Medical Testing and Insurance Markets

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1. Introduction

Major developments in the technology of medicine tend to arouse controversy that reflects, no doubt, our perception of their probable effects on our lives. Although there is certainly nothing new in the use of medical tests by insurance companies and employers to determine whom they will insure or hire, and on what terms, the recent developments in the possibilities of genetic testing seem to have generated a new, higher level of concern and debate, resembling, but far exceeding, that surrounding HIV testing in the 1980's. Critics point to the creation of a "genetic underclass", its members irrevocably tagged as a result of genetic testing, in such a way that they will not be able to obtain life and health insurance or employment.[1] The picture should be more finely drawn than this, as we argue below, but the concern is real.[2] Could unrestricted use of genetic testing and of the information it provides significantly worsen the welfare of those individuals unlucky enough to be shown by these tests to be costly to insurers and employers, and, if so, what should be the appropriate policy response? The purpose of this paper is to consider the ways in which economists have tried to formulate and answer these questions in their relation to insurance markets.

2. Genetic Insurance

Although it was by no means the first to deal with this question, Alexander Tabarrok's paper "Genetic testing: an economic and contractarian analysis" has received the most prominence. In it, Tabarrok argues that competitive pressures on insurance markets will, given the availability of genetic tests, separate indi-

[1] The question of health insurance obviously depends on the type of health system one is faced with. In the US, where much of the literature on these issues has been generated, health insurance is supplied by a private market and health insurance and employment are very closely linked.

[2] Already, for example, someone who for reasons of known family history is at high risk of contracting Huntington's disease cannot obtain life insurance before the age of 40. People with a close family history of particular diseases are under private, non-employment related health insurance in the US often charged higher insurance premia. Would the ability to detect genetic susceptibility to health damage from the working environment lead to change in the composition of the workforce rather than modification of the working environment?

viduals into "genetic classes", with the lucky benefiting from marginally lower insurance premia, while the unlucky will face "staggering bills" for insurance, or no insurance at all. He sees this as providing a *disincentive to be tested* , which is a socially undesirable outcome, since he holds the direct social benefits of testing to be strongly positive. These stem largely from the possibilities of early preventive or remedial measures, given the information provided by the tests. He also questions the *fairness* of such premium differentiation, given that people possessing defective genes may represent high risks to insurers through no fault of their own. Finally he points out that this premium differentiation cannot induce efficiency gains, in the sense that people cannot change their behaviour to reduce the risk.[3]

These points have been well known for some time in the insurance literature. The first, the disincentive to be tested, is usually referred to as *premium risk.* Thus suppose there is a large population of individuals each facing an independent risk of losing[4] €100,000. For 10% of these individuals, the probability of this loss is 0.5, while for the other 90%, this probability is only 0.01. If no-one, including the individuals themselves, has any way of knowing which are the high risk and which

[3] Underlying this point is the distinction between *moral hazard* and *adverse selection* in insurance markets.

[4] This can be thought of as the amount required to restore the individual to perfect health following occurrence of an illness.

are the low risk individuals, a competitive insurance market[5] will offer full cover against this loss at a premium of €5900. This is because the randomly drawn individual has a loss probability of

$$(0.1)(0.5) + (0.9)(0.01) = 0.059 \tag{2.1}$$

and so faces an expected value of loss of €5900.

All individuals will buy full insurance at the fair premium of €5900, given that they are risk-averse.[6] Under such risk pooling, low risk individuals are cross subsidizing high risk individuals. If, however, insurance buyers do not themselves know whether they are high or low risk, this is sustainable as a market equilibrium. Each considers her own risk of loss to be the pooled probability of 0.059, in which case she is more than happy to buy full cover at the fair premium. This suggests the importance of the *information status* of an individual, i.e. whether she knows her own risk probability or not. We shall discuss this more extensively later.

[5] That is, one in which, in equilibrium, all insurers earn zero profits in expectation. Implicit in this definition however is the assumption that the firms' costs of providing insurance can be ignored, possibly because they are offset by investment returns on premium income.

[6] Implicit in the example is the assumption that the utility someone derives from a sum of money is independent of the state of the world in which they have it, and that they have enough income or wealth to be able to pay the premium. As Strohmenger and Wambach (2000) convincingly argue, neither of these assumptions may be particularly appropriate in the context of health insurance, and the implications of that can be very powerful.

Now suppose some genetic test becomes available, which will identify exactly who is high risk and who is low risk in this population,[7] with the results *freely available to insurers.* Then, those testing positive will have to pay a (fair) premium of €50,000, while those testing negative will pay €1,000, again for full cover in each case. For later reference, we call these contracts H^* and L^* respectively. Return now to the position *before* the test has been introduced, and ask: what value would each individual place on having the test, given the initial state of ignorance? The answer is that, if they are risk-averse, this value is negative - they would have to be paid to induce them to take the test. The reason is of course that the risk of testing positive and the concomitant increase in premium outweighs the attractiveness of testing negative and receiving a lower premium. Everyone rejects the gamble involving a 10% chance of an increase in premium to €50,000 and a 90% chance of a reduction in premium to €1,000. This is shown more formally in the Appendix.

Note that a possible intrinsic positive value of testing does not appear in this example. We could for example assume that early treatment for those testing positive could reduce the probability of loss and therefore they would end up

[7] Note that we do not assume that the test shows who will suffer the loss *for certain.* This seems realistic in general. On the other hand, it does assume that the test allocates people to their risk class without error. In reality an important aspect of testing is the possibility of false positives.

paying a lower premium. It is however not hard to construct examples under which, even when they take this benefit into account, premium risk will still deter risk averse individuals from taking the test, although there will also be cases in which it does not.[8]

Suppose now however that tests are introduced with the restriction that insurers cannot have access to the results.[9] Then insurers will realise that at least some policy holders may now know their risk type, and the pooling equilibrium is no longer sustainable. In particular, a number of policy holders will know that they are low risk and are paying much more than the fair premium for their type. They would therefore be receptive to an offer of, say, loss cover of €70,000 at a premium of €750, where these numbers have been chosen so as to make this contract unattractive to high risk individuals.[10] Note that this contract yields positive expected profits of €50 to the insurer, when bought only by low risk individuals. Ultimately, of course, competition will drive this profit down to zero, but for a transitional period positive expected profits could be earned, and this is sufficient to eliminate the previous pooling contract.[11] Thus, there will be offered

[8] See the Appendix for an example.

[9] For example most states in the USA have introduced legislation essentially banning insurers from requiring genetic tests, or requiring that the results of tests taken be given to them.

[10] It can be shown formally that, on the assumptions of the model, such a contract always exists as long as individuals know their types. See the Appendix for a specific example.

[11] See the paper by Cutler and Zeckhauser (1998) for an interesting real world example of this

on the market, if insurers know that some people know their risk types, contracts with differing fair premia, and so those who do not yet know their risk type perceive that they would indeed run a premium risk if they took the test. But this then implies, argues Tabarrok, that such people will not take the test, implying in turn that the benefits from taking the test, in terms of early prevention and treatment, are lost. However, as we shall shortly show, this conclusion does not survive a more subtle and careful analysis of the equilibrium outcome on a competitive insurance market.

In an economy where the health insurance system is publicly rather than privately owned and operated[12], a move away from the pooling equilibrium could occur as a result of political as opposed to market forces. If the large majority of people, who will as a result of testing learn that they are low risk, perceive that they are paying well in excess of *their* fair premium, and are not prepared to accept the degree of cross-subsidization of high risk individuals implicit in the pooling situation, then political entrepreneurs will have an incentive to offer policies which eliminate this cross-subsidization, in order to win votes. One obvious candidate policy would be privatisation, the creation of a private health insurance market,

kind of process.

[12] For example Australia, Canada, the UK.

because, as we have seen, that then makes cross subsidization unsustainable as an equilibrium.

The question of the fairness and efficiency of having people pay insurance premia that reflect their loss probabilities has also been thoroughly discussed in the literature.[13] Consider again the above example, and now suppose that testing has been introduced, and that insurers can identify the risk type of every individual. Then, in equilibrium, those testing positive will receive contract H^* and pay a premium of €50,000, while those testing negative will receive contract L^* and pay €1,000, for full loss cover in each case. This is an economically efficient equilibrium, but *not because high risk individuals are paying their fair premium.* It is efficient because *all insurance buyers are receiving full cover.* This is clearly a socially desirable outcome, and has the property that no-one could be made better off without making someone else worse off, *i.e.* it satisfies the conditions for a Pareto efficient resource allocation.

There is no intrinsic desirability of the fair premium as such. The argument for it is the same as that for marginal cost pricing in a market for physical commodities. The fair premium, as an instrument to achieve an efficient resource allocation, has the standard property of a competitive equilibrium market price:

[13] See in particular Crocker and Snow, (1984), (1986), (1992), and Hoy (1982), (1984), (1989).

it induces, in a decentralised way, buyers to demand and sellers to supply the optimal quantity of the good, in this case insurance cover equal to the amount of loss. For that reason, simply regulating the insurance premia out of a concern for fairness, without understanding the role they play in determining insurance demands, could lead to adverse selection and the collapse of the market. If, for example, a regulator specifies that only the pooled premium of €59 per €1000 of cover could be charged, the result would be that, if they were able to do so, low risk individuals would buy less than full cover, high risks buy more than full cover, and insurers would expect to go bankrupt. Even if maximum cover were restricted to the amount of loss, this adverse selection effect would remain as long as low risk individuals could buy less than full cover. To avoid this, regulation to enforce the pooled fair premium would have to be accompanied by the requirement that everyone buy full cover, no more and no less, *i.e.* price and quantity regulation would both be necessary. This is what is often achieved in a publicly run health insurance system with enforced pooling.

However, such detailed regulation of the insurance contract is not the only policy that could achieve fairness as well as efficiency. It is possible to charge the fair premia to the respective risk classes, and then simply impose a lump sum tax on low risk contracts to finance a lump sum subsidy to high risk contracts, to any extent necessary to bring about what would be regarded as a fair sharing of the burden of financing the insurance costs.[14] Indeed, the situation in which everyone chooses full cover at their appropriate fair premia is achievable as such a tax/subsidy equilibrium.

Tabarrok, however, explicitly rejects the possibility of public intervention in the outcomes of the working of private health insurance markets. He does not seem to consider a tax-subsidy solution, subsuming this under what he calls "nationalized medicine", which he equates with "making the nation a single compulsory group"[15]. He rejects this as a solution, on the grounds first, that it is "inefficient and unresponsive to consumer demand", and secondly, that the danger that governments would use genetic testing to "discriminate against and control their citizens" is too great. He also discusses and rejects the attempt to solve the premium risk problem by legal solutions such as a "consent law", under which insurers would have access to the results of genetic tests only with the consent of the individual concerned. He is clearly only in favour of his own proposed solution,

[14]This can be done, whether or not the "policy maker" knows each individual's risk type. The key point is that the subsidies are associated with the high and low risk contracts, which still have to satisfy a self selection or incentive compatability condition. See Crocker and Snow (1985) for a thorough discussion.

[15]Here he seems to be confusing *health insurance* with the *provision of health services*. As the cases of Australia and Canada show, it is perfectly possible to have publicly run health insurance, with a great deal of risk pooling, and at the same time physician services that are privately produced.

that of *genetic insurance*.

This is simply insurance against premium risk. Suppose that it is made compulsory[16] to buy insurance on the outcome of a genetic test before taking the test, although the decsion to take the test is still voluntary. The policy would offer to pay whichever premium for health insurance will be charged after the test. With a probability of 0.1 this will be €50,000, with a probability of 0.9 this will be €1,000, and so a fair premium on this insurance contract would be €5,900, exactly the pooled premium in the pre-genetic testing case. Then the risk associated with the test is fully shifted from the individual to the insurer and there is no longer a disincentive to take the test. As well, both the fairness and the efficiency of the previous pooled equilibrium are preserved.

In fact, where testing allows, say, a reduction in probability of loss due to preventive measures, the insurance market could produce a positive incentive to take the test. Suppose the high risks' probability of loss can be reduced to 0.25 at a cost of €10,000 once the risk has been identified. Then the expected cost

[16] This element of compulsion is stressed but not really explained by Tabarrok, who says only that genetic testing should be illegal unless this insurance is bought, and that this is "necessary to avoid adverse selection problems". This surely warrants far more discussion in an approach which stresses the voluntary "contractarian" nature of this solution "behind the veil of ignorance". This point is more fully discussed below.

resulting from a positive test result would be

$$0.1[€10,000 + 0.25 \times €100,000] = €3,500 \tag{2.2}$$

while the expected cost from a negative result is again $0.9(0.01 \times €100,000) = €900$, and so the fair premium for genetic insurance would be €4,400, or €1500 below the pooled premium, therefore providing a sizeable incentive to take the test.

On the face of it this seems an attractive proposal. It does however contain flaws. We can begin to see what these are by turning to a literature which shows that, contrary to Tabarrok's contention, in fact informational regulations such as consent laws may also solve the premium risk problem.

3. Informational Status and Premium Risk

Although it is not obvious from Tabarrok's paper, there is a long-established literature on the adverse selection problem, into which the genetic testing issue fits rather neatly.[17] The adverse selection literature considers the type of situation

[17] The foundational papers of this literature are Rothschild and Stiglitz (1976) and Wilson(1977). The further developments of most relevance for the subject of this paper are Crocker and Snow (1984), (1986), (1992), Doherty and Thistle (1996), Hoy (1982), (1989), Hoy and Polborn (2000), and Strohmenger and Wambach (2000). For a useful general survey in the health

given in the above example, with a competitive insurance market and two types of insurance buyer, high and low risk, who are otherwise identical.[18] The important difference to the example is that at the outset, buyers are perfectly informed about their own risk type. If insurers are also perfectly informed, the market equilibrium has everyone receiving full cover at the fair premium appropriate to their type, as in the "post-testing" situation discussed above, i.e. they receive the contracts H^* and L^* respectively. If insurers know that buyers know their type, but cannot themselves observe it at any cost that would make it worth their while, then an equilibrium also involves the offer of two contracts. One gives full cover at a fair premium for the high risk types, €50,000 in the example. The other offers only partial cover, at a fair premium for that amount of cover for the low risk types, for example, let us say, cover of €20,000 at a premium of €200. For later reference we will call the latter contract for low risks, which solves the adverse selection problem[19], L^A. Clearly L^A is a worse contract for low risk individuals than L^*. In a very real sense the low risk buyers lose as compared to the full information

insurance context see Cutler and Zeckhauser (2000).

[18] That is, all have the same incomes, the same loss in the "bad" state, and identical preferences or attitudes to risk.

[19] This solution of the adverse selection problem on a competitive insurance market was first proposed by Rothschild and Stiglitz (1976) and Wilson (1977). An important problem, which we here neglect, is that for a sufficiently high proportion of low risk types an equilibrium does not exist, *i.e.* the model fails to predict an outcome of the market process. This problem can be solved by changing the concept of equilibrium, for example as in Wilson (1977), but taking this point explicitly into the present discussion would unduly complicate it.

situation, the reason being that high risk types must be deterred from taking the low risk contract by the relatively low level of cover it offers. If we think of this as containing an €80,000 deductible, high risk buyers are deterred by the greater likelihood that they will have to come up with this in the event of a loss.

All in all, this market outcome does not look particularly attractive. Yet, it can be shown that it is the best that can be achieved by a competitive insurance market. In particular, the pooled contract looks in many respects more attractive since it gives everyone full cover, but because, as shown earlier, of the cross-subsidisation of the high by the low risks, and the opportunities for transitional profits that this implies, it cannot be sustained as a market equilibrium, in the absence of regulation or the appropriate tax/subsidy policy.

Consider in this context the social benefit arising from the existence of costless tests that inform insurers about the true risk type of the insured. We will then have the full information equilibrium, in which case low risk individuals benefit from the substantially increased level of coverage - they receive contract L^* and not L^A. They no longer have to "signal their type" by their willingness to accept a much lower level of cover. At the same time, high risk policy holders are made no worse off, since they are receiving the same contract, H^*, in each case. Allowing people to take the test and report its results to their insurers (obviously only low risk types will bother to take the test) results in a Pareto improvement. This argument applies only to the case in which all individuals initially know their risk type, whereas it is reasonable to assume that many people do not. Ultimately, however, we can show that the basic intuition of this case goes through in the more realisitic situation.

We begin the formal analysis[20] of this issue with the classification of individuals on the basis of their informational status. The set of all individuals in the population is partitioned into a subset that knows it is high risk, **H,** a subset that knows it is low risk, **L**, and a subset that is completely uninformed about its type, **U**, which can be further subdivided into subsets consisting of high risk and low risk individuals, $\mathbf{U}_H$ and $\mathbf{U}_L$. The proportions of the total population in each of these subsets are assumed to be given, and known by everyone. Consistent with our earlier example, 10% of the individuals are high risk and so in $\{\mathbf{H} \cup \mathbf{U}_H\}$, while 90% are low risk and so in $\{\mathbf{L} \cup \mathbf{U}_L\}$. Thus there are still only two risk types, in the same proportions in the overall population as before, but now there is a further distinction on the basis of *informational status* - whether one knows one's own risk type or not. What turns out to be crucial is whether insurers can observe the informational status of an individual, that is, whether they know if

[20] See in particular Crocker and Snow (1992) and Doherty and Thistle (1996).

she knows which risk type she is, or is uninformed.

Thus, suppose that insurers can observe whether an individual knows her risk type or not, *i.e.* whether she is in, or not in, **U**. Then, regardless of whether or not the insurer can observe the actual risk type, there is premium risk and no individual who starts off in subset **U** will take the test. This is the kind of case assumed by Tabarrok.

The argument goes as follows. If the insurers can observe both informational status *and* risk type, they offer full cover at the respective fair premia to individuals in **H** and **L**, and full cover at the appropriate pooled premium[21] to those in **U**. This pooled contract would clearly be more attractive to the high risk individuals than their own contract H^*, since it involves cross subsidization from the low risk types in **U,** but they would not be allowed to buy it by the insurers, who can restrict this contract to the people they know are uninformed. Likewise, the contract offered to low risks, L^*, would be more attractive to the uninformed individuals than their own contract, since it gives full cover at a lower premium (no cross subsidization of high risks), but they would not be allowed to buy it, since the insurer knows they are uninformed and therefore may be high risk. Then, as

[21] If the proportion of individuals in **U** who are in $\mathbf{U}_H \subset \mathbf{U}$ is λ_U, then the pooled probability $\bar{p}_U = 0.5\lambda_U + 0.01(1 - \lambda_U)$, and the pooled fair premium is $\bar{p}_U$€$100,000$.

we have already seen, the uninformed buyers are faced with premium risk and would not take the test, *i.e.* become informed, since then they would lose the pooled contract and be given either H^* or L^*.

Suppose on the other hand that insurers can observe informational status *but not* risk type. Then they continue to offer full cover at the pooled fair premium to uninformed individuals, but are faced with an adverse selection problem among the informed individuals. This they solve by offering two contracts as discussed above: full cover at the high risk fair premium, and partial cover at a fair premium appropriate to low risk buyers, contracts H^* and L^A. This means that the premium risk facing uninformed individuals is now even greater, since the high type contract is just the same and the low type contract L^A is worse than L^*, and so *a fortiori* they do not take the test.

It seems realistic to assume, as in the adverse selection model, that insurers **cannot** observe risk type. If we further assume, as also seems realistic, that insurers **cannot** observe the individual's information status, then it can be shown that, if individuals are allowed, at their own discretion, to report test results to their insurers:

(a) the premium risk disappears and there is a positive incentive to take the test;

(b) both types will receive full cover, at the respective fair premia, i.e. they will receive contracts H^* and L^*.

The argument can be sketched as follows.[22]

Suppose that insurers start off by assuming that the uninformed **do not** take the test. They know they are faced with three types of buyer, but they cannot tell who is of which type. This implies that they have an adverse selection problem. This they solve by offering the following menu of contracts:

- H^*: full cover at a fair premium for **high risks;**

- U: partial cover, chosen so as to make high risk types just indifferent between this contract and the contract H^*, with a fair premium at the appropriate pooled probability for **uninformed individuals.** This is, so to speak, designed to ensure that high risks do not prefer the contract intended for uninformed individuals.

- L^U: partial cover, chosen so as to make uninformed individuals just indifferent between this contract and the contract U, with a fair premium for **low risks.** This is designed to ensure that uninformed individuals do not prefer the contract intended for low risks.

[22] For more rigorous discussion see Doherty and Thistle.

In other words we have three contracts designed to solve the three-type adverse selection problem insurers face.

We now show that there is in this situation a positive incentive to take the test. This means insurers should not start off by assuming that no-one takes the test. Thus suppose an uninformed individual is tested and turns out to be a high risk type. In that case she will buy the H^* contract, which she will regard as just as good as her present one U. On the other hand, if she turns out to be a low risk type, she will buy the L^U contract, which she will positively prefer to the U contract[23]. It follows that there is a chance that she will be strictly better off and no chance that she will be worse off by taking the test, and so she will do so. Thus insurers are wrong to start off by assuming that the uninformed will not take the test, and this cannot be part of an equilibrium.

Suppose instead insurers assume that the uninformed **will** take the test, and offer the contract L^* to anyone reporting that the test result is negative, and H^* to everyone else. Given that people may voluntarily supply the test information to the insurer, everyone who tests negative will report that fact. Moreover, it pays those who know they are low risk also to take the test and report the results -

[23] This can be shown to follow from what is known as a *single crossing property* in this model. The lower the risk probability, the steeper the indifference curve of an individual through any given point in the state contingent income space.

they have a costless signal with which to verify their type. We just have to check that in this case the uninformed will indeed take the test. This is easy to see. If they test positive, they need not report the results but will in any case receive H^*, so they are no worse off than not taking the test. If they test negative they can report this and receive L^*, in which case they are strictly better off than not taking the test. Thus there is *ex ante* a positive expected value from taking the test.

So we see that allowing voluntary provision of test results ensures that everyone (except those who already know they are high risk) will take the test, and also solves the problem of adverse selection. Everyone ends up with full cover at the appropriate fair premium.

4. Policy Conclusions

The conclusion of the theoretical literature is that Tabarrok's concern, that premium risk will provide a disincentive to testing, thus leading to the loss of social benefits, is unfounded, provided individuals are permitted to supply test results voluntarily to insurers. Furthermore, the market equilibrium will be one in which everyone receives full cover, with high and low risks paying their respective fair premia. It differs therefore from a situation in which everyone is uninformed and there is an equilibrium with full cover at the fair premium pooled across the entire population, only in the distributional and not the efficiency properties of the equilibrium. High risk individuals are worse off and low risk individuals better off in the new situation. This could however be neutralised by an appropriate tax/subsidy policy.

There are a number of limitations of the kind of model we have been considering, which suggest the need for further analysis to address the issues raised by genetic testing. One strong assumption is that the loss resulting from the occurrence of the "bad" state is less than income. This is not fully appropriate in health insurance markets. It is quite conceivable that the cost of treatment required to restore someone's health, the interpretation of the "loss" in the above model, is well in excess of a high risk individual's income. In that case, as Strohmenger and Wambach show formally,[24] high risk individuals may well simply drop out of the insurance market altogether, since the high risk premium may be greater than their willingness or ability to pay for insurance. Thus, economic analysis suggests that Tabarrok's concern that testing will not take place is unfounded, but the problem remains that high risk individuals in a private insurance market will be

[24] A further realistic aspect of their model, which plays an important role, is that the individual's utility is state dependent, so that the utility of income to an individual depends on whether she is healthy or sick.

seriously disadvantaged, and that the market itself may well shrink.[25]

A further important limitation is that the test was assumed to classify someone accurately and unambiguously as high or low risk. More generally, a genetic test should be viewed as providing new information which would lead to a revision of the prior probability of loss for the individual concerned to a posterior probability, according to Bayes' Rule. This would also allow the risk of false positive and negative results to be taken into account, i.e. inaccuracies in the tests. On the other hand, a reformulation of the model in this direction does not seem likely to change the main results.

What of Tabarrok's proposal of "genetic insurance", under which the intervention of the policy maker is restricted to making this compulsory if a test is to be conducted. One is tempted to argue that if, on a private insurance market, it generated the benefits claimed for it, then it would not have to be made compulsory. The essential problem is that such insurance would not be sold behind the "veil of ignorance" necessary for it to work. Because of family history, individuals are likely to have some knowledge of the risks they face of testing positive. If insurers do not have this information, the market for genetic insurance will be subject to

[25] That this is not fanciful is borne out by the situation in the USA, where approaching 20% of households do not have health insurance cover.

adverse selection, so that low risks will receive partial cover and high risks will pay high premia. If insurers have this information, there will still be high premia for high risks. Thus the problem of the high risk individuals will not be solved, essentially because pooling in this market will not take place across the entire population, but only within groups consisting of those with high risks because of family history, on the one hand, and those with low risks because of absence of family history, on the other.

Appendix

Premium risk.

The individual is risk averse with strictly concave utility function $u(y)$, where y is income. Let θ denote the proportion of low risks in the population, p_L and p_H the loss probabilities of low and high risk individuals respectively, and d is the amount of loss, which is less than initial income. Finally let

$$\bar{p} \equiv \theta p_L + (1-\theta)p_H \tag{4.1}$$

be the pooled probability. We assume the insurance premium is always fair. Thus, before testing, with everyone uninformed, everyone buys full cover at the fair premium $\bar{p}d$, while after testing, if the insurer knows everyone's type, the fair premia will be $p_L d$ and $p_H d$ respectively. Thus each individual has a utility of $u(y-\bar{p}d)$ if testing does not exist, and $u(y- p_L d)$ with probability θ, and $u(y- p_H d)$ with probability $(1-\theta)$, if testing is introduced. Then strict concavity of utility implies

$$u(y-\bar{p}d) > \theta u(y-p_L d) + (1-\theta)u(y-p_H d) \tag{4.2}$$

since

$$y - \bar{p}d = \theta(y - p_L d) + (1-\theta)(y - p_H d) \tag{4.3}$$

Risk reduction from prevention may remove premium risk

Suppose the individual has a utility of income function $u = \ln y$, and an initial income of €60,000. Following a positive test result, she can at a cost of €10,000 undertake preventive treatment which reduces the risk of the illness, and concomitant loss of €100,000, from 0.5 to $\hat{p}_H$. She will therefore be able to buy full cover for a premium of $\hat{p}_H(€100,000)$. The premium risk therefore disappears if and only if the utility from insuring without taking the test is less than the expected utility from taking the test, learning one's type, and undertaking preventive treatment if one is high risk, *i.e.* if

$$\ln[60,000 - 5900] \leq 0.1 \ln[60,000 - 10,000 - \hat{p}_H(100,000)] + 0.9 \ln[60,000 - 1,000] \tag{4.4}$$

or

$$\ln 54,100 \leq 0.1 \ln x + 0.9 \ln 59,000 \tag{4.5}$$

giving a solution

$$50,000 - \hat{p}_H(100,000) = x = 24,800 \tag{4.6}$$

from which we obtain

$$\hat{p}_H \leq 0.25 \tag{4.7}$$

Thus, provided the probability of loss was reduced by at least a half, from 0.5 to 0.25 as a result of the preventive treatment, there is no premium risk. A lower cost of this treatment raises $\hat{p}_H$, a higher cost reduces it.

Example of why pooling is not a Nash (Rothschild-Stiglitz) equilibrium

Suppose all buyers have the same utility function and initial income as in the previous example. Then, under the pooling contract they all have a utility of $\ln[60,000 - 5900] = 10.8986$. Let an enterprising insurer, who expects other insurers to go on offering the pooling contract, now offer the contract with a premium of €750 and a cover of €70,000. A low risk buyer will switch to this contract because

$$0.9 \ln[60,000 - 750] + 0.1 \ln[60,000 - 30,000] = 10.9215 > 10.8986 \tag{4.8}$$

whereas a high risk buyer will prefer to stay with the original contract because

$$10.8986 > 0.5 \ln[60,000 - 750] + 0.5 \ln[60,000 - 30,000] = 10.6492 \qquad (4.9)$$

Note, however, that if all insurers offering the pooled contract withdrew it, because it became loss making when bought only by the high risk buyers, and then these high risk buyers all switched to the new contract, this would now make losses, because the premium of €750 is well below the premium of €4130 ($= 0.059 \times$ €$70,000$) required to break even when *all* buyers take this contract. This point led C Wilson (1977) to argue that, in anticipation of this, no insurer would offer the contract to tempt away low risk buyers in the first place. He then shows that if this idea is formally built into the equilibrium concept (which is therefore no longer that of Nash equilibrium) there is a particular, unique pooling contract which, under certain circumstances (namely when the proportion of low risks is sufficiently high that no Nash equilibrium exists), is the equilibrium contract. The advantage of this is that it takes care of the troubling issue of the non-existence of a Nash equilibrium, as long as we are prepared to accept that insurers will show this anticipatory foresight, requiring among other things that they expect other insurers to withdraw the pooling contract virtually instantaneously with their offer of the new contract, otherwise they would make at least transitory excess profits.

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