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Genetic testing and repulsion from chance*

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Abstract:

A central theme in the international debate on genetic testing concerns the extent to which insurance companies should be allowed to use genetic information in their design of insurance contracts. We analyse this issue within a model with the following important feature: A person's well-being depends on the perceived probability of becoming ill in the future in a way that varies among individuals. We show that both tested high-risks and untested individuals are equally well off whether or not test results can be used by insurers. Individuals who test for being low-risks, on the other hand, are made worse off by not being able to verify this to insurers. This implies that verifiability dominates non-verifiability in an ex-ante sense.

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1. Introduction

The mapping of the human genome creates a potential for revealing individuals' susceptibility to disease and for preventing the outbreak of disease by means of genetic engineering. Hence, this research offers a promise of huge health improvements. At the same time, however, a central theme in the debate on genetic testing concerns who should have access to an individual's genetic information. The question of whether insurers should be allowed to ask for genetic information for underwriting purposes is at the forefront of the discussion. Presently, regulations vary between countries,[1] and the need for knowledge about properties of alternative information regimes seems to be urgent.

Our analysis adds to the discussion by drawing attention to the importance of individuals' inherent need to know (or not) about their risk status. An individual's perceived risk of future disease may influence the anxiety about the future and, hence, today's utility. Compared to an individual's situation as untested, testing may result in either an upward or a downward adjustment of the risk. Hence, the test is like a lottery, and the testing decision is likely to be influenced by the estimated risk in the alternative states and the individual's attitude towards risk. Because of a dislike for knowing the test result, an individual may choose to stay uninformed even if becoming informed would be beneficial for the purpose of buying insurance. In this paper, we are interested in studying how this phenomenon affects the insurance market under alternative regulations of insurers' access to testing information.

The empirical literature as found in medical journals provides the stylized facts we need. This literature is based on surveys of people with elevated risks of diseases where genetic tests either are available or are likely to be available in the near future. Studies are of two types. The *ex-ante* type examines the factors contributing to people's stated intentions to undergo testing. In the *ex-post* type of study, the factors distinguishing those who actually have been tested from those who have not, are examined. The reviewed surveys contain information from individuals with elevated risk of having one out of five diseases: Hereditary breast cancer (BRC1 and BRC2), hereditary nonpolyposis colorectal cancer (HNPCC), hereditary prostate cancer, Alzheimer's disease, and Huntington's disease.

[1] For a brief overview of regulations and policy statements, see Hoel and Iversen (2002).

The genetic test for Huntington's disease is presymptomatic in the sense that a positive test implies that the outbreak of Huntington's disease certainly will occur during a later stage of life. There is no preventive action that could be taken. Codori, *et al.* (1994) study three groups of at-risk persons. The first group is those who had considered, but not chosen genetic testing; the second group is those who had postponed the decision to a later date; and the third group is those who had previously been tested. Of the two untested groups, a significantly greater number of the No group had chosen not to be tested because they anticipated problems associated with their emotional reactions. The persons in the tested group had less often anticipated problems with their emotional reactions.

This result corresponds to the summary by Marteau and Croyle (1998) of empirical knowledge about factors influencing intentions to undergo testing. They suggest that the fraction of people who wish to undergo testing is higher for diseases where the result may have positive consequences for prevention (BRCA 1 and BRCA 2, HNPCC) than for diseases without known preventive actions (Huntington's disease). They also emphasize that, for some people, living in uncertainty is worse than knowing the facts, even if the facts should turn out to be bad news. Several studies show that reducing uncertainty is one of the most common reasons for undergoing a predictive DNA test (*e.g.*, Codori and Brandt, 1994; Roberts, 2000). This result, combined with the fact that some people choose not to be tested, emphasizes the importance of an individual's attitude to health risk for the testing decision.

Motivated by these stylized facts, our modeling approach highlights two features not analyzed simultaneously in the literature until now. The first feature is the loss of utility related to information about the probability of a future disease, and the second feature is the role of the verifiability of test results for the attainment of beneficial insurance. An individual chooses to test prior to buying insurance if the expected utility with a test is greater than the expected utility without it.[2] Her expected utility depends not

[2] We consider tests that are predictive in the sense that the occurrence of a future disease is uncertain even after the test is done. Furthermore, we consider voluntary health insurance and disregard possible preventive actions against disease. We also disregard information prior to the test, for instance based on family history.

only on income in the healthy and the unhealthy states, but also on the loss of utility related to information about the probability of a future disease. The importance of this probability is assumed to vary among individuals. While some are attracted to chance, others are repelled from chance. The first group is more reluctant to choose testing than the other one. Since the insurance contracts offered depend on whether test results are verifiable, the fraction of individuals who decide to undergo testing depends on the amount of verifiable information, and hence on the distribution of the attitude of being informed. In an insurance market with asymmetric information about consumers' probability of having a disease, we find that the fraction of individuals performing a genetic test is higher when test results are verifiable than when they are not. The outcome in the verifiability case is also more efficient, in a second-best sense. Thus, allowing insurers to use test results when they can be made verifiable is welfare improving.

We model individuals' attraction to, respectively repulsion from, chance by introducing a utility loss from the probability of disease. This modeling approach is in the spirit of Pope (1983), who insists that uncertainty should be modeled as a flow, distinguishing between what she calls *the pre-outcome period* and *the subsequent period*. The utility loss from the *ex ante* probability corresponds to her pre-outcome period, while the standard expected utility from the uncertain prospect of getting ill corresponds to the subsequent period. Also our terminology of attraction to versus repulsion from chance is taken from Pope; see, in particular, Pope (1998).

The decision to undertake genetic testing and the potential interaction with the insurance market are also analyzed by Doherty and Thistle (1996).[3] Like us, they assume that a consumer's information about his risk status is endogenous, in that a consumer decides whether or not to obtain information from testing, and find that the menu of insurance contracts a consumer is offered depends on the verifiability of test results.[4] In

[3] Other analyses of genetic testing and health insurance include Strohmenger and Wambach (2000) and Kuehn and Wambach (2001). In Strohmenger and Wambach (2000), consumers derive utility directly from their health status. In Kuehn and Wambach (2001), consumer preferences feature time inconsistency.

[4] See also Hoel and Iversen (2002), who introduce the possibility of disease prevention following a genetic test. They are particularly concerned with the combination of compulsory and voluntary health insurance in this context.

their set-up, there is no heterogeneity among consumers, however, apart from differences in the probability of getting ill. This lack of heterogeneity is why Doherty and Thistle report non-existence of an equilibrium when the cost of a genetic is positive but low. One way out is to assume, at the outset, some heterogeneity in the population with respect to the cost of a test. This is not a very realistic assumption, however. Based on the empirical evidence reported above, we choose here another modeling strategy, by letting consumers differ with respect to the disutility of being informed about future health status. To simplify further, we let testing be costless for all consumers.

The paper is organized as follows. In section 2, we present the theoretical novelties of this paper. The benchmark solution, derived from a setting with uncertain but symmetric information, is provided in section 3, where we focus mainly on a person's incentive to take a test so as to get information about her future health status. When being offered full insurance contracts, only individuals sufficiently repelled from chance will choose to take a test. In section 4, we assume asymmetric information coupled with the test outcome being verifiable. Because a tested high-risk person under a regime of full insurance will have an incentive to disguise the test outcome by claiming not to have been tested, the equilibrium contracts will now be modified so as to offer untested individuals only partial insurance. But this modification of the menu of contracts will induce a larger fraction of the group of person repelled from chance to take a test. Finally, in section 5, we relax the assumption that the test outcome is verifiable. Because both untested individuals and tested high-risk ones will have incentives to pretend being low-risk, the insurance contract designed for tested low-risk individuals has to be modified. Hence, in this case, tested low-risk persons are offered partial insurance, and so are also untested persons. Section 6 concludes.

2. The model

Consider a continuum of individuals where each individual faces a risk of getting ill. In particular, each individual will end up in one of two states: In the good state 1, she is healthy with an income equal to y; in the bad state 2, she is ill and suffers an income loss d such that income equals $y – d$, where $0 < d < y$. There are two types of individuals, high-risks and low-risks, with probabilities of getting ill equal to p^H and p^L, respectively, where $0 < p^L < p^H < 1$. The fraction of high-risk individuals in the population is given by $\lambda \in (0,1)$. Initially, any individual is uninformed about her risk status and thus has a probability λ of being high-risk and a probability

$$p^U := \lambda p^H + (1 - \lambda)p^L \tag{2.1}$$

of getting ill.

Insurance is provided by a set of risk-neutral firms. Buying insurance from one of these firms means trading the state-contingent income $(y, y - d)$ for an income mix $(y - a_1, y - d + a_2)$, where $a := (a_1, a_2)$ is an insurance contract with a premium a_1 payable in state 1 and a net indemnity a_2 received in state 2. An insurer's profit from selling a contract a to an individual who is believed to become ill with a probability p equals:

$$\pi(a, p) = (1 - p)a_1 - pa_2 \tag{2.2}$$

Individuals are risk averse. An individual with a probability p of having an accident and an attraction to chance given by θ obtains the following expected utility when buying contract a:

$$u(a, p; \theta) := V(a, p) - g(p, \theta) = (1 - p)v(y - a_1) + pv(y - d + a_2) - g(p, \theta), \tag{2.3}$$

where v is a strictly increasing, twice continuously differentiable, and strictly concave von Neumann-Morgenstern utility function. The attraction to chance is modeled through the utility loss $g(p, \theta)$, where p is the probability, possibly after testing, that the individual becomes ill, and θ is a measure of the importance of this probability for the individual's well-being. We assume that θ varies across individuals according to a cumulative probability distribution $F(\theta)$, which is strictly increasing and twice continuously differentiable on the fixed support $[\underline{\theta}, \overline{\theta}]$. We assume, moreover, that $g(p, \theta)$ is sufficiently differentiable, with $\partial g/\partial p > 0$, $\partial^2 g(p, \underline{\theta})/\partial p^2 > 0$, $\partial^2 g(p, \overline{\theta})/\partial p^2 < 0$, and $\partial^3 g/\partial p^2 \partial \theta < 0$. Whether an individual is attracted to or repelled from chance is determined by the curvature of g with respect to p. In particular, let:

$$\Delta_g(\theta) := g(p^U, \theta) - [\lambda g(p^H, \theta) + (1 - \lambda)g(p^L, \theta)]. \tag{2.4}$$

Loosely speaking, $\Delta_g(\theta) > [<]\ 0$ if $g(\cdot, \theta)$ is concave [convex] around p^U. An individual for which $\Delta_g(\theta) < 0$ has an expected utility loss which is smaller when she does not know her risk, by Jensen's Inequality. Thus, when this condition holds, we say the individual is *attracted to chance*. The opposite is true when $\Delta_g(\theta) > 0$: the individual's utility loss is now smaller when she does know her risk and we say such an individual is *repelled from chance*. Our assumptions on g ensure that there exists a critical $\theta^* \in (\underline{\theta}, \bar{\theta})$ such that $\Delta_g(\theta^*) = 0$, and individuals attracted to [respectively, repelled from] chance having a $\theta \in (\underline{\theta}, \theta^*)$ [respectively, $\theta \in (\theta^*, \bar{\theta})$].

Prior to making a decision whether to buy insurance, an individual may take a test at no cost. If she does not take a test, then she learns nothing more than what she already knew, with a probability of getting ill equal to p^U. On the other hand, if she takes a test, then she will learn her risk to be $p \in \{p^H, p^L\}$.

In the next section, we derive the equilibrium for the benchmark case of symmetric information, where no individual can disguise her risk category. We then proceed by considering the case where insurance companies only know the test result of individuals who *voluntarily reveal their private information*. At last, we discuss the equilibrium contracts in the case when the companies are restricted from using test outcome when designing their menus of contracts, which amounts to test results being non-verifiable,

3. Symmetric information

Consider first the case when the available information about an individual's risk is public, *i.e.*, what the individual herself knows is also known by insurance companies. In this case, each individual is offered a full-insurance, zero-profit contract. In particular, an individual with a probability p^K of getting ill is offered the contract $[p^K d, (1 - p^K)d]$ and obtains an expected utility equal to

$$v(y - p^K d) - g(p^K, \theta), \quad K \in \{U, H, L\}. \tag{3.1}$$

A risk-averse individual who is attracted to chance will not take the test in this case. To see this, note that the net benefit for an individual from taking a test is:

$$\begin{aligned} \Delta_S(\theta) &= \lambda u(a_S^H, p^H; \theta) + (1-\lambda) u(a_S^L, p^L; \theta) - u(a_S^U, p^U; \theta) \\ &= \lambda[v(y - p^H d) - g(p^H, \theta)] + (1 - \lambda)[v(y - p^L d) - g(p^L, \theta)] \\ &\quad - [v(y - p^U d) - g(p^U, \theta)] = \Delta_g(\theta) - \Delta_S^V, \end{aligned} \tag{3.2}$$

where the subscript S denotes the present case of symmetric information, and where $\Delta_g(\theta)$ is defined in the previous section, while

$$\Delta_S^V := v(y - p^U d) - \left[\lambda v(y - p^H d) + (1-\lambda) v(y - p^L d)\right]. \tag{3.3}$$

Due to strict concavity of the utility function, we have, from Jensen's Inequality, that $\Delta_S^V > 0$. From the definition of attraction to chance in Section 2, it thus follows:

Proposition 1: With symmetric information about risk, full insurance will prevent an individual who is attracted to chance from taking a test; i.e., $\forall\, \theta \in \left[\underline{\theta}, \theta^*\right],\ \Delta_S(\theta) < 0.$

Thus, in order for an individual to be willing to take a test in the case of symmetric information, she must be sufficiently repelled from chance. In order to compare this case with the subsequent cases, we assume that the distribution of θ in the population is such that there are individuals being repelled from chance to such an extent that, under symmetric information, they are willing to take the test. Hence, we impose:

Assumption S: $\Delta_S(\overline{\theta}) > 0$

We then have:

Proposition 2: There exists a critical value of θ, denoted $\theta_S \in \left(\theta^*, \overline{\theta}\right)$, *such that, in the case of symmetric information, any individual with* $\theta\, \in \left[\theta_S, \overline{\theta}\right]$ *will take a test.*

(*Proof:* This result follows from Assumption *S* and the assumption that $\Delta_S(\theta)$ is continuous and strictly increasing in θ.)

4. Asymmetric information – verifiable test result

Suppose now that an individual's risk is private information *if* she knows it, *i.e.*, if she has been through a test, but that the test result is verifiable. An individual who has tested to be a low-risk person, obviously wants to reveal her test outcome, since this ensures her the [$p^L d$, $(1 - p^L)d$] contract, if full insurance should be offered. The situation is different for one who has tested high-risk. As long as there are individuals around who have not tested and therefore are without any knowledge about their risk beyond what is provided by p^U, a high-risk individual may have an incentive to pretend to be untested by not revealing her test outcome. Insurers will have to cope with this problem by offering a contract for untested individuals that satisfy a self-selection constraint: Individuals who know they are high-risk must find it in their own interest to choose the high-risk contract instead of the no-test contract. This constraint results in a partial-insurance contract for untested individuals, *i.e.*, one where $a_1 + a_2 < d$. In addition, competition ensures that the no-test contract earns zero expected profit, with the expectation being taken with respect to a population of uninformed individuals.

The insurance market for tested high-risks and untested ones works exactly as the insurance market for high-risks and low-risks in Rothschild and Stiglitz (1976). Thus, similarly to their analysis, an equilibrium in pure strategies exists only if the number of tested high-risk individuals is sufficiently high relative to the number of uninformed. In our case, this will be ensured by the fraction of tested individuals being sufficiently high, which will hold with suitable assumptions on g and F. We have:

Proposition 3: With asymmetric information, but the test result being verifiable, and with g and F such that the ratio of tested high-risks to untested is sufficiently high, insurers in equilibrium offer the following set of contracts:

- *the low-risk contract* $a^L = [p^L d, (1 - p^L)d]$ *to individuals who verify they are low-risk; and*
- *the menu* $\{a^H, a_V^U\}$ *to the others, where* $a^H = [p^H d, (1 - p^H)d]$ *is chosen by high-risks and* a_V^U *is chosen by no-test individuals and is defined as the unique contract satisfying:*

$$V(a_V^U, p^H) = V(a^H, p^H), \text{ and}$$

$$\pi(a_V^U, p^U) = 0.$$

(*Proof:* The result follows directly from the self-selection constraint for a tested high-risk individual, who should be prevented from disguising herself as untested. To induce a high-risk person to reveal her true type, the contract offered to the group of untested individuals should be made less advantageous (partial insurance).)

Comparing the two cases of symmetric information on the one hand and asymmetric, but verifiable, information on the other hand, we note that tested individuals, both high-risks and low-risks, are equally well off in the two cases. The difference is with respect to the uninformed individuals, who clearly are worse off in the case of asymmetric information, since the zero-profit contract they now get is one of partial rather than full insurance. Thus, the incentive to take the test is greater in the case of asymmetric and verifiable information than in the case of symmetric information. We have:

Proposition 4: There exists a $\theta_V < \theta_S$*, such that, when information is asymmetric but verifiable, any individual with* $\theta \in \left[\theta_V, \bar{\theta}\right]$ *will take the test.*

5. Asymmetric information – non-verifiable test results

Suppose now, as in the previous case, that an individual's risk is private information. Let test results, however, be non-verifiable; the non-verifiability could for example follow from regulations making it politically infeasible to offer contracts contingent upon test results. Now, also the low-risk contract will have to satisfy a self-selection constraint. As demonstrated by Doherty and Thistle (1996, p. 90: contract menu *C*"), the binding incentive constraint is the one making sure that individuals who are untested do not pick the low-risk contract. But this is the only contract that will be affected by non-verifiability. We have:

Proposition 5: When there is asymmetric information about risk after a test, test results are non-verifiable, and g and F such that both the ratio of tested high-risks to untested and the ratio of untested to tested low-risks are sufficiently high, insurers offer the following set of contracts in equilibrium:

$\{a^H,\ a_V^U,\ a_N^L\}$, *where*

$a^H = [p^H d, (1 - p^H)d]$ is chosen by tested high-risks;

a_V^U, defined in Proposition 3, is chosen by no-tested individuals;

and a_N^L is chosen by tested low-risks and is defined as the unique contract satisfying:

$$V(a_N^L, p^U) = V(a_V^U, p^U), \text{ and}$$

$$\pi(a_N^L, p^L) = 0.$$

Note that the conditions for existence of this equilibrium are quite strict, a problem overlooked by Doherty and Thistle (1996). In order to avoid the existence of a pure-strategy equilibrium being destroyed by cross-subsidizing deviations, there have to be, for each adjacent pair of types, sufficiently many of the higher-risk type; see Rothschild and Stiglitz (1976) for details in the two-type case. Presently, there are three types: tested low-risks, untested, and tested high-risks. What is needed is a sufficiently high fraction of high-risks to untested individuals, and a sufficiently high fraction of untested to low-risks. But note that the former calls for a sufficiently high number of individuals taking the test, while the latter calls for the opposite. Thus, we cannot be sure that the equilibrium proposed in Proposition 5 actually exists for a non-empty set of primitives. It is, however, easy to verify that the existence problem is less severe, the less risk-averse individuals are.

Leaving the existence problem aside, we can compare the incentives to take the test in the cases with verifiable and non-verifiable test results. Both tested high-risks and untested individuals are equally well off whether the test results are verifiable or not, since they are offered and choose the same contracts in both cases. Individuals who test for being low-risks, on the other hand, are made worse off by not being able to verify this result to insurers. Thus, incentives to take the test are lower with non-verifiable than with verifiable test results.

In order to state our result, we need to relax Assumption *S* slightly. Define:

$$\Delta_N(\theta) := \lambda u(a^H, p^H, \theta) + (1-\lambda) u(a_N^L, p^L, \theta) - u(a_V^U, p^U, \theta)$$

We add the following assumption:

Assumption N: $\Delta_N(\bar{\theta}) > 0$

Thus, even in the case of asymmetric information and non-verifiable test results, there are some individuals who are so repelled from chance that they choose to go ahead with the test. We have:

Proposition 6: There exists a $\theta_N > \theta_V$ *such that, in the case of asymmetric information and non-verifiable test results, any individual with* $\theta \in \left[\theta_N, \bar{\theta}\right]$ *will take the test.*

In terms of efficiency, we note that the verifiability case dominates the non-verifiability case: Insurers, tested high-risks, and untested are equally well off in the two cases, whereas tested low-risks are better off with verifiable test results.[5] This also implies that verifiability dominates non-verifiability in an ex-ante sense.

6. Concluding remarks

An important feature of our model is that, during a time period in which a person is in perfect health, the person's well-being depends on the perceived probability of becoming ill in the future. Moreover, the exact property of the relationship between this probability and the person's well-being varies among individuals. We believe that the references we gave in the Introduction justify this assumption.

Formally, we model the feature above by introducing the term $g(p,\theta)$ representing the utility loss associated with a probability p of future illness. It is the variation across individuals in a particular property of this function, given by the term $\Delta_g(\theta)$ defined by (2.4), that makes people differ in their attitude towards taking a genetic test. The main results of our paper would be valid also if we had not included the feature represented by the term $g(p,\theta)$ but instead had assumed heterogeneous test costs across individuals. There is, however, no empirical justification for assuming potentially large variations in test costs across individuals.

[5] This is dominance in the sense of interim efficiency, see Holmström and Myerson (1983).

In our formal model, we have assumed that there are no costs of taking a test. However, extending the analysis to include test costs would be straightforward. If these costs were c for everyone, we would simply need to include the term $-c$ in the expression (3.2) giving the net benefit for an individual from taking the test. Nothing of substance would be changed if we were to introduce a test cost in this way. Note that this is in sharp contrast to what Doherty and Thistle (1996) find: In their model, there exists an equilibrium when test results are non-verifiable and there are no test costs. In this equilibrium, everyone gets tested. However, if a small but positive test cost is introduced, an equilibrium no longer exists in their model.

In addition to the benchmark case of symmetric information, we have considered two cases of asymmetric information. While the case of symmetric information is useful as a benchmark, it is not a case we would expect to find in practice. In practice, it is difficult to imagine any policies making it possible for an insurance company to obtain the test result of a person who has taken a test but who wishes to conceal this fact (which will be the case for tested high-risk persons). The politically interesting cases are thus the two cases with asymmetric information.

The difference between the two cases with asymmetric information is whether or not an insurance company can verify a test result showing that a person is tested low-risk. This is, in turn, a policy issue. As mentioned in the Introduction, and discussed in more detail in Hoel and Iversen (2002), several countries have introduced, or are considering to introduce, legislation that prevents insurers from using genetic information in their design of insurance contracts. One of the reasons frequently given for such legislation is that a person has the right not to know his or her genetic make-up. In our model, persons who are attracted to chance – i.e. persons with a negative value of the term $\Delta_g(\theta)$ – will prefer to stay untested if there are no economic differences between being tested or not. Comparing our two cases of asymmetric information, we have shown that more people take a test when test results are verifiable than when they are not. If some of the people taking a test when test results are verifiable are attracted to chance (*i.e.*, if $\theta_V < \theta^*$, in our notation) and thus take the test only for economic reasons, one could argue that legislation making test results non-verifiable is to the advantage of these people. However, our results have shown that this is not the case: We have shown that, in terms of efficiency, the verifiable case dominates the non-verifiable case. In particular, those who have such a high attraction to chance that they do not test themselves in either case, are equally well off in the two cases. Those who test themselves in the verifiable case but not in the non-verifiable case do so because, if they are found in the test to be low-risks, they are better off in the verifiable case than in the non-verifiable case. If they end up as high-risks, on the other hand, they will be unaffected by whether or not the test result is verifiable.

When the costs of a test are zero, Doherty and Thistle (1996) show that all individuals will choose to be tested when insurers cannot distinguish between untested individuals and tested individuals who are high-risk (corresponding to the two cases discussed in our Sections 4 and 5). This is hardly in accordance with the stylized facts we have described in the introductory section. From our model, we are able to explain why some people choose to stay uninformed even when information on test status is asymmetric. This feature of our model adds realism and thus increases our understanding of people's genetic-testing decisions.

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