in prevention technology and demonstrate that DD tends to enhance the value of information: If high risks are equipped with the more efficient prevention technology, i.e., there is an effective treatment option available to them, the bad news from being a high risk is alleviated and information might still be valuable. Nevertheless, we demonstrate that also situations of CD or even ID might have a positive value of information due to prevention being relatively efficient.

This finding that the value of information can be of both signs in a full insurance environment is related to Proposition 2 in Bajtelsmit and Thistle (2008), where they study in a liability setting how the provision of liability insurance affects effort levels and the choice to acquire information. However, heterogeneity in risk type in their model corresponds to heterogeneity in loss size and prevention technology is homogeneous across agents. Therefore, their setting is not suitable to study adverse selection issues as mimicry of types does not work for heterogeneous loss sizes, as the insurer always observes amounts claimed. Doherty and Posey (1998) also find that the value of information can be of both signs and that positivity stems from the treatment option for high risks. We confirm their result and extend it to our more general setting. Even in situations of CD and ID the opportunity to mitigate the risk can create informational value.\(^{13}\)

Recall that in the absence of loss prevention the value of information will be negative due to classification risk. Here, as specified in the proposition, the value of information may well be positive. The intuition is that in the absence of loss prevention opportunities risk classification imposes classification risk on the individuals meaning that by learning their risk type they face a lottery between cheap and expensive insurance coverage, whereas without information they pay the average premium. Hence, classification.

\(^{13}\)In the appendix we construct a numerical example that under ID the private value of information can be valuable.
cation is a mean preserving spread disliked by risk-aversers. As soon as individuals are able to invest in loss prevention this harsh conclusion is alleviated. If individuals may adjust expenditures on prevention according to the information acquired, information may well be valuable.

2.4 Level of Coverage and Optimal Effort

For the analysis below we also need to understand how the amount of coverage will influence the effort exerted. In adverse-selection problems it is well known that the availability of coverage might be restricted due to the informational asymmetry. Hence, it is important to know how individuals adjust their spendings on effort if they cannot take out the optimal amount of insurance coverage.

As we consider competitive markets, an insurance contract is determined by its amount only. If a type $i$ individual purchases insurance covering $\alpha \cdot 100$ percent of the loss, the premium will be $\alpha p_i(x)l$. For the moment, we take insurance coverage as exogenously given which will be relaxed later in the adverse selection section. The objective function is then given by

$$V_i(x) = p_i(x)u(w - \alpha p_i(x)l - (1 - \alpha)l) + (1 - p_i(x))u(w - \alpha p_i(x)l) - c(x), i \in \{H, L, U\},$$

with associated first-order condition

$$V_i'(x) = p_i'(x)(u(y_l) - u(y_n)) - \alpha p_i'(x)l(p_i(x)u'(y_l) + (1 - p_i(x))u'(y_n)) - c'(x) = 0.$$  

Thereby, subscript $n$ indicates final wealth in the no-loss state, subscript $l$ denotes final wealth in the loss state. Optimal prevention is chosen to balance marginal benefit, which here consists of the marginal benefit from the reduction in loss probability and the marginal benefit from reducing the insurance premium, and marginal cost. Let $x_i^\alpha$ denote the solution of the first-order condition for a type $i$ individual. Note that $x_i^0 = x_i^1$ is the optimal effort level in the absence of insurance and $x_i^1 = \hat{x}_i$ is the optimal effort level under full coverage. The implicit function theorem yields

$$\frac{\partial x_i^{\alpha}}{\partial \alpha} = -\frac{1}{V_i'(x)} \frac{\partial V_i'(x)}{\partial \alpha},$$

hence $\text{sgn}\left(\frac{\partial x_i^{\alpha}}{\partial \alpha}\right) = \text{sgn}\left(\frac{\partial V_i'(x)}{\partial \alpha}\right)$. Now

$$\frac{\partial V_i'(x)}{\partial \alpha} = p_i'(x)l(1 - 2p_i(x))(u'(y_l) - u'(y_n))$$

$$-\alpha p_i'(x)l^2 p_i(x)(1 - p_i(x))(u''(y_l) - u''(y_n)),$$
which is negative if the loss probability does not exceed \(1/2\) and if the decision-maker is prudent, \(u'' > 0\).\(^{14}\) Under these circumstances higher insurance coverage induces the agent to lower spendings on prevention and we observe substitution between insurance and prevention though preventive effort is observable. The marginal benefit from prevention here consists of two components, the marginal benefit from the reduced loss probability itself and the marginal benefit from a reduced insurance coverage. Raising insurance coverage has three marginal impacts. The marginal benefit from loss prevention will be lower due to the amplified coverage, but the marginal benefit regarding a lower insurance premium is higher, as more insurance comes at a higher premium in absolute terms. The condition that loss probability stays below \(1/2\) is necessary and sufficient for the first effect being dominant. However, there will also be an income effect as more insurance coverage alters the wealth distribution which also affects the marginal benefits regarding the premium reduction. This third effect can in general not be signed unambiguously, but in case of prudence it will also be negative.

3 Presence of Adverse Selection

3.1 Preliminaries

Let us now assume that the insurer is unable to distinguish agents with respect to prevention technology. It may well be able to monitor spending on prevention, i.e., the amount of \(x\) put into the prevention technology; the efficiency of prevention is, however, private information.

Let us first come to a situation with two different prevention technologies, \(p_H\) and \(p_L\). The question arises of how insurance can be offered in this set-up. In a Rothschild and Stiglitz (1976) self-selection design, the H-types will be offered full insurance, whereas the L-types can only be offered partial insurance such that the H-types are just indifferent between their contract and the L-type contract, i.e.,

\[
\begin{align*}
p_H(\tilde{x})u(w - \alpha p_L(\tilde{x})l) & + (1 - p_H(\tilde{x}))u(w - \alpha p_L(\tilde{x})l) - c(\tilde{x}) \\
& = u(w - p_H(\tilde{x})l) - c(\tilde{x}_H). \tag{4}
\end{align*}
\]

Regarding the choice of effort \(\tilde{x}\) by an H-type who wants to take out the partial insurance contract at the L-type rate one has to take into account that we assume effort choices

\(^{14}\)Alternatively, a sufficient condition for negativity would be to assume a loss probability above \(1/2\) and imprudence which seems not practical for the vast majority of applications.
to be observable by the insurer. Hence, mimicry only works if H-types pretend to be L-types also in terms of effort levels selected. Denote by $x^\alpha_L$ the level of effort chosen by an L-type, if she picks an L-type partial insurance contract covering $\alpha$ percent of the loss, i.e., let $x^\alpha_L$ be such that it maximizes

$$p_L(x)u(w - \alpha p_L(x)l - (1 - \alpha)l) + (1 - p_L(x))u(w - \alpha p_L(x)l) - c(x),$$

with associated first-order condition as given in section 2.4. H-types will prefer the L-type partial insurance contract if utility from picking that contract and exerting effort $x^\alpha_L$ exceeds utility from picking the H-type full insurance contract and selecting effort $\hat{x}_H$. Therefore, we will determine $\alpha$ such that this cannot happen.

Note that for $\alpha = 0$ the LHS of (4) offers no insurance, H-types will therefore select $x^*_L$ to mimic L-types, and the right hand side (RHS) is greater. Formally,

$$u(w - p_H(\hat{x}_H)l) - c(\hat{x}_H) > u(w - p_H(x^*_L)l) - c(x^*_L) > p_H(x^*_L)u(w - l) + (1 - p_H(x^*_L))u(w) - c(x^*_L),$$

where the first inequality holds as $\hat{x}_H$ maximizes utility with full insurance for H-types and the second holds as at constant effort levels more actuarially fair priced insurance coverage is always preferred to less. For $\alpha = 1$ the LHS offers full coverage at the L-type rate, H-types will select $\hat{x}_L$ to mimic L-types, and therefore expected utility exceeds the RHS. Formally,

$$u(w - p_L(\hat{x}_L)l) - c(\hat{x}_L) > u(w - p_L(\hat{x}_H)l) - c(\hat{x}_H) > u(w - p_H(\hat{x}_H)l) - c(\hat{x}_H),$$

where the first inequality holds as $\hat{x}_L$ is such that it maximizes the LHS and the second holds as H-type loss probability at a given effort level exceeds L-type loss probability.

For reasons of continuity there is at least one value of $\alpha \in (0, 1)$ where the self-selection constraint binds and H-types receive full and fairly priced insurance coverage and L-types obtain partial and fairly priced insurance coverage that leaves H-types just indifferent between choosing their contract and effort $\hat{x}_H$ and choosing the L-type partial insurance contract and mimicking L-type effort $x^\alpha_L$. Hence the amount of insurance for L-types will be endogenously determined via self-selection to resolve the adverse selection problem.\(^{16}\)

\(^{15}\)Of course, if there is no insurance there is no need for mimicry and H-types would rather select $x^*_H$ to maximize their utility. Our existence result for $\alpha$, however, rests on a continuity assumption and therefore we assume a choice of $x^*_L = x^0_L$ in order to avoid a discontinuity when increasing $\alpha$ beyond zero.

\(^{16}\)We do not treat potential problems of equilibrium non-existence due to an insufficient share of high risks in the market in this paper, but rather assume that all contract menus considered are stable.
3.2 Unobservable Risk Type

Now we are ready to state the first proposition regarding a situation where informational status is observable, i.e., the insurer knows whether an insurance applicant is informed about her prevention technology or not. This is for example the case in South Africa where insurers operate under the Code of Conduct (Chapter 20) and may not ask or coerce the applicant to undergo any genetic test in order to obtain insurance. However, all previous tests should be disclosed, i.e., the insurance company knows whether a test has been taken or not. Then, the insurer is able to identify U-types, will offer them full and fair insurance coverage and they choose effort accordingly. For the H-types and L-types a self-selection design will be implemented to entail screening. Let $\alpha \in (0, 1)$ be the level of coverage where the self-selection constraint (4) binds and $x^\alpha_L$ be the level of effort chosen by an L-type under this policy. The endogenous value of information is then given by

$$I_2 = \theta_H V_H(\hat{x}_H) + \theta_L V^\alpha_L(x^\alpha_L) - V_U(\hat{x}_U)$$

$$= \theta_H u(w - p_H(\hat{x}_H)l)$$
$$+ \theta_L (p_L(x^\alpha_L)u(w - \alpha p_L(x^\alpha_L)l - (1 - \alpha)l) + (1 - p(x^\alpha_L))u(w - \alpha p_L(x^\alpha_L)l))$$
$$- u(w - p_U(\hat{x}_U)l) - (\theta_H c(\hat{x}_H) + \theta_L c(x^\alpha_L) - c(\hat{x}_U)).$$

Comparing this to the situation above where both informational status and risk type are observable, we obtain

$$I_1 - I_2 = \theta_L(V_L(\hat{x}_L) - V_L(x^\alpha_L))$$
$$= \theta_L(u(w - p_L(\hat{x}_L)l) - p_L(x^\alpha_L)u(w - \alpha p_L(x^\alpha_L)l - (1 - \alpha)l)$$
$$- (1 - p(x^\alpha_L))u(w - \alpha p_L(x^\alpha_L))) - \theta_L(c(\hat{x}_L) - c(x^\alpha_L)),$$

which is positive as expected utility under full insurance and associated effort always exceeds expected utility in a situation with partial insurance and associated effort. This can be seen formally via

$$V_L(\hat{x}_L) = u(w - p_L(\hat{x}_L)l) - c(\hat{x}_L) > u(w - p_L(x^\alpha_L)l) - c(x^\alpha_L)$$
$$> p_L(x^\alpha_L)u(w - \alpha p_L(x^\alpha_L)l - (1 - \alpha)l) + (1 - p_L(x^\alpha_L))u(w - \alpha p_L(x^\alpha_L)l) - c(x^\alpha_L)$$
$$= V^\alpha_L(x^\alpha_L),$$

equilibrium configurations. It would, however, be very interesting to see how the incentives to acquire information about risk depend on the equilibrium concept applied to the adverse selection economy, especially as there is an ongoing debate about the suitability of the equilibrium definitions in use.
where the first inequality holds due to the optimality of $\hat{x}_L$ and the second due to the fact that full insurance for a fixed loss probability always is superior over partial insurance in expected utility terms. Therefore, the value of information declines from a situation when risk types are observable and in one situation informational status is and in the other is not. Note also that under the assumptions in section 2.4 there is a cost effect: The presence of H-types exerts a negative externality on L-types as the availability of insurance coverage is restricted, which in turn leads to substitution between insurance and loss prevention. This unambiguously raises expenditures on care for L-types in case risk type is not observable. When comparing utilities both directions of the effect are possible. On the one side prevention is higher leading to a lower loss probability which is welfare enhancing. On the other side only partial insurance can be obtained which decreases individual welfare for L-types. The overall effect is ambiguous, but in case it is positive the cost effect must prevail as the overall value of information decreases.

**Proposition 2.** Let informational status be observable; the endogenous value of information is smaller if risk type is unobservable than when it is observable.

The marginal impact of the structure of prevention technology heterogeneity is difficult to determine. In the case of CD and DD, we still have $\hat{x}_H > \hat{x}_U$, as H-type and U-type utility is unaffected. However, under the conditions from section 2.4, L-types will exert more effort compared to a situation with full insurance coverage. Hence, $\hat{x}_U > \hat{x}_L$ might no longer hold.

In a situation where individuals cannot undertake loss prevention measures, the value of information under unobservability of risk type will also be smaller than under complete information and hence be negative. Note, however, that we are not able to exclude the possibility of $I_2$ being positive in the presence of loss prevention possibilities! As the value of information under complete information about type and informational status might well be positive, the same is true for the value of information if only type is observable. Consider for instance a situation where the insureds are highly risk-averse and therefore value coverage a lot. Hence, the insurance contract offered to L-types

\[ I_2 = \theta_H u(w - p_H l) + \theta_L (p_L u(w - \alpha p_L l - (1 - \alpha)l) + (1 - p_L)u(w - \alpha p_L l)) - u(w - p_L l), \]

for the self-separating level of insurance coverage $\alpha < 1$. With the same argument as above it will be lower than $I_1$ due to lower expected utility of L-types, because the existence of unidentifiable H-types restricts the available coverage.

---

17 Loss probability was assumed to be sufficiently small ($< 1/2$) and agents were assumed to be prudent ($u''' > 0$).

18 It is given by

\[ I_2 = \theta_H u(w - p_H l) + \theta_L (p_L u(w - \alpha p_L l - (1 - \alpha)l) + (1 - p_L)u(w - \alpha p_L l)) - u(w - p_L l), \]
will entail less than full coverage due to the information asymmetry, however, coverage
will be close to full due to high risk aversion. If in addition prevention is sufficiently
effective, the expected utility loss due to less coverage, which decreases the value of
information, can be partly compensated by investing more in prevention, so that the
overall effect is not too strong. Hence, the possibility to adjust prevention expenditures
to the information acquired alleviates the harsh conclusion in the extant literature that
under this regime the value of information is always negative.

3.3 Unobservable Informational Status

The second situation is when risk type can be made observable by revelation of the
consumer, but informational status is unobservable. These assumptions resemble a
situation of consent law where results from genetic testing can only be revealed at the
consent of the consumer. Therefore individuals will only choose to reveal results if they
are favorable and the insurer is left with having to separate uninformed from informed
individuals with an unfavorable result.

As said, L-types will reveal themselves as they can then take out full coverage and
attain a higher level of expected utility than with any (partial) insurance contract at
the U-type or H-type rate, formally

\[ V_L(\hat{x}_L) > V_L(x_L^\alpha) > p_L(x_L^\alpha)u(w - \alpha p_j(x_L^\alpha) - (1 - \alpha)l) + (1 - p_L(x_L^\alpha))u(w - \alpha p_j(x_L^\alpha)l) - c(x_L^\alpha), \]

for arbitrary \( \alpha \in [0, 1] \) and \( j \in \{U, H\} \), where \( x_L^\alpha \) is again such that it maximizes the
RHS if a type L individual takes out the contract offering coverage \( \alpha \) at the rate \( p_j(\cdot) \).

The first inequality holds due to the optimality of \( \hat{x}_L \) the second as full coverage at a
given loss probability is always preferred to partial coverage at a given loss probability
and as the low risk premium for given effort is always the most favorable.

H-types, however, will have an incentive to state that they have no information, i.e.,
they will try to mimic the Us. Hence, self-selection has to be implemented to separate
those individuals. U-type coverage is therefore restricted according to the appropriate
incentive constraint in the spirit of equation (4). Let \( \beta \) be the amount of coverage
available for U-types and \( x_U^\beta \) denote their effort level given the amount of insurance.

The endogenous value of information is given by

\[ I_3 = \theta_H V_H(\hat{x}_H) + \theta_L V_L(\hat{x}_L) - V_U(x_U^\beta) \]

\[ = \theta_H u(w - p_H(\hat{x}_H)l) + \theta_L u(w - p_L(\hat{x}_L)l) - p_U(x_U^\beta)u(w - \beta p_U(x_U^\beta)l - (1 - \beta)l) \]

\[ - (1 - p_U(x_U^\beta))u(w - \beta p_U(x_U^\beta)l) - \left[ \theta_H c(\hat{x}_H) + \theta_L c(\hat{x}_L) - c(x_U^\beta) \right]. \]
Comparing this to the situation where both informational status and risk type are observable, we obtain
\[ I_3 - I_1 = V_U(\hat{x}_U) - V_U(x_\beta^U), \]
which is positive due to
\[
V_U(\hat{x}_U) = u(w - p_U(\hat{x}_U)l) - c(\hat{x}_U) > u(w - p_U(\hat{x}_U)l) - c(x_\beta^U)
\]
\[ > p_U(x_\beta^U)u(w - \beta p_U(x_\beta^U)l - (1 - \beta)l) + (1 - p_U(x_\beta^U))u(w - \beta p_U(x_\beta^U)l) - c(x_\beta^U) \]
\[ = V_U(x_\beta^U). \]

The first inequality holds due to the optimality of \( \hat{x}_U \), the second holds, as full insurance always dominates partial insurance for a given loss probability. We see that, given \( L \)-types can credibly reveal test results, moving from a regime where informational status is observable to a regime where it is not increases the endogenous value of information.

**Proposition 3.** Assume risk type can be revealed by consumers; the endogenous value of information is higher if informational status is not observable than when it is observable.

Similarly to section 3.2, the impact of the structure of prevention technology heterogeneity is complicated. Given the conditions developed in 2.4, U-type effort increases due to less coverage being available. Therefore, under CD and DD, \( x_\beta^U > \hat{x}_L \) holds, but the relationship between H-type and U-type effort might be reversed compared to the full information benchmark case.

The result in the previous proposition corresponds to proposition 2 in Doherty and Thistle (1996) where the value of information is shown to be non-negative if informational status is observable or can be concealed. We extend this result by showing that concealment increases the value of information compared to the benchmark case in an environment where loss prevention is possible. Whether or not \( I_3 \) is positive, cannot be unambiguously determined.

Introducing loss prevention into the picture helps to better understand that the situation with increased value of information due to unobservable informational status is not necessarily superior to a situation of complete observability. It can only raise the incentives to obtain information to the point where information will in fact be obtained, if the value of information is negative in the complete observability benchmark case and positive, if informational status is observable. However, it does so by sacrificing efficiency in terms of risk allocation between insurer and insured, as a portion of the risk exposure of the uninformed is retained and will not be transferred to the insurer.
3.4 Both Risk Type and Informational Status Unobservable

Let us finally analyze a situation where the use of genetic information by insurance companies is completely banned. In this case insurance companies are neither allowed to inquire whether tests have been taken, nor are they allowed to use genetic information for rate-making. In some countries, there are voluntary moratoria not to use genetic information until the government finds a solution, in other countries there are limitations by law and lastly there are countries in which there is a government ban in place to completely prohibit the use of genetic information.\(^{19}\)

Coming back to the model, it is clear that in an environment where both risk type and informational status cannot be observed, there will be an incentive to mimic L-types as they are offered the cheapest rate for insurance coverage which would yield H- or U-types higher overall utility. Formally,

\[
    u(w - p_i(\hat{x}_i)l) - c(\hat{x}_i) < u(w - p_L(\hat{x}_i)l) - c(\hat{x}_i) < u(w - p_L(\hat{x}_L)l) - c(\hat{x}_L), i \in \{H, U\},
\]

where the first inequality holds due to the fact that L-types enjoy the lowest rate and the second holds due to the optimality of \(\hat{x}_L\).

Hence, self-selection must be utilized to separate H- and U-types from the L-types. However, the H-types also have an incentive to mimic the U-types to benefit from their cheaper premium rate. Therefore, also self-selection between those two has to be enforced. Let \(\beta\) be the level of coverage available for U-types, implicitly defined via

\[
    p_H(x_{U}^\beta)u(w - \beta p_U(x_{U}^\beta)l - (1 - \beta)l) + (1 - p_H(x_{U}^\beta))u(w - \beta p_U(x_{U}^\beta)l - c(x_{U}^\beta)) = u(w - p_H(\hat{x}_H)l) - c(\hat{x}_H),
\]

the self-selection condition for H-types. It is identical to the amount of coverage, if risk type alone is observable. Let \(\alpha\) denote the insurance coverage obtained by L-types with

\[
    p_U(x_{U}^\alpha)u(w - \alpha p_L(x_{L}^\alpha)l - (1 - \alpha)l) + (1 - p_U(x_{U}^\alpha))u(w - \alpha p_L(x_{L}^\alpha)l - c(x_{L}^\alpha)) = p_U(x_{L}^\alpha)u(w - \alpha p_L(x_{L}^\alpha)l - (1 - \alpha)l) + (1 - p_U(x_{L}^\alpha))u(w - \alpha p_L(x_{L}^\alpha)) - c(x_{L}^\alpha)
\]

being the respective self-separating condition. Note that for \(\alpha = 0\) the RHS is smaller than the LHS, as fair partial insurance at a given loss probability is always superior to

\(^{19}\)In the US, state legislation on privacy of medical information is built upon the background of the Health Insurance Portability and Accountability Act (HIPAA) from 1996 and the Genetic Information Nondiscrimination Act of 2008 (GINA). In Germany, the so-called law for genetic engineering states that insurers are not allowed to ask for predictive genetic information in the medical questionnaire. In life insurance, however, if the sum insured exceeds 300,000\(€\) or the annuity exceeds 30,000\(€\) insurers may inquire genetic information.
no insurance and as \( x_U^\beta \) is chosen to maximize the LHS. Furthermore, for \( \alpha = 1 \) the RHS is larger than the LHS, as full insurance at the L-type rate at effort \( x_L^* \) is superior to the effort choice \( x_U^\beta \), which is superior to full insurance at the U-type rate at effort \( x_U^\beta \), which is superior to partial insurance at this rate. Hence, due to reasons of continuity the existence of \( \alpha \) is guaranteed.

The endogenous value of information is given by

\[
I_4 = \theta_H V_H(\hat{x}_H) + \theta_L V_L(x_L^\alpha) - V_U(x_U^\beta) \\
= \theta_H u(w - p_H(\hat{x}_H)) \\
+ \theta_L (p_L(x_L^\alpha)u(w - \alpha p_L(x_L^\alpha)l - (1 - \alpha)l) + (1 - p_L(x_L^\alpha))u(w - \alpha p_L(x_L^\alpha)l)) \\
- \left( p_U(x_U^\beta)u(w - \beta p_U(x_U^\beta)l - (1 - \beta)l) + (1 - p_U(x_U^\beta))u(w - \beta p_U(x_U^\beta)l) \right) \\
- \left[ \theta_H c(\hat{x}_H) + \theta_L c(x_L^\alpha) - c(x_U^\beta) \right].
\]

We cannot directly compare the value of information in this situation to the situation under symmetric information, but we can, however, compare it to the preceding case. Remember that U-types take out the same amount of insurance as before, so that one obtains

\[
I_3 - I_4 = \theta_L (V_L(\hat{x}_L) - V_L(x_L^\alpha)),
\]

which is positive due to

\[
V_L(\hat{x}_L) = u(w - p_L(\hat{x}_L)l) - c(\hat{x}_L) > u(w - p_L(x_L^\alpha)l) - c(x_L^\alpha) \\
> p_L(x_L^\alpha)u(w - \alpha p_L(x_L^\alpha)l - (1 - \alpha)l) + (1 - p_L(x_L^\alpha))u(w - \alpha p_L(x_L^\alpha)l) - c(x_L^\alpha) \\
= V_L(x_L^\alpha).
\]

The first inequality holds as \( \hat{x}_L \) is chosen to maximize a fully insured L-type’s objective, the second due to the fact that for a given rate fair full insurance is always superior to fair partial insurance.

**Proposition 4.** Let informational status be unobservable; the endogenous value of information is higher if risk type can be revealed than when it cannot be revealed.

Again we can see that if risk type is no longer observable the value of information will be decreased compared to a situation where it is observable. Or the other way round, if risk type is not observable, again, the possibility of concealment increases the endogenous value of information. Similar to above three cases can be distinguished which will be omitted here for reasons of brevity.
4 Discussion and Conclusion

We examine the endogenous value of information in an insurance market where individuals may invest in loss prevention. There is heterogeneity in loss prevention technology and individuals may or may not be informed about their technology, which both give rise to adverse selection along the efficiency dimension of prevention. Using a second-best pricing approach, we calculate the endogenous value of information under different assumptions on observability of risk type and informational status and compare them to each other and to a situation without loss prevention possibilities.

Given our real-world examples from the introduction, the inclusion of loss prevention seems natural in many circumstances. If a genetic test reveals positive or negative results regarding a specific mutation, individuals will adjust their lifestyle to the information acquired. If a firm detects a high potential for health related instances of product liability for a new, innovative product, it will try to appropriately direct R&D expenses to reduce the likelihood of adverse health outcomes for consumers. Hence, risk management behavior highly depends on the information acquired. Furthermore, strong medical progress regarding certain diseases and the prevalence of highly innovative, but scarcely researched technologies in terms of potential health perils for consumers, give an additional stimulus for the incorporation of risk mitigation opportunities into the analysis of endogenous information.

In our theoretical model, we find that if risk type and informational status are observable the endogenous value of information might well be positive, as individuals can adjust their self-protection expenditures according to the information acquired. This is in sharp contrast to the standard result of a negative value of information and thus can be attributed to the fact that the modeling implicitly assumed that individuals passively receive information without adjusting behavior to the new situation.

However, the ordering with respect to different informational scenarios is preserved. If informational status is observable, the endogenous value of information is larger, if risk type is observable than if it is not. If risk type is observable, the endogenous value of information is higher, if informational status is not observable than when it is observable. And finally, if informational status is unobservable, the endogenous value of information is higher if risk type is observable than when it is not observable. Therefore, we conclude that the relative ranking of endogenous values of information under different informational scenarios from the canonical adverse selection model is robust to the inclusion of loss prevention.

In terms of regulation there is an ongoing debate on how to deal with information re-
vealed from genetic tests for insurance contracting. In the US, the Genetic Information Nondiscrimination Act (GINA) was signed in 2008.\textsuperscript{20} The law prevents discrimination by health insurers and employers based on individuals’ DNA.\textsuperscript{21} Behind this is the idea that concealment helps consumers and restores sufficient incentives for information to be valuable. Another example for legislation in the area of genetic testing and the use of genetic information in insurance is the Gene Diagnostics Law in Germany, which came into force in 2010.\textsuperscript{22} Insurers are not allowed to force insurance applicants to undergo a genetic test and they are prohibited to use information from existing tests for the pricing of life insurance policies, annuities, or disability insurance policies. However, they may use this kind of information in life insurance with a sum insured above 300,000 EUR. Again, it becomes apparent that the possibility of concealment is thought to be beneficial to insurees.

Let us have a look at this issue in light of our propositions. Proposition 1 found that a first-best efficient insurance market with fairly priced and full coverage for all types might well provide sufficient incentives to have private information valuable. Let us compare this to a situation where informational status can be concealed, i.e. to the situation of proposition 3. We can distinguish three cases. If information is valuable in a complete observability regime, i.e. $I_1 > 0$, then, of course, it will also be positive if the possibility of concealment is introduced. However, in terms of risk allocation, a situation with unobservable informational status is worse as the risk-averse uninformed customers have to bear a strictly positive share of the risk. This would clearly speak against introducing concealment. If the value of information is negative under complete observability, switching to a regime of concealment might increase the value of information to the point where it is positive and hence remedy the insufficient revelation of information. However, and this is the last case, even under a policy of consent law, information might have negative private value and would thus be rationally not obtained. In this case again a situation of unobservable informational status is the same in terms of incentives for information acquisition compared to the benchmark case, but is worse in terms of risk allocation and therefore should not be privileged.

Hence, by introducing loss prevention into the picture we can identify circumstances where introducing concealment sacrifices allocative efficiency without the additional benefit of providing sufficient incentives to render information valuable, and this will be

\textsuperscript{20}For further information, please visit http://www.genome.gov/24519851.

\textsuperscript{21}The law does not state explicitly that discrimination in life insurance, annuities and long term care insurance are prohibited.

\textsuperscript{22}Further information can be obtained from http://dipbt.bundestag.de/dip21/btd/14/066/1406640.pdf and http://dipbt.bundestag.de/dip21/btd/15/005/1500543.pdf.
the case if there is either a relatively efficient treatment option for high risk individuals, or if prevention in general is relatively efficient. Hence, it may depend on the specific disease under consideration whether consent law should be favored or not. Comparison of proposition 2 to proposition 4 provides a similar rationale. We, therefore, confirm the results from Doherty and Posey (1998) and extend them to a more general framework of loss mitigation and by considering more informational scenarios. We furthermore derive conclusions regarding the trade-off between efficiency in terms of risk allocation and incentives regarding the acquisition of information.

This paper demonstrates that the possibility of loss prevention which is a very reasonable assumption in the context of health insurance or product liability insurance, may have an important impact on the endogenous value of information and could prove existing recommendations for regulation to be not sufficient. Hence, judging loss mitigation opportunities contingent on the information acquired is important to evaluate the incentives to obtain information.
References


Appendix

A Value of Information without Insurance

Let us assume for simplicity that $\delta'(x) = \gamma$ for a constant $\gamma \in \mathbb{R}$. $\gamma = 0$ resembles the case CD, $\gamma > 0$ the case ID, and $\gamma < 0$ the case DD. Integration yields

$$\int_0^x \delta'(t) dt = p_H(x) - p_H(0) - p_L(x) + p_L(0) = \gamma x.$$ 

Taking $p_L(x)$ as given, we obtain

$$p_H(x) = p_L(x) + \gamma x + p_H(0) - p_L(0),$$

$$p_U(x) = p_L(x) + \theta_H \gamma x + \theta_H(p_H(0) - p_L(0)).$$

Rearranging (2) yields

$$I = \left( \theta_H p_H(x_H^*) + \theta_L p_L(x_L^*) - p_U(x_U^*) \right) (u(w - l) - u(w))$$

$$- \left( \theta_H c(x_H^*) + \theta_L c(x_L^*) - c(x_U^*) \right).$$

Denoting by $I(\gamma)$ the value of information if $\delta'(x) = \gamma$, we know that $I(0) = 0$. Furthermore, as prevention is optimal and satisfies (1), we can exploit the envelope theorem to obtain

$$\frac{\partial V_L(x_L^*)}{\partial \gamma} = 0,$$

$$\frac{\partial V_U(x_U^*)}{\partial \gamma} = \theta_H x_U^*(u(w - l) - u(w)),$$

$$\frac{\partial V_H(x_H^*)}{\partial \gamma} = x_H^*(u(w - l) - u(w)).$$

Therefore, the marginal effect of a variation of $\gamma$ on the value of information is given by

$$\frac{\partial I}{\partial \gamma} = \theta_H (x_H^* - x_U^*)(u(w - l) - u(w)),$$

which is zero for $\gamma = 0$, positive for $\gamma > 0$, and negative for $\gamma < 0$. Applying the implicit function theorem, we can also calculate the second derivative to find that

$$\frac{\partial^2 I}{\partial \gamma^2} = \theta_H (u(w - l) - u(w))^2 \frac{\theta_H V''_H(x_H^*) - V''_U(x_U^*)}{V''_H(x_H^*) V''_U(x_U^*)}.$$ 

For the special case of CD, i.e., $\gamma = 0$, we find that

$$\frac{\partial^2 I}{\partial \gamma^2} \bigg|_{\gamma=0} = -\theta_L V''_H(x_H^*) > 0,$$

This assumption entails the restriction $p_H''(x) = p_L''(x) \forall x$ on prevention technologies.
confirming that \( I(\gamma = 0) = 0 \) is a local minimum. It is also a global minimum, as there are no zeros of \( \partial I/\partial \gamma \) except \( \gamma = 0 \). The following picture illustrates a possible shape of \( I(\gamma) \).

![Figure 1: Shape of the value of information function without insurance](image)

Hence, it is clear that information about type is always valuable, as it allows individuals to adjust their behavior in terms of risk management to the information acquired.

### B Value of Information with Full Information

Again, we choose the specification \( \delta'(x) = \gamma \) to facilitate the calculation of marginal effects of altering the structure of prevention technology heterogeneity. Prevention technologies are as before. By use of the envelope theorem, we obtain

\[
\begin{align*}
\frac{\partial V_L(\hat{x}_L)}{\partial \gamma} &= 0, \\
\frac{\partial V_U(\hat{x}_U)}{\partial \gamma} &= -\theta_H \hat{x}_U l u'(w - p_U(\hat{x}_U)l), \\
\frac{\partial V_H(\hat{x}_H)}{\partial \gamma} &= -\hat{x}_H l u'(w - p_H(\hat{x}_H)l),
\end{align*}
\]

Hence, we obtain for the endogenous value of information

\[
\frac{\partial I_1}{\partial \gamma} = \theta_H l \left( \hat{x}_U l u'(w - p_U(\hat{x}_H)l) - \hat{x}_H l u'(w - p_H(\hat{x}_H)l) \right)
\]

Under CD and DD, we have that \( \hat{x}_H > \hat{x}_U \), hence \( p_U(\hat{x}_U) < p_U(\hat{x}_H) < p_H(\hat{x}_H) \) and therefore \( \partial I_1/\partial \gamma \) is negative. Due to continuity, it will also be negative for a range
\[ \gamma \in (0, \bar{\gamma}) \]. Hence, the value of information should improve when moving from ID over CD to DD. Let us illustrate a possible shape of \( I_1(\gamma) \) in the following figure.

![Figure 2: Shape of the value of information function with full insurance](image)

The blue line represents a scenario where the value of information is always negative. Here classification risk prevails and insurance deters information acquisition which is due to rather inefficient prevention opportunities. The green line represents a situation where for some low values of \( \gamma \) information is valuable and for high values it is not. This is a situation where efficient prevention opportunities for high risks improve on the value of information and help to overcome the deterring effect of classification risk. The red line represents a situation where even for some positive values of \( \gamma \) information is valuable. Efficient risk mitigation opportunities can alleviate classification risk up to the point that the private value of information becomes positive, even if high risk individuals are equipped with the less favorable prevention technology.

\section*{C Numerical Example for a Positive Value of Information in the Benchmark Case}

In this section we provide a numerical example for a positive value of information if both informational status and risk type are observable. We introduce quadratic loss prevention technologies, discuss the case of risk neutrality with linear prevention costs and show how it extends to the general set-up introduced above.
C.1 Quadratic Loss Prevention Technology

For analytical convenience we standardize effort to the unit interval \( x \in [0, 1] \). Let loss probability be given by 
\[
p(x) = \xi x^2 + \psi x + \varphi
\]
with \( \xi \in (0, 1) \), \( \psi \in [-(\xi + 1), -2\xi] \) and \( \varphi \in [-(\xi + \psi), 1] \). Hereby \( \xi > 0 \) ensures that \( p''(x) = 2\xi > 0 \) \( \forall x \) and \( \xi < 1 \) entails that the interval for \( \psi \) is nonempty. \( \psi \geq -(\xi + 1) \) renders the parameter region for \( \varphi \) nonempty and \( \psi < -2\xi \) lets \( p'(x) = 2\xi x + \psi < 0 \) \( \forall x \). Finally, \( \varphi \geq -(\xi + \psi) \) and \( \varphi \leq 1 \) ascertain that \( p(1) \geq 0 \) and \( p(0) \leq 1 \) respectively.

We now incorporate prevention technology heterogeneity by specifying
\[
p_H(x) = \xi_H x^2 + \psi x + \varphi \quad \text{and} \quad p_L(x) = \xi_L x^2 + \psi x + \varphi,
\]
with \( 0 < \xi_L < \xi_H < 1 \). Furthermore, \( \psi \) shall be picked from the interval \( [-(\xi_L + 1), -2\xi_H] \) and \( \varphi \) from the interval \( [-(\xi_L + \psi), 1] \). We impose the condition \( 2\xi_H < \xi_L + 1 \) to ensure that the first interval will be nonempty.\(^{24}\) For ease of exposition we define \( \xi_U := \theta_H \xi_H + \theta_L \xi_L \) and then \( p_U(x) = \xi_U x^2 + \psi x + \varphi \).

C.2 The Value of Information under Risk Neutrality and Linear Prevention Cost

Let us assume that utility is given by \( u(w) = w \) resembling risk neutral decision making and that prevention cost be given by \( c(x) = x \) for \( x \in [0, 1] \). In this tractable case we obtain
\[
I_1 = \theta_H (w - p_H(\hat{x}_H)l) + \theta_L (w - p_L(\hat{x}_L)l) - (w - p_U(\hat{x}_U)l) - \theta_H \hat{x}_H - \theta_L \hat{x}_L + \hat{x}_U
\]
\[
= p_U(\hat{x}_U)l - \theta_H p_H(\hat{x}_H)l - \theta_L p_L(\hat{x}_L)l + \hat{x}_U - \theta_H \hat{x}_H - \theta_L \hat{x}_L
\]
for the endogenous value of information if both informational status and risk type are observable.

The optimal effort levels maximize \( w - p_i(x)l - x = w - (\xi_i x^2 + \psi x + \varphi)l - x \) and therefore satisfy the first order conditions \( (2\xi_i x + \psi)l + 1 = 0 \).\(^{25}\) They are given by \( \hat{x}_i = -\frac{1}{2\xi_i} \left( \frac{1}{l} + \psi \right) \). Let \( l \) be contained in the open interval \( \left( -\frac{1}{\psi}, -\frac{1}{2\xi_L + \psi} \right) \), which is nonempty in any case. This ensures that we only consider interior maxima and the first order approach is legitimate.

\(^{24}\)The second is nonempty in any case then.

\(^{25}\)The second order conditions are satisfied, \(-2\xi_i l < 0\).
Plugging the effort levels into the expression for $I_1$, we obtain

\[
I_1 = \xi_U \cdot \frac{1}{4\xi_U^2} \left( \frac{1}{l} + \psi \right)^2 l - \frac{\psi}{2\xi_U} \left( \frac{1}{l} + \psi \right) l + \varphi l \\
-\theta_H \left( \xi_H \cdot \frac{1}{4\xi_H^2} \left( \frac{1}{l} + \psi \right)^2 l - \frac{\psi}{2\xi_H} \left( \frac{1}{l} + \psi \right) l \right) \\
-\theta_L \left( \xi_L \cdot \frac{1}{4\xi_L^2} \left( \frac{1}{l} + \psi \right)^2 l - \frac{\psi}{2\xi_L} \left( \frac{1}{l} + \psi \right) l \right) \\
-\frac{1}{2\xi_U} \left( \frac{1}{l} + \psi \right) + \frac{\theta_H}{2\xi_H} \left( \frac{1}{l} + \psi \right) + \frac{\theta_L}{2\xi_L} \left( \frac{1}{l} + \psi \right) \\
= \left[ \frac{1}{2\xi_U} - \frac{\theta_H}{2\xi_H} - \frac{\theta_L}{2\xi_L} \right] \cdot \frac{(1 - \psi l)^2}{2l} - (\psi + \psi^2 l) - \left( \frac{1}{l} + \psi \right) \\
= \theta_H \theta_L \left( \frac{\xi_H - \xi_L}{2\xi_H \xi_U l} \right)^2 \left( 1 + \psi l \right) > 0.
\]

Hence, in this case the endogenous value of information is always positive which means that uninformed individuals will from an ex-ante perspective always prefer to obtain information and to adjust effort accordingly to staying uninformed and exerting effort based on average prevention technology.

C.3 Extension to the General Model

In order to construct a numerical example with risk aversion and convex prevention cost we use a parametrization that nests risk neutrality and linear cost. Therefore let $u(w) = \frac{w^{1-\mu}}{1-\mu}$ and $c(x) = x^\nu$ with $\mu \geq 0$ and $\nu \geq 1$. The case above corresponds to the choice $(\mu, \nu) = (0, 1)$. Now we can express the value of information as a function of these new variables, $I_1 = I_1(\mu, \nu)$ and it is straightforward that $I_1$ is a continuous function of $(\mu, \nu)$. From above we know that $I_1(0, 1) > 0$ and therefore we find an open neighborhood of $(0, 1)$ where it is still positive. Picking parameters $\mu > 0$ and $\nu > 1$ from that open environment we obtain the example.