Endogenous Information and Adverse Selection under Loss Prevention

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Abstract

We examine the endogenous value of information in an insurance market where there is potential adverse selection in the efficiency of loss prevention technology. We show that by introducing observable preventive effort for all risk types then classification risk is alleviated or might even be overcome: If people can adjust their loss prevention behavior to the information acquired, information might be valuable.

Allowing for loss prevention does not change the ordering of the value of information across disclosure regimes compared to a situation without loss prevention opportunities. In particular, a first-best efficient risk allocation does not necessarily deter information acquisition. This has important public policy implications for the areas of genetic testing, HIV testing and product liability.

Keywords: information value, loss prevention, adverse selection

JEL-Classification: D11, D82, G22, G28

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1 Introduction

There are many situations in which individuals must decide whether to learn about the potential risks they face. Consider, for example, an individual deciding whether to take a genetic test or an HIV test. Alternatively, consider a firm deciding whether and how much to invest in better understanding the exact product liability risks when launching a new product. Under which conditions will information about risk type be acquired? In both examples, the specific insurance possibilities impact the value of information, i.e., the extent to which insurance companies utilize potential customers' information is crucial in determining whether individuals decide to become informed. In addition, individuals may adjust their risk mitigation behavior in response to the information acquired, which in turn has implications for insurance pricing. Put differently, health and liability risks are not only determined by individuals' risk types, but also by environmental factors over which individuals have some control.

Milgrom and Stokey (1982) show that, if ex-ante efficient contracts are negotiated in a complete market economy, 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 (1986) show that, when it is costless, using categorical variables in pricing insurance increases welfare. Rothschild (2011) shows that the government can offer partial social insurance such that lifting a ban on categorical discrimination is weakly welfare increasing, even if categorization is costly. These analyses assume individuals are exogenously endowed with knowledge of their risk type.

Other researchers have examined environments where individuals are initially uninformed. 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. This implies that information will not be obtained and that 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 suggests genetic insurance as a possible solution to the classification risk posed by genetic testing. Strohmenger and Wambach (2000) model an insurance market with state-dependent consumer preferences and treatment costs exceeding the individual's willingness to pay. Then 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. However, when thinking about health related risks or liability risks, one observes that uninformed consumers or low risks will also invest in risk mitigation. Our model will take this into account.

The above stream of literature focuses mainly on the canonical Rothschild and Stiglitz (1976) model. However, not only heterogeneity of risk types, but also heterogeneity of individual measures of prevention seem to be important, especially in the contexts of health risks and liability risks.[1] For instance, the medical treatment for HIV has made important improvements during the last 15 to 20 years. It is a reasonable assumption that individuals who obtain a positive test result will adjust their lifestyle to the recommendations given by doctors.[2] However, the lifestyle choices of uninformed individuals and individuals with a negative test result will also matter when it comes to determining the probability of falling ill. Their choices cannot be ignored. More generally, the interplay between risk type and factors that can at least partially be controlled by consumers determines the insurable risk.

Another example is genetic testing for breast cancer risk. 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 substantial medical progress has been made in therapies for breast cancer, especially when detected early (e.g., Goldhirsch et al., 2007). It is a reasonable assumption that a positive result for a BRCA1 or BRCA2 mutation will change individual prevention behavior in terms of the frequency of seeing a doctor to detect indications of breast cancer as early as possible. But 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 also determines their final probability of

[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.

[2] 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 instancePalella 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.

disease.[3] Many genetic risks are multifactorial because individuals do not passively acquire information, but adjust their risk-relevant behavior to the information obtained.

For liability risks it is natural to assume that once the specific 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 risks. This issue appears particularly relevant for highly innovative production technologies where there is little knowledge or experience about potential risks to consumers. To give an example, there is rapid development in the area of nanotechnologies.[4] However, there is still little knowledge about long-term health risks due to respiration of nanoparticles, due to contact with skin, or via gastrointestinal absorption. According to Warheit et al. (2008) research on the health and environmental effects of nanotechnology lags behind technological progress. 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?

These examples demonstrate that a mere focus on an exogenously given distribution of risks in the population is insufficient to judge the incentives to obtain information in an adverse selection framework. Typically decision-makers react to the information acquired by adjusting loss prevention effort. This does not only apply to "bad news". Consequently, the risks are endogenous for all individuals. Therefore, the goal of the paper is to analyze the impact of loss prevention on the endogenous value of information in adverse selection economies.

We find that the introduction of loss prevention does not affect the ordering of endogenous values of information with respect to assumptions on observability of informational status and risk type. However, the benchmark changes. The endogenous value of information under symmetric information can be negative or positive, whereas without prevention opportunities it is unambiguously negative. Hence, the result that a first-best risk allocation does not provide incentives to obtain

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[3] In the case of breast cancer typical (endogenous) risk factors are nutrition habits, alcohol consumption, smoking before the age of 16 and exercising habits amongst others (Colditz and Frazier, 1995; Thune et al., 1997). In general, any habits that might disturb the hormonal balance might lead to moderate increases in breast cancer risk.

[4] Some internet databases suggest annual average growth rates of 40% from 2006 to 2012, see for instance `http://www.nanotechproject.org/inventories/consumer/analysis_draft/`.

information about risk is no longer true. With loss prevention situations can arise where full insurance at a fair price is available for all groups of consumers, but there are still sufficient incentives to make the acquisition of information worthwhile, especially if high risk individuals are endowed with the more efficient prevention technology.

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. We can thus derive public policy implications from these observations. Regulatory responses to genetic testing, e.g., the Genetic Information Nondiscrimination Act (GINA) in the U.S. and the Gene Diagnostics Law in Germany, can be judged from the viewpoint of informational incentives and allocative efficiency within our analysis. If individuals have sufficient control over environmental factors, their ability to adjust to the information can provide sufficient informational incentives. Hence, whether banning the use of genetic information for rate-making purposes is desirable depends on the specific kind of genetic information itself and specifically its productivity. In this respect there is considerable heterogeneity across risks for which information can be obtained so that a uniform regulatory treatment can hardly be appropriate.

The paper proceeds as follows. The next section outlines the basic model and introduces the different prevention technologies. Section 3 introduces adverse selection by allowing for different assumptions on the observability of informational status and risk type of consumers. Section 4 discusses welfare and section 5 offers public policy implications and concludes.

2 The Basic Model

2.1 General Assumptions

Following the classical insurance demand literature, we consider risk-averse individuals with utility of final wealth u, which is assumed to be strictly 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 effort x which reduces the probability of loss and comes at costs of $c(x)$. The cost of effort is increasing and convex ($c' > 0,\ c'' > 0$).[5] Also note that we assume costs to be separable.[6]

We assume that the probability of loss consists of a component that is exogenous and of a component over which the individual has some control and which 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. Furthermore, as in Doherty and Posey (1998), treatment decisions and their effectiveness will typically depend on the level of information. In this respect, we mean by preventive action all kinds of behavior conducted by the individual that might decrease the probability of illness.

We assume that individuals are identical except for prevention technology, such that a fraction θ_H of the population is considered high risk and a fraction θ_L is considered low risk. High risk individuals have the loss probability $p_H(x)$ while low risks have the loss probability $p_L(x)$. We assume p_H and p_L are strictly decreasing and strictly convex. For any given level of effort, high risks face a higher loss probability than low risks, formally $1 > p_H(x) > p_L(x) > 0$, for all 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 $p_U(x) = \theta_H p_H(x) + \theta_L p_L(x)$ due to rational expectations.[7] Subscript U denotes the uninformed individual.

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5 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 loss reduction or self-insurance action can be found in Barigozzi and Henriet (2011).

6 We abstract from heterogeneity in the dimension of prevention cost. Separability is sufficient for the first order approach to be valid (Rogerson, 1985; Jewitt, 1988).

7 We abstract from ambiguity aversion. 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. (2013).

To analyze heterogeneous prevention technologies 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 have the more efficient technology compare to the L-types. For instance, there might be a promising treatment option available that significantly lowers the probability of a severe case of the disease. The current situation regarding HIV treatment could be an example for that case. CD resembles a situation where H-types are equally efficient at loss prevention as L-types, e.g., if there is no effective treatment available and the detection of a genetic mutation simply means enhanced likelihood of the occurrence 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 occurrence of the disease, moreover means of preventing the occurrence are no longer efficient compared to healthy people without the mutation. 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_H or p_L.

2.2 Effort Choices Without Insurance

We initially assume that insurance is not available. Then the individual's expected utility is given by

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

with first-order condition

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

Optimal effort is chosen such that it balances marginal benefit from prevention and marginal cost. Let x_i^0 denote optimal effort for a type i individual. It is straightforward to show that under CD we have $x_H^0 = x_U^0 = x_L^0$, under DD we have $x_H^0 > x_U^0 > x_U^0$ and under ID we have $x_H^0 < x_U^0 < x_U^0$. This is intuitively plausible as the marginal cost of prevention does not depend on type. Therefore, in case of CD where marginal benefit from prevention is equal among types everybody choses the same effort level. Under DD H-types have the more efficient technology so that the optimal effort is higher. This is reversed in the case of ID.[8]

The value of information is defined as the change in expected utility from acquiring the information

$$I = \theta_H V_H(x_H^0) + \theta_L V_L(x_L^0) - V_U(x_U^0). \tag{2}$$

The value of information is zero in the CD case. For the other two cases, we have

$$I = \theta_H V_H(x_H^0) + \theta_L V_L(x_L^0) - V_U(x_U^0) > \theta_H V_H(x_U^0) + \theta_L V_L(x_U^0) - V_U(x_U^0) = 0,$$

where the inequality holds due to the optimality of x_H^0 and x_L^0, respectively. In the ID and DD cases, the information has clinical value, as individuals use the information to adjust their effort levels to their loss prevention technology. As Savage (1954) points out, the individual is free to ignore the information and hence it cannot be disadvantageous. This option value of information raises the value of information.

2.3 Actuarially Fair Insurance Coverage

Now assume that insurance is available in a perfectly competitive market at actuarially fair prices. We first abstract from informational asymmetries, i.e., the insurer is able to observe both informational status and risk type. This is a situation in which the insured has a duty to disclose.

In our example of 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. This might be the case 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. In our 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

[8] Due to the endogeneity of loss prevention effort the indifference curves over final wealth in the two states of the world might not be convex. They are decreasing in any case due to the envelope theorem, but the curvature reflects effort adjustments. Technical conditions to ensure convexity are long-winded and not very insightful so that we assume convexity wherever needed.

managing threats of product liability.

An insurance policy $C_i = (\pi_i, \alpha_i, x_i)$ consists of a premium, π, a coverage level, α, and a level of prevention activity, x. Expected utility is then

$$V_i(C_i) = p_i(x)u(w - \pi) + (1 - p_i(x))u(w - \pi - (1 - \alpha)l) - c(x).$$

Since the market is competitive, insuring a proportion α of the loss l comes at a premium of $\pi_i = \alpha p_i(x)l$ for a type i individual. We know from classical insurance demand theory that full insurance coverage will be obtained, see for instance Mossin (1968).[9] The objective of a type i individual is therefore to maximize

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

which yields the first-order condition

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

where the prime denotes differentiation with respect to x. We let $\hat{x}_i$ denote the first-best effort level for a type i individual, and let $\hat{C}_i$ denote the first-best policy for type i.

For the CD case, the H-types and L-types are equally efficient at loss prevention. However, H-types have a higher premium rate and therefore they will exert more effort to reduce the premium. For the DD case, the H-types are more efficient at loss prevention than the L-types, hence again they will exert more effort than L-types. So for the CD and DD cases we have $\hat{x}_H > \hat{x}_U > \hat{x}_L$. For the ID case, there are two competing effects. H-types have a higher premium rate which induces them to exert more effort than L-types. However, they are less efficient at loss prevention and this induces them to exert less effort. Therefore, the overall effect is ambiguous.

9 Of course, Mossin (1968) abstracts from prevention and considers a fixed premium only, but in case prevention expenditures are observed, optimality of full insurance coverage still holds.

The value of information is given by

$$\begin{aligned}
I_1 &= \theta_H V_H(\hat{C}_H) + \theta_L V_L(\hat{C}_L) - V_U(\hat{C}_U) \\
&= \theta_H u(w - p_H(\hat{x}_H)l) + \theta_L u(w - p_L(\hat{x}_L)l) - u(w - p_U(\hat{x}_U)l) \\
&\quad - (\theta_H c(\hat{x}_H) + \theta_L c(\hat{x}_L) - c(\hat{x}_U)) \\
&= u(w - (\theta_H p_H(\hat{x}_H) + \theta_L p_L(\hat{x}_L))l - \rho) - u(w - p_U(\hat{x}_U)l) \\
&\quad - (c(\theta_H \hat{x}_H + \theta_L \hat{x}_L + \sigma) - c(\hat{x}_U)),
\end{aligned}$$

for constants $\rho, \sigma > 0$. The risk premia ρ and σ capture the effect of classification risk on wealth and the cost of care, respectively. Again, the optimality of $\hat{x}_H$ and $\hat{x}_L$ implies that

$$I_1 > \theta_H V_H(\hat{C}_U) + \theta_L V_L(\hat{C}_U) - V_U(\hat{C}_U)$$

that is, information has clinical value. However, this is not sufficient to guarantee that the value of information is positive. Individuals who choose to become informed are exposed to classification risk, and we cannot unambiguously sign I_1.[10] We conclude that the following two conditions are sufficient for positivity of the value of information,

$$\begin{aligned}
p_U(\hat{x}_U)l &> (\theta_H p_H(\hat{x}_H) + \theta_L p_L(\hat{x}_L))\, l + \rho, \\
\hat{x}_U &> \theta_H \hat{x}_H + \theta_L \hat{x}_L + \sigma.
\end{aligned} \tag{3}$$

If the insurance premium when uninformed exceeds the expected insurance premium when informed plus a constant accounting for the aversion to classification risk, and if average prevention effort is sufficiently below the effort of uninformed individuals, consumers will decide to become informed and learn about their 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.*

In the appendix we parameterize the heterogeneity in prevention technology and demonstrate that

[10] In the absence of prevention, information has no clinical value but individuals are exposed to classification risk. Then the private value of information with full insurance is given by

$$I = \theta_H u(w - p_H l) + \theta_L u(w - p_L l) - u(w - p_U l) = u(w - p_U l - \rho) - u(w - p_U l)$$

for a positive risk premium $\rho > 0$, and is therefore negative.

DD tends to enhance the value of information. If high risks have an effective treatment option, and therefore have the more efficient prevention technology, the “bad news” from being a high risk is alleviated and information might still be valuable. We also demonstrate that there are situations in the CD and ID cases where sufficiently efficient treatment technologies can lead to a positive value of information.

This finding is related to Proposition 2 in Bajtelsmit and Thistle (2008) about the incentive to acquire information in a competitive market for liability insurance. However, in their analysis, heterogeneity in risk type corresponds to heterogeneity in loss size and prevention technology is homogeneous across agents. Consequently, adverse selection cannot be addressed as the insurer always observes amounts claimed. Proposition 1 is also related to Doherty and Posey’s 1998 finding that the value of information can be positive or negative and that a positive value of information 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.

2.4 Level of Coverage and Optimal Effort

It is worthwhile to examine how the level of insurance coverage will influence the optimal effort. In adverse-selection problems it is well known that the availability of coverage might be restricted due to the informational asymmetry. This change in the availability of insurance will typically be accompanied by a change in loss prevention effort.

For the moment, we take insurance coverage as exogenously given. (We relax this assumption later in the analysis.) Consider an insurance policy C_i with fixed coverage α, and actuarially fair premium $\pi_i = \alpha p_i(x)l$. The objective function is then given by

$$V_i(C_i) = p_i(x)u(w - \alpha p_i(x)l - (1-\alpha)l) + (1 - p_i(x))u(w - \alpha p_i(x)l) - c(x),$$

for $i \in \{H, L, U\}$. The first-order condition is

$$V_i'(C_i) = p_i'(x)(u(w_l) - u(w_n)) - \alpha p_i'(x)l(p_i(x)u'(w_l) + (1 - p_i(x))u'(w_n)) - c'(x) = 0,$$

where w_n and w_l are final wealth levels in the no-loss state and in the loss state, respectively. Optimal prevention is chosen to balance the marginal benefit, which here consists of the marginal benefit from the reduction of the loss probability and the marginal benefit from reducing the insurance premium, and the marginal cost.

Let x_i^α denote the solution of the first-order condition for a type i individual with coverage α. Note that $x_i^1 = \hat{x}_i$ is the optimal effort level with full insurance. The implicit function theorem yields

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

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

$$\frac{\partial V_i'(C_i)}{\partial \alpha} = p_i'(x)l(1-2p_i(x))(u'(w_l)-u'(w_n)) - \alpha p_i'(x)l^2 p_i(x)(1-p_i(x))(u''(w_l)-u''(w_n)),$$

so $\partial V_i'(x)/\partial\alpha$ is negative as long as the loss probability is less than $1/2$ and the individual is prudent.[11] Under these circumstances higher insurance coverage induces the agent to exert a lower prevention effort and substitute insurance for prevention. 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 premium. Raising insurance coverage has three marginal impacts. The marginal benefit from loss prevention will be lower due to the increased coverage, but the marginal benefit of a lower insurance premium is greater at a higher premium. The condition that the loss probability stays below $1/2$ is necessary and sufficient for the first effect to be dominant.[12] 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. In general, this third effect cannot be signed unambiguously; prudence is sufficient to ensure it is negative.

[11] Alternatively, a sufficient condition for negativity would be to assume a loss probability above $1/2$ and imprudence which seems not reasonable for the vast majority of applications.

[12] As noted by Ehrlich and Becker (1972), the effect that observable prevention effort lowers the insurance premium can lead to complementarity between both risk mitigation instruments.

3 Adverse Selection

3.1 Preliminaries

Let us now assume that the insurer is unable to distinguish agents with respect to their prevention technology. The insurer is able to monitor prevention effort, x, but the efficiency of prevention is private information. The question arises of how insurance can be offered in this set-up. In a Rothschild and Stiglitz (1976) self-selection design, the equilibrium policies (C_L^*, C_H^*) maximize expected utility for the low risks, subject to the self-selection constraint $V_H(C_H) \geq V_H(C_L)$ and the individual policies satisfying breakeven (zero expected profit) constraints. In addition, there is no other policy that, if offered, would earn non-negative expected profit. The H-types will be offered full insurance, $C_H^* = \hat{C}_H$. 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., the self-selection constraint is

$$V_H(C_L) = V_H(\hat{C}_H). \tag{4}$$

Since the choice of effort is observable, mimicry by H-types implies that they must pretend to be L-types in terms of both the policy chosen and the effort level selected. Therefore, we need to determine α such that the H-types are unwilling to mimic the L-types. Note that for $\alpha = 0$ the LHS of (4) offers no insurance, and $V_H(C_L) < V_H(\hat{C}_H)$. For $\alpha = 1$ the left-hand side of (4) offers full coverage at the L-type rate, and $V_H(C_L) > V_H(\hat{C}_H)$. By continuity there is at least one value of $\alpha \in (0, 1)$ where the self- selection constraint binds.[13] Then 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 $\hat{C}_H$ and choosing the L-type partial insurance contract C_L^* and mimicking the L-type effort x_L^α. Hence, the amount of insurance for L-types will be endogenously determined via self-selection to resolve the adverse selection problem.[14]

[13] In the cases CD and ID H-type indifference curves are flatter than L-type indifference curves, as in the standard model. For DD, where H-type effort is higher than L-type effort for a given wealth profile, the resulting loss probability of high risks might be lower than the resulting loss probability of L-types, which seems however an unrealistic case: The treatment option would be so efficient that the resulting probability of disease is smaller than for healthy people. This can be excluded by assuming that δ does not decrease too quickly. For the parameterization presented in the appendix the condition would be that γ be bounded from below.

[14] 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 equilibrium configurations.

3.2 Unobservable Risk Type

We first consider the situation where informational status is observable but risk type is not. For the health insurance example, this is 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 must be disclosed, i.e., the insurance company knows whether a test has been taken or not but not the result of the test. Alternatively, the insurance company might pay for the tests, ans so knows the individual is informed, but the test results are sent to the individual's private physician for interpretation. For the liability situation this corresponds to the case in which insurance companies have an idea about R&D expenses trying to evaluate the riskiness of new products, but might find it difficult to evaluate the results.

The insurer is then able to separately identify the informed and uninformed. The insurer will offer the uninformed individuals full and fair insurance coverage and they choose effort accordingly. For the informed H-types and L-types a self-selection design will be implemented. Let $\alpha \in (0,1)$ be the level of coverage where the self- selection constraint (4) binds and x_L^α be the level of effort chosen by an L-type under this policy. The endogenous value of information is then given by

$$\begin{aligned} I_2 &= \theta_H V_H(\hat{C}_H) + \theta_L V_L(C_L^*) - V_U(\hat{C}_U) \\ &= \theta_H u(w - p_H(\hat{x}_H)l) + \theta_L(p_L(x_L^\alpha)u(w - \alpha p_L(x_L^\alpha)l - (1-\alpha)l) + (1 - p(x_L^\alpha))u(w - \alpha p_L(x_L^\alpha)l)) \\ &\quad -u(w - p_U(\hat{x}_U)l) - (\theta_H c(\hat{x}_H) + \theta_L c(x_L^\alpha) - c(\hat{x}_U)). \end{aligned}$$

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

$$I_1 - I_2 = \theta_L(V_L(\hat{C}_L) - V_L(C_L^*)) > 0.$$

This is positive since expected utility under full insurance and associated effort always exceeds expected utility in a situation with partial insurance and associated effort. If the insurance company can observe the consumers' informational status, the value of information declines if informed consumers cannot reveal their risk type.

Note also that under the assumptions of prudence and sufficiently small loss probabilities, there is a substitution 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 when risk type is not observable.[15]

Proposition 2. *Let informational status be observable; the endogenous value of information is larger if individuals are allowed to reveal their risk type when informed.*

In a situation where individuals cannot undertake loss prevention measures, the value of information when risk type is not observable will also be smaller than under complete information and hence be negative.[16] However, when information has clinical value, I_2 may be positive. Consider for instance a situation where the insureds are highly risk-averse and therefore place a high value on coverage. Hence, the insurance contract offered to L-types 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 that information has clinical value may alleviate the conclusion in the extant literature that under this regime the value of information is always negative.

3.3 Unobservable Informational Status

In some situations, informational status is unobservable, but risk type can be credibly revealed by the consumer. For example, there may be a consent law where results from genetic testing can only be revealed with 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. In the liability context this corresponds to a situation in which the insurance company cannot directly infer the level of information a company has about the riskiness of their products, however, some companies might be able to credibly demonstrate that their exposure to product liability is comparatively low.

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[15] The marginal impact of the structure of prevention technology heterogeneity is difficult to assess. 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 derived in 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.

[16] It is given by

$$I_2 = \theta_H u(w - p_H l) + \theta_L \left(p_L u(w - \alpha p_L l - (1-\alpha)l) + (1-p_L)u(w - \alpha p_L l)\right) - u(w - p_U l),$$

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.

In these situations, L-types will reveal themselves since they can then take out full coverage. H-types, however, will have an incentive to state that they have no information, i.e., they will try to mimic the U-types. Hence, self-selection has to be implemented to separate those individuals, $V_H(\hat{C}_H) \geq V_H(C_U)$. Let C_U^* be the contract that satisfies the self-selection constraint separating the high risks and the uninformed. Let β be the amount of coverage available for U-types and x_U^β denote their optimal effort level given the amount of insurance. Then the value of information is given by

$$I_3 = \theta_H V_H(\hat{C}_H) + \theta_L V_L(\hat{C}_L) - V_U(C_U^*).$$

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

$$I_3 - I_1 = V_U(\hat{C}_L) - V_U(C_U^*) > 0,$$

since full insurance is always preferred to partial insurance for a given loss probability. We see that, given that the 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. *The endogenous value of information is higher if informational status is not observable but risk type can be revealed by the consumer than when informational status is observable.*

Let us investigate the structural heterogeneity of prevention technology again. Assuming prudence and a loss probability less than 1/2, U-type effort increases due to less coverage being available. Therefore, under both CD and DD, $x_U^\beta > \hat{x}_L$ holds, with β being the level of coverage available to U-types and x_U^β being the implied effort choice. The relationship between $\hat{x}_H$ and x_U^β is ambiguous.

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 unobservable 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.

3.4 Both Risk Type and Informational Status Unobservable

Finally, we analyze the situation where the insurance company cannot observe the informational status of its customers and consumers cannot reveal their risk type even if they wanted. For the health risk, this corresponds to a complete ban of genetic information in insurance. In this case insurance companies are neither allowed to inquire whether tests have been taken, nor are they allowed to use existing 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 that completely prohibits the use of genetic information.[17] For the liability example this would be a situation where the insurance company finds it hard to evaluate the extent to which firms know all potential liability risks attached to their products and furthermore firms cannot credibly demonstrate their knowledge even if they wished to do so.

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. Hence, self-selection must be utilized to separate the H-types from the U-types and to separate the U-types from the L-types. The self-selection constraints are

$$V_H(C_U) \leq V_H(C_H)$$

and

$$V_U(C_L) \leq V_U(C_U).$$

The equilibrium contracts (C_H^*, C_U^*, C_L^*) maximize expected utility for the low risks, subject to the self-selection constraints, to the breakeven constraints on the individual contracts and to no other contracts being able to earn non-negative expected profits. In equilibrium, the H-types receive full coverage, $C_H^* = \hat{C}_L$, and the self-selection constraints are binding.

The endogenous value of information is given by

$$I_4 = \theta_H V_H(\hat{C}_H) + \theta_L V_L(C_L^*) - V_U(C_U^*)$$

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. Observe that the H-types and U-types take out the same contracts as before. Then, since the low risks obtain full insurance

[17] 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. However, if the sum insured in a life insurance policy exceeds € 300,000 or if an annuity exceeds € 30,000 insurers may inquire genetic information.

when their risk type is observable and partial coverage when it is not, we have

$$I_3 - I_4 \;=\; \theta_L(V_L(\hat{C}_L) - V_L(C_L^*)) > 0.$$

This immediately leads to the following result.

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 the possibility of using favorable information about type enhances the value of information. This extends Proposition 2 to the case in which informational status is not observable by the insurance company. Consequently, the use of favorable test results increases the value of information independent of whether informational status is observable or not.

4 Welfare Implications

As shown in the last two sections, how policyholders' information is used for rate-making in insurance crucially impacts the value of information. After analyzing informational incentives as implied by the contracts offered in equilibrium and the actions taken by the individuals, we now focus on welfare implications under the different scenarios. When there is a duty to disclose that a test has been taken and the result of the test, so that both informational status and risk type are observable, the value of information is I_1. When there is a code of conduct, so that the fact a test has been taken, but not its results must be revealed, then the value of information is I_2. The value of information is I_3 under a consent law, where test results can be credibly revealed, and is I_4 under a ban on the use of any testing information.

Let us again look at Proposition 2. We showed that the value of information is higher in the complete information benchmark case as compared to a situation in which informational status is observable, but knowledge about risk type must not be revealed. Formally, we derived $I_1 > I_2$. There are three cases are possible. If $0 > I_1 > I_2$, then neither regime provides incentives to acquire information. Uninformed individuals receive the first-best policy in either case, so there is no effect on consumer welfare. If, however, $I_1 > 0 > I_2$, then the duty to disclose provides incentives to obtain information, whereas a code of conduct does not. Consequently, all uninformed consumers under a duty to disclose would become informed, whereas uninformed consumers stay rationally ignorant under a code of conduct. This would constitutes a welfare loss due to the fact that $I_1 > 0$

implies that

$$\theta_H V_H(\hat{C}_H) + \theta_L V_L(\hat{C}_L) > V_U(\hat{C}_U).$$

The group of uninformed individuals is on average better off acquiring the information under a duty to disclose than staying uninformed under a code of conduct. Lastly, it could be the case that $I_1 > I_2 > 0$. Then, both regimes provide sufficient incentives to acquire information and all individuals would become informed in any case. However, under the code of conduct L-types are only partially insured as test results cannot be made available to the insurer. In this sense, a duty to disclose is superior to a code of conduct in terms of allocative efficiency.

A similar analysis can be conducted for the other situations. Under a consent law, we have $I_3 > I_1$. If $0 > I_3 > I_1$, information is never valuable and a duty to disclose is preferable as U-types can be fully insured. If $I_3 > 0 > I_1$, all uninformed consumers will become informed under a consent law. However,

$$\theta_H V_H(\hat{C}_H) + \theta_L V_L(\hat{C}_L) < V_U(\hat{C}_U),$$

due to the fact that $I_1 < 0$, so this constitutes a welfare loss as uninformed consumers receive higher expected utility when staying uninformed and being fully covered than when acquiring information. Lastly, if $I_3 > I_1 > 0$, then both regimes provide sufficient incentives to obtain information, consequently uninformed consumers will become informed. As revealed risk types are fully insured at their fair rate, the two scenarios are equally efficient in terms of risk allocation.

Our last result was to establish that a complete ban is inferior to a policy of consent law in terms of informational incentives, i.e., $I_3 > I_4$. If $0 > I_3 > I_4$, then both regimes do not provide incentives to acquire information, but under a consent law revealed L-types can be fully insured. If $I_3 > 0 > I_4$, then uninformed individuals will become informed under a consent law and this is also welfare improving compared to a regime of a complete ban as

$$\theta_H V_H(\hat{C}_H) + \theta_L V_L(\hat{C}_L) > V_U(C_U^*).$$

If $I_3 > I_4 > 0$, both regimes lead uninformed consumers to become informed. However, under a consent law full insurance is provided to revealed low risks and the consent law is therefore preferable.

5 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. This implies there is the potential for adverse selection along the efficiency dimension of prevention. Under observable preventive effort, 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.

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 depends on the level of information.

We find that if risk type and informational status are observable, the endogenous value of information can be positive or negative. Information has clinical value, as individuals can adjust their loss prevention behavior based on the information acquired. This is in contrast to the existing result that, when individuals cannot undertake preventive activities, the value of information is negative. When individuals can take preventive actions, the clinical value of information may be sufficient to outweigh the classification risk inherent in taking the test.

However, the ordering of the values of information is the same whether individuals can undertake preventive activities or not. When informational status is observable, the endogenous value of information is larger if risk type is observable than if it is not. When risk type can be revealed, the endogenous value of information is higher if informational status is not observable than if it is observable. And finally, when informational status is unobservable, the endogenous value of information is higher if risk type can be revealed than if it cannot. Therefore, we conclude that the relative order 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 revealed from genetic tests for insurance contracting. In the U.S., the Genetic Information Nondiscrimination

Act (GINA) was signed into law in 2008.[18] The law prevents discrimination by health insurers and employers based on individuals' DNA.[19] In Germany, the Gene Diagnostics Law came into force in 2010.[20] 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 some cases for large policies.

These policies can be critically evaluated in light of our results. In Proposition 1 a first-best efficient insurance market with fairly priced and full coverage for all types can provide positive informational incentives. The analysis conducted in section 4 revealed that this regime is in all cases superior to a scenario where informed L-types cannot credibly reveal their results to the insurance company. Furthermore, we could show that also in the cases where insurance companies cannot observe the informational status it is always recommendable to allow informed low risk types reveal their results. However, when comparing I_1 to I_3, we found that the answer is ambiguous: There might be cases where it is advisable to leave uninformed consumers fully insured under regime I_1 as their expected utility from becoming informed is inferior. In this sense, from a utilitarian welfare perspective, concealment of test results might be a) unnecessary and b) welfare deteriorating. It is unnecessary if the symmetric information regime already provides sufficient incentives for the acquisition of information and it might lower societal welfare if the value of information I_1 is negative.

Hence, by introducing loss prevention into the picture we can identify circumstances where concealment of informational status might not be advisable, whereas the possibility to reveal favorable knowledge about risk type always enhances utility of L-types and therefore increases the endogenous value of information. So in the end it may depend on the specific disease under consideration or on the structure of the liability risk whether current regulation is appropriate or not. This is due to the fact that risks differ immensely in the (clinical) productivity of the information so that a uniform regulatory approach can hardly be appropriate. We confirm the results from Doherty and Posey (1998) and extend them to a more general framework of loss mitigation and by considering various informational scenarios. We furthermore derive conclusions regarding the trade-off between

[18] For further information, please visit `http://www.genome.gov/24519851`.

[19] The law does not state explicitly that discrimination in life insurance, annuities and long term care insurance is prohibited.

[20] 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`.

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 insufficient. Hence, judging loss mitigation opportunities contingent on the information acquired is important to evaluate the incentives to obtain information.

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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

$$\begin{aligned} p_H(x) &= p_L(x) + \gamma x + p_H(0) - p_L(0), \\ p_U(x) &= p_L(x) + \theta_H \gamma x + \theta_H (p_H(0) - p_L(0)). \end{aligned}$$

Rearranging (2) yields

$$\begin{aligned} I &= (\theta_H p_H(x_H^*) + \theta_L p_L(x_L^*) - p_U(x_U^*))\,(u(w-l) - u(w)) \\ &\quad - (\theta_H c(x_H^*) + \theta_L c(x_L^*) - c(x_U^*))\,. \end{aligned}$$

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

$$\begin{aligned} \frac{\partial V_L(x_L^*)}{\partial \gamma} &= 0, \\ \frac{\partial V_U(x_U^*)}{\partial \gamma} &= \theta_H x_U^* (u(w-l) - u(w)), \\ \frac{\partial V_H(x_H^*)}{\partial \gamma} &= x_H^* (u(w-l) - u(w)). \end{aligned}$$

Therefore, the marginal effect of a variation of γ 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

$$\left.\frac{\partial^2 I}{\partial \gamma^2}\right|_{\gamma=0} = -\theta_L V_H''(x_H^*) > 0, \tag{5}$$

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 $I(\gamma)$.

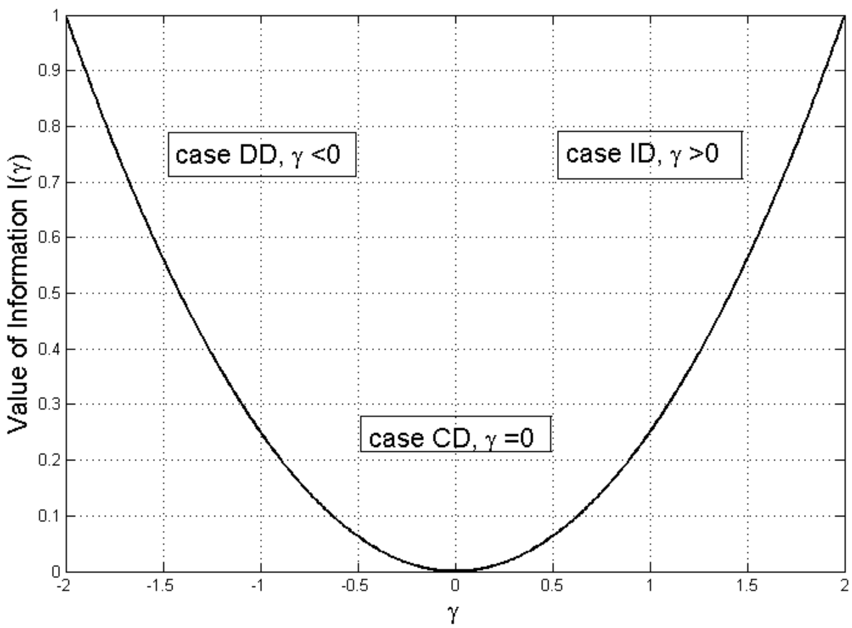

Figure 1 – Shape of the value of information function without insurance

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

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

Hence, we obtain for the endogenous value of information

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

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 $\gamma \in (0, \overline{\gamma})$. Hence, the value of information increases when moving from ID over CD to DD. Let us illustrate a possible shape of $I_1(\gamma)$ in the following figure.

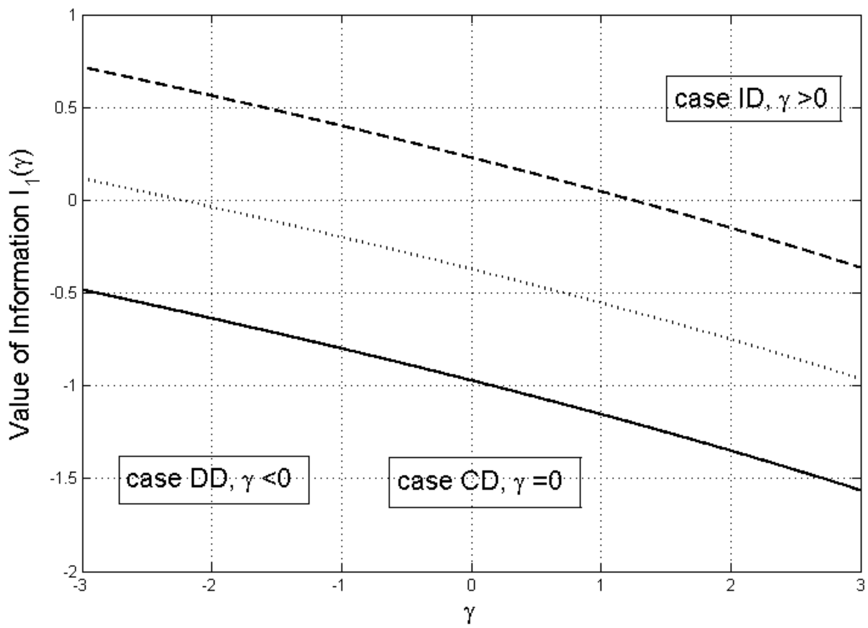

Figure 2 – Shape of the value of information function with full insurance

The solid 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 dotted line represents a situation where for some low values of γ 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 dashed line represents a situation where even for some positive values of γ 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.

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 Preventione 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 ψ is nonempty. $\psi \geq -(\xi+1)$ renders the parameter region for φ 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

$$p_H(x) = \xi_H x^2 + \psi x + \varphi \qquad \text{and} \qquad p_L(x) = \xi_L x^2 + \psi x + \varphi,$$

with $0 < \xi_L < \xi_H < 1$. Furthermore, ψ shall be picked from the interval $[-(\xi_L+1), -2\xi_H)$ and φ 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.[21] 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

$$\begin{aligned} I_1 &= \theta_H(w - p_H(\hat{x}_H)l) + \theta_L(w - p_L(\hat{x}_L)l) - (w - p_U(\hat{x}_U)l) - \theta_H \hat{x}_H - \theta_L \hat{x}_L + \hat{x}_U \\ &= p_U(\hat{x}_U)l - \theta_H p_H(\hat{x}_H)l - \theta_L p_L(\hat{x}_L)l + \hat{x}_U - \theta_H \hat{x}_H - \theta_L \hat{x}_L \end{aligned}$$

[21] The second is nonempty in any case then.

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 $(2\xi_i x + \psi)l + 1 = 0$.[22] 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.
Plugging the effort levels into the expression for I_1, we obtain

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

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. The reason is that risk-neutral agents are not affected by classification risk.

C.3 Extension to the General Model

In order to construct a numerical example with risk aversion and convex prevention cost we use a parameterization that nests risk neutrality and linear cost of effort. 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 (μ, ν). 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.

[22] The second order conditions are satisfied, $-2\xi_i l < 0$.

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