

Thesis for Master of Science- degree.

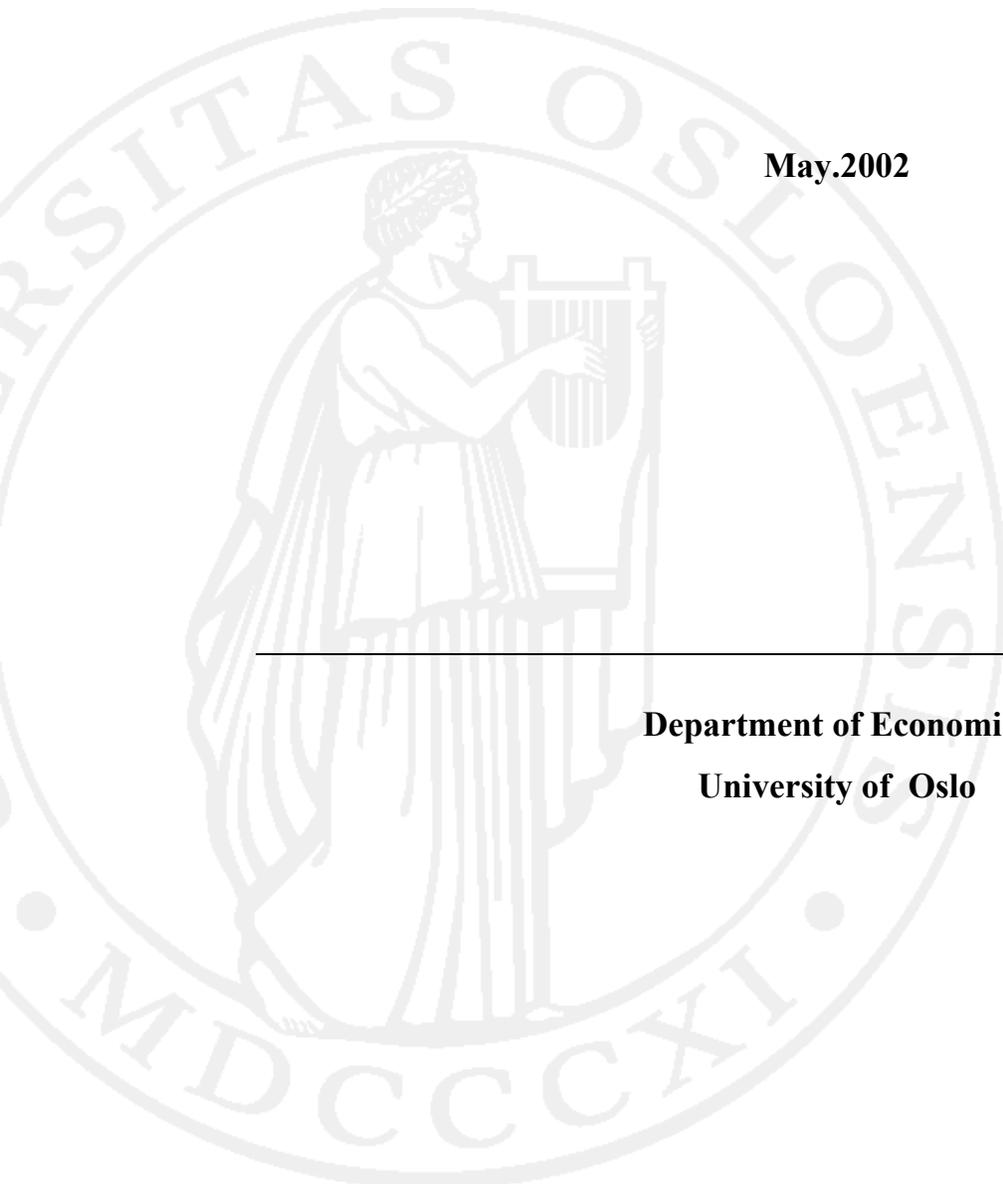
The Value of Genetic Information in Health Insurance Market

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Preface

Two years ago I came to University of Oslo as an exchanged student from Fudan University, China, following MSc degree in Environmental and Developmental Economics. I felt that I have made considerable progress in economic theory during the two years' study. Every progress of mine is attributed to the contribution of the Economic Institute. It assigned top professors to give us lectures and I benefited a lot.

To my luck, Prof. Tor Iversen acted as my supervisor for my thesis of MSc. Master degree. He gave me a lot of suggestions as to where to start, how to find the literature and how to organize the whole thesis. He always encouraged me when I lost confidence and drove me up when I made little progress with the thesis. He even helped me to correct the mistakes of spellings and grammar. He is so patient and responsible that I feel sincere gratitude for him. I must admit that I cannot finish the thesis on time without his help and encouragement.

During the study here, I also benefited a lot from the advanced library of the University. It's really a good source for research work.

And the coordinators in the International Office have also helped us a lot. Their excellent work makes it available for us to get the loans and scholarship on time and that is so important for our livings here.

There are also a lot of anonymous acknowledgement should be mentioned here. For all of those who helped us I just want to say: "thank you very much!"

Summary

With the coming prospect of genetic testing a lot of problems will arise. In the health insurance market there are concerns that the insurers will misuse the genetic information for risk classification and the problem of genetic discrimination will come out. Many countries have made policies to limit the insurers to get access to genetic information.

But there is another problem that the consumers on the other hand have the freedom to choose to be tested or not. They will judge whether it is valuable for them to accept the test and whether to reveal the testing results to the insurers. It is about the value of genetic information.

In this thesis I pay special attention to the private value of genetic information. That is, the ex ante value of genetic information to the individuals and their choice to be tested or not. I think it is of primary importance because if the individuals do not accept the testing, then there is no significance of setting policies limiting the insurers to use it for underwriting purposes.

In the introduction I give some concepts clarification such as adverse selection, risk classification and genetic testing. Then I make literature review as to the researches done in this field. Third I introduce the structure of this thesis.

The main body of this paper is devoted to the private value of genetic information. The analysis is extended from three perspectives: public/private information; prevention unavailable/available; information cost zero/positive. But the third point is just touched but not analyzed adequately because of the unavailability of enough information on this point.

In section 2 the situation of public information is analyzed. First a case of no prevention and costless information is given as a benchmark for further analysis. The result is that for risk-averse individuals the value of genetic information is negative and they would

remain uninformed and accept the uniform contract for all people. Secondly the prevention is taken into consideration and still with the assumption of costless information. A simple model is given for the value of information with insurance coverage and prevention cost as variables. Then the conclusion is that the value of genetic information is ambiguous with the prevention available. It depends on the comparison of positive value of prevention and negative value of risk classification. If the latter has greater influence then the value will be negative. Otherwise the value will be positive.

In section 3 the situation of private information is considered. Firstly it is still assumed that the prevention is not available. Much has been drawn upon the paper written by Doherty and Thistle (1996) as background for my analysis. Then with the price-quantity mechanism and self-selection constraints as tools for analysis, several circumstances are considered one by one. First, it is assumed that the risk type is private information but the information status of the individuals is known to the insurer. Then it is shown that the value of genetic information is negative. Second, it is assumed that informational status is private information as well as risk types. In this case, the value of genetic information is non-negative. Third, it is assumed that the consumers can choose to reveal negative results and conceal positive results. Then the value of information is positive. In the end, the effect of positive information cost was considered. Secondly it is assumed that the prevention is available. For simplicity the prevention cost is set to be a fixed number. And it is assumed that the prevention is socially efficient for the high-risk individuals. Two circumstances are considered. First, the informational status is private information. Then it was derived that the value of information is positive. Second, the individuals can choose to reveal good risks and conceal bad risks. In this situation the value of information is also derived to be positive.

In section 4 the social efficiency aspect of the genetic information is investigated. But there is no formal analysis. Some of the conclusions given by other researchers are introduced here. After that some policies are introduced and some suggestions on the avert of adverse selection after genetic testing are given.

In the last section 5 some concluding remarks are given.

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1. Introduction

1.1 Some concepts closely related to the problem

1.1.1 *Adverse selection in health insurance market*

The problem of adverse selection will arise if the population is heterogeneous in terms of the risk to be insured and asymmetry of information is present. Here, asymmetry of information means that the individual knows his risk whereas the insurance company cannot observe it. Therefore, the company is constrained to offer insurance on equal terms to everyone.

The impact of asymmetric information on the working of markets was first expounded by Akerlof (1970) in his essay “the Market for Lemons”. The quintessence of this famous essay is that an information advantage of the seller over the buyer of a good with non-uniform quality causes bad quality to chase good quality from the market. This is called “adverse selection”. The same problem occurs in health insurance market.

Assume that the population is heterogeneous in terms of the risk of becoming ill π^j as well as in terms of the cost of treatment in case of illness L^j , and every individual j knows his pair of values. The insurer, however, lacks discriminatory power to assign the appropriate values of risk parameters to applicants. He will therefore only offer a standard policy, which is characterized, for example, by a partial payment of claims in case of illness, r ($0 < r < 1$) and by a premium P . The value of r and P must be set such that expected payments for claims of the insurance company are at least covered by the premium. Assume that there is no cost of administration and perfect competition of the insurance market, then the risk neutral profit maximizing insurance company will get zero profit. This assumption will hold throughout the paper.

Let us presume that the insurance company only writes an insurance contract with full coverage ($r = 1$), which it believes to be sold to a representative sample of the population.

This means that the premium P is calculated on the basis of expected values of π and L . Such a policy will be attractive to all “bad risks”, which are those individuals with a high value of π^j and L^j , and, given risk aversion, also for average risks. In contrast, very good risks, that is, individuals with values of π^j and L^j well below average, will avoid buying such a policy (unless they are extremely risk averse). The reason is that the ratio between premium and expected costs of illness is very unfavorable to them. On the other hand, because of the reasons mentioned (lack of discriminatory power on the part of the insurance company), a more favorable premium cannot be offered to this group because all other insureds would also demand these better terms.

Since the best risks drop out, the basis upon which the insurance company calculated its risk premium changes, causing the premium to rise. Thus the offered policy becomes unattractive for another group of individuals with relatively low values of π^j and L^j , who drop out in their turn, so that the premium required to cover costs rise even more. This process, called adverse selection, continues until in equilibrium, only the worst risks remain in the insurance pool.

In this situation, a separating equilibrium policy set may exist as stated by Rothschild and Stiglitz (1976). They showed that in an insurance market with imperfect information, the seller specifies both the prices and quantities of insurance purchased. In most competitive markets, sellers determine only price and have no control over the amount their customers buy. They define equilibrium in a competitive insurance market as a set of contracts such that, when customers choose contracts to maximize expected utility. 1) No contract in the equilibrium set makes negative expected profits. And 2) there is no contract outside the equilibrium set that, if offered, will make a non-negative profit. Then at equilibrium, the high-risk individuals exert a negative externality on the low-risk individuals. The low risks can not get full coverage at actuarially fair rate. But the high-risk individuals are no better off from the losses of the low-risk individuals. We will exert this result later in our analysis.

1.1.2 Risk classification of insurance company

Adverse selection is technically defined as the tendency of persons with knowledge of their poorer than average health expectations to apply for or renew insurance to a greater extent than persons with average health risks. Concerns about adverse selection are two-folded: 1. Low-risk insureds will unfairly subsidize high-risk insureds and 2. Through inadequate rates and large insurance purchases by high-risk individuals, the insurers' financial solvency is jeopardized. By collecting medical information about its applicants, insurers can avoid losses from applicants who have undergone medical testing and withheld testing results. "Risk classification", in turn, is a process by which an individual's premium may be determined. The goal of risk classification is to determine the applicant's expected losses and to place insureds with similar expected losses into the same class so that each may be charged the same rate. The most important underwriting factors used to classify insureds are age, current health status and future health status. Current health status is assessed from the application, physical examination and medical testing. The traditional medical testing required by insurers include routine biochemical tests, urinalyses, electrocardiograms and x-rays. Future health status typically is predicted on the basis of current or past health conditions and the potential for exacerbation or recurrence. The coming prospect of genetic testing undoubtedly will dramatically increase the risk classification power of the insurers.

1.1.3 Genetic testing

On June 26th, 2000, the leaders of both the privately and the publicly funded human genome projects announced that a draft of the human genome has been made. During the next few years, this knowledge is likely to be applied in the development of predictive tests for many diseases. The test will be able to distinguish between high- and low- risk individuals at a pre-symptomatic stage of disease. Presently, tests for over 800 diseases are offered, including tests for Huntington's disease and cystic fibrosis. Two important breast cancer genes have been identified, and the US Food and Drug Administration has approved a gene-based test that may help to predict the recurrence of breast cancer. The number of tests is expected to increase rapidly in a few years, in parallel to the mapping of the human genes. For instance, tests for genes that imply an elevated risk of several types of cancer,

cardiovascular disease, and Alzheimer's disease are already available or are expected to be available in the near future.

The information from gene-based tests may be of various values. First, it may be used to initiating measures for postponement and prevention of disease. Second, it has an impact on health insurance. There is a concern that insurers can make use of information to deny coverage or require prohibitively high premium for individuals with an increased risk of disease. Many countries have approved restrictive laws for insurers to get access to information out of genetic testing. For instance, the Council of Europe, recommends (R(92)3 and R(97)5) that predictive genetic tests should not be used when the terms of insurance is decided. In the US, a majority of the states have banned the use of genetic information by insurers. Although there are different voices declaring that genetic information should be available to insurers, the main theme is prevention of insurers from getting access to information generated from genetic testing.

1.2 Literature review

But with the enforcement of those restrictive laws concerning insurer's access to genetic information, a lot of problems will arise: would the individual like to take a genetic test and know his genetic mutation indicating increased likelihood to develop a particular disease? If this information is private that only the individual knows and the insurer doesn't know, will there be the problem of adverse selection? What's the private and social value of genetic information? When taken into consideration the prevention possibility (of course with cost) and information with cost, will the individual like to be tested? How to avert the problem of adverse selection coming out of the endogenous information?

Much research has been done on the impact of genetic testing on health insurance market ever since 1980's. And a lot of literature can be found on this problem. Among them there are some needed to be reviewed before the formal discussion of this paper.

Studies by Crocker and Snow(1986), Dahlby(1983), Hoy(1982, 1984) and Schmalensee(1984) have analyzed the economic effect of categorical discrimination in insurance markets when information is asymmetric. These models characterize heterogeneity among individuals by assuming that insureds possess exogenous specified loss probabilities that vary according to risk type. The individuals are assumed to possess perfect and private information regarding their risk type. These studies show that there may be both beneficial efficiency effects and adverse distribution effects resulting from categorization. Distribution effects are caused directly by the use of risk class prices while efficiency improvements may arise as a result of the elimination or mitigation of the adverse selection problem.

Michael Hoy published an article “ the Value of Screening Mechanism under Alternative Insurance Possibilities” in 1989. He investigated the welfare implications of symmetrical improvements in information and accompanying screening mechanism which allow for improved matching of individuals to their respective risk classes. He assumed that the individuals differ not only according to exogenous specified loss probabilities, but also according to self-protection technologies. He ruled out the problem of adverse selection by assuming that risk class information is provided symmetrically to both insureds and insurers. Nonetheless, he still demonstrated that improvements in such information affect both efficiency and distribution as for the case when adverse selection does persist. He showed that efficiency effect may occur either directly as a result of better knowledge concerning the relative effectiveness of self-protection across risk types or indirectly through the incentives created by effects of information on market prices for insurance.

Tabarrok(1994) also gave some idea concerning the benefits and costs of genetic testing. The greatest benefit of testing occurs when a deterministic disease with highly effective therapies is detected. The collection of data on genetic defects, when correlated with environmental and other factors, can lead to improved therapies. He suggested that the costs of genetic testing fall into two categories, the actual cost of the tests (social cost) and the distribution cost (private cost). He assumed that the social benefits exceed the social cost of the tests. And then the more important is the distribution cost or private cost. But he didn't give deep analysis of this problem. However, he gave an important proposal about genetic insurance. We are used to thinking of insuring against sickness but here he suggested insuring against a potential high probability of sickness. Before taking a genetic test, it

should be made mandatory for every individual to purchase genetic insurance. For a small fee genetic insurance would insure against the possibility of a positive test result. If the test came back positive the customer would be paid a large sum of money, enough to cover the expected costs of his disease or equivalently enough to allow him to purchase health insurance at the new risk premium. If the test turns out negative the customer would lose his genetic insurance fee but would gain the results of the test and also lower health insurance premium. This proposal require some legislation, enforcement on buying genetic insurance before taking the test but it avoids the problem of adverse selection. So it has drawn great attention and been approved by many researchers since the concept been brought out.

Doherty and Thistle(1996) contributed a lot to the analysis of adverse selection with endogenous information in insurance market. Traditional models of adverse selection always assume that the risk types are known to the consumers but not to the insurer. Doherty and Thistle considered the risk information to be endogenous and the incentive for the individual to gather information. They showed that the private value of information is non-negative only if insurers cannot observe consumer's information status, or if consumers can conceal their information status. They also showed that the positive value of information does not depend on consumer's initial information; rather, it is a consequence of the non-observability of information status. Policy-holders' information value must be positive for them to have an incentive to learn their risk type, and for adverse selection to arise endogenously. But they didn't consider the possibility of prevention and their analysis apply to general test instead of genetic test. The difference between the two kinds of tests is that general test is always required by the insurance company before issuing the insurance policy and the genetic test maybe forbidden to be required by the insurance company.

In a newly published paper, Hoel and Iversen(2000) analyzed two types of social inefficiencies occurring when information about prevention and test status is private. Their analysis is based on the assumption that prevention is available to reduce the risk of disease for the high-risk individuals and there is mix of compulsory and voluntary insurance. The two types of inefficiencies are: genetic testing may not be done when it is socially efficient and may be done when it is socially inefficient. The first type of inefficiency is shown to be likely for consumers with compulsory insurance only while the second type of inefficiency is more likely for those who have supplemented the compulsory insurance with substantial

voluntary insurance. And the second type of inefficiency is more important the less effective prevention is. They assumed costless information but in reality, genetic testing will not be too cheap to be available easily. It brings the individual an expected cost when considering accepting a genetic testing.

1.3 The structure of this thesis

With the coming prospect of genetic testing being used for diagnostic purposes, many problems will arise. Will it be of positive or negative value for each individual being tested? Should the insurers and employers use the information for risk classification and promotion? If so, will there be unfair genetic discrimination? How can economic theory shed light on such problems? Is there anything the policy makers can do to balance the interests of different agents?

Of the various questions, I am particularly interested in the private value of genetic information for those considering accepting a test because any advancement in technology should bring benefits to the general individuals. If it is of no value or even negative value, there will be a waste to invest on the development of such technology. If the genetic information has positive value for the individuals, they will be likely to take a test and make use of prevention if revealed to be high risk. This is of great significance to not only the individual himself but also to his family and other people related. If the genetic information has negative value for the individual, he will not choose to be tested and remain uninformed even if he is of high-risk group. Hence, a timely prevention may be delayed and harmful consequences may come out.

So the main body of this paper will be devoted to the private value of genetic information. The analysis is extended from three perspectives: public/private information; prevention unavailable/available; information cost zero/positive. But the third point is just touched but not analyzed adequately because of the unavailability of enough information on this point.

In section 2 the situation of public information is analyzed. First a case of no prevention and costless information is given as a benchmark for further analysis. The result is that for risk-averse individuals the value of genetic information is negative and they would rather remain uninformed and accept the uniform contract for all people. Secondly the prevention is taken into consideration and still with the assumption of costless information. A simple model is given for the value of information with insurance coverage and prevention cost as variables. Then the conclusion is that the value of genetic information is ambiguous with the prevention available. It depends on the inter-act of the positive value of prevention and negative value of risk classification. If the latter has greater influence then the value will be negative. Otherwise the value will be positive.

In section 3 the situation of private information is considered. Firstly it is still assumed that the prevention is not available. Much has been drawn upon the paper written by Doherty and Thistle (1996) as background for my analysis. Then with the price-quantity mechanism and self-selection constraints as tools for analysis, several circumstances are considered one by one. First, it is assumed that the risk type is private information but the information status of the individuals is known to the insurer. Then it is shown that the value of genetic information is negative and uninformed would choose to remain uninformed. Second, it is assumed that informational status is private information as well as risk types. In this case, the value of genetic information is non-negative. Third, it is assumed that the consumers can choose to reveal negative results and conceal positive results. Then the value of information is positive. In the end, the effect of positive information cost was considered. Secondly it is assumed that the prevention is available. And for simplicity the prevention cost is set to be a fixed number and the loss probability will be decreased to a proportion of the original amount. And it is assumed that the prevention is socially efficient for the high-risk individuals. As the analysis before, the self-selection mechanism is used here. Two circumstances are considered. First, the informational status is private information. Then it was derived that the value of information is positive. Second, the individuals can choose to reveal good risks and conceal bad risks. In this situation the value of information is also derived to be positive. Then this result is consistent with the result given by Hoel and Iversen (2002) and some of their analysis is introduced here.

In section 4 the social efficiency aspect of the genetic information is investigated. But there is no formal analysis. Some of the conclusions given by other researchers are introduced here. After that some policies are introduced and some suggestions on the avert of adverse selection after genetic testing are given.

In the last section 5 some concluding remarks are given.

2. The situation of public information

In this section I will give a formal analysis of the value of genetic information in the situation of public information. I denote information as public if the insurer has access to as much information relevant for risk assessment of a potential policy holder as the policy holder has himself. The information includes the individual's risk type, whether or not he has taken a genetic test, the test result, the prevention undergone by the high risk individual and its effect on the risk of getting ill, etc. So this is a very strong assumption and it's not quite realistic. But it will be a starting point for further analysis.

First, I will give a simple model with the assumption that there is no prevention available to the individual. The information cost is set to be zero. Some basic assumptions concerning the individual and the insurer will be given here. Although the model is too simple, it will serve as a benchmark for further discussion.

Second, the prevention will be taken into consideration. Of course there is a cost for it. But the information is still assumed to be costless as above. In this part, a model will be given to reveal the value of genetic information. Then it will be shown that with prevention available, the value of genetic information is ambiguous under public information.

2.1 No prevention is available.

And first information is assumed to be free, i.e., the information cost is zero.

Some basic assumptions:

- 1). There are two possible states of nature for every individual: the state of sickness (s for short) and the state of good health (h for short).

-
- 2). There are two population H and L with different risk of sickness π_H and π_L , with $0 < \pi_L < \pi_H < 1$.
- 3). The proportion of the high risk group in the population is μ and the proportion of the low risk group is $1 - \mu$.
- 4). The good health state yields an income y and the sickness state entails a loss l . The loss l comes from treatment costs and loss of earnings.
- 5). The individuals are risk averse. Their utility function is state independent and depends only on the income in each state. The good health itself has a value but I ignore it here. The utility function $u(\cdot)$ is increasing and strictly concave that is $u'(\cdot) > 0$ and $u''(\cdot) < 0$.
- 6). The parameters π_H, π_L and μ are assumed to be common knowledge.
- 7). Prior to the introduction of genetic testing, nobody knows his risk type. Hence, initially, as uninformed, the whole population is assumed to have an identical perception of their own risk equal to a weighted average of the actual risks of the two groups:
- $$\pi_U = \mu\pi_H + (1 - \mu)\pi_L.$$
- 8). The insurers are risk neutral and expected profit maximizing. They operate in a perfectly competitive market with administration cost. So they earn zero expected profit. If someone get positive profit, the competition of this market will drive the price of insurance down and the profit will decrease to zero.
- 9). The insurance contract is characterized by a pair of parameters (P, I) . P is the premium paid by the insured and I the indemnity paid by the insurer when there is a claim from the insured. $\sigma = \frac{P}{I}$ is the unit price of the insurance contract.

Some conclusions derived from the above assumptions:

- 1) Because the insurer gets zero expected profit, the expected payment for claims will just be covered by the expected revenues from the premium. So

$$\pi_i(1 - \sigma_i)I_i = (1 - \pi_i)\sigma_i I_i, \Rightarrow \sigma_i = \pi_i,$$

The insurance will be offered at actuarially fair rate.

- 2) With the insurance purchase of the individual, the expected incomes in both states will be:

$$\begin{aligned} y_i^s &= y - l - P_i + I_i = y - l + (1 - \sigma_i)I_i, \\ y_i^h &= y - P_i = y - \sigma_i I_i. \end{aligned} \quad (i = H, L)$$

And the expected utility will be

$$Eu_i = \pi_i \cdot u(y_i^s) + (1 - \pi_i) \cdot u(y_i^h)$$

The individual will maximize the expected utility with respect to the insurance coverage.

$$\begin{aligned} \max_{I_i} Eu_i &= \pi_i \cdot u(y_i^s) + (1 - \pi_i) \cdot u(y_i^h) \\ &= \pi_i \cdot u(y - l + (1 - \sigma_i)I_i) + (1 - \pi_i) \cdot u(y - \sigma_i I_i) \end{aligned}$$

The first order condition to be satisfied is

$$\frac{\partial Eu_i}{\partial I_i} = \pi_i \cdot u'(y_i^s) \cdot (1 - \sigma_i) - (1 - \pi_i) \cdot u'(y_i^h) \cdot \sigma_i = 0$$

so

$$\frac{u'(y_i^h)}{u'(y_i^s)} \cdot \frac{1 - \pi_i}{\pi_i} = \frac{1 - \sigma_i}{\sigma_i}$$

and because

$$\sigma_i = \pi_i, \text{ so } u'(y_i^h) = u'(y_i^s)$$

Then the marginal utilities in both states are equal. Because the utility function is increasing and concave, the expected income in both states are equal. This means full coverage for the risk-averse individual. The risk associated with treatment costs is completely covered by insurance.

The simple model:

Due to the identical perception of the individuals on their risk type, a uniform insurance contract will be supplied to the population with the unit price $\sigma_U = \pi_U = \mu\pi_H + (1 - \mu)\pi_L$

If an individual decides to take a genetic testing, this will bring him before an information lottery. With probability μ he will be revealed to be a high risk one and with probability $1 - \mu$ a low risk one. The expected income after the testing will be respectively $y_H = y - \pi_H I$ and $y_L = y - \pi_L I$.

But if the individual does not take the test, he will be offered the uniform contract and the expected income is $y_U = y - \pi_U I$. Since $\pi_L < \pi_U < \pi_H$, the expected incomes in three states are conversely $y_L > y_U > y_H$ and the expected value of the information will be

$$VI = \mu \cdot u(y_H) + (1 - \mu) \cdot u(y_L) - u(y_U)$$

and because $y_U = \mu y_H + (1 - \mu) y_L$, then for risk averse individual, the expected utility of the two incomes y_H, y_L will be less than the utility of the expected income y_U .

After comparing the utility of the information lottery and the utility of the state of ignorance, the ex ante private value of genetic information for the individual will be negative and he will choose not to be tested. The intuition of this result is obvious. Since abnormal genetic mutation indicating an increased likelihood of some disease is always rare compared with the normal mutation. A large proportion of the population belongs to the group of low risk. Illustrated by the figure 1, it is shown that y_H is very small and y_U near y_L . So the individual will be fined a lot by a much more expensive insurance contract offered to him if revealed to be a high risk one. On the other hand, he will get little by a little cheaper contract available if revealed to be a low risk one. A risk averse individual would rather pay a little more than the best contract than game to be fined a lot by taking the genetic testing and being revealed to be a high risk one. The uniform contract is so cheap that they ignore the price difference between the cheapest contract.

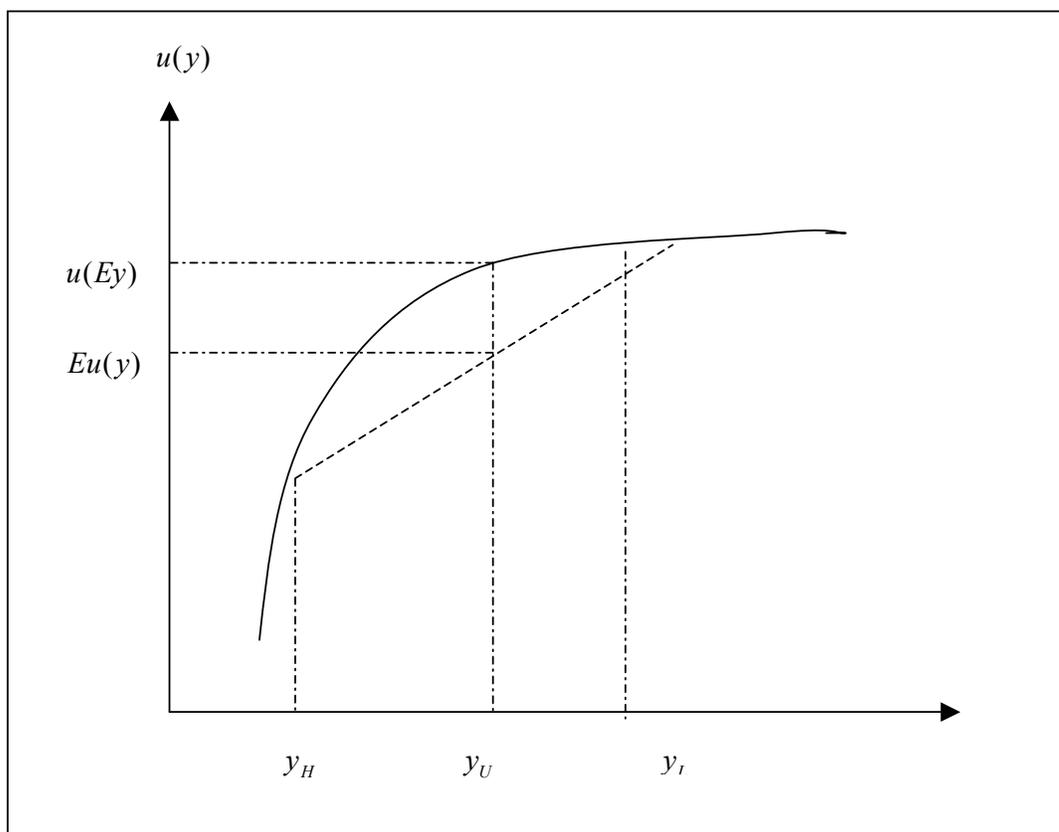


figure 1: The utility for risk-averse individual

When the information has a cost out of the personnel fee and equipment cost the private value of the information is even more negative. Because in addition to the risk classification cost to the individual, a fixed amount of money has to be paid before the test regardless of the test result.

Proposition 1: In the circumstance of public information and no prevention available and regardless of the information cost zero or positive, the private value of genetic information is negative. The risk-averse individual will choose not to be tested and stay behind the veil of ignorance to maintain an average level of utility by purchasing a uniform insurance contract.

2.2 Prevention is available for the high risk individual.

In this situation, an individual in the group of high risk can choose a level of prevention measured by the prevention cost v in utility terms and choose the insurance coverage to maximize the expected utility after prevention. Assume that the production function of the prevention is $\pi_H(v)$ and it has the following properties:

$$\pi_H(v), \pi_U, \pi_L > 0 \quad (\text{a})$$

$$\pi_H'(v) < 0, \pi_H''(v) > 0 \quad (\text{b})$$

$$\pi_H(\infty) > \pi_L \quad (\text{c})$$

$$\pi_U = \mu\pi_H(0) + (1 - \mu)\pi_L \quad (\text{d})$$

Property (c) means that the high-risk one can never be turned into a low-risk one just buy means of prevention. There is also an implicit assumption that only high-risk individuals will take prevention while the uninformed will not.

Due to the symmetry of information in the health insurance market, actuarially fair insurance contracts will be offered to the applicants. The insurance available by the individual after prevention is at the price $\pi_H(v)$, and the utility to be maximized is

$$\begin{aligned} \max_{I,v} Eu &= \pi_H(v) \cdot u(y-l + (1-\pi_H(v)) \cdot I) \\ &+ (1-\pi_H(v)) \cdot u(y-\pi_H(v)I) - v \end{aligned}$$

The first order conditions to be satisfied are as following:

$$\frac{\partial Eu}{\partial I} = \pi_H(v) \cdot u'(y^s)(1-\pi_H(v)) - (1-\pi_H(v)) \cdot \pi_H(v) \cdot u'(y^h) = 0 \quad (1)$$

And this condition lead to $u'(y^s) = u'(y^h)$, because the utility function is increasing and concave the incomes in both states are equal $y^s = y^h$. It means full insurance coverage for the individual. The risk of treatment cost in case of sickness is fully covered by the insurance indemnity.

$$\begin{aligned} \frac{\partial Eu}{\partial v} &= \pi'_H(v) \cdot u(y^s) - \pi_H(v)u'(y^s)\pi'_H(v)I \\ &- \pi'_H(v) \cdot u(y^h) - (1-\pi_H(v)u'(y^h)\pi'_H(v)I - 1 = 0 \end{aligned} \quad (2)$$

because $y^s = y^h$, the above condition can be transformed into

$$-u'(y^s)\pi'_H(v)I = 1 \quad (3)$$

In equation (3) the marginal cost of prevention is 1 and equal to the marginal benefit, which consists of three components: firstly, the marginal reduction in the loss probability $\pi'_H(v)$. Secondly, this reduction leads to the saving of premium in absolute value as $-\pi'_H(v)I$. And thirdly, the saving of expenditure on premium measured in utility term: $u'(y^s)$ is the utility increase with a unit increase in income, $u'(y^s)$ times $-\pi'_H(v)I$ is the increase in utility from the premium reduction caused by a marginal increase in prevention.

Suppose the high-risk individual will choose an optimal level of prevention v^* to satisfy the above mentioned condition (3).

The individual will be offered the contract $C_{H(v^*)}$ if he is revealed to be a high risk one and take prevention at the level v^* . If he remains uninformed, the uniform contract C_U is available for him. So the testing now presents an information lottery to him. With probability μ he will be revealed to be a high risk one and to maximize the expected utility he will take prevention and with probability $1 - \mu$ he will be revealed to be a low risk one and be offered the contract C_L with the lowest insurance price. Assume that the expected utility received by a consumer with probability of loss π under the insurance policy C is $V(C, \pi) = (1 - \pi) \cdot u(y - P) + \pi \cdot u(y - l - P + I)$.

The value of information in this circumstance is

$$VI(v) = \mu \{u(C_{H(v^*)}, \pi_H(v^*)) - v^*\} + (1 - \mu)u(C_L, \pi_L) - u(C_U, \pi_U)$$

When $v^* = 0$ this is the case discussed above: public information without prevention available and the result is that $VI(0)$ is negative.

When $v^* > 0$, we can transform the value of information by adding and subtracting $\mu \cdot u(C_H, \pi_H)$ into the following form:

$$VI(v^*) = \mu \{u(C_{H(v^*)}, \pi_H(v^*)) - v^* - u(C_H, \pi_H)\} + \{\mu \cdot u(C_H, \pi_H) + (1 - \mu)u(C_L, \pi_L) - u(C_U, \pi_U)\}$$

Now the value of genetic information can be separated into two parts:

- 1) The value of the preventive option: with probability μ the individual will be recognized as a high risk one. This brings him to the risk of buying an expensive contract at the unit price π_H . But this also opens him to the possibility of prevention to reduce the risk of disease to $\pi_H(v^*)$ by spending cost v^* on prevention. When the prevention is of value (positively marginal productivity), this term is positive.
- 2) The value of risk classification lottery: the decision to take the test exposes the individual to a lottery, either to turn out as a high risk one with probability μ or as a low

risk one with probability $1 - \mu$ of getting ill. On the other hand, if uninformed, the individual has a policy offering full insurance coverage at a fair price π_U . As discussed above, for a risk-averse individual, the lottery reduces expected utility which implies that the second term is negative.

So we can summarize the conclusion as following:

The value of genetic information that is also known by the insurance company is ambiguous when there is a preventive option for high-risk individual. When the value of the preventive option exceeds the absolute value of the risk classification lottery, it is positive in all and the uninformed will choose to take a test and take prevention at optimal level if revealed to be high risk. This applies to the case of some diseases with effective prevention or treatment. But for the case without effective prevention, the value of information is negative. The risk-averse individual will choose not to be tested.

When the information is not free to get, the result is still ambiguous. Suppose that the information cost is r and $VI > 0$, if $r > VI$, the information cost is greater than its benefit; if $VI < 0$, the information has still more negative value. And in the only case that $VI > r$, the value of information is positive and the uninformed will choose to be tested.

Proposition2: in the situation of public information and prevention available, the value of genetic information is ambiguous. It is positive if the positive effect of prevention is greater than the negative effect of risk classification and negative if the prevention is not so effective to overcome the negative effect of risk classification.

3. The situation of private information

3.1 No prevention available

As in the last section, there is a continuum of consumers who are assumed to be identical in all easily observable respects. Each consumer has a fixed income y in state of good health and suffers a loss l in state of illness. The disease is determined by an abnormal genetic mutation. Consumers may be high risk, with probability π_H or low risk with probability π_L and $0 < \pi_L < \pi_H < 1$. The population proportion of high-risk and low-risk types are μ and $1 - \mu$. These parameters are assumed to be common knowledge.

An insurance policy is described by $C = (P, I)$, where P is the premium and I is the gross indemnity. The expected utility received by a consumer with probability of loss π under the insurance policy C is

$$V(C, \pi) = (1 - \pi) \cdot u(y - P) + \pi \cdot u(y - l - P + I).$$

We let $C_t = (\pi_t \cdot l, l)$ denote a policy that offers full insurance coverage at an actuarially fair rate for a policyholder with loss probability π_t .

Adverse selection models traditionally assume that individuals are endowed with a prior knowledge of their true risk type. That is, it is assumed to be common knowledge that all consumers have an informational endowment that includes the individual's risk type, either high or low risk. In this case, the Nash equilibrium consists of a self-selection mechanism in which informed consumers are offered their choice from a menu of policies. These policies satisfy the self-selection constraints:

$$V(C_H, \pi_H) \geq V(C_L, \pi_H),$$

$$V(C_L, \pi_L) \geq V(C_H, \pi_L).$$

We let $C' = \{C_H^*, C_L'\}$ denote the menu consisting of the Rothschild/Stiglitz equilibrium separating policies. Both of these Policies earn zero expected profit and high risk types are fully insured while low types are rationed to less than full coverage. $C_L' = (\pi_L \cdot k' \cdot l, k' \cdot l)$, $0 < k' < 1$. As illustrated by the following figure.

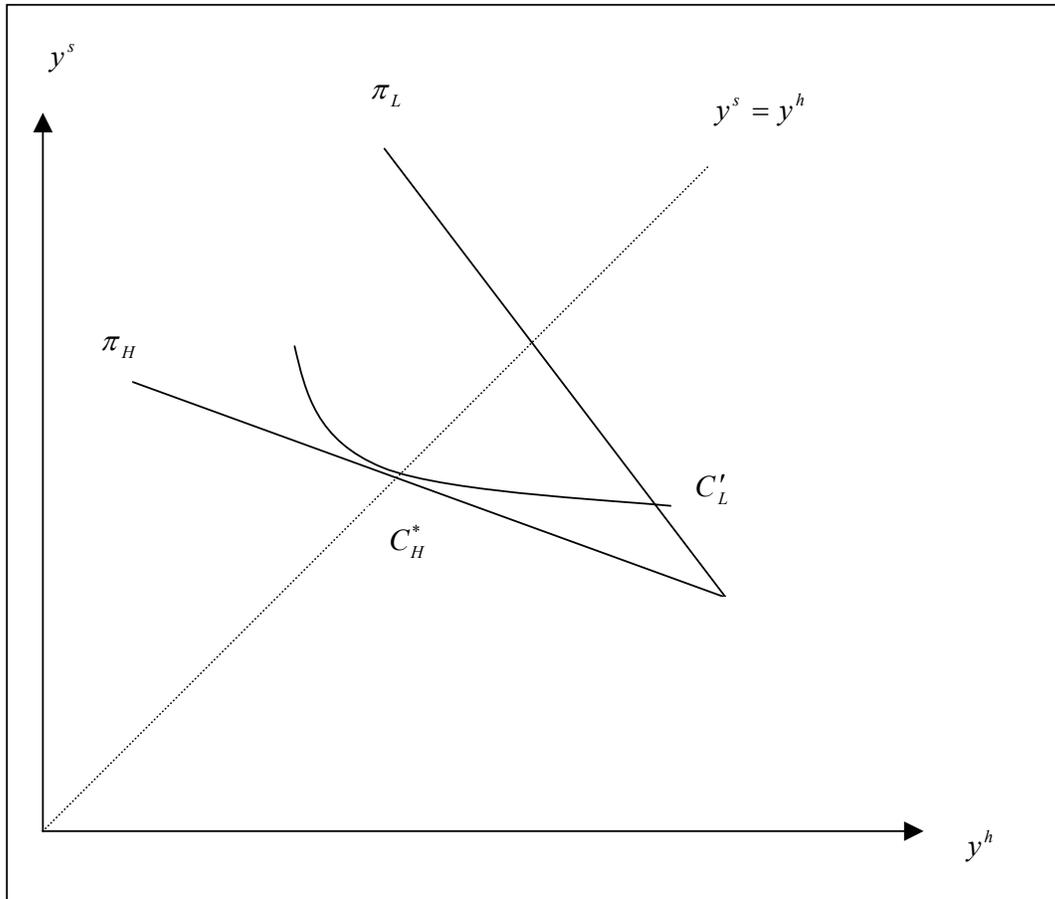


figure 2: private information, no prevention

$$V(C_L', \pi_H) = V(C_H^*, \pi_H)$$

$$V(C_L^*, \pi_L) > V(C_L', \pi_L)$$

$$V(C_L', \pi_L) > V(C_H^*, \pi_L)$$

Let's assume that the proportion of the population λ_U , ($0 \leq \lambda_U \leq 1$) has an informed endowment that does not include the individual's risk type. The proportion λ_H and λ_L ($0 \leq \lambda_H, \lambda_L < 1$) of the population are endowed with the information that they are high and

low risk types. Let μ_H and μ_L be the proportions of uninformed consumers that are high and low risk types; $0 < \mu_H, \mu_L < 1$ and $\mu_H + \mu_L = 1$. We then have $\lambda_H + \lambda_U \mu_H = \mu$, $\lambda_L + \lambda_U \mu_L = 1 - \mu$. All these proportions are assumed to be common knowledge. The probability of loss for uninformed consumers is $\pi_U = \pi_H \mu_H + \pi_L \mu_L$. As assumed in section 2, all the consumers are initially uninformed, then $\lambda_U = 1$ and $\lambda_H = \lambda_L = 0$ and

$$\mu_H = \mu, \mu_L = 1 - \mu, \pi_U = \mu \pi_H + (1 - \mu) \pi_L$$

We also assumed that consumers choose to be informed if the value of genetic information is at least equal to its cost. As assumed first that the information cost is zero, the consumers choose to be informed if the value of genetic information is non-negative.

Let $z = 0$ if consumer is uninformed and $z = 1$ if consumer is informed. As been discussed in the benchmark, if all consumers are initially uninformed and choose not to be become informed, then there is no informational asymmetry and the market will not exhibit adverse selection. The insurer and policyholders share the same estimate of the latter's probability of loss. The premium is perceived by all to be actuarially fair given the absence of information and individuals purchase full insurance. A "no information" equilibrium will prevail and all policyholders will be fully insured. As shown above, the private value of information is negative and the Pareto-optimal policy is $C^*_U = (\pi_U \cdot l, l)$.

3.1.1 The insurer can observe the informational status of the consumers.

That is, the insurer knows which consumer is uninformed and which is informed. Then informed consumers will be offered a menu of policies $\{C^*_H, C'_L\}$, with the self-selection constraints being satisfied:

$$V(C'_L, \pi_H) = V(C^*_H, \pi_H)$$

$$V(C'_L, \pi_L) > V(C^*_H, \pi_L)$$

And the uninformed individuals will be offered the contract C_U^* . Again, the decision to become informed is, ex ante, a choice between C_U^* with certainty and a lottery over C_H^* and C_L' . Since C_L' yields a lower expected utility than C_L^* , the value of information in this situation is

$$\begin{aligned} VI &= \mu \cdot V(C_H^*, \pi_H) + (1 - \mu)V(C_L', \pi_L) - V(C_U^*, \pi_U) \\ &< \mu \cdot V(C_H^*, \pi_H) + (1 - \mu)V(C_L^*, \pi_L) - V(C_U^*, \pi_U) \\ &< 0 \end{aligned}$$

Risk-averse consumer again prefers C_U^* with certainty and the private value of information is negative. The intuitive reason for this result is that insurers can write contracts that depend on the policyholders' informational status, offering different policies to the informed and uninformed whether or not the test result is observed by the insurer.

This situation is likely to happen if a not very strict law is enforced concerning the insurers' access to genetic information. Suppose in some countries the test result about a specific consumer's risk type is forbidden to be supplied to the insurer for risk classification. But a name list of those accepting the genetic test is available to the insurers. In this case, the insurer can determine who are informed and who are uninformed and supply the respective contract menu or contract of certainty to the consumers. In this case, we say that the informational status is observable to the insurer. And regardless of the information cost zero or positive, the value of information is negative. The uninformed will choose not to be informed and stay in the state of ignorance of their risk type.

But if in some countries, very strict law forbids the insurer to get access to any information about whether consumers accept test or not and the test result, then the informational status will be unobservable for the insurer, what will be the value of genetic information in this case?

3.1.2 Unobservable informational status

Now we assume that the insurer is unable to observe which policyholders know their risk type and which do not, i. e, there is asymmetric possession of the informational status.

We now assume that insurers expect consumers to become informed. If there is equilibrium then it is at the contract $C = \{C_H^*, C_L'\}$, uninformed policyholders would purchase the low-risk policy because as illustrated by figure 3, it offers higher utility for the uninformed than the policy for the high-risk individuals. The value of information is

$$VI = \mu \cdot V(C_H^*, \pi_H) + (1 - \mu)V(C_L', \pi_L) - V(C_L', \pi_U)$$

Because the contract C_L' has the same value as C_H^* for the high-risk consumers, $V(C_L', \pi_H) = V(C_H^*, \pi_H)$, and because the expected utility property given by Hal R. Varian in “Microeconomics Analysis”: $u(\mu \circ x \oplus (1 - \mu) \circ y) = \mu \cdot u(x) + (1 - \mu) \cdot u(y)$,

which means that the utility of a lottery is the expectation of the utility from its prizes. Then the value of information can be transformed into

$$\begin{aligned} VI &= \mu \cdot V(C_L', \pi_H) + (1 - \mu)V(C_L', \pi_L) - V(C_L', \pi_U) \\ \because \pi_U &= \mu\pi_H + (1 - \mu)\pi_L, \\ \therefore VI &= V(C_L', \mu\pi_H) + V(C_L', (1 - \mu)\pi_L) - V(C_L', \pi_U) \\ &= V(C_L', \mu\pi_H + (1 - \mu)\pi_L) - V(C_L', \pi_U) = 0 \end{aligned}$$

The value of information is zero and according to our assumption before, the uninformed will choose to become informed. Of course this is a very weak dominant strategy.

Next we will consider the case in which insurers expect consumers to remain uninformed.

Suppose there is equilibrium at the policy set $C'' = \{C_H'', C_U'', C_L''\}$. These policies satisfy the zero expected profit conditions and the self-selection constraints:

$$V(C_H'', \pi_H) > V(C_L'', \pi_H),$$

$$V(C_H'', \pi_H) = V(C_U'', \pi_H),$$

$$V(C_U'', \pi_U) = V(C_L'', \pi_H),$$

$$V(C_U'', \pi_U) > V(C_H'', \pi_U),$$

$$V(C_L'', \pi_L) > V(C_H'', \pi_L),$$

$$V(C_L'', \pi_L) > V(C_U'', \pi_L).$$

Where the policy C_H'' is the same as C_H^* that offers full coverage for the high risks. And C_U'' offers the same utility as C_H'' for the high risks but less utility than the full coverage policy C_U^* for the uninformed individuals. The policy C_L'' offers the same utility as C_U'' for the uninformed ones but less utility than the full coverage policy C_L^* for the low-risk individuals.

The policy set is illustrated by the following figure:

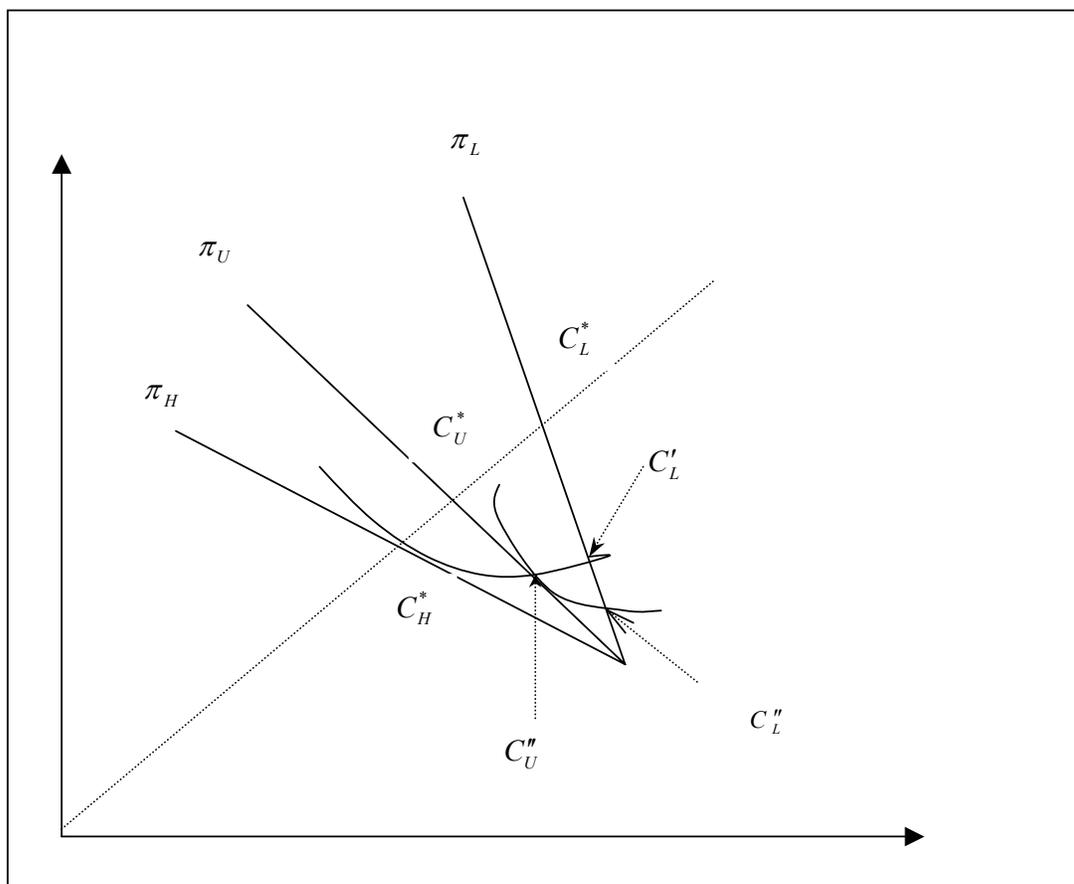


figure 3: no prevention, unobservable information status

Now the value of information is

$$VI'' = \mu_H \cdot V(C_H'', \pi_H) + (1 - \mu_H)V(C_L'', \pi_L) - V(C_U'', \pi_U)$$

Because $V(C_U'', \pi_U) = V(C_L'', \pi_U)$ and adding and subtracting $\mu_H \cdot V(C_L'', \pi_H)$ yields

$$\begin{aligned} VI'' &= \mu_H \{V(C_H'', \pi_H) - V(C_L'', \pi_H)\} \\ &\quad + \{\mu_H V(C_L'', \pi_H) + (1 - \mu_H)V(C_L'', \pi_L) - V(C_L'', \pi_U)\} \end{aligned}$$

Since $\pi_U = \mu_H \pi_H + (1 - \mu_H)\pi_L$, the second term is zero, We can get

$$VI'' = \mu_H \{V(C_H'', \pi_H) - V(C_L'', \pi_H)\} > 0,$$

because the policy C_H'' is preferred by the high-risk individuals to C_L'' .

Thus, uninformed policyholders would choose to become informed. But after being informed, the consumer will buy a policy C_H^* if revealed to be a high-risk one and a policy C_L' if revealed to be a low-risk one. The equilibrium will be the policy set $C' = (C_H^*, C_L')$. So there can not be an equilibrium when insurers expect consumers to be uninformed.

3.1.3 Unreported bad risks and verifiable good risks

We now consider the case in which the consumer has an incentive to report favorable results and conceal unfavorable results. Imagine a genetic test for Huntington's disease. Those who take the test and receive a negative result report that result to the insurer and receive a policy priced according to the favorable result. Those who take the test and receive a positive result clearly have an incentive to conceal their having taken the test. This asymmetric reporting may be reinforced by a "consent law" which requires that consumers give their consent before test results can be revealed to third parties. Thus, the insurer cannot differentiate between those who are uninformed and those who have been tested positive.

In this case we first assume that insurers expect consumers to become informed. Those been tested negative (low-risk types) will report the test result to the insurer and will receive C_L^* , all others are offered C_H^* , these are both the full coverage policies. The value of information then will be:

$$\begin{aligned}
I^* &= \mu_H V(C_H^*, \pi_H) + (1 - \mu_H) V(C_L^*, \pi_L) - V(C_H^*, \pi_U) \\
&= \mu_H V(C_H^*, \pi_H) + (1 - \mu_H) V(C_H^*, \pi_L) - (1 - \mu_H) V(C_H^*, \pi_L) \\
&\quad + (1 - \mu_H) V(C_L^*, \pi_L) - V(C_H^*, \pi_U) \\
&= (1 - \mu_H) [V(C_L^*, \pi_L) - V(C_H^*, \pi_L)] \\
&\quad + \mu_H V(C_H^*, \pi_H) + (1 - \mu_H) V(C_H^*, \pi_L) - V(C_H^*, \pi_U) \\
&= (1 - \mu_H) (V(C_L^*, \pi_L) - V(C_H^*, \pi_L)) > 0,
\end{aligned}$$

because the policy C_L^* is preferred by the low risks to C_H^* .

Second assume that the insurers expect consumers to remain uninformed. It will still offer C_L^* to those been tested negative. However, since the insurer cannot distinguish between the uninformed and those concealing positive test results, the insurer offers a submenu of contracts $C_H^* = (C_H'')$ and C_U'' to those not reporting the test results. Since this submenu satisfies the self-selection constraints:

$$\begin{aligned}
V(C_H'', \pi_H) &= V(C_U'', \pi_H) \\
V(C_U'', \pi_U) &> V(C_H'', \pi_U)
\end{aligned}$$

The informed with positive results will select C_H^* and the truly uninformed will choose C_U'' . The set of contracts is $C^{**} = \{C_H^*, C_U'', C_L^*\}$. The value of information is then:

$$\begin{aligned}
VI^{**} &= \mu_H V(C_H^*, \pi_H) + (1 - \mu_H) V(C_L^*, \pi_L) - V(C_U'', \pi_U) \\
&= \mu_H V(C_U'', \pi_H) + (1 - \mu_H) V(C_U'', \pi_L) - V(C_U'', \pi_U) \\
&\quad + (1 - \mu_H) [V(C_L^*, \pi_L) - V(C_U'', \pi_L)]
\end{aligned}$$

The term in the first braces disappears and the value of information is

$$VI^{**} = (1 - \mu_H)[V(C_L^*, \pi_L) - V(C_U'', \pi_L)] > 0$$

The value of information is positive and the uninformed policyholders will choose to become informed.

Proposition: Assume that consumers can choose to observe their risk type at zero cost, informed and uninformed consumers cannot be distinguished, and risk type is not directly observed by insurers. We assume that consumers can choose whether or not to report verifiable test results and that this is the only information on risk type available to the insurer. Then in this case the information has positive value for the uninformed consumers and they choose to be informed.

Compare this with the situation under which the insurers can observe information status, this result is quite easy to explain. When information status is fully observable, the insurer can offer C_H^* , C_U^* , C_L^* respectively to the informed high-risk types, the uninformed and the informed low-risk types. The value of information to the uninformed is negative and they would never choose to become informed. This result contrasts with the positive value obtained when consumers can choose to reveal or conceal information status. Because they can always get a better contract of C_L^* if revealed to be a low-risk one and remain to accept the contract C_U'' or C_H^* with the same utility for them if revealed to be a high-risk one and conceal this result. So the test will supply more choice for them and make them better off.

3.1.4 Information costs

To this point we have assumed information could be acquired costlessly. We now introduce explicit information costs r and assume that utility is separable in information costs.

If the contract is C'' , then the value of information is $VI'' > 0$, as shown before. If $VI'' < r$, then the net value of information is negative for uninformed policy-holders. These individuals choose not to learn their risk type and the equilibrium contract set is C'' with C_H^* for the informed high risks and C_U'' for the uninformed and C_L'' for the uninformed low risks. If $VI'' > r$ then the net value of information is non-negative and the uninformed policyholders choose to be informed and then C'' cannot be an equilibrium. Because the high risks and those revealed high risks from the uninformed will buy the contract C_H^* . Those originally informed to be low risks and revealed to be low risks from the uninformed will buy the contract C_L'' .

And then can C' be an equilibrium? At C' the value of information is $VI' = 0 < r$ and uninformed policyholders choose not to learn their risk type. Moreover, the uninformed policyholders will still choose C_L' over C_H^* from the menu of policies. But then C_L' is a pooling policy for policyholders with loss probability π_L and π_U . And it follows that C' cannot be an equilibrium contract. So if $VI'' > r$, then no equilibrium exists.

3.2 Prevention available

When information is private and prevention is available, the choice of the uninformed consumers to be tested or not has been well studied in Hoel and Iversen (2002). They assume that there is a mix of compulsory and voluntary insurance available.

In this part we will first show some results similar to those given by Hoel and Iversen and then consider the impact of information cost on consumers' choice about whether to accept a test or not.

We assume that the prevention an individual undertakes is his private information. Also the cost of prevention is private information. Hence, an insurance contract cannot be made contingent on whether prevention is undertaken. We also impose the institutional constraint that insurers have no access to information about whether a person is tested. Since those tested then cannot be distinguished from those not been tested, insurance contracts can neither be contingent on whether a person is tested nor on the test result.

For simplicity, we assume that the prevention cost v is a fixed number but not a continuous variable chosen at an optimal level by those tested to be high risks. And the prevention can reduce the loss probability of the high risks from π_H to $s \cdot \pi_H$, while it cannot make the illness risk as low as it's for the low-risk consumers. So $1 > s \cdot \pi_H > \pi_L > 0$. We still assume no compulsory insurance as before and all consumers initially have the same perception of risk type as the weighted average of two risk types:

$$\pi_U = \mu\pi_H + (1 - \mu)\pi_L.$$

As illustrated by the figure, contract C_{HS}^* will be available for those been tested positive and take prevention. The net utility after prevention is greater than the utility of taking no prevention and purchasing the insurance of full coverage.

Case 1: consumers can reveal the negative results (low risk) and conceal the positive result (high risk). But the prevention is socially efficient for the high-risk persons.

By taking preventive measures, the endowment point A moves to A' because of preventive cost in both states. And the slope of the budget line also changes due to the effect of the prevention on loss probability. Full insurance policy C_{HS}^* will be offered to those people who have taken prevention after being tested positive.

If a person remains uninformed, he will be offered a contract C'_U with the self-selection constraints satisfied:

$$\begin{aligned}
VI_1 &= \mu V(C_{HS}^*, \pi_{HS}) + (1 - \mu)V(C_L^*, \pi_L) - V(C'_U, \pi_U) \\
&> \mu V(C_H^*, \pi_H) + (1 - \mu)V(C_L^*, \pi_L) - V(C'_U, \pi_U) \\
&> \mu V(C'_U, \pi_H) + (1 - \mu)V(C'_U, \pi_L) - V(C'_U, \pi_U) \\
&= 0
\end{aligned}$$

So the value of information is positive and the uninformed will accept the test. After testing, they will reveal the negative result to the insurer and take prevention if the result is positive.

The intuitive reason is obvious: the uninformed can always be better off by revealing the negative result and receiving a cheaper policy at full coverage. While he will have the same utility by taking prevention and buy a policy C_{HS}^* if revealed to be a high-risk one. So the total value of the genetic information is always positive and the equilibrium policy set is $C' = \{C_{HS}^*, C_L^*\}$.

But the above conclusion comes from the assumption of costless information. If there is a cost of information r and $r > VI_1$, the net value of information is negative. The consumers will remain uninformed. In this case, all consumers will accept the uniform policy C'_U and there is a highly signaling cost for the low-risk ones.

Case 2: the information status unobservable

In this case the insurer can not judge which one is informed or uninformed of the risk type. So they offer a contract set $C'' = \{C_{HS}^*, C'_U, C_L''\}$ for the consumers. These policies earn zero expected profit and satisfy the self-selection constraints:

$$\begin{aligned}
V(C_{HS}^*, \pi_{HS}) &= V(C'_U, \pi_{HS}) \\
V(C_H^*, \pi_H) &> V(C'_U, \pi_H) \\
V(C'_U, \pi_U) &= V(C_L'', \pi_U) \\
V(C_L'', \pi_L) &> V(C'_U, \pi_L)
\end{aligned}$$

$$V(C_L'', \pi_{HS}) < V(C_{HS}^*, \pi_{HS})$$

then the value of information is

$$\begin{aligned} I_2 &= \mu V(C_{HS}^*, \pi_{HS}) + (1 - \mu)V(C_L'', \pi_L) - V(C_U', \pi_U) \\ &> \mu V(C_H^*, \pi_H) + (1 - \mu)V(C_L'', \pi_L) - V(C_U', \pi_U) \\ &> \mu V(C_L'', \pi_H) + (1 - \mu)V(C_L'', \pi_L) - V(C_L'', \pi_U) \\ &= 0 \end{aligned}$$

So the value of information is positive and the uninformed will choose to be tested. If compared with the result got under the situation of private information and no prevention available, this result is quite reasonable. Because in the situation of no prevention, the value of genetic information is positive. Now with the prevention being available and socially efficient for the high-risk individual, it is even more valuable for the uninformed to choose to be tested and take prevention if revealed to be high risks afterwards. So in the situation of private information and prevention available and socially efficient for the high risks, the value of genetic information is positive and the uninformed will choose to be tested and take prevention if revealed to be high risks.

This is consistent with the situation given by Hoel and Iversen(2002) when there is no compulsory insurance. In their analysis, it is assumed that compulsory insurance covers a portion $x \leq l$ of the loss. It is exogenous and equal for all. Voluntary insurance covers loss in excess of x . And it is assumed that for a person who can buy unlimited supplementary insurance at an actuarially fair price and who does not know whether he is high risk or low risk, it is not worthwhile to undertake prevention. Formalization of this assumption is that $v > (1 - s)\mu \cdot \pi_H \cdot l$.

The left-hand side is the cost of preventive measures, while the right-hand side is the reduction a fully insured uninformed person gets in the actuarially fair insurance premium as a consequence of the preventive measures he undertakes.

Due to this assumption, it is ruled out of the choice of undertaking prevention without test. And the choice of test without prevention if revealed to be high risk is also ruled out because of the assumption that prevention is socially efficient for high-risk persons. Stated formally, it means:

$$v < (1-s)\pi_H \cdot l$$

The left-hand side is the cost of prevention and it's lower than the increase in expected income due to prevention for a person who is high risk.

Then the condition for an uninformed individual to choose to be tested and take prevention if revealed to be high risk is as follows:

$$v < (1-s)\pi_H(l-x) .$$

So here it is clear that the higher proportion of compulsory insurance, the less likely an individual will choose to be tested. In our analysis, $x=0$ and it is assumed to have no compulsory insurance. The result is the same that the consumers will choose to be tested since the value of information is positive for them.

To encourage a person with mixed compulsory and voluntary insurance to undertake testing and prevention, a kind of genetic insurance is highly recommended. It is suggested that the government should offer insurance against the cost of being identified as a high-risk person. Since the costs of being identified as a high-risk person compared to a low risk person is $(s\pi_H - \pi_L)(l-x) + v$, actuarially fair insurance can be offered at the cost $\mu[(s\pi_H - \pi_L)(l-x) + v]$. With fair insurance against the loss of being identified as high risk, an uninformed person will choose the testing and prevention option since this option now offers the highest expected income and utility.

This is also stated by Tabarrok(1994). He argues that the potentially negative effects of predictive testing on insurance coverage and income distribution could be avoided by introducing compulsory insurance against the financial consequence of becoming high risk when a person decides to be tested.

So according to the analysis above, we can put forward the following proposition: When there is prevention available and it being socially efficient for the high-risk individual, the value of genetic information is positive and the uninformed will choose the test and take prevention if revealed to be high risk. This applies especially to the case of no compulsory insurance. With a high proportion of compulsory insurance the uninformed will less likely to be tested. To encourage the test and prevention to be undertaken, a kind of new genetic insurance can be enforced by the government to avoid the economic loss of being identified as a high-risk individual.

4. Social efficiency and policy implications

4.1 The social value of genetic information

Till now we have considered the private value of genetic information. There is another important aspect of genetic information: the social value. There is no explicit definition for social value of genetic information but it is always put forward relative to the notation of private value. The latter is the benefit genetic testing brings to individual by increase of income due to less premium or better insurance policy with high utility. The former is the total effect of genetic testing to not only the individual being tested but also the other people affected. In this paper, we don't take into account the externality of genetic information due to altruism. This includes the pleasure felt by the family or friends when one is found to be low risk by taking a genetic test. We only consider the economic value of genetic information for the society.

Milgrom and Stokey(1982) have shown that if parties negotiate ex ante efficient contracts in a complete market, then subsequently generated information that does not create new investment opportunities has zero social value. By way of illustration, consider a person who takes a diagnostic test for Huntington's disease. Since there is little effective treatment, we can assume that the allocation set is not expanded by the test. But the information generated by the test can be used to redistribute income through life and health insurance. From Milgrom and Stokey we conclude that these insurance opportunities have zero social value.

Crocker and Snow's(1992) show that, if agents initially have no private information, then the Pareto-optimal contracts involve no signaling. It is the case of public information and actuarially fair insurance offered to each risk type. When individuals initially possess hidden information, additional hidden information brings social benefits since it permits agents to sort more finely. However, additional hidden information also increases the costs to some agents of signaling their risk type. It is respectively the case for high risks and for low risks.

On balance, the social value of information can be positive or negative depending on which effects dominates.

Doherty and Thistle(1996) analyze the case where insurers cannot observe whether consumers have obtained a test. They show that, in this context, acquiring information always has a positive private value. Since by taking the test the market possibilities (especially the price of insurance) do not change for the individual but better information allows consumers to make a more informed choice, that is, to adjust the amount of insurance they buy to what is optimal for their risk type. However, the social value of the testing opportunity is negative. If there were no asymmetric information before the test, all individuals would insure for a medium premium. If insurers could observe test results then, depending on the outcome of the test, some (those with good news) could buy insurance cheaper and for those with bad news, the premium would increase. By the martingale property of conditional expectation, the expected premium could be the same as the medium premium before. But since the premium is a random variable and individuals are risk averse, all are worse off from an ex ante perspective. Asymmetric information after the test aggravates this problem, since low risks cannot buy full insurance for the low premium but must signal their risk type by purchasing only partial coverage.

In Hoy and Polborn(2000), different results from above have been derived. They assume that the insurance demand change with the loss probability. The higher probability of getting ill, the more insurance coverage will be demanded when there is no premium risk. Knowing one's risk type allows one to make a more informed choice about the optimal level of insurance coverage. This is the case for health insurance market. Only people with high risk of disease will always buy a lot of insurance. However, when a sufficiently large number of individuals become better informed about their risk types, there will be market price effects as changes in demand by different risk types will lead to changes in the average cost of providing insurance.

They assume that in the reference situation only high risks buy life insurance. This is possible since the premium might be unacceptably high for low risks and uninformed individuals. Hence the premium will be based on the high risks' probability of illness. After

the genetic testing, the high- risk part of the uninformed will buy insurance. Therefore, the ex ante expected utility for uninformed consumers is increased by the testing opportunity.

Besides there being a possible positive value of insurance for those who take the test, there is also the possibility of positive price spillover effects for those who don't take the test. Suppose there is a range of risk types so that an uninformed individual who take the test may be determined to be one of a number of higher or lower risk types. If such a person initially does not buy insurance and upon testing discovers he is of a high- risk type but that he carries a risk level less than the average of those who initially purchase insurance. After his buying insurance the result will be a lower equilibrium price of insurance which will be to the advantage of the original pool of insurance buyers. Negative price spillover effects are also possible if he is discovered to be a risk type higher than the average risk of those originally purchasing insurance.

So the total effect of genetic testing on the social efficiency can be positive, negative or zero. It depends on the sum of positive value of insurance purchasing by those initially uninformed and the price spillover effects afterwards.

In Hoel and Iversen(2002) it is defined as socially efficient for genetic testing if the cost of prevention is less than the increased income due to cheaper insurance by taking prevention for a high risk individual. They also show that when information about prevention and test status is private, two types of social inefficiencies may occur. Genetic testing may not be done when it is socially efficient and it may be done although it is socially inefficient. The first type of inefficiency is more likely for those who have supplemented the compulsory insurance with substantial voluntary insurance. The second type of inefficiency is more important the less effective prevention is.

Yet the genetic therapy is likely to lag behind the development of genetic diagnostics. And hence, the scope for effective prevention is also limited. In the present years it is possible that genetic testing is expensive and effective prevention unavailable. So the problem of genetic testing is not so serious. But with the development of technology, much cheaper testing will be available and preventive measures will be discovered by and by. The question will arise that whether some institutions such as the insurance company and

employers should use the genetic information for underwriting? In the next part of this section, we will introduce some policies concerning the access of insurers to the genetic information.

4.2 Policy implications

There are different attitudes about whether insurers should get access to the genetic information and make use of it for risk classification. A number of national and international committees and advisory groups have developed and published recommendations for policy makers to protect individuals against genetic discrimination. Three solutions are usually proposed: 1) prohibition of any use of genetic information; 2) legislation prohibiting this below a certain amount of coverage; and 3) moratoria.

The approaches used in different countries vary greatly. In five European countries: Austria, Belgium, Denmark, France and Norway, any use of genetic information for business purposes is prohibited. In four countries, France, Germany, Sweden, and the United Kingdom, a moratorium or partial moratorium on the use of genetic information by insurers has been established. In the Netherlands, the Medical Examination Act (1998) prevents the acquisition of genetic information by insurers and employers below a certain amount of coverage. At the European level, the Council of Europe signed a convention for the Protection of Human Rights and Dignity of the Human Being with regard to the Application of Biology and Medicine in 1997. The same year, the UNESCO Universal Declaration on the Human Genome and Human Rights was signed. In the United Kingdom, there is a human Genetics commission addressing these policy issues, with specific committees in which consumers, business groups, geneticists and other stakeholders, work together to advise Government of developments and options. In the US, a majority of the states have banned the use of genetic information by insurers. The Congress in 1996 passed legislation that forbids group health organizations from denying coverage on the basis of genetic information. Effects are also being made to extend the prohibitions to all health insurers and to ban insurers from raising premiums based on genetic data. Recently (February 2001), a bill to prohibit discrimination on the basis of genetic information with

respect to health insurance was introduced in the US senate and referred to the committee on Health, Education, Labor and Pensions.

Despite the desire to restrict the use of genetic information for non-medical purposes, a balance appears necessary between the economic interests of insurers and employers, the interests of applicants and the interests of other policyholders and other employers. This is especially relevant and sensitive under health care systems and welfare sectors with increasing budgetary restrictions.

In the insurance market, adverse selection is a classical problem. It occurs when people have undergone testing and conceal positive results from insurers. Insurers require symmetry of information. If the insured person does not disclose information which the insurer needs to know, then this disrupts the equilibrium of the relationship and the possibility of adverse selection arises. If insurers are prohibited from having access to pertinent information at the time of underwriting or when the policy is renewed, the applicants could use genetic information to abuse the insurance system, taking advantage of private knowledge of the risks they submitting for coverage. The consequences of a lack of symmetry in information between insurers and applicants or insured persons could force insurers to adjust premiums. In the Netherlands, after the Medical Examination Act has been in force, insurers have taken measures to prevent the risk of adverse selection by implementing premium increases in advance. By prescribing a maximization of the pension pay out or basing payments on a maximum salary, or by including an option to increase the premium in the policy. Dutch insurers have also introduced waiting time for existing illness when issuing the insurance. This means that if, within a term stipulated in the waiting time, the insured becomes disabled or dies as a result of an illness that he had when he took out the insurance, no payment will be made. As in our analysis before, when the informational status is asymmetric, the value of information is always positive and people will choose to undertake testing. This will induce insurers to take the above mentioned measures to avert the problem of adverse selection. But then there is great signaling cost for the low-risk individuals. Except in the situation that they can reveal negative results to the insurers, they will suffer a high premium or not full coverage due to the problem of adverse selection. As the enforcement of prohibitive laws in many countries, this problem will be aggravated.

There are several ways to alleviate this consequence as the prohibitive laws become more and more general in many countries.

1. A compulsory insurance can be implemented to cover partial loss of illness. As analyzed by Hoel and Iversen, the higher the proportion of compulsory insurance, the less likely the uninformed would choose to be tested and the less seriousness of the problem of adverse selection. A proper amount of compulsory insurance will make the high risks and the low risks both better off. The bad risks profit from the subsidization by the good risks while the good risks pay a little more than fair premium for a basic protection from insurance.
2. Advance of technology: with the development of technology, more and more effective measures will be found to prevent genetic diseases and decrease the probability of getting ill. Then the high-risk people can protect themselves by taking prevention instead of purchasing large amount of insurance. This prospect is not so dreaming since technology has always been developed rapidly. So the governments can invest even more on bio-technology to find more effective prevention or treatment for genetic diseases. This is to the benefit of all the human beings.
3. Consent-law: With the consent law the genetic information will be used by the insurers after the approval of insureds. This can at least make the low risks better off without threat to the benefits of other people. By revealing to be low risks, this group of people can get a cheaper and full insurance coverage. And as our analysis before, the high risks can be of the same well being by taking prevention and purchasing insurance policy at full coverage.
4. Genetic insurance: As highly recommended by a lot of researchers genetic insurance is really a new possibility for the solution of the problem generated by genetic testing. By a compulsory insurance against the probability of being identified as high risk, the high risks can get rid of the fear of financial loss from positive results. And the test results can then be used by the insurers for a more finely risk classification. The problem of adverse selection will not arise then. But there are still problems with this suggestion. First, many genetic diseases are multi-factorial. The disease occurs

because of not only abnormal genetic mutation but also other reasons such as the environment, the life habit and each individual's susceptibility. Then the exact influence of genetic disorder is hard to be estimated. And then the price of genetic insurance is hard to be specified. Second, there will also be the problem of adverse selection here. Those perceiving to be low risk would not like to undertake test and on the other hand, those perceiving to be high risk would like to be tested. Then the price of genetic insurance may be prohibitively high for it to be accepted by everyone. After all, it is a good suggestion to solve the problem of adverse selection after genetic testing.

Of course the application of these suggestions is a little far from the reality. Further research needs to be done with respect to the concrete details of policy implementation.

5. Concluding remarks

As analyzed in the previous sections, the existence of private information makes it always attractive to accept the genetic test for the uninformed individuals. And there is an incentive for high risks to conceal the results. This has a negative externality on the low risks while the high risks are not better off from the loss of the low risks.

So it seems preferable that genetic information should be shared by both the insureds and insurers. As stated in the Economist (2000), the government have a role to play in compensating the unfortunate in the lottery of the gene pool.

But there are different opinions regarding the importance of the issues that this paper has raised.

First, Watts (1999) and Bonn (2000), refer to geneticists who argue that the fears of the impact of genetic testing on insurance are unfounded. The predictive power of genetics is said to be exaggerated. Although there are some useful predictive genetic factors for multifactorial diseases, the associated risks are said to be too difficult to assess for underwriting purposes.

Second, genetic testing by health insurers primarily affects the market for individual policies. Group insurance and individual insurance are fundamentally different products, and their underwriting practices differ substantially. Medical underwriting is limited generally to the individual and small-group insurance market. Large-group insureds, on the other hand, are issued policies without direct considerations of the insurability of individual members of the group. If a high proportion of the population (say, 90%) is covered by group policies, is there significance of studying the impact of genetic testing on insurance market?

Third, raising insurance rates because of abnormal genetic tests is problematic because individuals are penalized for traits over which they have no control. Often, insurance rates

are raised to encourage responsible behavior. Thus, for example, smokers pay higher rates for nonsmokers; individuals with high cholesterol levels may also pay higher rates. In these cases, there is a genetic component to the high risk, but there is also an element of personal responsibility, and the higher rates are designed to influence personal behavior. With genetic tests, however, there is nothing the individual can do to affect the outcome. So if this argument justifies, there should be policy restricting insurers raising insurance rates due to people's genetic test revealing positive results. And then our analysis should consider this restriction then.

There are also some assumptions of our models need to be modified and explored in future research.

We have assumed that all consumers have the same perception of their risks prior to genetic testing. But this is not quite realistic. For instance, family history may be used to distinguish between high- and low- risk individuals. An important modification is then to allow for consumers to have some ex ante information of their risk type.

We assumed no preference for good health. The motivation for good health was confined to preference for income. The consequence of including health as a separate argument in the utility function should be explored in future work. Hence, the introduction of state dependent utility function, as in Strohmenger and Wambach (2000), will be an analytic tool in future work.

Finally, we assumed no compulsory insurance throughout. But in reality, a compulsory insurance is always supplied to maintain a basic need for insurance in many countries. So the introduction of a mix of compulsory and voluntary insurance is necessary for future research.

References

- Arrow, K. J. (1963), Uncertainty and the Welfare Economics of Medical Care, *American Economic Review* 53, 941-73
- Akerlof, G.(1970), the market for lemons: qualitative uncertainty and the Market Mechanism, *Quarterly journal of Economics* 84, 488-500
- Culyer, A. J. (1971), The Nature of the Commodity "Health Care" and its Efficient Allocation, *Oxford Economic Papers* 23,189-211
- Bonn, D., 2000. Genetic testing and insurance: fears unfounded. *The Lancet* 355, 1526.
- Doherty, N. A., Thistle, P. D., 1996. Adverse selection with endogenous information in insurance market. *Journal of Public Economics* 63, 83-102
- Eckstein, Z., Eichenbaum, M., and Peled, D. (1985), Uncertain Lifetimes and the Welfare Enhancing Properties of Annuity Markets and Social Security, *Journal of Public Economics* 26, 303-20
- European Society of Human Genetics Public and Professional Policy Committee,2000. Genetic information and testing in insurance and employment: technical, social and ethical issues. Background Document,17 November 2000.
- GAIC(Genetics and Insurance Committee),2000.First annual report, April 1999-June 2000,Department of Health, London.
- Hal R. Varian "Microeconomic Analysis" third edition. Chapter 11,172-195
- Hoy,M.,1989.The value of screening mechanisms under alternative insurance possibilities. *Journal of Public Economics* 39,177-206.
- Hoy,M.,Polborn,M.,2000.The value of genetic information in the life insurance market. *Journal of Public Economics* 78,235-252.
- Iversen, T., 1999. The interaction between predictive and health insurance. Manuscript.
- Rothschild, M., and Stiglitz, J. (1976), Equilibrium in Competitive Insurance Market: An Essay in the Economics of Incomplete Information, *Quarterly Journal of Economics* 90, 624-49.

Strohmenger,R., Wambach,A.,2000.Adverse selection and categorical discrimination in the health insurance market: the effects genetic test. Journal of Health Economics 19,197-218

Tabarrok, A., 1994. Genetic testing: An economic and contractarian analysis. Journal of Health Economics 13, 75-91.

The Economist,2000. Insurance in the genetic age. Opinion , The Economist,19 October 2000.

Hal R. Varian “Microeconomic Analysis” third edition. Chapter 11,172-195