# Existence of an Asymmetric Information Structure in Gene Diagnosis†
## ——The Mechanism by which Genetic Discrimination is Induced——

Nobuyuki SOGA*

Research Institute for Economics & Business Administration of Kobe University

**Abstract**

In this paper, equilibrium of the life/medical insurance market is analyzed under conditions where insurers demands that an insurant undergoes genetic testing, on the assumption that the Human Genome Project will allow direct insight into the precise manner of operation of individual genes. Also, equilibrium in this instance is studied with attention given to the existence of an asymmetric structure of information between an insurant and insurers, even if the insurers are able to propose a contract based on knowledge of the results of genetic testing. The model described in this paper led to a conclusion that equilibrium can exist in any instance. In this paper, I also show that there exists equilibrium totally opposite to that shown as a result of adverse selection depending on change in the ratio of individuals undergoing genetic testing, and on the basis of such equilibrium I discuss the mechanism which causes "genetic discrimination" which is increasingly being regarded as a potential problem.

*JEL classification:* D82, I10, O31.

*Keywords:* Genetic Testing, Genetic Discrimination, Adverse Selection, Risk Selection, Insurance Markets.

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*Nobuyuki SOGA.
Research Institute for Economics & Business Administration of Kobe University.
2-1 Rokkodai-cho, Nada-ku, Kobe-city, Hyogo, 657-8501, Japan.
Phone : +81-78-803-7030, E-mail : soga@rieb.kobe-u.ac.jp

# 1 Introduction

Until a few decades ago, it was generally believed that hereditary diseases were transmitted along certain family lines but did not occur in non-related individuals. However, the Human Genome Project and other genetic research carried out by private research institutes has revealed that genes are involved in the development of almost all human diseases, including cancer.

The scientific journal Nature announced in its December 1999 issued that the Human Genome Project has decoded all of human chromosome No.22. In this chromosome were located the genes responsible for 22 different diseases including those for leukemia, cataracts, and osteocarcinoma.

More information on human genes delivered by the Human Genome Project is set to make contributions to a wide range of fields, chiefly medicine. In particular, gene therapy is predicted to become a next-generation treatment. However, it is important not to ignore the social impact that this information will have. To be more specific, there are concerns about the development of a new type of discrimination based on the genetic information characteristic of individuals. In particular, the change in information structure resulting from the availability of genetic information may exert a major influence on market equilibrium in the labor and life/medical insurance markets.

Conventional economic analyses have provided general results in which information exchanged among different economic entities was asymmetric. However, introduction of genetic information in the life/medical insurance market is likely to cause a shift of the information structure from asymmetric to symmetric.

It is a common belief that an insurant[1] who undergoes genetic testing for a certain disease may make a false statement to the effect that they have not been diagnosed genetically if a particular disease should be found. In this instance, insurers are unable to know whether an insurant who claims to have not undergone genetic testing is morally opposed to undergoing the diagnosis or whether s/he is making a false statement after being informed of her/his predisposition to a disease. In short, even in a situation where genetic testing is available, an asymmetric information structure exists. Under these

[1] "An insurant" includes an applicant for insurance in my paper. So, hereinafter "an insurant" refers to an applicant for insurance.

circumstances, what form of equilibrium is the life/medical insurance market likely to assume?

This paper analyses equilibrium under the conditions of existence of asymmetric information on the assumption that genetic testing is available. The section 2 and 3 deal with my model and equilibrium in symmetric structures respectively. In the section 4, I carry out equilibrium analysis of an asymmetric structure, showing the ubiquitous existence of equilibrium as a conclusion. I describe the potential for separating contracts to be equilibrated, and that the separating contract may not be always equilibrated but equilibrated is a contract with which only insurants free from defective gene are allowed to conclude. Furthermore, this is an equilibrium totally unlike a conventional equilibrium, since it falls into adverse selection, and thus cannot be interpreted using conventional economic theory. In the section 5, I show my conclusions, discussing the problem of "genetic discrimination," a newly emerging social problem.

## 2 Model

In this model, we assume the insurance market to be in a situation where gene function is known. Suppose Disease $I$ is one type of disease but the death ratio depends on whether genetic information $g$ is defective or not. Also, suppose genetic information on Disease $I$ of an individual $j$ is $g_j$ $(j = 1, \dots, m)$ and an individual type is determined by whether the gene is defective or not.

Suppose that, unlike the asymmetric structure of conventional models where an insurant is informed of her/his risk whereas insurers are not able to know the risk faced by the insurant, this model is provided with an information structure where an insurant is not informed of her/his own risk in advance but can be informed of her/his risk through genetic testing. In other words, it is assumed that an insurant can be informed of her/his risk only by undergoing genetic testing. Namely, it can be given as $g_j \in \{0, 1, 2\}$ where the results show no defective gene if $g_j = 0$, and the gene is defective if $g_j = 1$. Furthermore, suppose $g_j = 2$ in the event that an insurant does not undergo genetic testing. In this instance, suppose that $1 - \gamma$ is the ratio of insurants undergoing genetic testing where $\gamma$ is the ratio of insurants not

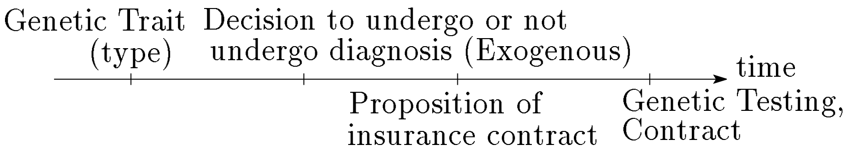


Figure 1

undergoing the test, then whether or not insurants elect to undergo genetic testing is determined exogenously.[2]

Procedures for concluding a contract include determination of a type of an insurant with regard to Disease $I$ and proposition of a contract covering the disease by an insurer. Whether or not an insurant undergoes genetic testing is determined exogenously, and s/he who has previously undergone diagnosis must submit the result to an insurer. The insurant not undergoing genetic testing must submit evidence in the form of a medical certificate showing s/he has not undergone genetic testing. The insurer will then propose the details of a contract in accordance with the results of the genetic test, and the insurant will make the final decision on whether to conclude the contract or not (Figure 1).

Suppose the insurance with which an insurant $j$ is covered is life/medical insurance subject to hereditary diseases. Also suppose insurants face two states (State 1 and 2): State 1 is designated as living/disease-free state wherein the income is $c_1^0$, while State 2 is designated as dead/morbid state wherein the income is $c_2^0 (= 0)$. Suppose the initial endowment is equal to all $j$.

Suppose an insurant is covered by insurance against State 2 (death/disease). Namely, the initial income state is exchanged to $c = (c_1, c_2)$ by a certain ratio of $p$. In other words, suppose that an insurant pays a premium $c_1^0 - c_1$ on concluding an insurance contract and the claim paid of $c_2 - c_2^0$ is settled when the insurant dies. Suppose the exchange rate of $\dfrac{c_1^0 - c_1}{c_2 - c_2^0} \equiv p$ is the insurance premium.

[2]Naturally, whether insurants elect to undergo genetic testing or not should be determined endogenously in the model. However, consideration should be given to the simultaneous determination issue in which insurants elect to undergo genetic testing and at the same time to enter into a contract with an insurer when they elect to undergo testing endogenously. As the result, the utility function becomes extremely complicated and obscures the issues to be investigated in this paper. Hence, in this paper, for the purpose of simplicity, selection of the diagnosis is assumed to be determined exogenously.

Now, the following groups are defined with regard to insurants.

**Definition 2.1** *Suppose*

$$H = \{j | g_j = 0\}$$

*where $j$ belongs to Group $H$ in the case of $j \in H$. Similarly, suppose*

$$L = \{j | g_j = 1\}$$

*where $j$ belongs to Group $L$ in the case of $j \in L$. Furthermore, suppose*

$$Q = \{j | g_j = 2\}$$

*where $j$ belongs to Group $Q$ in the case of $j \in Q$.*

Namely, where insurants who undergo genetic testing and are found to have a defective gene are classified into Group $L$, those who undergo testing and are found not to be genetically defective are classified into Group $H$, and those who do not undergo any diagnosis are classified into group $Q$. Suppose the probability that insurants $j$ will be killed by the Disease $I$ is $\pi_j$ $(j = 1, \ldots, m)$. Let $\pi_j$ be assumed as follows.

**Assumption 2.1** *Let $\pi_j = \pi_\eta,\ \eta = L, Q, H$ be assumed for a given $j$.*

Namely, suppose that the probability of an insurant who undergoes genetic testing facing State 2 is $\pi_H$ for Group $H$ and $\pi_L$ for Group $L$, and for an insurant who does not undergo testing, the probability of Group $Q$ facing State 2 is $\pi_Q$, thus providing $\pi_L > \pi_Q > \pi_H$. Suppose $\pi_\eta$ is equal among insurants in the respective groups.[3] Further suppose that the ratio of insurants with genetic disease who are predisposed to Disease $I$ in a whole market is $\delta$, and let $\pi_Q$ be[4]

$$\pi_Q \equiv \delta\pi_L + (1 - \delta)\pi_H. \tag{1}$$

[3]It would be more realistic to take into account the fact that in principle the probability of an insurant facing State 2 resulting from Disease $I$ may vary depending on the environmental states of an insurant. However, in this paper it is assumed that the probability of those facing State 2 resulting from Disease $I$ will be equal among insurants in their respective groups.

[4]From a more practical point of view, it would be possible that the probability that Group $Q$ will die due to Disease $I$ is not in compliance with the probability weighted with $\delta$ since an insurant will elect to undergo genetic testing based on the subjective probability. However, in this paper, for reasons of simplicity, the probability that Group $Q$ will die due to Disease $I$ is assumed to be equal to the probability weighted with $\delta$.

Suppose that both an insurant and insurers are informed of the exact value of $\gamma,\ \delta$.

Let the utility function of an insurant be

$$EU(c_1, c_2, \pi_\eta) = \pi_\eta u(c_2) + (1-\pi_\eta)u(c_1),\ \ \eta = L, Q, H \tag{2}$$

and let an insurant be risk-averse.

The following expression of (3) can be satisfied for the utility function from $\pi_L > \pi_Q > \pi_H$.

$(sorting - condition)$
In a given $c = (c_1, c_2)$,

$$\frac{\partial}{\partial \pi_L}\left(\frac{\partial EU/\partial c_2}{\partial EU/\partial c_1}\right) > \frac{\partial}{\partial \pi_Q}\left(\frac{\partial EU/\partial c_2}{\partial EU/\partial c_1}\right) > \frac{\partial}{\partial \pi_H}\left(\frac{\partial EU/\partial c_2}{\partial EU/\partial c_1}\right). \tag{3}$$

However,

$$\frac{\partial}{\partial \pi_\eta}\left(\frac{\partial EU/\partial c_2}{\partial EU/\partial c_1}\right) \equiv \frac{\partial}{\partial \pi_\eta}\left(\frac{\partial EU(c_1, c_2, \pi_\eta)/\partial c_2}{\partial EU(c_1, c_2, \pi_\eta)/\partial c_1}\right),\ \ \eta = L, Q, H.$$

Namely, on the basis of a certain utility, the marginal rate of substitution at a given $c$ is expressed as

$$-\left.\frac{dc_1}{dc_2}\right|_{\bar{U}} = \frac{\partial EU/\partial c_2}{\partial EU/\partial c_1} = \frac{\pi_\eta}{1-\pi_\eta}\frac{u'(c_2)}{u'(c_1)},\ \ \eta = L, Q, H, \tag{4}$$

and the respective rates obtained for Group $L$, Group $Q$ and Group $H$ increase in the increasing order of Group $L$, Group $Q$ and then Group $H$.

Suppose insurers are risk-neutral and exposed to perfect competition. In other words, suppose insurers are allowed to advance into the market freely and to conclude a contract with insurants (for example, with Group $H$ or with Group $QL$ only). Furthermore, supposes that the insurers can tell the insurant to which group, $L$, $H$ or $Q$, s/he belongs based on a certificate issued from a medical institution in charge of genetic testing. Suppose that the expected profit obtained by the insurer from a contract with an insurant belonging to Group $\eta$ is

$$\Pi(c_1, c_2, \pi_\eta) = \pi_\eta(c_2^0 - c_2) + (1-\pi_\eta)(c_1^0 - c_1),\ \ \eta = L, Q, H. \tag{5}$$

Under the above conditions, equilibrium is defined as follows.

**Definition 2.2** *Suppose that with regard to a contract of* $\{\lambda, \mu, \nu\}$*, Group L is covered by* $\lambda$*, Group Q is covered by* $\mu$*, and Group H is covered by* $\nu$*. In order for a contract of* $\{c^*_L, c^*_Q, c^*_H\}$ *to be equilibrated with Disease I, for a given* $\eta = L, Q, H$*,*

1. $\Pi(c^*_{1\eta}, c^*_{2\eta}, \pi_\eta) = 0.$
2. *There exists no contract of* $\{c_L, c_Q, c_H\}$ *that meets the following conditions,*
$$\Pi(c_{1\eta}, c_{2\eta}, \pi_\eta) \geq \Pi(c^*_{1\eta}, c^*_{2\eta}, \pi_\eta)$$
*and*
$$EU(c_{1\eta}, c_{2\eta}, \pi_\eta) \geq EU(c^*_{1\eta}, c^*_{2\eta}, \pi_\eta)$$
*and*
$$max[\Pi(c_\eta, \pi_\eta) - \Pi(c^*_\eta, \pi_\eta), EU(c_\eta, \pi_\eta) - EU(c^*_\eta, \pi_\eta)] > 0.$$
3. *For a given group* $\eta = L, Q, H,$
$$EU(c^*_{1\eta}, c^*_{2\eta}, \pi_\eta) \geq EU(c^0_1, c^0_2, \pi_\eta)$$
*and*
*for a given group* $\zeta = L, Q, H,$
$$EU(c^*_{1\eta}, c^*_{2\eta}, \pi_\eta) \geq EU(c^*_{1\zeta}, c^*_{2\zeta}, \pi_\eta).$$

Namely, in this equilibrium, the expected profit by insurers is zero and there exists no new contract assuring the insurers of profit greater than the equilibrium at the same time as providing an insurant with greater utility.[5] Furthermore, suppose that the equilibrium meets individual rationality (IR) and incentive compatibility (IC).

# 3 Equilibrium Analysis (Benchmarking):The Symmetric Information Structure

In the first place I will discuss equilibrium in a symmetric information structure where perfect information is available, namely, an insurant will submit

[5]In this Condition 2, neither expected utility nor expected profit shall meet $\{c^*_\eta\}$ and the equality sign with regard to contract $\{c_\eta\}$, for which condition is $max[\cdot] > 0$.

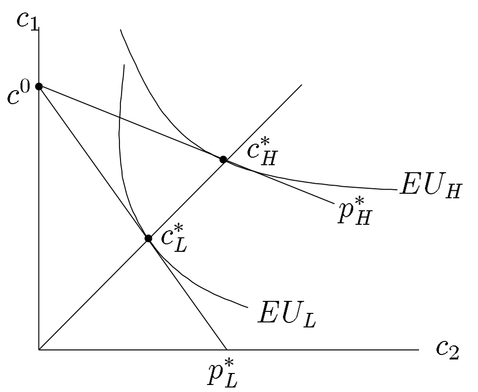

Figure 2-1

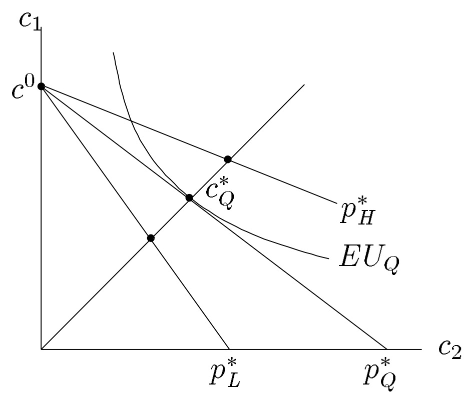

Figure 2-2

true and accurate results of genetic testing and an insurer is able to compulsorily separate groups of insurants on the basis of the diagnostic results. In this instance, if equilibrium is obtained with $\{c_L^*, c_Q^*, c_H^*\}$, $c_\eta^*$ meets the following expression.

$$\frac{\pi_\eta}{1-\pi_\eta}\frac{u'(c_{2\eta}^*)}{u'(c_{1\eta}^*)} = p_\eta^*, \ \left(p_\eta^* \equiv \frac{\pi_\eta}{1-\pi_\eta}, \ \eta = L, Q, H\right). \tag{6}$$

When an insurant undergoes genetic testing for Disease $I$, s/he can be informed of her/his type and insurers are also able to be informed of her/his classification of the group by means of a medical certificate. Then, the insurers can impose $c_H^*$ on Group $H$ and $c_L^*$ on Group $L$, thus equilibrating their contracts (Figure 2-1).

On the other hand, where an insurant does not undergo genetic testing, neither insurer nor insurant is informed of her/his type. In other words, an insurant is in Group $Q$, and insurers are able to propose a contract $c_Q^*$ on the basis of a medical certificate declaring that s/he has not undergone genetic testing, thus equilibrating the contract (Figure 2-2).

In this instance, an insurant who is found to be in Group $L$ through diagnosis is not able to make a false statement that s/he has not received a diagnosis (Group $Q$) or belongs to $H$. This is because if an insurant who is found to be in Group $L$ through genetic testing were to claim not to have received a diagnosis, s/he would be required to submit a medical certificate as evidence to this effect. Medical institutions in charge of genetic testing are able to locate the details and history of an individual diagnosis. Namely, because an insurant who did not undergo genetic testing can be traced retrospectively to find out her/his true history, s/he found by diagnosis to be Group $L$ is not able to make a false statement.

In this instance, the information structure is symmetric and full coverage insurance offered to the respective groups is equilibrated.

# 4 Existence of an asymmetric information structure and equilibrium

In the previous section, I discussed the analysis of equilibrium under conditions where the results of genetic testing are available before concluding an insurance contract. This type of insurance realizes a state of full coverage on the assumption of a true and accurate statement of diagnostic results by an insurant, allowing insurance coverage of the respective groups.

However, a problem is evident in that not all insurants may make a true and accurate statement. As discussed in the previous section, although a complete availability of diagnostic history would eliminate doubt, if an insurant is found to be in Group $L$ by means of genetic testing, s/he would have a powerful incentive to claim that s/he had not undergone testing.

Here, I assume a situation where insurers are able to propose a contract on the basis of the results of an insurant's genetic test results but not able to see whether or not that insurant who does not undergo genetic testing belongs in reality to Group $Q$. In other words, I study the situation where a statement by her/him not receiving diagnosis to the effect that s/he does not undergo testing is not reliable.[6] The insurant who is found to fall into Group $L$ by means of genetic testing could then make the false claim that s/he is in Group $Q$. Insurers are not able to confirm the truth of an insurant's claim that s/he has not undergone diagnosis, or whether s/he has made a false statement that s/he belongs to Group $Q$ after s/he was found in fact to be in Group $L$.

In this instance, a contract of $\{c_L^*, c_Q^*, c_H^*\}$ as explained in the section 3 is no longer equilibrated. It is only in Group $H$ that insurers are able to obtain full information and to propose $c_H^*$ to Group $H$. However, insurers

[6] To be more specific, this is a situation where insurers will not make a request to an insurant who has not undergone genetic testing to submit a certificate to that effect. This issue will be discussed in detail in the section 5.

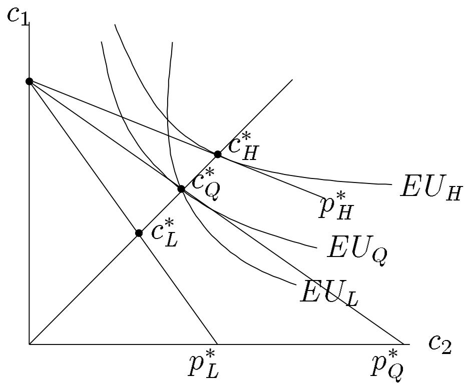

Figure 3

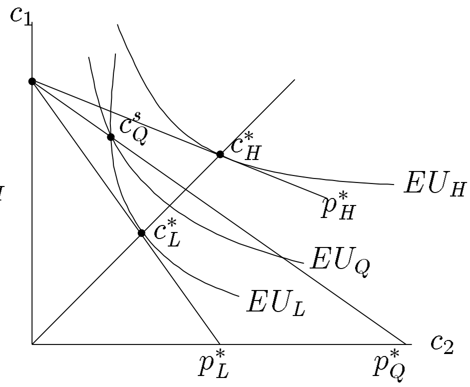

Figure 4

are not able to see whether an insurant who have not undergone gene testing is in reality one belonging to Group $Q$, or one belonging to Group $L$ who is making a false statement, resulting in a negative profit (Figure 3).

In order to avoid this situation, insurers must design a contract which will not allow an individual belonging to Group $L$ to make a false statement. Insurers can propose a contract of $\{c_L^*, c_Q^s, c_H^*\}$ for this purpose. Suppose that $c_Q^s$ is a contract with a premium of $p_Q^* = \dfrac{\pi_Q}{1-\pi_Q}$, satisfying

$$EU(c_{1Q}^s, c_{2Q}^s, \pi_L) = EU(c_{1L}^*, c_{2L}^*, \pi_L) \tag{7}$$

with respect to the expected utility of Group $L$ (Figure 4).

In this instance, the difference between $c_Q^s$ and $c_L^*$ makes indifference to Group $L$, and will not motivate the group to make a false statement. Therefore, Group $L$ will select $c_L^*$, Group $Q$ will select $c_Q^s$ and Group $H$ will select $c_H^*$. The profit of an insurer can be expressed as

$$\Pi(c_{1L}^*, c_{2L}^*, \pi_L) + \Pi(c_{1Q}^s, c_{2Q}^s, \pi_Q) + \Pi(c_{1H}^*, c_{2H}^*, \pi_H) = 0 \tag{8}$$

and no contract exists which can yield a greater profit than $\{c_L^*, c_Q^s, c_H^*\}$.

However, whether or not $\{c_L^*, c_Q^s, c_H^*\}$ is equilibrated depends on the proportion of Group $Q$ in the market. From the relationship of $\delta$ with $\gamma$, the ratio of each group in the market can be expressed as

$$L \ : \ Q \ : \ H \ = \delta(1-\gamma) \ : \ \gamma \ : \ (1-\delta)(1-\gamma). \tag{9}$$

At this time, the premium obtained by weighting the premiums of Group $L$ and Group $Q$ according to their ratio is defined as

$$p_{QL} \equiv \frac{\delta(1-\gamma)}{\delta(1-\gamma)+\gamma} p_L^* + \frac{\gamma}{\delta(1-\gamma)+\gamma} p_Q^*. \tag{10}$$

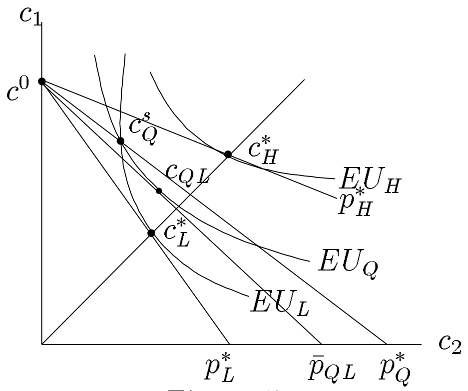

Figure 5

Furthermore, suppose that $c_{QL} = (c_{1QL}, c_{2QL})$ is a contract which can meet

$$EU(c_{1Q}^s, c_{2Q}^s, \pi_Q) = EU(c_{1QL}, c_{2QL}, \pi_Q), \tag{11}$$

$$\frac{\pi_Q}{1-\pi_Q}\frac{u'(c_{2QL})}{u'(c_{1QL})} = p,\ \ p \in [p_Q^*, p_L^*], \tag{12}$$

and a premium for $c_{QL}$ gives $\bar{p}_{QL}$ (Figure 5). Namely, suppose that a tangent line coming from the point of $c^0$ and extending to the indifference curve of Group $Q$ passing through $c_Q^s$ gives $\bar{p}_{QL}$.

In this instance, suppose that when a number of groups are insured via an insurance contract of $c$, a contract of $\{c, c, c\}$ is defined as a pooling contract. Also suppose that a pooling contract consisting of two given groups is singled out as a $\eta\zeta$ pooling contract ($\eta, \zeta = L, Q, H,\ \ \eta \neq \zeta$).

Whether or not $\{c_L^*, c_Q^s, c_H^*\}$ can be equilibrated is dependent on the the degree of relation of $p_{QL}$ with $\bar{p}_{QL}$.

**Lemma 4.1** *When $\bar{p}_{QL} > p_{QL}$, $\{c_L^*, c_Q^s, c_H^*\}$ is not equilibrated.*

**Proof** When $\bar{p}_{QL} > p_{QL}$, there exists in the shaded part of Figure 6 a $QL$ pooling contract of $\tilde{c}_{QL}$ which can meet

$$EU(\tilde{c}_{1QL}, \tilde{c}_{2QL}, \pi_\eta) > EU(c_{1L}^*, c_{2L}^*, \pi_\eta),\ \ \eta = L, Q \tag{13}$$

with respect to Group $L$ and Group $Q$. In relation to this contract, the expected utility of Group $H$ can be expressed as

$$EU(\tilde{c}_{1QL}, \tilde{c}_{2QL}, \pi_H) < EU(c_{1H}^*, c_{2H}^*, \pi_H). \tag{14}$$

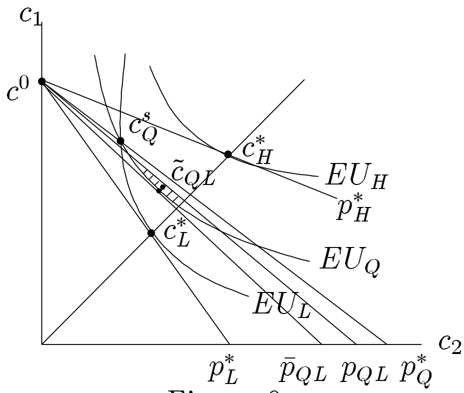


Figure 6

Consequently, Groups $L$ and $Q$ will select $\tilde{c}_{QL}$ and Group $H$ will select $c_H^*$. The profit of an insurer can be expressed as

$$\sum_{\eta \in L,Q} \Pi(\tilde{c}_{1QL}, \tilde{c}_{2QL}, \pi_\eta) + \Pi(c_{1H}^*, c_{2H}^*, \pi_H) \geq 0, \tag{15}$$

so $\{c_L^*, c_Q^s, c_H^*\}$ cannot meet the conditions of equilibrium. **Q.E.D.**

However, $\{\tilde{c}_{QL}, \tilde{c}_{QL}, c_H^*\}$ is not equilibrated either, because a new contract exists with Group $Q$ which yields a greater profit than $\tilde{c}_{QL}$, which disequilibrates the $QL$ pooling contract. Consequently, no contract is concluded with insurants of Groups $Q$ and $L$. Insurers are able to acquire full information on the insurants in Group $H$ from the results of their gene diagnosis genetic tests and to always propose a contract of $c_H^*$ to them. Thus, only $\{c^0, c^0, c_H^*\}$ can be equilibrated when $\bar{p}_{QL} > p_{QL}$.

**Lemma 4.2** *In order for $\{c_L^*, c_Q^s, c_H^*\}$ to be equilibrated, the necessary and sufficient condition is $p_{QL} \in [\bar{p}_{QL}, p_L^*)$.*

**Proof** (Necessity) Suppose not, namely, suppose that $\{c_L^*, c_Q^s, c_H^*\}$ is equilibrated and $\bar{p}_{QL} > p_{QL}$ is obtained. In this instance, from the subsidiary Lemma 4.1, $\{c_L^*, c_Q^s, c_H^*\}$ is not equilibrated; therefore, $\bar{p}_{QL} \leq p_{QL}$ is obtained.

From $0 \leq \delta \leq 1$, $0 \leq \gamma \leq 1$, $p_L^* \geq p_{QL}$ is always obtained. When $p_L^* = p_{QL}$, $\gamma = 0$ is obtained, namely, no Group $Q$ exists, which denies the equilibrium of $\{c_L^*, c_Q^s, c_H^*\}$. Therefore, $p_L^* > p_{QL}$ is obtained.

(Sufficiency) Suppose $p_L^* > p_{QL} \geq \bar{p}_{QL}$ is obtained. In this instance, Group $L$ makes a self-selection of $c_L^*$, Group $Q$ selects $c_Q^s$, and Group $H$ selects $c_H^*$

with respect to $\{c_L^*, c_Q^s, c_H^*\}$. The profit of insurers is zero, and no contract exists which can increase the utility of all insurants and at the same time generate more profit for insurers in relation to $\{c_L^*, c_Q^s, c_H^*\}$. **Q.E.D.**

From the above, the following is obtained.

**Proposition 4.1** *Suppose that an incentive is given to an insurant who is found by means of genetic testing to be Group L to make a false statement, on the assumption that genetic testing is available for Disease I. If insurers are not able to detect the false statement from an individual in Group L,*

1. $\bar{p}_{QL} > p_{QL} \iff \{c^0, c^0, c_H^*\}$ *is equilibrated.*

2. $p_{QL} \in [\bar{p}_{QL}, p_L^*) \iff \{c_L^*, c_Q^s, c_H^*\}$ *is equilibrated.*

This is an equilibrium entirely opposite to that conventionally surmised. In particular, it is found that there is a situation where the only available contract is $c_H^*$ depending on the ratio of Group $Q$. This can be interpreted as an event totally opposite to the adverse selection so far surmised to takes place.

In general, economic analyses based on asymmetric information have so far pointed out the possibility that only Group $L$ may exist in the market and the market may fall into adverse selection. It was a key conclusion that in order for the market not to fall into adverse selection, insurers are not able to propose to Group $H$ full coverage insurance of $c_H^*$ which can maximize the utility, and have no choice but to propose a contract with less favorable conditions so that the insurers can gain protection from false statements by Group $L$. However, in my model, the availability of genetic testing and the existence of Group $Q$ will reduce the degree of asymmetry of information. As the result, when $\bar{p}_{QL} > p_{QL}$, or the ratio of Group $Q$ is higher, the equilibrium is reversed, resulting in the presence of only Group $H$ in the market. Furthermore, Group $H$ is always assured of the full coverage insurance of $c_H^*$. This fact is totally opposite to the conventional analysis results which suggest the risk of falling into adverse selection. In this way, a situation where only Group $H$ exists in the market is a market falling into *risk selection.*

# 5 Conclusions

In this paper, the existence of an asymmetric information structure and analysis of equilibrium under these conditions were studied on the assumption that genetic information is known and gene therapy is actually available.

If the decoding of our genetic information by the Human Genome Project increases the information available to an insurer concerning insurants, the information is symmetric in structure. If so, there may exist no uncertainty between an insurant and insurers.

However, this model allows the presence of insurants who have not undergone genetic testing. So that there is an incentive for an insurant who knows, by means of genetic testing, that s/he is in Group $L$ to state falsely that s/he has not been tested. Therefore, it is generally thought that the information between an insurant and insurers is asymmetric in reality. This is a situation where the history of diagnosis is not well managed.

Where an insurant undergoes genetic testing at that point, insurers are able to propose full coverage insurance to the respective groups on the basis of the information in her/his medical certificate. However, insurers are compelled to propose to Group $Q$ a contract with less favorable conditions than the full coverage insurance because the insurers are not able to know whether an insurant in Group $Q$ (the group not undergoing genetic testing) has in fact not undergone diagnosis or if s/he masquerading as members of Group $Q$ in spite of the fact that s/he has previously been found by genetic testing to be in Group $L$. Hence, the separating contract of $\{c_L^*, c_Q^s, c_H^*\}$ is a form of equilibrium (Figure 4).

However, whether the contract can be equilibrated or not is dependent on the ratio of Group $Q$ in the market. Hence, a higher ratio of Group $Q$ not undergoing genetic testing ($\bar{p}_{QL} > p_{QL}$) undermines the justification for contracts for Groups $Q$ and $L$, causing a situation where only insurants found to be $H$ after diagnosis can be insured (Proposition 4.1). In other words, in a situation where genetic testing is available, there is no possibility of the market falling into adverse selection but there is a possibility of the market falling into *risk selection* in which insurants with a higher risk are excluded from the market.

The above situation may be called a model for genetic discrimination. The mechanism for creating genetic discrimination in this model can be summarized as follows. Insurants found to be in Group $L$ after diagnosis is motivated to make false statements. Insurers are not able to know whether an insurant who claims not to have undergone genetic testing is telling the truth or is making a false statement in the knowledge, gained through genetic testing, that s/he is in Group $L$. As a result, *risk selection* takes place in a state of higher $\gamma$ value.

The system of insurance contracts sets forth in the section 4 of this paper is, to be specific, a contract in which insurers will not require an insurant who has not undergone genetic testing to submit a medical certificate as evidence to this effect. As discussed so far, this system gives an incentive to an insurant found to be in Group $L$ after genetic testing to state falsely that s/he has not been tested.

In opposition to the above system, however, it is quite possible that insurers may propose a contract system in which the insurers demands an insurant who claims not to have undergone genetic testing to submit a certificate of it as evidence. In this instance, no incentive to make a false statement is given to an insurant found to be in Group $L$ after diagnosis. This contract system is a system in which insurers will compulsorily separate insurants; the equilibrium under these conditions was discussed in the section 3.

When these two systems are compared, the latter, in which insurers compulsorily separate insurants is preferable for an insurant to the former, in that maximum utility is obtained for insurants in all groups. However, from the insurer's viewpoint, both systems generate zero profit, so there is little to choose between them. Hence, it is of a great importance to discuss the former system.

Recent years have seen a gradual but steady permeation of knowledge of genetics into our society. Hereinafter, information on the decoding of human genes will make a significant contribution to various aspects of our society, but at the same time, as previously pointed out, will cause many social problems. Genetic discrimination, or the creation of a 'genetic underclass' is a worst-case example of one of these problems. Thus, there is increasing demand that genetic testing be banned for the purposes of medical examinations of insurants. Furthermore, in the United States, President Clinton, who is concerned about the risk of misuse of genetic information leading to discrimination, issued an Executive Order banning the use of results of genetic testing by federal government organizations when hiring personnel. He also expressed support for a bill imposing a ban on such utilization by private companies in general (New York Times, 9 February 2000).

On the other hand, taking into account the injustice whereby a majority of insurants who are healthy have to bear a high premium equal to that paid by a minority of insurants or high-risk insurance, insurers will find genetic information necessary when proposing to all insurants a fair insurance contract.

In this paper, I will not deal with the economic impact caused by the banning of genetic discrimination. It is important to gain as much information as possible on hereditary diseases, specifically to what degree defective genes result in hereditary diseases. It is also true that individuals possessing oncogenes can delay or avoid the onset of cancer by making the correct lifestyle and dietary choices, whereas individuals free from defective genes may, conversely, make themselves vulnerable to lung cancer by smoking. This issue is related to moral hazard and requires further research. It is of a critical importance that one should be aware that genetic makeup and fate are not necessarily closely linked.

Much remains unknown regarding the functions of genes. It is clear, though, that the degree of availability of genetic information will have a major influence on the information structure of the insurance market. The Human Genome Project will continue to have an increasingly important influence on the life/medical insurance market. It is a fact that in a few years, the Human Genome Project will have completely decoded the information held in human genes, making it a matter of urgency to prepare for what will be a new era. Information on the human genome has been subjected to various discussions from the perspective of bioethics, and now requires examination from the economic viewpoint.

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