Genetic Testing and Adverse Selection

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"Genetic testing has the potential to revolutionize medicine. But revolutions can have casualties."

Francis Collins, Director of the Human Genome Project, Newsweek, December 23, 1996

"All progress is precarious, and the solution of one problem brings us face to face with another problem."

Martin Luther King

Introduction•

After the initial planning process for the human genome project culminated in 1990 with the publication of a joint research plan, "Understanding Our Genetic Inheritance: The U.S. Human Genome Project. The First Five Years FY 1991-1995," what was supposed to be a 15 year project began. On 26 June 2000, however, the International Human Genome Sequencing Consortium announced the working draft of the human genome and on 15 February 2001 the complete human genome sequence was announced in the two leading scientific journals, *Nature* (NIH/DOE) and *Science* (Celera). The successful completion of the project provides great hope for remarkable advances yet to come in the medical sciences; it also raises fears. In his 9 September 2000 remarks President Clinton said:

> "The fear of misuse of private genetic information is already very widespread in our nation. Americans are genuinely worried that their genetic information will not be kept secret, that this information will be used against them. As a result, they're often reluctant to take advantage of new breakthroughs in genetic testing -- making a point I think we cannot make too often -- if we do not protect the right to privacy, we may actually impede the reach of these breakthroughs in the lives of ordinary people, which would be a profound tragedy."[1]

At least forty of the fifty United States have legislation or moratoria prohibiting the use of genetic testing results in underwriting health insurance. Currently there is a five-year moratorium in effect on insurers' use of genetic testing information in the United Kingdom. Other countries in Europe ban its use with either a moratorium or legislation. The concern is widespread because, if insurers or employers use genetic test results for profit, there is the potential to create an underclass of uninsurable risks and another underclass of unemployable risks. On the other hand, if genetic testing results are prohibited from being used by insurers or employers, then another problem is created. The insurance and labor markets will be characterized by hidden information, and this lack of transparency has the potential to create significant social costs. The adverse selection problems created in insurance markets necessitate increased premiums as the pool of insured risks becomes more heavily dominated by the poorer risks. It is still too early to measure the extent of the adverse selection problem that will occ the moratoria in various countries and states become permanent. At its worst, the adverse selection problem can cause market failure.

Should insurers have access to genetic test results? If not then how costly will the adverse selection problem be? If so then will it create groups that are uninsurable or unemployable? Should the state be an insurer of last resort?

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[1] See http://www.usis-australia.gov/hyper/2000/0209/epf309.htm

The literature on genetic testing and adverse selection is small, e.g., (MacDonald 1999; Subramanian, Lemaire et al. 1999; Lemaire, Subramanian et al. 2000)[2]. The Markov models in the literature have generated the evidence on adverse selection costs. There is a price inelastic assumption, however, that limits the extent of the adverse selection problem that can be revealed by the current versions of these Markov models. The first step in the analysis here will be to introduce a model in which the insurance demand and supply are endogenous and so allow for price elastic behavior. This first step will suppose that the market is characterized by pooling equilibria. This will allow the full impact of the adverse selection problem to be investigated. The initial results show that the market may be characterized by either a single unstable equilibrium or multiple equilibria, some of which are unstable. The price impact is yet to be gauged.

The second step in the analysis will be to assume that the moratoria on genetic testing are continued indefinitely and to show that it is possible to generate a partial separating equilibrium in which all individuals can purchase a pooling contract and that another contract offering additional coverage can be purchased; the additional contract is structured so that only those testing positive for the genetic mutation have the incentive to purchase the additional coverage. Such an equilibrium always exists and may be easier for insurance firms to implement than the separating contracts found in the Rothschild-Stiglitz analysis (Rothschild and Stiglitz 1976).[3] The third step in the analysis will be to assume that insurers can ask for and receive information on genetic testing. This will provide a transparent set of insurance premia; this assumption will also allow the underclass of uninsurable risks notion to be studied. The final step will be welfare comparisons between the equilibria directed at answering questions such as the following: Can we make all individuals in the hidden information case better off by revealing the information?

The paper is structured as follows: The next section provides a hidden information model in which individuals test positive or negative for a genetic mutation. Here the individual demand functions are derived as are the insurer supply functions. The character and magnitude of the adverse selection problem are considered. The following sections will include hidden and transparent information equilibria and make welfare comparisons.

Hidden Information Model

Suppose each agent in the insurance market has a genetic test for particular mutation or set of mutations, e.g., BRAC1, BRAC2, APOE2, and APOE4,[4] and that the test is accurate. The test divides the population into two groups. Those who test positive, i.e., have the mutation, and those who test negative, i.e., do not have the mutation. Those who test positive have an increased risk of contracting breast cancer given the BRAC1 mutation or Alzheimer's disease given the APOE4 mutation. Given a health insurance market characterized by symmetric information, the insurers would be able to sell different policies based on the test results. Countries in North America and Europe, however, either have regulations prohibiting insurance companies from asking or using the results of genetic tests or moratoria requiring essentially the same forbearance. If the insurance market is characterized by asymmetric information due to regulations or moratoria then a classic adverse selection problem may

[2] An extensive literature exists on the adverse selection problem. See Dionne, G. and N. A. Doherty (1992). Adverse Selection in Insurance Markets: A Selective Survey. Contributions to Insurance Economics. G. Dionne. Boston, Kluwer Academic Publishers: 97-140. This along with the more recent literature neither gauge the extent of the adverse selection problem nor consider the costs and benefits of eliminating the adverse selection problem and moving to an equilibrium with transparent contracts.

[3] Such an equilibrium is consistent with the notion of a Nash equilibrium because individuals are able to purchase more than one insurance contract. It is also an equilibrium that cannot be broken by another contract in the manner shown by Rothschild and Stiglitz for their own quasi-Nash equilibrium concept.

[4] Mutations in the BRAC1 gene on chromosome 17q have been identified as causes for a predisposition to breast, ovarian and other cancers. The BRAC1 mutation has been estimated at 1 in 500 of the US population. Mutations in the BRAC2 gene on chromosome 13q have also been identified as a cause of cancer. The APOE4 is a genetic mutation that reveals an increased likelihood of developing Alzheimer's disease. Provide additional background on APOE4 and APOE2.

exist in the market. If the premium on the health insurance policy is set at an actuarially fair level then those testing negative have the incentive to reduce their coverage or exit the market; that, in turn, changes the characteristics of the insured pool and the premium must be raised to cover expected losses; that exacerbates the incentive for those testing negative to further reduce coverage and so increases the actuarially fair premium, etc. In the limit, only those testing positive may remain in the market if the premium is still economically feasible for them.

Demand

Consider the behavior of individuals seeking health insurance coverage in a voluntary market. The demand is a behavioral function that indicates the maximum number of contracts that the individuals are willing to buy at each possible premium. The following notation is used in the development of the demand.

w	Wealth *now*
Λ_j	Random loss per type j risk $\Lambda_j = \Gamma_j + \Delta_j$
n_j	Proportion of risk j =1, 2 insured
p	Insurance premium for full coverage
M_j	Number of risks of type j = 1, 2
r	Interest rate in financial market
W_j	Random wealth *then*, i.e., $W_j \equiv (w - p\, n_j)(1 + r) - (1 - n_j)\, \Lambda_j$
a	Measure of absolute risk aversion
$-e^{-aW_j}$	Constant absolute risk aversion utility function

Each risk type j has Λ_j losses each of size one dollar where Λ_j is Poisson(λ_j). The agent selects the proportion of full coverage to buy in order to maximize the expected utility of wealth *then*. The expected utility is

$$E\left[-e^{-aW_j}\right] = -E\left[e^{-a\left((w-pn_j)(1+r)-(1-n_j)\Lambda_j\right)}\right]$$

$$= -e^{-a(w-pn_j)(1+r)}\, E\left[e^{a(1-n_j)\Lambda_j}\right] \qquad (1)$$

$$= -e^{-a(w-pn_j)(1+r)}\, M_{\Lambda_j}\left(a(1-n_j)\right)$$

where M_{Λ_j} is the moment generating function for Λ_j. Since the moment generating function for a Poisson random variable is

$$M_{\Lambda_j} = e^{\lambda_j\left(e^{a(1-n_j)}-1\right)} \tag{2}$$

It follows that (1) may be equivalently expressed as

$$\begin{aligned} E\left[-e^{-aW_j}\right] &= -e^{-a(w-pn_j)(1+r)} M_{\Lambda_j}\left(a(1-n_j)\right) \\ &= -e^{-a(w-pn_j)(1+r)+\lambda_j\left(e^{a(1-n_j)}-1\right)} \end{aligned} \tag{3}$$

Observe that maximizing the expected utility in (3) is equivalent to maximizing the expression in the following equation:

$$-a(w-pn_j)(1+r)+\lambda_j\left(e^{a(1-n_j)}-1\right) \tag{4}$$

The first order condition for an interior maximum is

$$ap(1+r)-a\lambda_j e^{a(1-n_j)}=0 \tag{5}$$

It may be equivalently stated as follows:

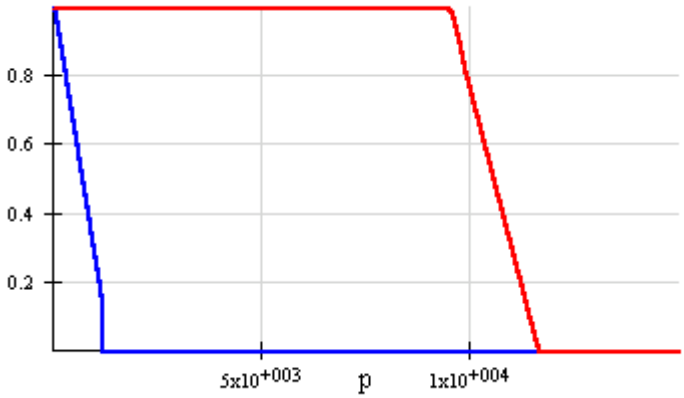
$$\begin{aligned} & p(1+r)=\lambda_j e^{a(1-n_j)} \\ \Leftrightarrow\ & e^{a(1-n_j)} = \frac{p(1+r)}{\lambda_j} \\ \Leftrightarrow\ & a(1-n_j)=\ln\left(\frac{p(1+r)}{\lambda_j}\right) \end{aligned} \tag{6}$$

The insurance demand of an individual risk j is bounded between zero and one and so the demand is of the following form:

$$n_j = \min\left\{1, \max\left\{0, 1-\frac{\ln\left(\frac{p(1+r)}{\lambda_j}\right)}{a}\right\}\right\} \tag{7}$$

Suppose j = 1 indicates the individual that tests negative for the genetic mutation and let the parameters be a = 0.2, λ_1 = \$1,000, and r = .05, where the parameters represent the measure of risk aversion, expected loss and interest rate, respectively; the demand for the individual testing negative is the blue function in the next figure. Suppose j = 2 indicates the individual that tests positive for the genetic mutation and has an expected loss of λ_2 = \$10,000; the demand for the individual testing positive is the red function in the next figure. It may be noted that, given the small measure of absolute risk aversion, the demand is for full coverage exists for all premia below the present value of the expected loss and zero above it. In the following figure, the premium is represented on the horizontal axis while the proportion of full coverage is measured along the vertical axis.

Figure 1: Individual Demand[5]



Aggregating across all type j risks the demand for type j risks is $d_j(p)$, i.e.,

$$d_j(p) = M_j n_j$$
$$= M_j \min\left\{1, \max\left\{0, 1 - \frac{\ln\left(\frac{p(1+r)}{\lambda_j}\right)}{a}\right\}\right\} \tag{8}$$

Finally aggregating across all risks yields the market demand d(p) is

[5] The price elasticity of demand for risk j is

$$\varepsilon_j = -\frac{\frac{dn_j}{n_j}}{\frac{dp_j}{p_j}} = \frac{1}{a - \ln\left(\frac{p(1+r)}{\lambda_j}\right)}$$

At the fair premium for risk j, $p = \frac{\lambda_j}{1+r}$ and the elasticity is $\frac{1}{a}$.

$$d(p) = d_1(p) + d_2(p)$$

$$= M_1 \min\left\{1, \max\left\{0, 1 - \frac{\ln\left(\frac{p(1+r)}{\lambda_1}\right)}{a}\right\}\right\} + M_2 \min\left\{1, \max\left\{0, 1 - \frac{\ln\left(\frac{p(1+r)}{\lambda_2}\right)}{a}\right\}\right\} \tag{9}$$

Supply

Consider the insurance firm operating in this insurance market characterized by the two risk types. Consider the following additional notation:

S	Surplus *now*
n	contracts sold *now* to any risk type
$\theta(p)$	Proportion of contracts purchased by type one risks
L	The random loss exposure
Π	The random firm payoff *then* $\Pi = (pn+S)(1+r) - nL(p)$

The random loss of the insurance company is a linear combination of Poisson random variables and the proportion of the demand from each risk type determines the combination coefficients. The proportion of the demand from type one risks is

$$\theta(p) = \frac{d_1(p)}{d_1(p) + d_2(p)} \tag{10}$$

The random loss per agent is

$$L(p) = \theta(p)\Lambda_1 + (1 - \theta(p))\Lambda_2 \tag{11}$$

The loss per insured in (11) reflects the proportion changing characteristics of the insured pool as the premium changes. As the premium increases the better risks, i.e., those testing negative, have an incentive to exit the insured pool and so the characteristics of the pool will change. The expected loss per insured is

$$EL(p) = \theta(p)E\Lambda_1 + (1 - \theta(p))E\Lambda_2$$

$$= \theta(p)\lambda + (1 - \theta(p))\delta \tag{12}$$

If the insurance firm is risk neutral then the expected payoff of the company is

$$E\Pi = (pn+S)(1+r) - nEL(p) \tag{13}$$

and the first order condition for expected profit maximization is

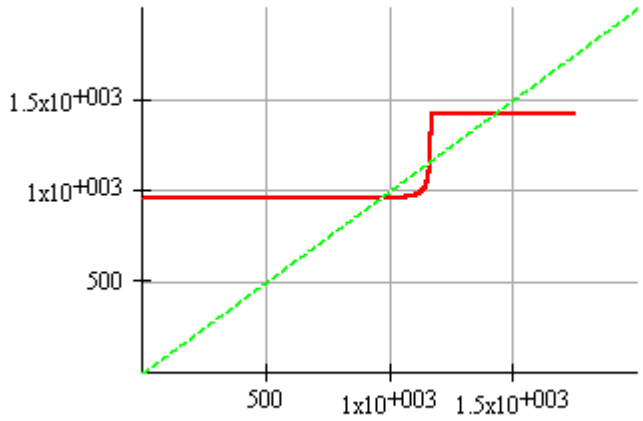
$$\frac{d}{dn}E\Pi = p(1+r) - EL = 0 \tag{14}$$

Equivalently

$$p = \frac{EL}{1+r} \tag{15}$$

This, of course, says that the premium on the next contract must equal the present value of the expected loss on that contract. If the insurers are risk neutral then the premia that equal the present value of the expected unit loss are shown in the next figure and represent the equilibria in the market.

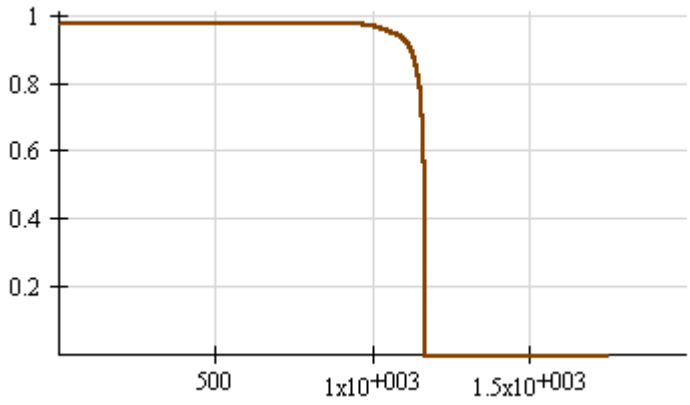
Figure 2: Equilibria



The premium is represented along the horizontal axis while the present value of the expected loss per contract is represented along the vertical axis. The extreme intersections represent equilibria both of which are stable while the middle intersection represents an unstable equilibrium. Consider the first intersection; to the left of that equilibrium the expected loss per contract is greater than the expected revenue per contract and so competition increases the premium. Similarly to the right of that intersection the expected loss per contract is less than the expected revenue per contract and so competition generates a decrease in the premium. Similarly, to the left of the middle equilibrium the marginal revenue exceeds the marginal contract cost and so competition decreases the premium; to the right of the middle equilibrium, the marginal contract cost exceeds the marginal revenue and so competition increases the premium. The two effects make the middle equilibrium unstable.

It remains to show what portion of those testing negative remain in the market at each equilibria and how the premium compares to the expected loss in the absence of the adverse selection problem.

Figure 3: Low risk proportion in the market



Next consider the case of a risk averse insurer. . . . The moment generating function for L is a linear combination of the moment generating functions for each risk type.

$$\begin{aligned} M_L(x) &= M_{\Lambda_1}(\theta x) M_{\Lambda_2}\left((1-\theta)x\right) \\ &= e^{\left[\lambda_1\left(e^{\theta x}-1\right)+\lambda_2\left(e^{(1-\theta)x}-1\right)\right]} \end{aligned} \tag{16}$$

Now the expected utility of the insurance firm is

$$\begin{aligned} Eu(\Pi) &= -e^{-a\Pi} \\ &= -e^{-a(pn+S)(1+r)}\, e^{anL} \\ &= -e^{-a(pn+S)(1+r)}\, M_L(an) \\ &= -e^{-a(pn+S)(1+r)}\, e^{\left[\lambda_1\left(e^{\theta an}-1\right)+\lambda_2\left(e^{(1-\theta)an}-1\right)\right]} \end{aligned} \tag{17}$$

The firm selects the number of policies to sell by maximizing the expected utility in (17). Maximizing (17) with respect to n is equivalent to maximizing the following:

$$a(pn+S)(1+r)-\left[\lambda_1\left(e^{\theta an}-1\right)+\lambda_2\left(e^{(1-\theta)an}-1\right)\right] \tag{18}$$

The first order condition (FOC) may then be expressed as

$$ap(1+r)-\left[\lambda_1\theta a e^{\theta an}+\lambda_2(1-\theta)a e^{(1-\theta)an}\right]=0 \tag{19}$$

The FOC does not appear to have a closed form solution like the demand function but (19) does establish the existence of the market supply s(p). It is also possible to establish the existence of equilibrium. To see this, suppose the FOC is evaluated at the demand quantity d(p). When the FOC is satisfied at d(p) the quantity is on the supply function as well as the demand function and so the equilibrium is achieved. Now, observe that

$$
\begin{aligned}
e^{\theta a d(p)} &= e^{\theta a\left\{M_1\left(1-\frac{\ln\left(\frac{p(1+r)}{\lambda_1}\right)}{a}\right)+M_2\left(1-\frac{\ln\left(\frac{p(1+r)}{\lambda_2}\right)}{a}\right)\right\}} \\
&= e^{\theta a(M_1+M_2)}\, e^{\theta a\left\{-M_1\frac{\ln\left(\frac{p(1+r)}{\lambda_1}\right)}{a}-M_2\frac{\ln\left(\frac{p(1+r)}{\lambda_2}\right)}{a}\right\}} \\
&= e^{\theta a(M_1+M_2)}\, e^{-\theta M_1 \ln\left(\frac{p(1+r)}{\lambda_1}\right)}\, e^{-\theta M_2 \ln\left(\frac{p(1+r)}{\lambda_2}\right)} \\
&= e^{\theta a(M_1+M_2)}\, e^{\ln\left(\frac{p(1+r)}{\lambda_1}\right)^{-\theta M_1}}\, e^{\ln\left(\frac{p(1+r)}{\lambda_2}\right)^{-\theta M_2}} \\
&= e^{\theta a(M_1+M_2)}\left(\frac{p(1+r)}{\lambda_1}\right)^{-\theta M_1}\left(\frac{p(1+r)}{\lambda_2}\right)^{-\theta M_2} \\
&= e^{\theta a(M_1+M_2)}\,\lambda_1^{\theta M_1}\lambda_2^{\theta M_2}\left(p(1+r)\right)^{-\theta(M_1+M_2)}
\end{aligned}
\tag{20}
$$

To be continued . . .

Concluding remarks

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Notes for revision

See Science online to find out about this:

Deconstructing the Blues

Stressful life events such as the loss of a job can lead to depression, but not everyone shows this response. A study of a large group of young adults in New Zealand by Caspi et al. (p. 386; see the news story by Holden) provides evidence that stress is more likely to cause depression in individuals who carry a particular allelic variant of the gene encoding the serotonin transporter, a protein that controls serotonin levels at brain synapses. These results reinforce the emerging view that mental illness and other complex diseases cannot always be explained by genetic or environmental factors alone, but more likely arise from an interaction between the two.