Testing frequency and severity risk under various information regimes and implications in insurance

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June 12, 2023

Abstract

We build on Peter et al. (2017) who examined the benefit of testing frequency risk under various information regimes. We first consider testing only severity risk, and whether the principle of indemnity, i.e. the usual contract term that excludes claims payments above the resulting insured loss, affects the insurance contracts offered and purchased. Under information regimes which are less restrictive (in terms of obtaining and using customer information), it is possible for the insurer to offer different contracts for tested and untested individuals. In the absence of the principle of indemnity, individuals will test their severity risk and a separating equilibrium ensues. With the principle of indemnity, given an actuarially fair pooled contract, individuals will not test for severity under less restrictive information regimes; a pooling equilibrium thus ensues. Under more restrictive information regimes, the insurer offers separating contracts. Individuals will test for severity and purchase appropriate contracts. We also consider testing for both frequency and severity risk. The results here are more varied. The highest gain in efficiency from testing results from one of the more restrictive information regimes. Generally under all information regimes, there is a greater gain in efficiency without the principle of indemnity than with the principle of indemnity.

1 Introduction

In this paper, we examine an individual in an insurance purchasing situation who is uncertain of her risk and subsequently needs to decide whether to gather information through testing. We compare the insurance contracts offered and purchased when severity risk is considered instead of frequency risk, and when both types of risk are taken into consideration. From Rothschild and Stiglitz (1976), we know that in the case where the risk type is defined by frequency, high risk types often benefit if insurance companies are neither able to observe the risk type information nor use the information for pricing while low risk types benefit if information can be revealed. However, whether information can be revealed depends on the information regime[1]. Additionally, we consider the situation when both frequency and severity risk are taken into consideration.

As in Peter et al. (2017), we look at four information regimes: 1) a disclosure duty regime under which test results must be revealed to the insurance company, 2) a code of conduct, under which the existence but not the result of previous tests must be revealed, and there is no obligation to undergo a test, 3) a consent law, under which the insurance company may use test information if the customer agrees to provide the information and 4) an information ban which forbids the use of test results for insurance contract offers.

For our results, the presence of the 'principle of indemnity' is essential. It excludes claims payments above the occurred insured loss. Individuals will test for severity in the absence of the principle of indemnity and subsequently purchase the contracts designed for their specific level of severity risk. With the principle of indemnity, individuals find it beneficial not to test under the disclosure duty and code of conduct regimes, hence purchase the actuarially fair pooled contract. Under the consent law and information ban, individuals find it beneficial to test severity risk, hence a separating equilibrium exists. If only severity risk is considered under the disclosure duty and code of conduct, the presence of the principle of indemnity determines whether individuals take a test.

When frequency risk is considered in addition to severity risk, under the code of conduct and information ban, frequency risk adds an additional layer of adverse selection under the code of conduct and information ban without the principle of indemnity. Individuals who choose to get informed under these two regimes will be separated by frequency risk but the low frequency types will not be separated by severity risk. With the principle of indemnity, informed individuals are separated by both frequency and severity risk. Under the code of conduct and information ban, informed individuals with low frequency risk do not receive full coverage. Under the disclosure duty and consent law, informed individuals are separated by both frequency and severity risk and fully covered against losses. There is a greater benefit to gathering information without the principle of indemnity, and the consent law yields the greatest efficiency gain from gathering information.

The COVID-19 pandemic gives a recent example for the relevance of differentiating between high and low severity risk types: within a household of friends, everyone may have an equal probability of contracting the COVID-19 disease. However, not everyone

[1]Information regime: the regulatory framework of information gathering and processing

is aware of the underlying health conditions and therefore, the disease severity. Some individuals might have a genetic condition which leads to more severe repercussions. Hence, it can be important for individuals to obtain information about their health characteristics to better mitigate the monetary loss from different costs of treatment.

Another example is about cancer: people with certain characteristics are more likely to get cancer (and recurrence) with different levels of severity (Cooley, Short, and Moriarty 2003; Lutz et al. 2001; Stenkvist et al. 1982). For a given recurrence probability, cancers can resurface in the same place or in a different part of the body depending on various health characteristics. Different treatments at different cost levels might therefore be needed (Mahvi et al. 2018), which, in principle, implies the need for different health insurance coverage.

There are further examples in the non-health area. The July 2021 cyber attack on Kaseya (an IT management software) has affected tens of thousands of organizations all over the world, from supermarket chains to public transportation providers (Browning 2021). Such organizations face a somewhat equal probability of experiencing an attack, but the severity of the fallout differs since some companies may handle more sensitive customer data than others. It is worthwhile for these companies to gather information on how vulnerable their systems are in order to mitigate the damages through an appropriate cyber insurance contract (Zhang and Zhu 2019).

The paper is organized as follows: Section 2 provides a brief literature review. Section 3 sets up the model which considers testing only severity risk. Section 4 sets up the model which considers testing both frequency and severity risk. Section 5 provides a discussion. Section 6 concludes.

2 Literature Review

Our paper contributes to the literature on information gathering for insurance purchasing decisions and genetic testing. Individuals who test should select contracts which are more appropriate for their risk type (Finkelstein and Poterba 2004). The type of risk considered is often frequency risk. We consider severity risk and the combination of frequency and severity risk. Testing risk can increase the efficiency of insurance pricing. However, with that comes the risk of discrimination (Crocker and Snow 1986). The papers closest to ours are Barigozzi and Henriet (2011) and Peter et al. (2017) which examine the gain in welfare from testing frequency risk under four different information regimes: disclosure duty, code of conduct, consent law and information ban.

Barigozzi and Henriet (2011) find that the value of information can either be positive or negative under the disclosure duty and code of conduct, with the value of information being at least as large in the disclosure duty as in the code of conduct. Under the consent law, the value of information is always positive and under the information ban, the value of information is non-negative. With only frequency risk considered, the consent law leads to the greatest gain in utility from testing. We find similar results when considering both frequency and severity risk together. Peter et al. (2017) also examine the different regulatory regimes for the use of genetic information in the health insurance market when prevention is endogenous; and extend Barigozzi and Henriet

(2011) by incorporating prevention into the model. The disclosure duty information regime is weakly optimal. An information ban leaves individuals worse off since they are unable to choose appropriate secondary prevention measures.

The equilibrium conditions arise from the contracts offered under each information regime. In information regimes which offer less protection for individuals, insurance companies can engage in price discrimination by only offering certain contracts to particular types of individuals. Similarly, insurance companies operating in information regimes which offer more protection for individuals can price discriminate to some extent by indirectly motivating individuals to reveal type information. Otherwise, insurance companies need to offer contracts based on predictions of individual decisions to test. Table 1 summarizes the results from Barigozzi and Henriet (2011) and Peter et al. (2017) by listing the contracts ($\{q,d\}$, where q is the premium rate and d is the coverage) offered under each information regime.

Regime	H-type	L-type	Uninformed	Test
DD	$\{q_H,d_F\}$	$\{q_L,d_F\}$	$\{q_U,d_F\}$	N
CC	$\{q_H,d_F\}/\{q_L,d_P\}$	$\{q_H,d_F\}/\{q_L,d_P\}$	$\{q_U,d_F\}$	N
CL	$\{q_H,d_F\}$ $\{q_U,d_F\}$	$\{q_L,d_F\}$ $\{q_U,d_F\}$	$\{q_H,d_F\}$ $\{q_U,d_F\}$	Y N
IB	$\{q_H,d_F\}/\{q_L,d_P\}$ $\{q_U,d_F\}$	$\{q_H,d_F\}/\{q_L,d_P\}$ $\{q_U,d_F\}$	$\{q_H,d_F\}/\{q_L,d_P\}$ $\{q_U,d_F\}$	Y N

where q_H: premium rate for high-risk individual
q_L: premium rate for low-risk individual
q_U: population weighted premium rate
d_F: full coverage
d_P: partial coverage

Table 1: Summary of contracts offered in the frequency case

From Table 1, it can be seen that contracts depend on whether individuals test and their type. In the frequency case[2], it is assumed that actuarially fair contracts are offered. Under the disclosure duty (DD), which offers the least protection to individuals' privacy, insurance companies can offer type-specific contracts. Tested H-type individuals are offered a coverage of d_F at a premium rate of $q_H = \mu_H$ (contract: $\{q_H,d_F\}$) while tested L-type individuals are offered a coverage of d at a premium rate of $q_L = \mu_L$ (contract: $\{q_L,d_F\}$). Untested/uninformed individuals are offered a coverage of d_F at the actuarially fair premium rate of q_U, which is the weighted average of q_H and q_L (contract: $\{q_U,d_F\}$). Given these contracts, individuals choose not to test under the disclosure duty. Under the code of conduct (CC), since insurance companies are unable to differentiate between types who are tested, it is necessary to offer incentive compatible contracts, i.e. the coverage for the L-type is reduced to $d_P < L$ (contract: $\{q_L,d_P\}$). Since being the L-type makes one worse off from lower coverage, individuals are better off not testing and purchasing the pooled contract. Under the consent law, while insurance companies cannot observe type or testing status, individuals can reveal

[2]In the frequency case, there are two types of individuals. The types are differentiated by the probability of suffering the loss, d_F. In the population, individuals either suffer the loss with probability μ_H or μ_L, where $\mu_H > \mu_L$.

type information. If insurers anticipate that individuals test, the contract with the higher premium rate is offered to everyone, while the contract with the lower premium rate is offered to individuals who present a test stating that they are the L-type. Otherwise, only the actuarially fair pooled contract is offered. Given the information ban, no exchange of information can occur between the insurer and individual even if the latter is willing to provide information on testing status and type. This creates adverse selection. Hence, insurance companies need to first anticipate whether individuals test. If individuals test, insurance companies offer two incentive compatible contracts, $\{q_H, d_F\}$ and $\{q_L, d_P\}$. Otherwise, the actuarially fair pooled contract is offered.

Other papers in the genetic testing literature examine whether testing is worthwhile depending on what individuals can do to reduce risk. Bardey and De Donder (2013) examine the impact of genetic tests on previously uninformed individuals under the condition that prevention is endogenous. If insurance companies are able to observe the probability of an individual suffering a particular illness, individuals will agree to get tested if the effort cost is neither trivial nor prohibitive. If the effort is unobservable, then individuals will only agree to get tested if the effort cost to prevent the disease is low. Crainich (2017) studies how genetic testing can help individuals adjust the amount of self insurance. If genetic information is private, under a pooling equilibrium, high frequency risk individuals copy the amount of self insurance a low frequency risk individual partakes in. In the Rothschild and Stiglitz (1976), Miyazaki (1977), and Spence (1978) equilibria, high frequency risk individuals exert a different amount of effort on self insurance than low risk individuals. If genetic information is public, high risk individuals increase the self insurance effort while low risk individuals decrease self insurance.

Doherty and Thistle (1996), Hoy et al. (2003) and Hoel et al. (2006) examine the equilibria which arise as a result of testing.

Doherty and Thistle (1996) ask what incentivizes insurance customers to be informed. Individuals decide to gather information depending on whether insurance companies can verify the information. The authors show in a theoretical model that the private value of having genetic information is non-negative only if insurance companies are unable to observe the information of the individual who took the test.

Hoy et al. (2003) provide an overview of the impact of genetic testing on the health insurance market. They show in a theoretical model that if the proportion of individuals with a high probability (frequency) of suffering a disease is large, then separating contracts prevail. A pooling equilibrium results if the proportion of low risk individuals is large.

Hoel et al. (2006) discuss the extent to which insurance companies should be allowed to use genetic information to price insurance contracts. The authors show in a theoretical model that individuals are more likely to take a test if the results are verifiable. Individuals with a low probability of contracting a disease are better off if results are verifiable than if the results are not. Individuals with a high probability of contracting a disease are unaffected by whether the results are verifiable. Individuals who choose not to be tested are unaffected. The authors then conclude that a regulatory regime in which insurance companies are able to use genetic information is optimal.

3 Setup

This section introduces the model we use to examine whether individuals test for severity risk under different information regimes. Suppose there is an individual who can suffer a loss of i where $i \in \{L, H\}$ and $L < H$, i.e. the individual who suffers a loss of H is the high severity risk type and the individual who suffers a loss of L is the low severity risk type. There is a unit mass of individuals where θ_H is the share of H-types and θ_L is the share of L types and $\theta_H + \theta_L = 1$. The individual is unable to manipulate her risk type. The probability of suffering this loss is μ. The individual is initially unaware of her risk type and must decide whether to inform herself through testing at a cost of c and also whether to purchase an insurance contract, $\{q, d\}$ where q is the actuarially fair premium rate and d is the indemnity paid out in the event of a loss (therefore, the premium is qd). The individual is endowed with a wealth of w where $i < w$. The individual's von Neumann-Morgenstern utility function, $u()$, has the following properties: $u'() > 0$ and $u''() < 0$.

3.1 Contracts in the absence of the principle of indemnity

In the absence of the principle of indemnity, an individual's indemnity payment in the event of a loss is not limited to the loss size. Common contracts for which the principle of indemnity does not apply include life insurance (Swan 1981), and to a certain extent, property insurance[3].

If an individual is informed and suffers a loss of severity i, she has to find the amount of coverage, $d_{I,np}$[4], which maximizes the expected utility, V_I:

$$V_{I,np} = \max_{\mathrm{d_{I,np}}} \{\mu u(w - q d_{I,np} - i + d_{I,np} - c) + (1-\mu) u(w - q d_{I,np} - c)\} \tag{1}$$

where c is the monetary cost of information, which, for simplicity, is normalized to zero. Since we assume that insurance is actuarially fair (i.e. $q = \mu$), we know that the optimal coverage $d^*_{I,np} = i$, i.e. full coverage (Mossin 1968). Without adverse selection, an informed individual will not have an incentive to deviate from the contract meant for her respective severity risk.

An uninformed individual needs to find the indemnity, $d^*_{U,np}$[5], which maximizes the expected utility V_U:

$$\begin{aligned} V_{U,np} = \max_{\mathrm{d_{U,np}}} \{ & \theta_H[\mu u(w - q d_{U,np} - H + d_{U,np}) + (1-\mu) u(w - q d_{U,np})] \\ & + \theta_L[\mu u(w - q d_{U,np} - L + d_{U,np}) + (1-\mu) u(w - q d_{U,np})]\} \end{aligned} \tag{2}$$

Let $A = \theta_H H + \theta_L L$ be the mean loss size in the population.

[3]It is sometimes possible that replacement cost coverage leads to an increase in the value of an asset, for example, by increasing the *"useful life of the asset"* (Williams 1960; Lindblad 1976).

[4]I stands for informed, while np stands for no principle of indemnity

[5]U stands for uninformed

Proposition 3.0. *Given that $q = \mu$, the necessary condition for an optimal d is:*

$$\theta_H u'(w - qd^*_{U,np} - H + d_{U,np^*}) + \theta_L u'(w - qd^*_{U,np} - L + d^*_{U,np}) = u'(w - qd^*_{U,np}) \tag{3}$$

*The optimal coverage which satisfies the above condition for the uninformed individual is $d^*_{U,np} > A$ in the absence of the principle of indemnity. Proof in the **Appendix**.*

To determine whether it is worthwhile to test for severity risk, the individual needs to compare the utility from testing and forgoing information.

Proposition 3.1. *Suppose there are three contracts available: $\{q,H\}$, $\{q,L\}$, $\{q,d^*_{U,np}\}$; since these contracts are actuarially fair, $q = \mu$. Without the principle of indemnity an individual always tests for severity and a separating equilibrium exists. Proof in the **Appendix**.*

Corollary 3.2. *Without the principle of indemnity, the value of information is the same in all four information regimes.*

The insurance company is able to offer both separating contracts for the tested and a pooled contract for the individuals who did not get tested without making a loss due to the absence of adverse selection. Given that the insurance company always offers these three contracts, individuals always test for severity risk. As the separating contracts are incentive compatible, individuals will then sort themselves by purchasing the appropriate coverage. As a consequence, there will be no demand for the pooling contract.

3.2 Contracts in the presence of the principle of indemnity

Given the principle of indemnity, an individual's payout in the event of loss is limited to the loss size even if the coverage purchased exceeds the loss size. Most insurance contracts operate with the principle of indemnity (Rejda 2005).

On the one hand, an informed individual solves the same problem as the individual in the case without the principle of indemnity. As a result, an informed individual purchases full coverage appropriate for her risk level.

An uninformed individual who suffers a loss of size i, on the other hand, needs to find the indemnity, $d^*_{U,p}$[6], which solves the following maximization problem:

$$\begin{aligned} V_{U,p} = \max_{\mathrm{d_{U,p}}} \{ & \theta_H\{\mu u(w - q(d_{U,p})d_{U,p} - H + \min\{H, d_{U,p}\}) + (1-\mu)u(w - q(d_{U,p})d_{U,p})\} \\ & + \theta_L\{\mu u(w - q(d_{U,p})d_{U,p} - L + \min\{L, d_{U,p}\}) + (1-\mu)u(w - q(d_{U,p})d_{U,p})\}\} \end{aligned} \tag{4}$$

Since the insurance contract for the uninformed individual needs to be actuarially fair, the premium rate $q(d_{U,p}) \neq \mu$. The insurance company's expected profit for a pooling contract, Π, is given by:

[6] p stands for principle of indemnity

$$\begin{aligned}\Pi = q(d_{U,p})d^*_{U,p} - \mu(\theta_H d^*_{U,p} + \theta_L L) = 0 \\ \implies q(d_{U,p}) = \mu(\theta_H + \theta_L \frac{L}{d^*_{U,p}}) \\ \implies q'(d_{U,p}) = -\mu\theta_L \frac{L}{{d^*_{U,p}}^2} < 0\end{aligned} \tag{5}$$

Under the principle of indemnity, the value of $d^*_{U,p}$ which maximizes the individual's utility is $d^*_{U,p} = H$[7] and the premium rate is $q(H) = \mu(\theta_H + \theta_L \frac{L}{H})$.

The premium paid in the presence of the principle of indemnity ($q(H)H$) is less than the premium paid in the absence of the principle of indemnity ($qd^*_{U,np}$)[8]. Furthermore, the coverage provided is H (although the L-type individual would only receive L if a loss occurs) with a premium rate of $q(H) < q = \mu$[9] in the presence of the principle of indemnity, whilst in the absence of the principle of indemnity the coverage provided was $d^*_{U,np} > A$ with a premium rate of $q = \mu$.

Proposition 3.3. *With the principle of indemnity under the disclosure duty and code of conduct information regimes,* $\{q|q = \mu, H\}$*,* $\{q|q = \mu, L\}$*,* $\{q(H), H\}$ *are offered. An individual will not test her severity risk and purchases the pooled contract,* $\{q(H), H\}$*.*

Proof. The value of information is given by:

$$V^{sev}_{info,p} = \theta_H u(w - qH) + \theta_L u(w - qL) - u(w - q(H)H) \tag{6}$$

Since the individual's test status can be observed, the insurance company can restrict $\{q(H), H\}$ to those who did not get tested. Due to the concavity of the utility function, $V^{sev}_{info,p} < 0$. The individual never finds it beneficial to test severity risk. □

Proposition 3.4. *In the presence of the principle of indemnity under the consent law and information ban regimes, the pooled contract,* $\{q(H), H\}$*, can no longer exist. An individual will always test severity risk and a separating equilibrium ensues.*

Proof. Since the individual's test status cannot be observed, adverse selection is now present. If the pooled contract, $\{q(H), H\}$, was offered, a tested individual who suffers a loss of H can pretend to be untested. Under the consent law, this is not a problem, as a tested individual who suffers a loss of L is able to reveal type information to the insurer. This means that even if the tested individual who suffers a loss of H would like to hide information, it is not possible, since the insurance company knows that everyone is tested. Someone who hides information can be identified as the type which suffers a loss of H. As a result, the insurer would not offer $\{q(H), H\}$. Meanwhile, under an information ban, neither type is allowed to reveal information. To rectify the adverse

[7] $d^*_{U,p}$ is at least L. If $d^*_{U,p} < L$, the utility increases when coverage increases marginally for both types. Since $d^*_{U,p}$ is at least L, for the uninformed individual, there is no longer uncertainty associated with being the L-type. Hence, the uninformed individual can 'behave' as if she is the H-type. Using a similar line of reasoning, $d^*_{U,p} = H$. If $d^*_{U,p} < H$, utility can always be increased by marginally increasing coverage.

[8] $q(H)H = qA < qd^*_{U,np}$ since $d^*_{U,np} > A$

[9] $q(H) = \mu(\theta_H + \theta_L \frac{L}{H}) < q = \mu(\theta_H + \theta_L \frac{H}{H}) = \mu(\theta_H + \theta_L) = \mu$

selection, the insurer offers only $\{q|q=\mu,H\}$ and $\{q|q=\mu,L\}$. To an uninformed individual, either contract can be optimal under different parameters although there is a non-zero probability of the optimal contract being inefficient[10]. Therefore, the individual chooses to test severity risk. The value of information if the individual chooses $\{q|q=\mu,d\}$ is given by:

$$\begin{aligned} V^{sev}_{info,p} &= \theta_H u(w-qH)+\theta_L u(w-qL) \\ &\quad -\theta_H[\mu u(w-qd-H+d)+(1-\mu)u(w-qd)] \\ &\quad -\theta_L[\mu u(w-qd)]>0 \end{aligned} \tag{7}$$

□

Table 2 summarizes the results of this section. The contracts offered to each type are shown in each cell. Notice that when adverse selection is present under the principle of indemnity, the results are the same as in the frequency case. Under the disclosure duty and code of conduct, individuals do not find it optimal to test. Under the consent law and information ban in the severity case, if insurance companies offer more than one contract, individuals will always test. In the frequency case, it is necessary for insurance companies to predict whether an individual will test to decide which contracts to offer. In the severity case, the pooled contract is not offered altogether. Hence, the difference between the frequency and severity case under the consent law and information ban is that individuals may or may not test in the frequency case, but in the severity case individuals always test. In the absence of the principle of indemnity, the results from the frequency case are reversed under the disclosure duty and code of conduct, as individuals now test to avoid type-uncertainty. Under the consent law and information ban, the results are similar to the frequency case, where an individual's decision to test depends on the contracts offered.

[10] If an uninformed individual chooses the contract which provides a coverage of H, there is a non-zero probability, θ_L, of being over-insured. Likewise, if an uninformed individual chooses the contract which provides a coverage of L, there is a non-zero probability, θ_H, of being under-insured.

Regime	H-type	L-type	Uninformed	Test
DD	$\{q,H\}$	$\{q,L\}$	$\{q,d_{>A}\}$	Y
CC	$\{q,H/L\}$	$\{q,H/L\}$	$\{q,d_{>A}\}$	Y
CL/IB	$\{q,H/L/d_{>A}\}$	$\{q,H/L/d_{>A}\}$	$\{q,H/L/d_{>A}\}$	Y
	$\{q,H/L\}$	$\{q,H/L\}$	$\{q,H/L\}$	Y
	$\{q,d_{>A}\}$	$\{q,d_{>A}\}$	$\{q,d_{>A}\}$	N
Without principle of indemnity				
DD	$\{q,H\}$	$\{q,L\}$	$\{q(H),H\}$	N
CC	$\{q,H/L\}$	$\{q,H/L\}$	$\{q(H),H\}$	N
CL & IB	$\{q,H/L\}$	$\{q,H/L\}$	$\{q,H/L\}$	Y
With principle of indemnity				

where q: premium rate offered to informed individuals regardless of the principle of indemnity and to uninformed individuals in the absence of the principle of indemnity

$q(H)$: premium rate offered to uninformed individuals in the presence of the principle of indemnity in the DD and CC regimes

H, L, $d_{>A}$: coverage offered and $d_{>A} > A$

Table 2: Summary of contracts offered in the severity case

4 Testing both frequency and severity risk

In this section, we introduce frequency risk in addition to severity risk and consider an individual who tests both frequency and severity risk at once. Individuals can either suffer the loss with a probability of μ_H or μ_L where $\mu_H > \mu_L$. The share of individuals who suffer the loss with a probability of μ_H is γ_H, while the share who suffer the loss with a probability of μ_L is γ_L. Assume again that there is a unit mass of individuals in the population, and there are four types of individuals:

- Individuals who suffer a loss of H with probability μ_H (share in population: $\theta_H\gamma_H$)
- Individuals who suffer a loss of H with probability μ_L (share in population: $\theta_H\gamma_L$)
- Individuals who suffer a loss of L with probability μ_H (share in population: $\theta_L\gamma_H$)
- Individuals who suffer a loss of L with probability μ_L (share in population: $\theta_L\gamma_L$)

where $\theta_H\gamma_H + \theta_H\gamma_L + \theta_L\gamma_H + \theta_L\gamma_L = 1$. It is assumed that the shares in the population are the same as the shares of insurance customers. We will determine the testing and purchasing behavior on the one hand, and the supply of insurance on the other hand, and thus find out whether there is an insurance market equilibrium. It is assumed that taking one costless test reveals both frequency and severity risk. We restrict the frequency and severity parameters to the case where $\frac{\mu_H}{\mu_L} = \frac{H}{L}$. This restriction provides a starting point for us to derive a basic result. Without this restriction, the results become complex and will depend on the values of the parameters q_H, q_L, H and L. The reason for this restriction becomes clear in **Section 4.2**. Again, the cost of testing, c, is normalized to zero.

4.1 Disclosure duty

Under the disclosure duty, the insurer is aware of the individual's testing status and type. Due to this, the insurer can offer specific contracts for each type as long as the individual is tested: $\{q_H, H\}$, $\{q_L, H\}$, $\{q_H, L\}$ and $\{q_L, L\}$. Without the principle of indemnity the untested individual is offered a pooling contract $\{q_U, d_{>A}\}$, where $q_U = \gamma_H\mu_H + \gamma_L\mu_L$ and $d_{>A} > A = \theta_H H + \theta_L L$. With the principle of indemnity, the untested individual is offered a pooling contract $\{\widehat{q(H)}, H\}$, where $\widehat{q(H)} = (\gamma_H\mu_H + \gamma_L\mu_L)(\theta_H + \theta_L\frac{L}{H})$.

Proposition 4.1. *Regardless of whether the principle of indemnity is present, the value of information can either be positive or negative under a disclosure duty information regime. In the absence of the principle of indemnity, there is a larger difference of expected utilities between testing and forgoing information than in the presence of the principle of indemnity. Proof in the* ***Appendix****.*

4.2 Code of conduct

Under the code of conduct, the insurer is aware of the individual's testing status but not of the individual's type. As a result, it is necessary to offer incentive compatible contracts for the individuals who decided to get tested to prevent adverse selection.

Proposition 4.2. *In the absence of the principle of indemnity, tested individuals who suffer losses with a probability of μ_L are offered $\{q_L, d^{cc}_{np} | d^{cc}_{np} < L\}$. The other contracts offered are $\{q_H, H\}$ and $\{q_H, L\}$.*

Proof. Suppose the following contracts[11] are offered: $\{q_H, H\}$, $\{q_L, H\}$, $\{q_H, L\}$ and $\{q_L, L\}$. If an individual gets tested and discovers that she is either the type which suffers a loss with the probability μ_H or the type which suffers a loss of H with the probability of μ_L, she will prefer the $\{q_L, H\}$ contract. As a result, from the insurer's point of view, it is necessary not to offer the $\{q_L, H\}$ contract. This is because the type which suffers a loss of L with the probability of μ_H strictly prefers $\{q_L, H\}$ to $\{q_H, L\}$[12] in the absence of the principle of indemnity. Suppose the coverage, d^{cc}_{np}, for the type which suffers a loss of H with the probability of μ_L is $L < d^{cc}_{np} < H$. Along with the existence of the $\{q_L, L\}$ contract, the type which suffers a loss of L with the probability of μ_H strictly prefers $\{q_L, L\}$ and $\{q_L, d^{cc}_{np}\}$ to $\{q_H, L\}$. Therefore, it is necessary that $d^{cc}_{np} < L$ and that $\{q_L, L\}$ does not exist. □

Corollary 4.3. *Tested individuals who suffer a loss with probability μ_H purchase the appropriate coverage, while tested individuals who suffer a loss with probability μ_L purchase $\{q_L, d^{cc}_{np}\}$ where $d^{cc}_{np} < L$. There is no separation by severity risk among individuals who suffer a loss with probability μ_L.*

Proposition 4.4. *In the presence of the principle of indemnity, tested individuals are each offered incentive compatible contracts, thereby the types which suffer a loss with a*

[11]These are the same contracts offered under the disclosure duty.

[12]This is due to our simplifying assumption $\frac{\mu_H}{\mu_L} = \frac{H}{L}$. Without this assumption, it is possible for the $\{q_L, H\}$ to be more expensive than the $\{q_H, L\}$ contract. Thus, in the no-loss state, the $\{q_H, L\}$ can lead to higher wealth than $\{q_L, H\}$, outweighing the utility in the loss state, $u(w - q_L H - L + H)$, from purchasing $\{q_L, H\}$ instead of purchasing $\{q_H, L\}$ to yield a utility of $u(w - q_H L)$ in both loss and no loss states.

probability of μ_L do not receive full coverage.

Proof. Suppose the following contracts are offered: $\{q_H,H\}$, $\{q_L,H\}$, $\{q_H,L\}$ and $\{q_L,L\}$. If an individual gets tested and discovers that she is the type who suffers a loss of H with probability μ_H, she will prefer the $\{q_L,H\}$ contract. Similarly, if she discovers that she is the type who suffers a loss of L with probability μ_H, she prefers the $\{q_L,L\}$ contract. Since the payout in the event of loss is limited to the loss size, the insurer can decrease the coverage in the $\{q_L,H\}$ and $\{q_L,L\}$ contracts to $\{q_L,d^{cc}_{p,H}\}$ where $d^{cc}_{p,H} < H$ and $\{q_L,d^{cc}_{p,L}\}$ where $d^{cc}_{p,L} < L$. This result is observed in Peter et al. (2017). □

Corollary 4.5. *In the absence of the principle of indemnity, tested individuals who suffer a loss with probability μ_L are not separated by severity risk, while in the presence of the principle of indemnity, all tested individuals are separated by frequency and severity risk.*

Proposition 4.6. *For the code of conduct, the value of information can either be positive or negative (just like under the disclosure duty). The difference of expected utilities between testing and forgoing information is larger in the absence of the principle of indemnity than in the presence of the principle of indemnity. Additionally, regardless of the principle of indemnity, the value of information under the disclosure duty exceeds the value of information under the code of conduct. Proof in the* ***Appendix****.*

4.3 Consent law

Under the consent law, insurers can neither observe an individual's testing status nor type unless the individual chooses to reveal her type information. As a result, insurers can condition certain contracts on the presentation of a particular test result.

Proposition 4.7. *The insurer offers $\{q_H,H\}$ to individuals who do not present a test result. $\{q_L,H\}$, $\{q_H,L\}$ and $\{q_L,L\}$ are offered to individuals who present test results.*

Proof. In the case without the principle of indemnity, suppose the insurer offers $\{q_H,H\}$, $\{q_L,H\}$, $\{q_H,L\}$ and $\{q_L,L\}$ to individuals who present a test result and $\{q_U,d_{>A}\}$ to untested individuals. If individuals decide to get tested, the types which suffer a loss with a probability of μ_L will reveal their results. Furthermore, due to the restriction of parameters to the case where $\frac{\mu_H}{\mu_L} = \frac{H}{L}$, the individual who suffers a loss of L with a probability of μ_H is better off purchasing $\{q_H,L\}$ than pretending to be untested and purchasing $\{q_U,d_{>A}\}$, hence will also reveal type information. For the individual who suffers a loss of H with a probability of μ_H, either $\{q_H,H\}$ or pretending to be untested and purchasing $\{q_U,d_{>A}\}$ can be optimal depending on the parameters. The insurer, however, can identify the individual who suffers a loss of H with a probability of μ_H through the revelation of the types who suffer a loss with a probability of μ_L and the contract choice of the type who suffers a loss of L with a probability μ_H. However, the insurance company cannot observe who is tested until an individual reveals results or chooses a contract meant for tested types. Even after the insurer can confirm that individuals are tested, both $\{q_U,d_{>A}\}$ and $\{q_H,H\}$, are offered and the insurer will make an expected loss by selling $\{q_U,d_{>A}\}$ to the individual who suffers a loss of H with a probability of μ_H. As a result, the insurer does not offer $\{q_U,d_{>A}\}$. Instead, the insurer offers $\{q_H, H\}$ to individuals who do not present a test result[13]. Individuals prefer purchasing $\{q_H, H\}$ as opposed to remaining uninsured.

In the case with the principle of indemnity, suppose that the insurance company offers $\{q_H, H\}$, $\{q_L, H\}$, $\{q_H, L\}$ and $\{q_L, L\}$ to individuals who present a test result and $\{\widehat{q(H)}, H\}$ to untested individuals. Following a similar argument as in the case without the principle of indemnity, all types except the type which suffers a loss of H with a probability of μ_H will reveal type information to the insurer. The type which suffers a loss of H with a probability of μ_H pretends to be untested, leading to the insurer selling a contract with an expected loss. As a result, $\{\widehat{q(H)}, H\}$ is not offered and instead, $\{q_H, H\}$ is offered to individuals who do not present a test result. Again, individuals prefer purchasing $\{q_H, H\}$ as opposed to remaining uninsured. □

Proposition 4.8. *Regardless of the principle of indemnity, the value of information is always positive under the consent law. Furthermore, the value of information under the consent law exceeds the value of information under the disclosure duty. Proof in the* ***Appendix****.*

4.4 Information ban

Under an information ban, the insurer is unable to observe testing status and results, and individuals are not allowed to reveal information about their risk type. Insurers need to predict whether individuals get tested. However, individuals' testing decisions depend on the contracts on offer. To prevent adverse selection, insurers need to offer incentive compatible contracts, similar to the code of conduct. Following the proof of **Proposition 3.4** and **Proposition 4.7**, insurers do not offer actuarially fair pooled contracts.

The incentive compatible contracts offered without the principle of indemnity are $\{q_H, H\}$, $\{q_H, L\}$ and $\{q_L, d^{ib}_{np}\}$ where $d^{ib}_{np} = d^{cc}_{np}$. The incentive compatible contracts offered with the the principle of indemnity are $\{q_H, H\}$, $\{q_H, L\}$, $\{q_L, d^{ib}_{p,H}\}$ where $d^{ib}_{p,H} = d^{cc}_{p,H}$ and $\{q_L, d^{ib}_{p,L}\}$ where $d^{ib}_{p,L} = d^{cc}_{p,L}$.

Corollary 4.9. *Regardless of the presence of the principle of indemnity, the value of information is positive under an information ban. Each of the four contracts can be optimal depending on the parameters. Since the contracts are incentive compatible, by definition the value of information under an information ban is positive.*

It is unclear whether the value of information under the information ban exceeds the value of information under the disclosure duty and code of conduct if $V^{dd}_{info} > 0$ and $V^{cc}_{info} > 0$, since it depends on what the optimal contract for the untested individual is. If the optimal contract for the untested individual is $\{q_H, H\}$, then $V^{cl}_{info} > V^{ib}_{info}$, otherwise it is unclear which information regime leads to a greater gain in utility from testing.

Table 3 summarizes the contracts offered when an individual can test for both frequency and severity information. The types of contracts offered are similar to the case where an individual only tests for frequency, i.e. full coverage when tested types can be distinguished but reduced coverage when tested types cannot be distinguished. In the

[13] Note that the insurance company can offer any level of coverage to individuals who do not present a test result as long as the premium rate is q_H and premium is q_H multiplied by the coverage level.

absence of the principle of indemnity, individuals who suffer a loss with a lower probability all receive the same low coverage. I n the presence of the principle of indemnity, individuals with the lower probability of loss receive different reduced coverage based on severity risk. Under the disclosure duty and code of conduct, it is unclear whether individuals test, although under the consent law and information ban, individuals always experience positive value from testing provided that testing is costless.

<table>
<tr><th>Regime</th><th>H-sev,H-freq</th><th>H-sev,L-freq</th><th>L-sev,H-freq</th><th>L-sev,L-freq</th><th>Uninformed</th><th>Test</th></tr>
<tr><td>DD</td><td>$\{q_H, H\}$</td><td>$\{q_L, H\}$</td><td>$\{q_H, L\}$</td><td>$\{q_L, L\}$</td><td>$\{q_U, d_{>A}\}$</td><td>Un.</td></tr>
<tr><td>CC</td><td colspan="4">$\{q_H, H$ or $L\}$
$\{q_L, d_{<L}\}$</td><td>$\{q_U, d_{>A}\}$</td><td>Un.</td></tr>
<tr><td>CL</td><td colspan="4">$\{q_H, H$ or $L\}$
$\{q_L, H$ or $L\}$</td><td>$\{q_H, H\}$</td><td>Y</td></tr>
<tr><td>IB</td><td colspan="5">$\{q_H, H$ or $L\}$
$\{q_L, d_{<L}\}$</td><td>Y</td></tr>
<tr><td colspan="7">Without principle of indemnity</td></tr>
<tr><td>DD</td><td>$\{q_H, H\}$</td><td>$\{q_L, H\}$</td><td>$\{q_H, L\}$</td><td>$\{q_L, L\}$</td><td>$\{\widehat{q(H)}, H\}$</td><td>Un.</td></tr>
<tr><td>CC</td><td colspan="4">$\{q_H, H$ or $L\}$
$\{q_L, d_{<H}$ or $d_{<L}\}$</td><td>$\{\widehat{q(H)}, H\}$</td><td>Un.</td></tr>
<tr><td>CL</td><td colspan="4">$\{q_H, H$ or $L\}$
$\{q_L, H$ or $L\}$</td><td>$\{q_H, H\}$</td><td>Y</td></tr>
<tr><td>IB</td><td colspan="5">$\{q_H, H$ or $L\}$
$\{q_L, d_{<H}$ or $d_{<L}\}$</td><td>Y</td></tr>
<tr><td colspan="7">With principle of indemnity</td></tr>
</table>

where
q_H: premium rate for type who suffers loss with probability μ_H
q_L: premium rate for type who suffers loss with probability μ_L
q_U: weighted average premium rate for population
$\widehat{q(H)}$: premium rate in the presence of principle of indemnity for uninformed individual under dd and cc
H, L: full coverage amounts
$d_{>A}$: $d_{>A} > A$ = weighted coverage
$d_{<L}$: coverage < L
$d_{<H}$: coverage < H
Un.: Testing is optimal only for certain parameters

Table 3: Summary of contracts offered when both frequency and severity risk can be tested

5 Discussion

One of the major assumptions in our model is that one test can reveal information on both frequency and severity risk. In reality, the nature of information differs depending on its source, and this, in turns, affects individual choices. An individual can get tested at a hospital or get her telematics data from fitness apps analyzed as part of an insurance wellness program (Aziz and Dowling 2019). Information from different sources are not perfect substitutes. Hospitals might be able to provide information on how an individual's health and family history is linked to disease occurrence and the cost of various treatments available to treat such diseases. Insurance companies might be able to provide information on the average claims amount for an individual with certain characteristics. Information from different sources can have a complementary effect. Individuals can search for suitable insurance contracts (for e.g. deductibles or coinsurance discussed in Ligon and Thistle (2008)) or hospitals which provide the treatment for a lower price. It has also been assumed in this paper that the information is accurate but we need to be aware that it is possible that there can be uncertainty surrounding the obtained information. This can have implications on whether individuals decide to obtain information. The willingness to obtain information might then depend more on the price of information and the individual's perception of whether the price matches her belief of the reliability. Future research can address the complementary and reliability effects.

It would also be of interest to consider the cost of information. In this paper, we have assumed that information is costless and removes all uncertainty. In reality, there are more than two types of individuals. Removing all uncertainty can be expensive, hence individuals might only remove some uncertainty. The cost of information then depends on the reduction of entropy (Shannon 1948). Additionally, certain types of information may not reveal the type directly. An example is telematics data, which is often used in insurance wellness programs. Insurance companies use the health metrics collected to set premia for the individuals. Individuals who exerted greater effort in preventative measures often receive a discount on the premia (Sharpe and Schaller 2019). However, it is also possible for insurance companies to use these health metrics to discriminate against less healthy individuals (Prince 2020). In addition to insurance companies, conventional tech companies such as Google or manufacturers of fitness trackers (e.g. FitBit, Apple, Garmin) also handle large amounts of consumer health data and can predict health risks based on the individual characteristics and behavior (Bourreau et al. 2020). Competition or cooperation between conventional tech companies and insurance companies can also influence the cost of information (Pasquale and Ragone 2013). This might have implications on the structure of insurance products. With information, individuals might consider purchasing several individual contracts and have exactly the coverage needed. However, collecting large amounts of information is not only expensive in financial terms but also time consuming, leading individuals to purchase a non-optimal contract which covers multiple illnesses including certain illnesses the individual does not have a real risk of. Ultimately, the choice between a combination of individual contracts versus a bundle of pre-combined contracts depends on the out-of-pocket costs and the direct and indirect cost of information gathering. This may also be an avenue for future research.

6 Conclusion

While the probability of catching a disease or suffering a loss in general received much attention in research, loss severity has been insufficiently addressed. For most diseases, frequency and severity often go hand in hand, for example, if an individual experiences cancer recurrences more often, it is also likely that this individual will experience more severe symptoms. In this paper, we have made the distinction between frequency and severity. We examine the optimal testing decisions, given different information regimes, the subsequent optimal insurance decisions of individuals and the contracts offered under different information regimes.

Given the recent pandemic landscape, this distinction is highly relevant as it helps one prepare for not only different probabilities of contracting a disease but also how serious one's symptoms can be as a result of an underlying condition (with regards to a pandemic, some virus variants tend to be more contagious while others tend to cause more damage). It is important for policymakers to ensure that individuals are aware of their type and able to get sufficient coverage when determining how information from genetic testing can be used, especially given the far-reaching consequences of a pandemic.

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Appendix

Proof of Proposition 3.0

Suppose $d^*_{U,np} = A$, due to the convexity of $u'()$, the linear combination, $\theta_H u'(w - qd^*_{U,np} - H + d_{U,np^*}) + \theta_L u'(w - qd^*_{U,np} - L + d^*_{U,np})$, exceeds $u'(w - qd^*_{U,np})$. Now, suppose $d^*_{U,np} < A$. This means that the x-value of the linear combination, $w - qd^*_{U,np} + d^*_{U,np} - A$, lies to the left of, $w - qd^*_{U,np}$. As a result, the linear combination of $\theta_H u'(w - qd^*_{U,np} - H + d_{U,np^*}) + \theta_L u'(w - qd^*_{U,np} - L + d^*_{U,np})$ again exceeds $u'(w - qd^*_{U,np})$. Hence, it is necessary for the x-value of the linear combination, $w - qd^*_{U,np} + d^*_{U,np} - A$, to exceed of $w - qd^*_{U,np}$; this implies $d^*_{U,np} > A$.

Proof of Proposition 3.1

The value of information is given by:

$$\begin{aligned}V^{sev}_{info,np} &= \theta_H u(w-qH)+\theta_L u(w-qL)\\ &-\theta_H[\mu u(w-qd^*_{U,np}-H+d^*_{U,np})+(1-\mu)u(w-qd^*_{U,np})]\\ &-\theta_L[\mu u(w-qd^*_{U,np}-L+d^*_{U,np})+(1-\mu)u(w-qd^*_{U,np})]\end{aligned} \tag{8}$$

The first line is the expected utility of being informed (and choosing full coverage). The second and third lines depict the expected utility of remaining uninformed. Due to the concavity of the utility function, the utility resulting from purchasing full coverage always exceeds the utility of purchasing any other level of coverage. As a result, there is always a positive value from testing.

Proof of Proposition 4.1

The value of information without the principle of indemnity is:

$$\begin{aligned}V^{dd}_{info,np} &= \theta_H\gamma_H u(w-q_H H-c)+\theta_H\gamma_L u(w-q_L H-c)+\theta_L\gamma_H u(w-q_H L-c)+\theta_L\gamma_L u(w-q_L L-c)\\ &-\theta_H[(\gamma_H\mu_H+\gamma_L\mu_L)u(w-q_U A-H+A)]-\theta_L[(\gamma_H\mu_H+\gamma_L\mu_L)u(w-q_U A-L+A)]\\ &-[\gamma_H(1-\mu_H)+\gamma_L(1-\mu_L)]u(w-q_U A)\end{aligned} \tag{9}$$

The value of information with the principle of indemnity is:

$$\begin{aligned}V^{dd}_{info,p} &= \theta_H\gamma_H u(w-q_H H-c)+\theta_H\gamma_L u(w-q_L H-c)+\theta_L\gamma_H u(w-q_H L-c)+\theta_L\gamma_L u(w-q_L L-c)\\ &-u(w-\widehat{q(H)}H)\end{aligned} \tag{10}$$

Depending on the share of each type in the population, $V^{dd}_{info,p}$ and $V^{dd}_{info,np}$ can either be positive or negative.

Since $q_U A = \widehat{q(H)}H$, due to the concavity of the utility function, there is a larger difference in utility between purchasing the appropriate contract after getting tested and purchasing the pooled contract if uninformed for each type.

Proof of Proposition 4.6

The value of information without the principle of indemnity is:

$$\begin{aligned}V^{cc}_{info,np} &= \theta_H\gamma_H u(w-q_H H-c)+\theta_H\gamma_L[\mu_L u(w-q_L d^{cc}_{np}-H+d^{cc}_{np}-c)+(1-\mu_L)u(w-q_L d^{cc}_{np}-c)]\\ &+\theta_L\gamma_H u(w-q_H L-c)+\theta_L\gamma_L[\mu_L u(w-q_L d^{cc}_{np}-L+d^{cc}_{np}-c)+(1-\mu_L)u(w-q_L d^{cc}_{np}-c)]\\ &-\theta_H[(\gamma_H\mu_H+\gamma_L\mu_L)u(w-q_U A-H+A)]-\theta_L[(\gamma_H\mu_H+\gamma_L\mu_L)u(w-q_U A-L+A)]\\ &-[\gamma_H(1-\mu_H)+\gamma_L(1-\mu_L)]u(w-q_U A)\end{aligned} \tag{11}$$

The value of information with the principle of indemnity is:

$$
\begin{aligned}
V^{cc}_{info,p} = {} & \theta_H \gamma_H u(w - q_H H - c) + \theta_H \gamma_L [\mu_L u(w - q_L d^{cc}_{p,H} - H + d^{cc}_{p,H} - c) + (1-\mu_L) u(w - q_L d^{cc}_{p,H} - c)] \\
& + \theta_L \gamma_H u(w - q_H L - c) + \theta_L \gamma_L [\mu_L u(w - q_L d^{cc}_{p,L} - L + d^{cc}_{p,L} - c) + (1-\mu_L) u(w - q_L d^{cc}_{p,L} - c)] \\
& - u(w - \widehat{q(H)} H)
\end{aligned}
\tag{12}
$$

Depending on the share of each type in the population, $V^{cc}_{info,p}$ and $V^{cc}_{info,np}$ can either be positive or negative.

Since $q_U A = \widehat{q(H)} H$, due to the principle of concavity, there is a larger difference in utility between purchasing the appropriate contract after getting tested and purchasing the pooled contract if uninformed.

Regardless of the principle of indemnity, $V^{dd}_{info} > V^{cc}_{info}$. This is because without the principle of indemnity: $u(w - q_L H) > \mu_L u(w - q_L d^{cc}_{np} - H + d^{cc}_{np}) + (1-\mu_L) u(w - q_L d^{cc}_{np})$ and $u(w - q_L L) > \mu_L u(w - q_L d^{cc}_{np} - L + d^{cc}_{np}) + (1-\mu_L) u(w - q_L d^{cc}_{np})$. With the principle of indemnity: $u(w - q_L H) > \mu_L u(w - q_L d^{cc}_{p,H} - H + d^{cc}_{p,H}) + (1-\mu_L) u(w - q_L d^{cc}_{p,H})$ and $u(w - q_L L) > \mu_L u(w - q_L d^{cc}_{p,L} - L + d^{cc}_{p,L}) + (1-\mu_L) u(w - q_L d^{cc}_{p,L})$.

Proof of Proposition 4.8

The value of information without the principle of indemnity is:

$$
\begin{aligned}
V^{cl}_{info,np} = {} & \theta_H \gamma_H u(w - q_H H) + \theta_H \gamma_L u(w - q_L H) + \theta_L \gamma_H u(w - q_H L) + \theta_L \gamma_L u(w - q_L L) \\
& - \theta_H u(w - q_H H) \\
& - \theta_L [(\gamma_L \mu_L + \gamma_H \mu_H) u(w - q_H H - L + H) + (\gamma_L (1-\mu_L) + \gamma_H (1-\mu_H)) u(w - q_H H)] > 0
\end{aligned}
\tag{13}
$$

The value of information with the principle of indemnity is:

$$
\begin{aligned}
V^{cl}_{info,p} = {} & \theta_H \gamma_H u(w - q_H H) + \theta_H \gamma_L u(w - q_L H) + \theta_L \gamma_H u(w - q_H L) + \theta_L \gamma_L u(w - q_L L) \\
& - u(w - q_H H) > 0
\end{aligned}
\tag{14}
$$

Due to the concavity of the utility function, there is a larger gain in utility from testing without the principle of indemnity than with the principle of indemnity.

Furthermore, $q = \widehat{q(H)} H < q_H H \implies V^{cl}_{info} > V^{dd}_{info}$.

Value of information under the information ban

The value of information without the principle of indemnity is:

$$
\begin{aligned}
V^{ib}_{info,np} =& \theta_H\gamma_H u(w-q_H H)+\theta_H\gamma_L[\mu_L u(w-q_L d^{ib}_{np}-H+d^{ib}_{np})+(1-\mu_L)u(w-q_L d^{ib}_{np})]\\
&+\theta_L\gamma_H u(w-q_H L)+\theta_L\gamma_L[\mu_L u(w-q_L d^{ib}_{np}-L+d^{ib}_{np})+(1-\mu_L)u(w-q_L d^{ib}_{np})]\\
&-\theta_H[(\gamma_H\mu_H+\gamma_L\mu_L)u(w-q^{ib*}_{np}d^{ib*}_{np}-H+d^{ib*}_{np})]\\
&-\theta_L[(\gamma_H\mu_H+\gamma_L\mu_L)u(w-q^{ib*}_{np}d^{ib*}_{np}-L+d^{ib*}_{np})]\\
&-[\gamma_H(1-\mu_H)+\gamma_L(1-\mu_L)]u(w-q^{ib*}_{np}d^{ib*}_{np})
\end{aligned}
\tag{15}
$$

where $\{q^{ib*}_{np}, d^{ib*}_{np}\}$ is the optimal contract out of the three offered.

The value of information with the principle of indemnity is:

$$
\begin{aligned}
V^{ib}_{info,p} =& \theta_H\gamma_H u(w-q_H H-c)+\theta_H\gamma_L[\mu_L u(w-q_L d^{ib}_{p,H}-H+d^{ib}_{p,H}-c)+(1-\mu_L)u(w-q_L d^{ib}_{p,H}-c)]\\
&+\theta_L\gamma_H u(w-q_H L-c)+\theta_L\gamma_L[\mu_L u(w-q_L d^{ib}_{p,L}-L+d^{ib}_{p,L}-c)+(1-\mu_L)u(w-q_L d^{cc}_{p,L}-c)]\\
&-u(w-q^{ib*}_{p}d^{ib*}_{p})
\end{aligned}
\tag{16}
$$

where $\{q^{ib*}_{p}, d^{ib*}_{p}\}$ is the optimal contract out of the four offered.