Impact of Genetic Testing on Surveillance and Prevention

Lilia Filipova
University of Augsburg

Michael Hoy
University of Guelph

Department of Economics, University of Guelph
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Abstract

There is a prospect of substantial advancements in the understanding of the relationship between disease and genetics at least in the medium term to long term future. In this paper we consider the implications on two aspects of behaviour - surveillance to improve the chances of early detection of disease onset and preventive actions to reduce the probability of onset - that may change as a result of the acquisition of information from genetic tests. We argue that there are problems for both private insurance regimes, with risk-rating allowed according to genetic type, and public insurance regimes (or a private insurance system with an 'effective' community rating regulation) in generating potential health benefits from increased genetic information. In the public regime appropriate signals to obtain genetic information are not always provided while in the private regime premium risk can block otherwise fruitful acquisitions of this information. In both regimes moral hazard considerations can blunt the adoption of otherwise useful information with the further problem for public insurance of possibly encouraging excessive adoption of genetic testing.

Keywords: value of information, surveillance, prevention.

1 Introduction

By all accounts in the scientific literature the potential benefits of the so-called Human Genome Project in providing enhanced prevention and treatment of disease are nothing short of revolutionary. A rough road map of the human genome has been available since 2003, having been undertaken in 1990. Genomic science is now in something of a second phase of the *Genomic Revolution* in that current research involves not just the identification of so-called "disease genes" or, more appropriately, "disease alleles", but the understanding of how specific sequences of genes interact with each other and environmental factors to affect onset and influence treatment of disease. According to the Nuffield Trust Genetics Scenario Project (2000), *"The impact of the new genetics on existing health services in the United Kingdom has been compared to a tidal wave, a tsunami, sweeping all before it as it bursts upon the shore. A hyperbole perhaps; nevertheless the medicine that has been practised up to now, and the health service we have become familiar with, will undoubtedly be subject to enormous changes."* The project looks finally to lead to the real promise of vastly improved health care through genetic therapies and generally improved understanding of disease.[1] However, adoption of these advances will face a number of hurdles. There is evidence that many individuals fear genetic discrimination from insurers and employers if they take genetic tests and so the first step in developing personalized, genome specific medicine may be to foster acceptance of genetic testing within the population.[2] Many of these tests are quite expensive and so which tests to make available through health insurance plans, be they private or public, is also a challenge. Insurance providers are concerned about the possibility of escalating costs due to the introduction of costly genetic tests that may also lead to increased treatment and preventive costs (e.g., see report by Miller, et al. (2002) funded by the Ontario Ministry of Health and Long Term Care). Finally, what to make of the increased information and how this will be accommodated by health insurance plans also requires study. It is this aspect of increasing genetic information that we address in this paper.

Following the seminal papers by Rothschild and Stiglitz (1976) and Wilson (1977), there has been considerable effort to determine the welfare implications of asymmetric information in insurance markets. One critical aspect of the debate about allowing versus restricting use of genetic information by insurers is that the standard model of Rothschild

[1] See Filipova and Hoy (2008) for a description of the various potential uses to which this information can be applied, including pre-natal screening, genetic therapies, etc.

[2] Meiser and Dunn (2000) found that the percentage at risk who requested free testing for Huntington's Disease even in clinical settings when results were anonymous (i.e., outside of patients health records) varied from 9% to 20%. For reviews of related issues of privacy concerns in regulating genetic test information, see Hoy and Ruse (2005), Hoy (2008), and Lemmens, Luther, and Hoy (2008).

and Stiglitz (1976) is not necessarily of much use since a Nash equilibrium doesn't exist if the fraction of high risk types in the population is below a critical level. This is a very real possibility in the case of information from genetic tests at present and possibly even for some time into the future. Wilson's (1977) foresight assumption, which allows for a pooling equilibrium in this scenario, is more helpful in a pragmatic sense but does beg the question as to whether it is a reasonable outcome for insurance markets. Experience and modeling of life insurance markets and annuity markets, on the other hand, generally accept the principle of risk-pooling, with a different mechanism that generates adverse selection costs.[3] Roughly speaking, the results of this literature (see Hoy (1982, 1984), Crocker and Snow (1986), Hoy and Polborn (2000), and Hoy (2006)) are that under scenarios of pooling (or cross-subsidy separating) equilibria a ban on insurers basing prices on risk types (e.g., using genetic test results) *may* increase second-best welfare (provided the proportion of high risks is sufficiently small) since premium risk is avoided while if the proportion of risk-types in the population is sufficiently high that the classic Rothschild-Stiglitz separating pair of contracts is a Nash equilibrium, then a ban on risk rating would unambiguously worsen welfare. Introducing redistributive policies based on risk type can unambiguously improve welfare (see Crocker and Snow, 1985 and Rees and Apps, 2006); however this requires an ongoing mechanism for adjusting taxes and subsidies on policies to keep up with new genetic tests as they come online.[4] Besides tax-subsidy measures or bans on risk rating to ameliorate the equity or premium risk effects, special markets to insure against risk type discovery (e.g., so-called genetic risk insurance) have been proposed by Tabarrock (1994) and Hoel and Iversen (2002).

Most, although not all, of these papers in the literature indicated above treat the probability of financial loss as being exogenously determined. Our paper considers the implications of decisions that can improve expected health outcomes of individuals based on knowing their genetic risk type, either through changes in the degree of surveillance for disease onset or through preventive measures. We show how this impacts on the decision to acquire information from a genetic test.[5] In particular, we consider individuals' incentives to obtain information from genetic testing under alternative insurance arrangements when the implications of the information is to possibly alter one's degree of surveillance, such as the use of mammograms or colonoscopies, in light of a revised perception of risk of

[3] For example, see Abel (1986), Brugiavini (1993), Hoy and Polborn (2000), Villeneuve (2000, 2003), Pauly, et al. (2003), and Polborn, Hoy, and Sadanand (2006).

[4] Surveys on the problem of adverse selection and risk classification include Rea (1992), Dionne, Doherty, and Fombaron (2000), and Crocker and Snow (2000).

[5] Although a few papers do address this issue (eg., Doherty and Posey, 1998 and Hoel, et al. 2006), they adopt the presumption that the fraction of high risk types is sufficiently large that a separating pair of contracts, with no cross-subsidization, is the equilibrium. In any case, we consider a very different environment with compulsory full insurance coverage.

onset of disease. We also consider the possibility that such information may influence costly preventive measures that may reduce the probability of onset of disease in ways that depend on genetic type, such as the option to take a prophylactic drug such as tamoxifen for those who test positive for one of the so-called breast cancer genes.[6] Issues addressed in this paper include (1) individuals' incentives to obtain/accept a genetic test, (2) resulting behavioural implications of genetic test results concerning privately optimal levels of surveillance and/or prevention, (3) implications for (insured) health care costs, (4) implications for provision and targeting of surveillance and preventive technologies, (5) and in an admittedly cursory manner we consideration of structural changes to health care/insurance to enhance the welfare implications of genetic information.

We focus on stylized models of private versus public health insurance provision but do not address the bigger question of which type of provision generates higher societal welfare.[7] Rather, we consider the differential effects on private choice and social welfare resulting from the introduction of genetic tests for each type of insurance model separately. In some cases genetic tests will be sought out even when this leads to reduced welfare for all individuals due to second-best concerns associated with insurance. Although we presume standard moral hazard implications arise in either a private or public health insurance scheme, under certain conditions the availability of certain genetic tests will reduce welfare in a public health insurance scheme but not in a private one. Of course, this is not a strong argument in favour of private over public provision of health insurance since the result does not imply that overall welfare is generally higher under private than public health insurance provision. Rather, this result highlights the different challenges for public versus private provision. In an informal manner we consider possible alterations to the pricing/coverage relationship (coinsurance rates in particular) of both surveillance and preventive activities as well as health treatment costs for those who incur disease as a means of improving the match between private incentives and social welfare. We show that the pattern of this relationship can vary across individuals once genetic tests that create heterogeneity in risk types becomes available.

We stress here that we do not perform a full blown welfare analysis of the sort that searches for a pareto efficient allocation of surveillance and/or precautionary activities in conjunction with determining conditions under which offering genetic tests increases or decreases welfare. Instead, we presume health care provision is financed by one of a pair

[6] See Hoy (1989) and Doherty and Posey (1998) for related models of self-protection technologies that differ by individual's type.

[7] There is a broad range of issues, including the importance of personal preferences concerning relative desirability of heterogeneous insurance plans and efficient provision of service providers that must be weighed in determining the relative merits of private versus public provision of health insurance. This bigger question is beyong the scope of this paper.

of stylized models of public versus private health insurance where the same services are covered under both plans but where under the private system individuals will be assessed premiums based on their risk type, including whether or not they have undertaken a genetic test. This information is available to insurers and so no adverse selection arises. We also assume that individuals choose a privately optimal level of surveillance (or prevention) based on health concerns, excluding the implications of their decisions on the cost imposed on the insurance pool, which is a simple moral hazard problem. In both insurance models we presume that insurers naively allow insureds to choose according to their privately optimal decisions. This exercise points out the challenge for insurance schemes, public or private, in attempting to determine implications for provision of these services in a world of increasing information about relative risk of disease and how they might effect more efficient and better targeted choices by insureds without losing the risk protection of the respective insurance schemes.

In developing our results, we focus on the issue of surveillance. In any given initial state of information no one holds any genetic test information and so individuals are assumed homogeneous in all regards. Given the moral hazard implications, individuals may engage in either over or under use of surveillance, depending on whether their individually optimal choices are at a level such that, at the margin, increased surveillance leads to an increase or decrease in the financial cost of health care provision, respectively, where financial costs are absorbed by the insurance pool. We characterize how genetic testing can lead to changes in the pattern of over and under use of surveillance. Over-use is a problem that in principle can be easily resolved by rationing of the service but under-use is perhaps more problematic. In the context of our model everyone chooses the same level of surveillance in the absence of genetic test results being available and so there is no risk management role for insurance to cover the cost of surveillance ex ante to genetic testing.[8] After genetic testing, however, public insurance provision provides better risk-sharing properties in regards to the differential expected cost of health care provision which includes differential use of surveillance and different expected treatment costs for those who incur disease and so this phenomenon lends an advantage to publicly provided insurance (or a community rating regulation, if enforceable, for private insurance provision).[9] However, since in a private market setting individuals take into account the implications of obtaining a genetic

[8] Of course in a more realistic model there would be differences between individual risks of disease and hence different optimal usage of surveillance based on risk differences revealed by characteristics other than genetic test results. Our anlaysis then demonstrates additional risk or equity implications that might arise due to different genetic test results. For an application along these lines, see Hoy and Witt (2007).

[9] See Wynand, et al. (2007) for an empirical exercise that suggests risk adjustments designed to provide incentives for private insurers to accept community rating still did not avoid risk selection strategies for a set of European countries over the period 2000-2006.

test on their ultimate cost of insurance, there is no externality related to this decision as there is under public insurance provision. Therefore, it is possible that a genetic test, that would reduce individual welfare in either the private or public insurance scheme, would be rejected by the individuals in a private insurance market setting but accepted (demanded) in a public market setting. The results for prevention are to a large extent analogous.

2 Impact of Genetic Testing on Surveillance

In this section we take account of the fact that the results of genetic tests might influence the intensity of medical surveillance, which in turn affects the financial costs of providing health care as well as individual and societal welfare. We denote the probability of disease by ρ and this probability depends on the results of a genetic test. Once an individual is afflicted by a disease, this can be detected either early or late. The probability of early detection $p^{ED}(s)$ is a function of the level of medical surveillance $s \in [\underline{s}, \overline{s}]$. Increasing surveillance will increase the probability that the disease is detected early rather than late, however at a decreasing rate ($p^{ED\prime}(s) > 0$, $p^{ED\prime\prime}(s) < 0$). Individuals' welfare is made up of several components: the first is the utility of net income $u(\cdot)$, which is increasing and, possibly concave - we address both risk-neutrality and risk-aversion - ($u'(\cdot) > 0, u''(\cdot) \leq 0$); the second is a health-state dependent physiological (non-financial) cost, which is subtracted from utility in the case of disease, and which is larger in case that the disease is detected late rather than early ($\kappa_L > \kappa_E$), and the third component is a phsysiological (non-financial) cost of surveillance $\Phi(s)$, which is increasing and convex in the level of surveillance ($\Phi'(s) > 0, \Phi''(s) > 0$).[10] With this specification of utility,[11] the marginal utility of income is independent of the health state or physiological cost of surveillance and so the optimal level of surveillance, $s = \widehat{s}$, from the individual's perspective is independent of income and, hence, of the cost of insurance coverage *unless* that cost is explicitly related to s.

$$EU(s) = u(y - \overline{TC}) - \rho[(1 - p^{ED}(s))\kappa_L + p^{ED}(s)\kappa_E] - \Phi(s) \tag{1}$$

As can be seen in the above equation, net income is obtained by subtracting from the initial endowment y the per capita health care costs $\overline{TC}$.

In the case that an individual incurs the disease, the assigned treatment will cause financial costs, which are lower when the disease is detected early rather than late ($C^{DL} >$

[10] The physiological cost of surveillance may include discomfort/pain, a psychological component, time taken to have the procedure, and possible side effects (e.g., a certain fraction of colonoscopies result in damage - knicking - to the colon).

[11] This separation of utility into an income component and a health component is similar to Kiffman (2001). Strohmenger and Wambach (2000) also use a state contingent utility function in an adverse selection model.

C^{DE}).[12] This accounts for the fact that usually the severity of a disease grows when it is detected late, which in turn limits the choice of alternative treatment measures to those which are more aggressive and most expensive. There are also direct financial costs of surveillance $C(s)$, which are assumed increasing and convex in the level of surveillance $C'(s) > 0$, $C''(s) > 0$. We think of increased surveillance as further, more invasive and expensive technologies being applied, rather than simply repeated occurrences of a given technology. Thus, the per capita expected cost of providing health care will depend on the level of surveillance. Whether public or private, we assume mandatory full coverage insurance. Thus, the per capita health care costs are given by

$$TC(s) = \rho[p^{ED}(s)C^{DE} + (1 - p^{ED}(s))C^{DL}] + C(s) \tag{2}$$

Although in such a scenario each individual does not take into account his use of surveillance s on the financial cost of the health care system, given homogeneity of preferences each individual's optimal choice of surveillance, $\widehat{s}$, will be the same and this level determines this cost and so in this circumstance we would have $\overline{TC} = TC(\widehat{s})$ - the equilibrium per capita health cost.[13] One policy option would be to relax this assumption and investigate the possibility that the individual can influence his cost of health care by varying s as one would find under private (or even public) health care systems that have co-payments assigned to surveillance activities.[14]

In order to compare the situation before a genetic test (GT) is conducted with the situation after a genetic test, we denote the initially perceived probability of disease, which also equals the true population average probability of disease, by ρ^0. A genetic test classifies individuals (possibly imperfectly) into two risk groups: those who test positive (negative) have, on average, a probability of disease ρ^H (ρ^L), where $\rho^L < \rho^0 < \rho^H$. The proportion of individuals who test negative is denoted by η_L while the proportion who test positive is $\eta_H = (1 - \eta_L)$. Thus, before a GT, every individual perceives the probability of disease to be ρ^0, while after a GT fraction η_L (η_H) perceive the probability of disease to be ρ^L (ρ^H). For simplicity we will presume that the fractions testing positive and

[12] This assumption is not likely true for all diseases. Early detection of HIV that inevitably leads to full blown AIDS is probably more costly to treat since 'end costs' are the same while drug treatment through the pre-AIDS period is an additional cost. Note that for publicly provided insurance, the principal (government) would presumably include all social external costs of disease - not just those associated with health care provision.

[13] We use the same symbol $\widehat{s}$ to denote both the individual's privately optimal value of surveillance and, due to homogeneity, the equilibrium level. In its latter interpretation, $\widehat{s}$ determines the healthcare suppliers' total costs of service delivery, but individuals do not take account of this financial cost implication in choosing $\widehat{s}$.

[14] For example, many private health insurance plans in the US do not cover any fraction of the cost of colonoscopies and so co-payment in this case is 100%.

negative are fixed and that a more precise test is associated with lower rates of both false positives and negatives in a symmetric (or rather fixed) fashion as noted below. Since the population average probability of disease ρ^0 is constant, we have

$$\rho^0 = \eta_L \cdot \underbrace{(\rho^0 - \frac{\varepsilon}{\eta_L})}_{\rho^L} + \eta_H \cdot \underbrace{(\rho^0 + \frac{\varepsilon}{\eta_H})}_{\rho^H}, \tag{3}$$

with $\varepsilon > 0$ describing the 'degree of accuracy' of the information. In developing the intuition about the value of GTs, it turns out to be convenient to consider the effect of a marginal increase of information, i.e., an increase of ε. Thus, a more precise test implies the probabilities of disease for tested negatives and tested positives approach the true probabilities of the disease of low and high risks (denote them by ρ_T^L and ρ_T^H), which need not even be known. Note that $\rho^0 = \eta_L \rho^L + \eta_H \rho^H$ holds irrespective of the precision of the test.

2.1 Privately optimal demand for surveillance and acceptance of genetic tests

Individuals choose a level of surveillance to maximize their expected utility. As long as they do not pay directly for surveillance and treatment (on a user cost basis), individuals will not take into account how their choice affects the financial costs of health care. Thus, from a private perspective $\frac{\partial \overline{TC}}{\partial s} = 0$. Denote by $\hat{s}$ the privately optimal choice of surveillance for a given set of parameters, which is the solution to the first order condition

$$FOC : \rho \cdot p^{ED\prime}(\hat{s}) \cdot (\kappa_L - \kappa_E) - \Phi'(\hat{s}) = 0 \tag{4}$$

which equates the marginal non-financial benefit of surveillance, i.e. the "savings" in expected personal costs of disease which is caused by a higher probability of early detection, to the marginal physiological cost of surveillance.

For the second order condition (SOC) one gets that

$$\rho \cdot p^{ED\prime\prime}(\hat{s}) \cdot (\kappa_L - \kappa_E) - \Phi''(\hat{s}) < 0, \forall s. \tag{5}$$

The optimal level of surveillance depends on the probability of disease ρ. Specifically, there will be a critical level for the probability of disease, below which individuals will choose the smallest possible level of surveillance ($\hat{s} = \underline{s}$). Denote by $\underline{\rho}$ this critical level for the probability of disease, for which $\underline{\rho} \cdot p^{ED\prime}(\hat{s}(\underline{\rho})) \cdot (\kappa_L - \kappa_E) - \Phi'(\hat{s}(\underline{\rho})) = 0$ holds, where $\hat{s}(\underline{\rho}) = \underline{s}$. Thus, for any $\rho \leqq \underline{\rho}$ the individual will choose $\hat{s} = \underline{s}$. This critical level for the probability is $\underline{\rho} = 0$, if $\Phi'(\underline{s}) = 0$. In what follows, no matter if this latter condition holds, we focus only on the range of probabilities for which $\hat{s} > \underline{s}$.

Applying the implicit function theorem to the FOC yields

$$\frac{d\hat{s}}{d\rho} = -\frac{p^{ED\prime}(s)(\kappa_L - \kappa_E)}{\rho \cdot p^{ED\prime\prime}(s) \cdot (\kappa_L - \kappa_E) - \Phi''(s)} > 0 \tag{6}$$

and

$$\frac{d^2\hat{s}}{d\rho^2} = -\frac{\begin{array}{c} p^{ED\prime\prime}(s)\frac{d\hat{s}}{d\rho}(\kappa_L - \kappa_E)[\rho \cdot p^{ED\prime\prime}(s) \cdot (\kappa_L - \kappa_E) - \Phi''(s)] \\ -p^{ED\prime}(s)(\kappa_L - \kappa_E) \cdot [\rho \cdot p^{ED\prime\prime\prime}(s) \cdot \frac{d\hat{s}}{d\rho}(\kappa_L - \kappa_E) + p^{ED\prime\prime}(s) \cdot (\kappa_L - \kappa_E) - \Phi'''(s)\frac{d\hat{s}}{d\rho}] \end{array}}{(\rho \cdot p^{ED\prime\prime}(s) \cdot (\kappa_L - \kappa_E) - \Phi''(s))^2} \tag{7}$$

A sufficient condition for $\frac{d^2\hat{s}}{d\rho^2} < 0$ (concavity of the $\widehat{s}(\rho)$ schedule) is that $\Phi'''(s) \gtreqless 0$ and $p^{ED\prime\prime\prime}(s) \lesseqgtr 0$, the case depicted in Figure 1

Insert Figure 1 about here.

The implication of a genetic test on the demand for surveillance is clear. Tested positives, for which the probability of disease will be larger than before the test, will demand more surveillance and tested negatives, for which the reverse holds, will demand less surveillance. It can also be seen that the demand for surveillance is larger the higher is the marginal productivity of surveillance given the disease, i.e. the more sensitive is the probability for early detection to the level of surveillance, and the larger are the savings of the physiological costs of disease when it is detected early $(\kappa_L - \kappa_E)$. The demand for surveillance is smaller the faster the personal costs of surveillance increase (the larger is $\Phi'(\hat{s})$).

It is worth demonstrating some properties of the function $EU(s)$ in relation to the optimal choice of s $(\widehat{s})$ as well as the effect of a change in the probability of disease. First, due to the separability of income and health effects from surveillance, altering the cost of insurance simply creates a family of vertically parallel $EU(s)$-curves, with higher curves of course relating to lower payment for health care costs (insurance). This is illustrated in Figure 2 for a pair of values of health care costs (insurance premiums), with $\overline{TC}_1 < \overline{TC}_2$. Secondly, an increase in ρ obviously reduces the level of expected utility conditional on any given level of s and we have shown that the privately optimal level of s will increase with an increase in ρ. Thus, we have the configuration for $\rho_1 < \rho_2$, but $\overline{TC}$ constant, of the two curves $EU(s;\rho_1)$ and $EU(s;\rho_2)$ shown in Figure 3.

Insert Figure 2 about here.
Insert Figure 3 about here.

It is useful also to consider how the value of s that minimizes the per capita financial cost of providing health care, which we will refer to as $\widetilde{s}$, changes as ρ changes. A similar

comparative statics exercise as for $\widehat{s}$ leads to the conclusion that an increase in probability of disease, ρ, leads to an increase in $\widetilde{s}$, as illustrated in Figure 4. Thus, since individuals do not internalize the financial implications of their choice of surveillance ($\widehat{s}$), it follows that if $\widehat{s}$ is less than $\widetilde{s}$, as illustrated in Figure 5, a marginal increase in s beyond $\widehat{s}$ by all individuals in the insurance pool will have effectively no effect on each individual's expected utility (EU) based on the net effects of physiological health benefits and costs, which is all the consumer takes into account, while it would reduce per capita cost of health insurance for all in the pool, hence increasing everyone's welfare. This is a straightforward moral hazard problem. Thus, in this case the welfare maximizing choice of surveillance, s^*, will be greater than the privately optimal choice. The contrary implication would be the case if $\widetilde{s}$ were less than $\widehat{s}$. The implications of these patterns are developed more fully later in the paper.

Insert Figure 4 about here.
Insert Figure 5 about here.

Although individuals will change their demand for surveillance after they test, suggesting some 'production efficiency', it is nevertheless unclear whether they will accept a genetic test, even if it is costless. The decision whether to accept a genetic test is based on whether the ex ante expected utility, i.e., before knowing whether one will be tested positive ($\rho = \rho^H$) or negative ($\rho = \rho^L$), exceeds the expected utility without a genetic test, where the average probability of disease is ρ^0. Obviously, a genetic test involves uncertainty as to the risk group one is going to belong to and, depending on the kind of health insurance, that might have more or less negative implications from an ex ante point of view. Even though we restrict our analysis to mandatory full coverage insurance, it is still possible that the regulatory framework is such that it allows for risk rating or, alternatively, it might impose community rating. We consider the change of expected utility (and welfare) with risk-rating and community rating separately.

A) Risk rating (Mandatory full coverage private insurance)

To analyze the change in expected utility (welfare) associated with a genetic test from an individual's perspective denote the maximized value of expected utility (the individual's value function) for a given set of parameters, by $v = EU(\hat{s})$, which we can write as a function of the probability of disease, i.e., $v(\rho) = EU(\hat{s}(\rho))$. Without a genetic test individuals have expected utility value of $v(\rho^0) = EU(\hat{s}(\rho^0))$. After a genetic test individuals adjust their optimal surveillance decisions in line with the outcome of the test and so those who test negative end up with expected utility $v(\rho^L) = EU(\hat{s}(\rho^L))$ while those who test positive end up with expected utility $v(\rho^H) = EU(\hat{s}(\rho^H))$. From an ex ante perspective (i.e., before results of a genetic test are known), the expected utility (in equilibrium) from

taking a genetic test with information value ε is $EU^A(\varepsilon) = \eta_L v(\rho^L) + \eta_H v(\rho^H)$. Since $\rho^0 = \eta_L \rho^L + \eta_H \rho^H$, it follows that global convexity of the value function $v(\rho)$ implies that, from an individual's perspective, ex ante expected welfare from a genetic test is larger than the initial expected welfare (utility), while the reverse is implied by global concavity.

For the first derivative of the value function we have

$$\frac{dv(\rho)}{d\rho} = \underbrace{\frac{\partial EU}{\partial \widehat{s}}}_{=0} \frac{d\widehat{s}}{d\rho} + \frac{\partial EU}{\partial \rho} \tag{8}$$

First consider a marginal increase of information at the point of no information, i.e. at $\varepsilon = 0$. Applying the envelope theorem we see that the first term equals zero. Although the individual (correctly) does not perceive that his choice of s affects his per capita cost of health care insurance, the fact that everyone adjusts s accordingly means this cost is affected accordingly nonetheless. We write $TC^e(\rho) = TC(\widehat{s}(\rho), \rho)$ to reflect the equilibrium per capita cost of insurance given perceived probability of disease ρ and assume individuals know this relationship. Thus, the second term in the above equation is the partial derivative of (1) with respect to ρ (with $TC^e(\rho)$ replacing $\overline{TC}$) and so, for the (perhaps expected) case of $\frac{dTC^e}{d\rho} > 0$.[15] we have

$$\frac{dv(\rho)}{d\rho} = u'(y - TC^e(\rho))(-\frac{dTC^e}{d\rho}) - [(1 - p^{ED}(\widehat{s}(\rho)))\kappa_L + p^{ED}(\widehat{s}(\rho))\kappa_E] < 0. \tag{9}$$

The first term reflects the financial consequences of being risk rated while the second term reflects the perceived health consequences of learning that one faces an updated probability of disease onset. As noted above, although an individual doesn't take into account the (negligible) effect of his own choice of s on the cost of providing health care to the insurance pool, the individual does recognize that in being assigned to a different risk class with associated value of ρ will have financial implications regarding the insurance cost. This cost is determined by the optimal choices individuals make; i.e., $\widehat{s}(\rho)$. Therefore, we have

$$TC^e(\rho) = \rho[p^{ED}(\widehat{s}(\rho))C^{DE} + (1 - p^{ED}(\widehat{s}(\rho)))C^{DL}] + C(\widehat{s}(\rho)) \tag{10}$$

which implies

$$\begin{aligned} \frac{dTC^e}{d\rho} &= p^{ED}(\widehat{s}(\rho))C^{DE} + (1 - p^{ED}(\widehat{s}(\rho)))C^{DL} \\ &\quad -\rho[p^{ED\prime}(\widehat{s}(\rho))[C^{DL} - C^{DE}]]\frac{d\widehat{s}}{d\rho} + \frac{dC(\widehat{s}(\rho))}{d\widehat{s}} \cdot \frac{d\widehat{s}}{d\rho} \end{aligned} \tag{11}$$

[15] Note that individuals don't choose s to minimize TC but rather to maximize $EU(s)$ independently of any implications on the cost to the insurance pool. Thus, it is possible that an increase in ρ, which induces an increase in s, could lead to a decrease in TC^e, hence leading to the result $\frac{dTC^e}{d\rho} < 0$. Moroever, a similar result applies even if choice of s is that which maximizes social welfare since both $EU(s)$ and $TC(s)$ come into play.

Note that our use of $\widehat{s}$ to denote both the individual's optimal choice of surveillance as well as the equilibrium level is something of an abuse of notation. To be explicit consider the following more literal way of modeling this relationship. The total (financial) costs of medical care, per capita, is a function of each individual's surveillance level s_i, $i = 1, 2, ..., n$. We would then have $TC^e(\widehat{s}_1, \widehat{s}_2, ..., \widehat{s}; \rho)$ with

$$\frac{dTC^e}{d\rho} = \frac{\partial TC^e}{\partial \rho} + \frac{\partial TC^e}{\partial \widehat{s}_i}\frac{d\widehat{s}_i}{d\rho} + \sum_{j=1,(\neq i)}^{n} \frac{\partial TC^e}{\partial \widehat{s}_j}\frac{\partial \widehat{s}_j}{\partial \rho} \tag{12}$$

Individual i treats $\frac{\partial TC^e}{\partial \widehat{s}_i}$ as effectively zero, but the last (summation) term on the RHS reflects the sum total of the effect of all (others) individuals' choices regarding surveillance on cost of provision by the insurer and so can't be treated as zero. Given that agents are homogeneous in their choices ($\widehat{s}_j = \widehat{s}(\rho), \forall j = 1, ..., n$), we adopt a short form $\frac{\partial TC^e}{\partial \widehat{s}}\frac{\partial \widehat{s}}{\rho}$ to represent this overall effect of individuals altering their surveillance level on the per capita cost of provision. Thus, the first line of equation (11) reflects the (direct effect of) added cost of treating patients due to the higher incidence of disease (i.e., higher ρ). The two terms in the second line reflect the impact on health care costs due to the effect of a change in ρ on the equilibrium level of surveillance. The first of these two terms is negative, representing a reduction in health care costs since higher risk types engaging in more surveillance means they more frequently avoid the more costly late detection stage. The second of these terms is positive, representing the (direct) cost of providing a higher level of surveillance. Thus, overall the total derivative $\frac{dTC^e}{d\rho}$ *may be* negative.[16] Therefore, the counterintuitive effect of an increase in risk of disease onset leading to lower per capita cost of insurance is possible; that is, as a result of a GT the low risk types could end up paying more for health insurance while the high risk types pay less. Furthermore, if $TC^e(\rho)$ is strictly concave then a GT, which is a mean preserving spread (wrt the population) of the risk of disease onset, leads to a lower expected financial cost of providing health care, and vice versa if it is strictly convex. Thus, the curvature of $TC^e(\rho)$ also figures into the determination of whether a GT will enhance welfare. Moreover, it is important to recognize that, due to the assumptions of full insurance, unrestricted provision of surveillance costs, as well as separability of cost and physiological aspects of health effects, individuals don't take cost considerations into account when choosing their privately optimal level of surveillance. Individuals do, however, recognize the implications of risk-rating resulting from possible GT results and so do take these cost considerations into account when deciding whether to obtain a GT

We now derive an expression for the curvature of the value function.

[16] In fact, without further restrictions, we cannot sign either $\frac{dTC^e}{d\rho}$ or $\frac{d^2TC^e}{d\rho^2}$.

$$\frac{d^2\widehat{v}(\rho)}{d\rho^2} = \left\{u''(y-TC^e(\rho))(-\frac{dTC^e}{d\rho})^2 - u'(y-TC^e(\rho))\frac{d^2TC^e}{d\rho^2}\right\} + \left\{p'^{ED}(\widehat{s})[\kappa_L-\kappa_E]\frac{d\hat{s}}{d\rho}\right\} \quad (13)$$

where the first line reflects the financial implications of categorization through its effect on differential insurance costs. Since one risk group pays more for insurance while the other less, although perhaps surprisingly from the above argument we can't say which is which, the first term in line 1 reflects the effect of premium risk. This contributes to the possibility that the value function is concave, reflecting the negative impact of premium risk on expected utility. If $TC^e(\rho)$ is linear, the second term vanishes since in that case the additional cost associated with being assigned to one of the risk categories is exactly counterbalanced by the possibility of being assigned to the other (i.e., expected cost implications are zero). However, if this cost function is strictly convex this term contributes further to the negative effect of the first term - since convexity implies a rise in average cost of health care provision over the two groups due to the GT, and vice versa if it is strictly concave. Finally, the last term is positive and reflects the efficiency benefit of the information arising from more effective targeting of surveillance (i.e., reducing the overall number of individuals with disease onset who are detected at a late stage). If this latter effect is strong enough, then the value function will be convex and individuals will perceive a benefit to the lottery over probabilities as generated by a GT. Thus, we have:

Proposition 1. *Assume that risk rating is applied and, both before and after a genetic test, individuals choose the levels of surveillance such that they are optimal from a private perspective.*

1. If $u''(\bullet)=0$, *and* $\frac{d^2TC^e}{d\rho^2}\leq 0$ *then* $\frac{d^2\widehat{v}(\rho)}{d\rho^2}>0\ \forall\rho$. *Individuals' expected welfare will increase with a GT.*

2. If $u''(\bullet)<0$ *and* $\frac{d^2TC^e}{d\rho^2}=0$

a) there is a negative effect on individuals' expected welfare due to income risk. Individuals might still accept a genetic test, but the increase in expected welfare will be smaller due to financial risk-bearing considerations.

b) and

$$p'^{ED}(\widehat{s})[\kappa_L-\kappa_E]\frac{d\hat{s}}{d\rho} < -u''(y-TC^e(\rho))(-\frac{dTC^e}{d\rho})^2 \Leftrightarrow \frac{d^2\widehat{v}(\rho)}{d\rho^2}<0, \quad (14)$$

in which case individuals will reject a genetic test with a marginal increase of information on risk type.

With risk neutrality and a health care cost function that is linear in ρ, a genetic test will have only a positive efficiency effect in that individuals will be able to more

effectively tailor their level of surveillance to the actual probability of disease. Under risk aversion, a genetic test has also a negative effect on expected welfare due to premium risk and so a genetic test enhances private welfare only if the efficiency benefits from better targeted surveillance exceeds the cost of premium risk. Individuals are cognizant of the premium risk effect of obtaining a GT and so nobody is made worse off through the opportunity to obtain one. However, note that in consideration of the premium risk associated with risk-rating and the inherent moral hazard implications of individuals not taking into account the externality of their surveillance decisions on the insurance pool's (health care provider's) financial costs, the potential welfare benefits of genetic testing are limited by a variety of second-best considerations. If premium risk could be insured against and if the externality in choice of surveillance could be eliminated, welfare would be enhanced further and some GTs that are 'unacceptable' in the context of risk rating could be worthwhile.

In the model here individuals are homogeneous and so all individuals face the same trade-offs and so either everyone obtains a test and subjects himself to premium risk in exchange for the improved efficiency of surveillance - or not as the case may be. This analysis would become more complicated if individuals had differing tastes regarding risk aversion or other subjective elements in regards to preferences reflected in the expression $EU(s) = u(y - \overline{TC}) - \rho[(1 - p^{ED}(s))\kappa_L + p^{ED}(s)\kappa_E] - \Phi(s)$. Consider, for example, that some individuals subjective (non-financial) benefits of early detection is greater than for others. Those who place a higher value on early versus late detection will value the genetic test more highly. No externality from taking the test arises as long as insurers can observe test results *and* determine who has taken the test. However, if indivdiuals can hide test results, and whether they have taken a test, then those who take the test and test negative will have an incentive to present their test results while those who test positive cannot be distinguished from those who do not take the test and so may impose a negative externality on those who would (otherwise) prefer not to take the test.[17] We leave aside issues that arise under such complications for future research.

A fuller exploration of the effects of genetic tests becoming available in an environment of risk rating of insurance policies requires that we drop the restriction that information content about risk classes is treated as initially infinitessimal ($\varepsilon = 0$). In any case, the possibility that risk classification resulting from the genetic test leads to premium variation and possibly a reduction in welfare is not so surprising. It is well known that under mandatory full insurance or partial insurance with pooling contracts, risk rating according to some exogenously specified difference in probability of financial loss leads to (pure)

[17] Note, for example, the models of Doherty and Thistle (1996), Ligon and Thistle (1996), and Hoy (2005), Hoel, et al. (2006), and Rees and Apps (2006)..

premium risk and a reduction in ex ante welfare. Even if one has adverse selection costs in such a model, an ex ante welfare loss due to improved information for firms about risk types is generically possible for various scenarios involving pooling equilibria (see Hoy and Polborn (2000), Hoy (2006), Polborn, Hoy and Sadanand (2006)). However, in our model there are further effects to consider. Firstly, changes in information about the probability of disease affects individuals' optimal choice of surveillance which impacts directly on their utility. Physiological health costs and benefits are linear in the probability of disease in our model. Thus, for these effects there is no risk bearing cost associated with a mean preserving spread in the probability distribution of disease as is generated by a GT. Thus, conditional on s being fixed at any given level - and in particular the optimal level chosen in the absence of the genetic test - the expected utility derived from health effects, which is $-\rho^0[(1-p^{ED}(\overline{s}))\kappa_L+p^{ED}(\overline{s})\kappa_E]-\Phi(\overline{s})$, without a GT is the same as the ex ante expected utility from health benefits generated by taking the test (i.e.,

$$\begin{aligned}
& \eta_L[-\rho^L[(1-p^{ED}(\overline{s}))\kappa_L+p^{ED}(\overline{s})\kappa_E]-\Phi(\overline{s})] \\
& +\eta_H[-\rho^H[(1-p^{ED}(\overline{s}))\kappa_L+p^{ED}(\overline{s})\kappa_E]-\Phi(\overline{s})] \\
= \; & -(\eta_L\rho^L+\eta_H\rho^H)\{[(1-p^{ED}(\overline{s}))\kappa_L+p^{ED}(\overline{s})\kappa_E]-\Phi(\overline{s})\} \\
= \; & -\rho^0[(1-p^{ED}(\overline{s}))\kappa_L+p^{ED}(\overline{s})\kappa_E]-\Phi(\overline{s})
\end{aligned}$$

However, individuals respond to information about ρ by altering their choice of s in a way that increases expected utility conditional on ρ and so this generates an efficiency gain in the use of surveillance resulting from the GT from the individual's perspective, hence raising ex ante expected utility. As noted above, it is this aspect of the value of information, which is positive, that is reflected in the second line of equation (13), and so contributes to the possibility of the value function $v(p)$ being convex which would imply an ex ante utility gain from taking the test.

So now consider an initial value of $\varepsilon > 0$ and see how an increase in ε affects expected utility and costs. This way we can address the effects of an increasingly informative signal rather than one that offers a little information starting from none. This is important because it is not convincing to imagine that, for example, the function $v(p)$ is necessarily uniformly convex or concave. Also, this methodological approach is more useful when comparing the private insurance model here (with risk-rating) to the public insurance model (or private insurance with community rating). So, in this case we have (where for notational convenience we omit the $\widehat{\ }$ notation on s^H and s^L)

$$\begin{aligned}
EU^A \; = \; & \eta_L\{u(y-\overline{TC}^L)-\rho^L[(1-p^{ED}(s^L))\kappa_L+p^{ED}(s^L)\kappa_E]-\Phi(s^L)\} \\
& +\eta_H\{u(y-\overline{TC}^H)-\rho^H[(1-p^{ED}(s^H))\kappa_L+p^{ED}(s^H)\kappa_E]-\Phi(s^H)\} \quad (15)
\end{aligned}$$

remembering that individuals treat $\overline{TC}^L$ and $\overline{TC}^H$ as unaffected by their choice of surveillance, but these costs do end up depending on those choices (see relevant equation (11) for this effect). Thus, in terms of the value function, we need to account for equilibrium values for $\overline{TC}^L$ and $\overline{TC}^H$ which we will write as TC_e^L and TC_e^H . For convenience, break the above expression up into it's component parts, with $EU^A = \eta_L EU^L + \eta_H EU^H$, and separately write out $\frac{dEU^i}{d\varepsilon}$ for $i = L, H$.

$$\frac{dEU^A}{d\varepsilon} = \eta_L \frac{dEU^L}{d\varepsilon} + \eta_H \frac{dEU^H}{d\varepsilon} \tag{16}$$

with

$$\begin{aligned}\frac{dEU^L}{d\varepsilon} &= u'(y - TC_e^L) \cdot \left(-\frac{dTC_e^L}{d\varepsilon}\right) - \frac{d\rho^L}{d\varepsilon}[(1 - p^{ED}(s^L))\kappa_L + p^{ED}(s^L)\kappa_E] \\ &\quad -\rho^L \left[-\frac{dp^{ED}}{ds^L}\frac{ds^L}{d\rho^L}\frac{d\rho^L}{d\varepsilon} \cdot (\kappa_L - \kappa_E)\right] - \frac{d\Phi(s^L)}{ds^L}\frac{ds^L}{d\rho^L}\frac{d\rho^L}{d\varepsilon}\end{aligned} \tag{17}$$

and

$$\begin{aligned}\frac{dEU^H}{d\varepsilon} &= u'(y - TC_e^H) \cdot \left(-\frac{d\overline{TC}^H}{d\varepsilon}\right) - \frac{d\rho^H}{d\varepsilon}[(1 - p^{ED}(s^H))\kappa_L + p^{ED}(s^H)\kappa_E] \\ &\quad -\rho^H \left[-\frac{dp^{ED}}{ds^H}\frac{ds^H}{d\rho^H}\frac{d\rho^H}{d\varepsilon} \cdot (\kappa_L - \kappa_E)\right] - \frac{d\Phi(s^H)}{ds^H}\frac{ds^H}{d\rho^H}\frac{d\rho^H}{d\varepsilon}\end{aligned} \tag{18}$$

Note the following (to be substituted into the above two equations):

$$\frac{d\rho^L}{d\varepsilon} = -\frac{1}{\eta_L}\ ,\ \frac{d\rho^H}{d\varepsilon} = \frac{1}{\eta_H} \tag{19}$$

and

$$\frac{dTC_e^L}{d\varepsilon} = \frac{dTC_e^L}{d\rho^L} \cdot \frac{d\rho^L}{d\varepsilon}\ ,\ \frac{dTC_e^H}{d\varepsilon} = \frac{dTC_e^H}{d\rho^H} \cdot \frac{d\rho^H}{d\varepsilon} \tag{20}$$

Using the above, we can write:

$$\begin{aligned}\frac{dEU^A}{d\varepsilon} &= u'(y - TC_e^L) \cdot \left(\frac{dTC_e^L}{d\rho^L}\right) - u'(y - TC_e^H) \cdot \left(\frac{dTC_e^H}{d\rho^H}\right) \\ &\quad +[p^{ED}(s^H) - p^{ED}(s^L)] \cdot [\kappa_L - \kappa_E] \\ &\quad -\rho^L \frac{dp^{ED}}{ds^L}\frac{ds^L}{d\rho^L}(\kappa_L - \kappa_E) + \frac{d\Phi}{ds^L}\frac{ds^L}{d\rho^L} \\ &\quad +\rho^H \frac{dp^{ED}}{ds^H}\frac{ds^H}{d\rho^H}(\kappa_L - \kappa_E) - \frac{d\Phi}{ds^H}\frac{ds^H}{d\rho^H}\end{aligned} \tag{21}$$

Expressions for $\frac{dTC_e^L}{d\rho^L}$ and $\frac{dTC_e^H}{d\rho^H}$ are of the same form as that in the expression in equation (11) for $\frac{dTC^e}{d\rho}$. We can provide some intuition about each line of the four lines above:

Line 1 reflects an increase in risk effect due to different marginal utilities at the two net income levels if $u'' < 0$. One might expect that the more likely scenario is $TC_e^H > TC_e^L$

which favours the first line being negative. However, the relative sizes of $\frac{dTC_e^L}{d\rho^L}$ and $\frac{dTC_e^H}{d\rho^H}$ are not clear as this depends on the curvature of the function $TC^e(\rho)$. Moreover, as argued earlier it isn't even clear what is the sign of $\frac{dTC^e}{d\rho}$ and so without further restrictions we cannot determine the sign of the first line. However, for $TC^e(\rho)$ increasing and linear in ρ, or a fortiori strictly convex in ρ, we have $TC_e^H > TC_e^L$ and $u'(y - TC_e^H) > u'(y - TC_e^L)$ and so the first line would be negative.

line 2: Conditional on getting the disease, the expected cost of treatment depends on whether it is detected early or late. Since increased information about who is a high risk type and who is a low risk type leads to a shift in surveillance activity from low to high risk types ($\widehat{s}_H > \widehat{s}_L$), where its value in early detection is higher, the net effect of this aspect of improved information on expected utility is positive (i.e., enhanced targeting efficiency of surveillance). So this line, which is positive, represents an efficiency gain in the use of self-protection.

lines 3 and 4: Each line is the marginal effect on the decisions regarding s of L-types and H-types, respectively (i.e., their privately optimal decisions). Although these "move" in opposite directions, since the decisions are optimal ones the envelope theorem applies and each term is zero.

NOTE: To see that each of lines 3 and 4 is zero is more easily seen if rearranged as:

$$-\frac{d\widehat{s}^L}{d\rho^L} \cdot \left[\rho^L \frac{dp^{ED}}{d\widehat{s}^L}(\kappa_L - \kappa_E) - \frac{d\Phi}{d\widehat{s}^L}\right] \tag{22}$$

$$\frac{d\widehat{s}^H}{d\rho^H} \cdot \left[\rho^H \frac{dp^{ED}}{d\widehat{s}^H}(\kappa_L - \kappa_E) - \frac{d\Phi}{d\widehat{s}^H}\right] \tag{23}$$

B) Community rating (Publicly provided health insurance with no user-pay provision)

With community rating individuals are charged the population average costs after a genetic test is conducted. This means that there is no premium risk associated with a GT. One might expect this aspect of community rating would enhance the prospects for a GT to improve welfare. However, under community rating we presume that not only are those who obtain a GT assessed the same cost for health insurance regardless of test result, but also each individual's cost assessment is the same whether or not he/she obtains a test. Under risk rating (and assuming insurers can observe whether a GT has been taken) individuals who do not want to expose themselves to the financial implications of genetic testing, which includes the phenomenon of premium risk, can maintain their ignorance and avoid any cost implications. Thus, from an ex ante position individuals can never become worse off because of the availability of a GT. This is not the case under community rating. If all others take a GT and adjust their surveillance activities

accordingly, a single individual cannot avoid the implications on the average cost of health care provision. Hence, if the implication of individuals taking the GT leads to adjustments in surveillance which increase the average cost of provision, as was earlier seen to be possible (i.e., if $TC''(\rho) > 0$), there is no mechanism for an individual to opt out to avoid such cost increases. Moreover, there is no incentive for an individual to *not* accept a GT since a single individual's costs of doing so is passed on to the insurance pool (i.e., if the implication of the GT leads to adjustments in surveillance which increase the average expected cost of provision of health care services). Individuals who are not affected by cost considerations of taking a GT will always do so due to the (health) efficiency benefits of improved assignation of surveillance according to risk level. Thus, it is possible that all individuals will voluntarily submit to a GT even though it ultimately makes everyone worse off. To see explicitly why individuals always voluntarily choose to have a GT even when it may lead to lower welfare for all consider the following more formal argument. Financial cost is independent both of whether one has taken a test or, if one has, it is independent of the test result. Thus, the individual compares choosing s without information about ρ (so perceiving $\rho = \rho^0$) to choosing s conditional on taking a test and discovering ρ takes on a value of ρ^H with probability η_H or a value of ρ^L with probability η_L with $\rho^0 = \eta_H \rho^H + \eta_L \rho^L$. The individual's decision is based only on that part of expected utility associated with physiological health effects, including the disutility cost of surveillance, and so the individuals' effective objective function is

$$EU^A = -\rho[(1 - p^{ED}(s))\kappa_L + p^{ED}(s)\kappa_E] - \Phi(s) \tag{24}$$

Artificially fixing the value of s at its optimal value if $\rho = \rho^0$, say $s = \widehat{s}$, taking a GT is equivalent to submitting to a mean preserving spread in the probability ρ. EU^A is linear in ρ and so conditional on not re-optimizing on s conditional on revelation of ρ^L or ρ^H, the individual views such a lottery as neutral. However, the individual can increase conditional expected utility in each case by re-optimizing on s and so the individual, in ignoring any possible financial costs to the insurance pool of his choice, or that of others, to have the GT and adjust s accordingly, chooses the GT even if, in the end, it makes him worse off. Now we show it may lead to him, and everyone else, becoming worse off.

Repeat the same steps as were taken in the subsection on risk rating but making the appropriate adjustments, skipping to the case of $\varepsilon > 0$. In particular, let $\overline{TC}^A$ be the average (financial) cost of providing health care services to the insurance pool under community rating. If individuals obtain GTs, then this becomes

$$\overline{TC}^A = \eta_L \overline{TC}^L + \eta_H \overline{TC}^H$$

That is, all individuals pay the per capita cost of health care provision based on the weighted average of the cost of provision for each risk type. Recall that choice of surveil-

lance level depends on perceived probability of disease (ρ^L and ρ^H for low and high risk types respectively) as in the scenario under risk rating and these choices are independent of individuals' income net of insurance costs. Therefore, all steps in the subsection on risk rating are the same for determining the value of information except for this financial aspect of community rating and the fact that one cannot avoid cost implications by not taking a genetic test. In particular, as before, in terms of the value function, we need to account for equilibrium values for $\overline{TC}^L$ and $\overline{TC}^H$ which we will write as TC_e^L and TC_e^H. So, in the case of community rating we have

$$\begin{aligned} EU^A &= \eta_L\{u(y-TC_e^A)-\rho^L[(1-p^{ED}(s^L))\kappa_L+p^{ED}(s^L)\kappa_E]-\Phi(s^L)\} \\ &\quad +\eta_H\{u(y-TC_e^A)-\rho^H[(1-p^{ED}(s^H))\kappa_L+p^{ED}(s^H)\kappa_E]-\Phi(s^H)\} \end{aligned} \tag{25}$$

remembering that individuals treat TC_e^A as unaffected by their choice of surveillance, but of course cost does end up depending on the choices that individuals make (see relevant equation (11) for this effect). For convenience, again break the above expression into its component parts with $EU^A = \eta_L EU^L + \eta_H EU^H$, and separately write out $\frac{dEU^j}{d\varepsilon}$ for $i = L, H$.

$$\frac{dEU^A}{d\varepsilon} = \eta_L \frac{dEU^L}{d\varepsilon} + \eta_H \frac{dEU^H}{d\varepsilon} \tag{26}$$

with

$$\begin{aligned} \frac{dEU^L}{d\varepsilon} &= u'(y-TC_e^A)\cdot\left(-\frac{dTC_e^A}{d\varepsilon}\right)-\frac{d\rho^L}{d\varepsilon}[(1-p^{ED}(s^L))\kappa_L+p^{ED}(s^L)\kappa_E] \\ &\quad -\rho^L\left[-\frac{dp^{ED}}{ds^L}\frac{ds^L}{d\rho^L}\frac{d\rho^L}{d\varepsilon}\cdot(\kappa_L-\kappa_E)\right]-\frac{d\Phi(s^L)}{ds^L}\frac{ds^L}{d\rho^L}\frac{d\rho^L}{d\varepsilon} \end{aligned} \tag{27}$$

and

$$\begin{aligned} \frac{dEU^H}{d\varepsilon} &= u'(y-TC_e^A)\cdot\left(-\frac{dTC_e^A}{d\varepsilon}\right)-\frac{d\rho^H}{d\varepsilon}[(1-p^{ED}(s^H))\kappa_L+p^{ED}(s^H)\kappa_E] \\ &\quad -\rho^H\left[-\frac{dp^{ED}}{ds^H}\frac{ds^H}{d\rho^H}\frac{d\rho^H}{d\varepsilon}\cdot(\kappa_L-\kappa_E)\right]-\frac{d\Phi(s^H)}{ds^H}\frac{ds^H}{d\rho^H}\frac{d\rho^H}{d\varepsilon} \end{aligned} \tag{28}$$

Note the following (to be substituted into the above two equations):

$$\frac{d\rho^L}{d\epsilon} = -\frac{1}{\eta_L}\ ,\ \frac{d\rho^H}{d\varepsilon} = \frac{1}{\eta_H} \tag{29}$$

and

$$\frac{dTC_e^A}{d\varepsilon} = \eta_L\cdot\frac{dTC_e^L}{d\rho^L}\cdot\frac{d\rho^L}{d\varepsilon}+\eta_H\cdot\frac{dTC_e^H}{d\rho^H}\cdot\frac{d\rho^H}{d\varepsilon} \tag{30}$$

Using the above, we can write:

$$\begin{aligned}\frac{dEU^A}{d\varepsilon} &= u'(y - TC_e^A) \cdot \left[\frac{dTC_e^L}{d\rho^L} - \frac{dTC_e^H}{d\rho^H}\right] \\ &+[p^{ED}(s^H) - p^{ED}(s^L)] \cdot [\kappa_L - \kappa_E] \\ &-\rho^L \frac{dp^{ED}}{ds^L}\frac{ds^L}{d\rho^L}(\kappa_L - \kappa_E) + \frac{d\Phi}{ds^L}\frac{ds^L}{d\rho^L} \\ &+\rho^H \frac{dp^{ED}}{ds^H}\frac{ds^H}{d\rho^H}(\kappa_L - \kappa_E) - \frac{d\Phi}{ds^H}\frac{ds^H}{d\rho^H} \end{aligned} \tag{31}$$

Each line in the above equation can be interpreted in the same way as for equation (21) in the case of risk-rating *except* for the first line. Since community rating means each person pays the same price for insurance, there is no premium risk effect and so risk aversion ($u'' < 0$) is irrelevant. However, people assigned to different risk classes choose different levels of surveillance and face different probabilities of disease and so there are financial implications as measured by the term $\left[\frac{dTC_e^L}{d\rho^L} - \frac{dTC_e^H}{d\rho^H}\right]$.[18] If the cost function is linear in ρ this term disappears since this would imply that the per capita cost of providing health care is unaffected by a mean preserving spread in disease probabilities. If $TC_e(\rho)$ is strictly convex, then $\frac{dTC^L}{d\rho^L} < \frac{dTC^H}{d\rho^H}$ (due to $\rho^L < \rho^H$) and the expected cost of health care provision in the presence of information from genetic testing will rise and so the first term in equation (31) will be negative, and vice versa if $TC_e(\rho)$ is strictly concave.

Line 2 again reflects the efficiency gain in the use of surveillance. In fact, even the value of this efficiency gain is the same as in the case of risk-rating since it is only physiological health effects that drive the relevant decisions (i.e., levels of surveillance chosen by each type) with zero income effects present and so the way health insurance is priced doesn't impact on this effect. And again lines 3 and 4 each represent the marginal effect on the decisions regarding s of L-types and H-types, respectively (i.e., their privately optimal decisions). Again, the envelope theorem applies and each of these terms is zero. Thus, we have the following proposition.

Proposition 2. *Under community rating individuals will always voluntarily submit to a (costless) genetic test. However, due to noninternalized cost implications, the resulting welfare implications may be positive or negative.*

1. If $\frac{d^2TC_e}{d\rho^2} \leq 0$ *individuals' expected welfare will increase as a result of introducing GTs.*

2. If $\frac{d^2TC_e}{d\rho^2} > 0$ *there is a negative effect on individuals' expected welfare due to a resulting increase in per capita cost of health care provision. Individuals will experience*

[18] Recall that it is possible even that $\frac{dTC^e}{d\rho} < 0$. Let us assume here that it is positive, although it isn't important to do so.

an increase (decrease) in expected welfare if

$$[p^{ED}(s^H) - p^{ED}(s^L)] \cdot [\kappa_L - \kappa_E] > (<) \ -u'(y - TC_e^A) \cdot \left[\frac{dTC_e^L}{d\rho^L} - \frac{dTC_e^H}{d\rho^H} \right] \tag{32}$$

An interesting question is whether there are circumstances under which a GT would be accepted voluntarily in both scenarios of risk-rating and community rating with the result being a decrease in welfare for the scenario of community rating but an increase in welfare under risk-rating. Under community rating GTs are always accepted and a decrease in welfare is the result if the inequality $<$ holds in equation (32). A necessary condition for the same increase in information to lead to an increase in welfare under risk-rating (see also equation (21) is that

$$u'(y - TC^L) \cdot \frac{dTC_e^L}{d\rho^L} - u'(y - TC_e^H) \cdot \frac{dTC_e^H}{d\rho^H} > u'(y - TC_e^A) \cdot \left[\frac{dTC_e^L}{d\rho^L} - \frac{dTC_e^H}{d\rho^H} \right]$$

where we also require that the *RHS* of this expression is less than the negative of the efficiency gain from information from the GT, i.e., $[p^{ED}(s^H) - p^{ED}(s^L)] \cdot [\kappa_L - \kappa_E]$, while the *LHS* is not. The above inequality is equivalent to

$$\frac{dTC_e^L}{d\rho^L} \left[u'(y - TC_e^L) - u'(y - TC_e^A) \right] > \frac{dTC_e^H}{d\rho^H} \left[u'(y - TC_e^H) - u'(y - TC_e^A) \right]$$

For a GT to decrease welfare under community rating requires that the function $TC_e(\rho)$ be strictly convex, although it needn't be monotonic. Consider the particular case where $TC_e(\rho)$ is U-shaped and $TC_e(\rho^L) < TC_e(\rho^A) < TC_e(\rho^H)$ as depicted in Figure 6. The *LHS* is positive as $\frac{dTC_e^L}{d\rho^L} < 0$ and, since $TC_e^L < TC_e^A$, $\left[u'(y - TC_e^L) - u'(y - TC_e^A) \right] < 0$. The relatives sizes of ρ^L, ρ^0, and ρ^H in Figure 6 favour the *RHS* to be small and so as long as $\frac{dTC_e^H}{d\rho^H}$ is not 'too large' the above inequality will hold. On the other hand, if $TC_e(\rho)$ is monotonically increasing so that $\frac{dTC_e^L}{d\rho^L} > 0$ we have the *LHS* being negative and the *RHS* being positive so the inequality would not hold.

Insert Figure 6 about here.

Note that the expected (average) cost implications are the same for consumers in both insurance regimes. However, increased information may reduce the premium risk effect in the private regime if $\frac{\partial TC_e^L}{\partial \rho_L} < 0$.[19]

[19] Note that this result does not imply that after GTs the consumers in the private insurance scenario are better off than those in the public regime. They are not, but they do take the 'correct signal' given their regime to take the test.

2.2 Socially optimal level of surveillance and social welfare effect of genetic tests

We have seen in the previous section that a GT will never lead to worsening of individual's welfare under risk-rating provided individuals can demonstrate whether or not they have obtained such a test. This follows simply because an individual can avoid the negative impact of the premium risk if he views it as dominating the efficiency benefits of the information about risk of disease. In the case of community rating everyone pays the same price for insurance, whether they have had a GT or not and, if they have had a test, the price also does not depend on its result. If the equilibrium (financial) cost function for health care provision is strictly convex in the probability of disease, the resulting adjustments in surveillance activities after individuals know their risk type will lead to an increase in the average cost of health care treatment. This cost increase could dominate the effect of the efficiency gains (in health terms) from changes in surveillance activities. Due to community rating and the usual moral hazard effect from insurance, individuals can't avoid these effects by not having the test and it is always individually rational to obtain the test even if the resulting equilibrium makes all individuals worse off. In fact, perhaps rather counter-intuitively, it is even possible that the information from a GT could be adopted in both scenarios of risk-rating and community rating with a welfare improvement occurring under risk-rating but a worsening of welfare occurring under community rating. Here we investigate further the implications of these second-best considerations.

Individuals make their decision on how much surveillance to demand based on the physiological health costs and benefits and without taking into account what effect the new level of surveillance might have on the costs of provision of health care. That is why the socially optimal level of surveillance, which would be determined by a social planner, will generally deviate from the private choice - a standard moral hazard effect from insurance coverage. Due to separability of the utility function between financial considerations, $u(y-\overline{TC})$, and considerations of health characteristics, $-\rho[(1-p^{ED}(s))\kappa_L+p^{ED}(s)\kappa_E]-\Phi(s)$, the privately optimal choice of s is the same - conditional on ρ - under risk-rating or community rating. Therefore, we can describe the difference between the privately optimal choice of surveillance, $\widehat{s}$, the choice of surveillance that would minimize cost of health care provision, $\widetilde{s}$, and the socially optimal choice of surveillance, s^*, conditional on a given perceived probability of disease, ρ, in the same way for both pricing scenarios. What differs between the two insurance scenarios, however, are the financial implications of genetic testing and hence the incentives for obtaining genetic tests.

We have assumed that $p^{ED}(s)$ is concave while $\Phi(s)$ and $C(s)$ are convex, which together imply that $EU(s)$ is concave in s while $TC(s)$ is convex in s. For simplicity, let

us assume in all cases strict concavity/convexity as the case may be. Moreover, assume $EU(s)$ attains a private maximum at $\widehat{s}$, as done earlier, and also assume that $TC(s)$ attains a minimum at $\widetilde{s}$, where $\widehat{s}, \widetilde{s} \in (\underline{s}, \overline{s})$. We can characterize three sets of comparisons based on how the privately optimal choice deviates from the socially optimal choice, s^*. We refer to these cases as (1) under-utilitzation of surveillance ($\widehat{s} < s^*$), (2) appropriate utilization ($\widehat{s} = s^*$), and (3) over-utilitzation ($\widehat{s} > s^*$). As will become apparent below, it follows that in these three cases we also have (1) $\widehat{s} < s^* < \widetilde{s}$, (2) $\widehat{s} = \widetilde{s} = s^*$, and (3) $\widehat{s} > s^* > \widetilde{s}$.

First consider the case of under-utilization (Figure 7). The shape of $EU(s)$ is independent of the individuals income, and hence the cost of insurance which the individual treats as exogenous. Under-utilization (by definition) implies that at the privately optimal level ($s = \widehat{s}$) an increase (i.e., at least a small increase) in s by all individuals leads to an increase in the value of expected utility which in turn can occur only if $TC(s)$ is falling at $s = \widehat{s}$. That is; since the envelope theorem applies at $s = \widehat{s}$, this must mean that $TC(s)$ must be falling in order to generate an improvement in welfare, and so $TC(s)$ must achieve its minimum at a value $\widetilde{s} > \widehat{s}$. The socially optimal value for s must be less than $\widetilde{s}$ since once s reaches the level $\widetilde{s}$ the financial advantage from further increases in s will have already been dissipated and $EU(s)$ is also falling in terms of physiological health implications of increased surveillance. This case is demonstrated in Figure 7. Below we also illustrate the required marginal condition for the socially optimal value of s. At the social optimum, the marginal reduction in EU from an increase in s from changes to physiological health effects is just counter-balanced by the marginal reduction in the per capita financial cost of health care. This latter effect is not internalized by the individual decision maker due to the fact that the financial effects of surveillance on early detection, as well as the direct financial cost of s, are assumed covered by insurance.

Insert Figure 7 about here.

The case of over-utilitzation is essentially the opposite of under-utilitzation (see Figure 8). This occurs if the value of s at which $TC(s)$ is minimized is less than that at which $EU(s)$ is maximized. Finally, the case of appropriate utilization ($\widehat{s} = s^*$) occurs where the two curves $TC(s)$ and $EU(s)$ attain their minimum and maximum values, respectively, at the same value of s. This is not a generic result but is a useful benchmark case for demarcating possibilities as we see below.

Insert Figure 8 about here.

Earlier we showed that an increase in ρ leads to an increase in $\widehat{s}$. A similar (simple) comparative static analysis demonstrates that an increase in ρ also leads to an increase in

$\widetilde{s}$. So an increase in the probability of disease shifts the $EU(s)$ curve downwards and its maximum point 'to the right', while the $TC(s)$ curve is shifted upwards and its minimum point is also shifted 'to the right'. The effect on the socially optimal point s^*, however, is determined by how the slopes of the two curves change at a value(s) intermediate between $\widehat{s}$ and $\widetilde{s}$. It turns out that s^* may either increase or decrease when ρ increases, a relationship which we explore below. But first we describe the mathematical derivation of the marginal conditions characterizing the socially optimal level of surveillance. This involves a social planner choosing a level $s = s^*$ to maximize $EU(s)$ but, unlike individuals private decision making behaviour, the planner takes into account the effect of surveillance on total health care costs, $\frac{\partial TC}{\partial s}$. The first order condition, which we denote by FOC^* is

$$u'(y-TC(s^*))\cdot[\rho\cdot p^{ED\prime}(s^*)(C^{DL}-C^{DE})-C'(s^*)]+\rho\cdot p^{ED\prime}(s^*)\cdot(\kappa_L-\kappa_E)-\Phi'(s^*)=0 \quad (33)$$

For the second order condition, SOC^*, we get

$$u''(y-TC(s^*))\left(-\frac{\partial TC}{\partial s}|_{s^*}\right)^2+u'(y-TC(s^*))[\rho\cdot p^{ED\prime\prime}(s^*)(C^{DL}-C^{DE})-C''(s^*)] \quad (34)$$

$$+\rho\cdot p^{ED\prime\prime}(s^*)\cdot(\kappa_L-\kappa_E)-\Phi''(s^*)<0$$

where

$$\frac{\partial TC}{\partial s}|_{s^*}=-\rho\cdot p^{ED\prime}(s^*)(C^{DL}-C^{DE})+C'(s^*). \quad (35)$$

Similarly as in the previous section, if $\Phi'(\underline{s}), C'(\underline{s})>0$, there will be a critical level for the probability of disease $\underline{\rho^*}>0$, below which the resulting socially optimal level of surveillance is the smallest possible one $\underline{s}$. In what follows, we focus only on the range of probabilities of disease, for which $s^*>\underline{s}$.

In order to see the relationship between the probability of disease and the socially optimal level of surveillance, we apply the implicit function theorem on equation (33) and get

$$\frac{ds^*}{d\rho}=-\frac{\left\{\begin{array}{c}-u''(y-TC^*)\cdot\left(\frac{\partial TC^*}{\partial\rho}\right)\cdot\left(-\frac{\partial TC}{\partial s}|_{s^*}\right)\\ +p^{ED\prime}(s^*)[u'(y-TC^*)(C^{DL}-C^{DE})+(\kappa_L-\kappa_E)]\end{array}\right\}}{SOC^*|_{s=s^*}}?0 \quad (36)$$

where

$$\frac{\partial TC^*}{\partial\rho}=p^{ED}(s^*)C^{DE}+(1-p^{ED}(s^*))C^{DL}, \quad (37)$$

$$-\frac{\partial TC}{\partial s}|_{s^*}=\rho\cdot p^{ED\prime}(s^*)(C^{DL}-C^{DE})-C'(s^*), \quad (38)$$

and $SOC^*|_{s=s^*}$ is the expression in equation (34). Note that in describing the planner's problem we need to recognize that the interpretation of cost as a function of ρ is different

from that in the private optimization problem where ρ induces choice $\widehat{s}(\rho)$ and so leads to $TC^e(\rho) = TC(\widehat{s}(\rho), \rho)$, the resulting cost from the equilibrium. For the social optimum, the planner facing disease probability ρ is not constrained to choose the privately optimal value of surveillance but can pick whatever value of s that maximizes the value of individual welfare (i.e., taking into account cost implications). This implies some schedule or relationship $s^*(\rho)$ and hence some resulting total cost $TC^*(\rho) = TC(s^*(\rho), \rho)$, although this function $s^*(\rho)$ is not a constraint but rather an implication of the planner's optimization decision.[20] Comparing these schedules $\widehat{s}(\rho)$ and $s^*(\rho)$, as well as $TC^e(\rho)$ and $TC^*(\rho)$ is of interest in considering policy implications of genetic testing as developed below.

It is helpful to rewrite the first-order condition in two ways:

$$FOC^*a: \ \rho \cdot p^{ED\prime}(s^*) \cdot [\kappa_L - \kappa_E] - \Phi'(s^*) = -u'(y - TC(s^*)) \left[\rho \cdot p^{ED\prime}(s^*)(C^{DL} - C^{DE}) - C'(s^*)\right]$$

and

$$FOC^*b: \ \rho \cdot p^{ED\prime}(s^*) \cdot \left[(\kappa_L - \kappa_E) + u'(y - TC(s^*))(C^{DL} - C^{DE})\right] = \Phi'(s^*) + u'(y - TC(s^*))C'(s^*)$$

The first equation above (FOC^*a) illustrates that the socially optimal level of surveillance equates the net marginal health benefits for individuals (i.e., $EU'(s^*)$ ignoring any effect on financial cost implications for health care) to the net marginal (financial) cost of providing health care. Notice than for the under-utilization case both these values are negative (see Figure 7) while for the over-utilization case both these values are positive (see Figure 9). The second equation (FOC^*b) reinterprets the socially optimal level of surveillance as that which equates the gross marginal benefit of surveillance to the gross marginal cost (i.e., for combined health and financial aspects). The gross marginal benefit is made up of that part due to physiological health benefits from early detection ($\rho \cdot p^{ED\prime}(s^*) \cdot (\kappa_L - \kappa_E)$) plus that part due to financial savings from early detection. The gross marginal cost is made up of that part associated with physiological aspects of surveillance plus that part due to direct financial cost of providing surveillance. Notice that the 'financial parts' are multiplied by the scale or conversion factor $u'(y - TC(s^*))$ to reflect the marginal utility value of dollar costs. Under risk neutrality, this conversion factor is unchanged by any change in ρ and hence any change in the level of TC. So an increase in ρ increases both the marginal health benefits and financial benefits of surveillance (LHS of FOC^*b) while leaving the marginal cost terms (RHS of FOC^*b) unchanged. Thus, an increase in ρ increases the marginal *net* benefit of surveillance which implies a corresponding increase in s^*.

[20] Hence, unlike the term $\frac{dTC^e}{d\rho}$ used in the derivation of the welfare implications of a change in ρ for the value function shown in equations (11) and (12), there is no need for any indirect effect from $\frac{ds^*}{d\rho}$ to be considered in the planner's problem.

Now, consider the case of risk aversion, $u''(\bullet) < 0$. Since an increase in ρ increases TC, the scale factor $(u'(y - TC))$ on financial terms in FOC^*a (RHS) increases. So if $\frac{\partial TC}{\partial s}|_{s^*} < 0$ an increase in ρ enhances the effective net marginal financial benefit of surveillance (i.e., since an increase in s at s^* reduces this cost). Since an increase in ρ also (always) enhances the marginal net (physiological) health benefit of surveillance, it follows that under risk aversion and $\frac{\partial TC}{\partial s}|_{s^*} < 0$ we also have that $\frac{ds^*}{d\rho} > 0$. This is always so for the case of under-utilization of surveillance. However, if $\frac{\partial TC}{\partial s}|_{s^*} > 0$, the fact that an increase in ρ leads to higher TC and hence higher marginal utility of net income means the effective marginal financial cost of surveillance rises due to an increase in ρ (i.e., since an increase in s at s^* increases this cost in this case). Whether or not s^* will rise or fall due to an increase in ρ under these conditions depends on whether the increase in the marginal financial cost is greater or smaller than the associated increase in the marginal net health benefit of surveillance. We can summarize this result in the following proposition and corollary:

Proposition 3. *For the relationship between the probability of disease and the socially optimal level of surveillance we have that, under risk-aversion,* $u''(\bullet) < 0$*:*

1. $TC'(s^*) = C'(s^*) - \rho \cdot p^{ED\prime}(s^*)(C^{DL} - C^{DE}) \leq 0$ *is a sufficient condition for* $\frac{ds^*}{d\rho} > 0$.

2. If $TC'(s^*) = C'(s^*) - \rho \cdot p^{ED\prime}(s^*)(C^{DL} - C^{DE}) > 0$, *then*
$\frac{ds^*}{d\rho} \gtreqless 0 \Leftrightarrow TC'(s^*) \lesseqgtr \alpha$,
where

$$\alpha = \frac{p^{ED\prime}(s^*)[u'(y - TC^*)(C^{DL} - C^{DE}) + (\kappa_L - \kappa_E)]}{-u''(y - TC^*)[p^{ED}(s^*)C^{DE} + (1 - p^{ED}(s^*))C^{DL}]} \tag{39}$$

$$= \frac{p^{ED\prime}(s^*)[(C^{DL} - C^{DE}) + \frac{(\kappa_L - \kappa_E)}{u'(y - TC^*)}]}{A(y - TC^*)[p^{ED}(s^*)C^{DE} + (1 - p^{ED}(s^*))C^{DL}]} > 0 \tag{40}$$

and $A(y - TC^*) = -\frac{u''(y - TC^*)}{u'(y - TC^*)}$.

Corollary *In the case of under-utilization we have* $\frac{ds^*}{d\rho} > 0$ *for* $u''(\bullet) \leq 0$ *while in the case of over-utilization* $\frac{ds^*}{d\rho} > 0$ *for* $u''(\bullet) = 0$ *but the sign for* $\frac{ds^*}{d\rho}$ *is indeterminate if* $u''(\bullet) < 0$.

The intuition for the above results is more fully developed below. In the previous subsection it was shown that, when only the *non-financial* benefits and costs of surveillance are taken into consideration, the level of surveillance should increase as the probability of disease increases. The reason was that a higher probability of disease raises the marginal non-financial benefit of surveillance. Here, in addition, we have to consider the *financial* benefits and costs of surveillance. With risk-neutrality, the marginal utility of income, and hence the willingness to pay for surveillance, is constant. A higher probability of disease

increases the benefit of saving treatment costs by more surveillance, which along with the higher non-financial marginal benefit, is the reason for the optimal level of surveillance to increase.

With risk aversion, the marginal utility of income decreases in net income, and hence the willingness to pay for surveillance increases in income.

First assume that, at the initially optimal level of surveillance, the marginal savings of treatment costs exceed the marginal surveillance costs, $TC'(s^*) < 0$. Hence, a marginal increase of surveillance will increase net income and thus increase the willingness to pay for more surveillance. A higher probability of disease will, other things equal, increase both the financial and non-financial marginal benefit of surveillance. The increase of the marginal benefits of surveillance, together with the higher willingness to pay for surveillance, lead unambiguously to an increase of the optimal level of surveillance.

However, in case that the marginal financial costs of surveillance $C'(s^*)$ exceed the marginal financial savings $\rho \cdot p^{ED\prime}(s^*)(C^{DL} - C^{DE})$, so that $TC'(s^*) > 0$, all other things equal, an increase in the level of surveillance reduces net income and thus decreases the willingness to pay for more surveillance. The income effect of more surveillance, which is negative, counteracts the positive financial and non-financial effect of more surveillance when the probability of disease becomes larger. If the negative (indirect) income effect of surveillance is strong enough, i.e. if health care costs increase sufficiently fast in the level of surveillance, an increase of the probability of disease which, other things equal reduces net income, can even lead to a decrease of the optimal level of surveillance.[21]

Observing the above expressions, a negative relationship between the probability of disease and the socially optimal level of surveillance is more likely to result: (1) the smaller are the marginal savings of financial treatment and non-financial psychological costs when the disease is detected early rather than late (the smaller are $(C^{DL} - C^{DE})$ and $(\kappa_L - \kappa_E)$, and the less effective is s - the less sensitive is $p^{ED}(s^*)$ to the level of surveillance, i.e., the stronger is the curvature of $p^{ED}(s)$), (2) the larger are the marginal financial costs of surveillance $C'(s^*)$ (i.e., the faster the costs of surveillance increase in the level of surveillance), (3) the higher are the treatment costs in general ($\frac{\partial TC}{\partial \rho}$), and (4) the higher is the degree of absolute risk aversion.

We now develop some results concerning the pattern of over versus under-utilitzation of surveillance for different information scenarios (i.e., concerning the perceived probability of disease both in the absence and presence of genetic tests). It is certainly possible that both in the absence of a person having a genetic test ($\rho = \rho^0$) and for both risk types conditional on a genetic test ($\rho = \rho^L$ or ρ^H as the case may be), either all individuals

[21] Note that this is an indirect income effect since utility from income is separable from activity associated with any change in health status.

under-utilize or all individuals overutilize surveillance. It seems unlikely, however, that the extent to which this would be the case would be uniform over these different information sets. Below we show conditions under which one group may overutilize while another group under-utilizes surveillance. Thus, a single policy developed to try to rectify this problem, say rationing or taxing (through coinsurance payments) of surveillance in the former case or encouraging additional surveillance by some means in the latter case, would not be appropriate. We address this exercise using what one may consider the perhaps more plausible case of moderate surveillance costs such that, when the probability of disease increases, the socially optimal level of surveillance will increase.

Assumption 1: $TC'(s^*) < \alpha$ and hence $\frac{ds^*}{d\rho} > 0$ for all relevant values for ρ.

The following assumption is not intended to be a realistic expectation concerning an original scenario in the absence of a genetic test, but rather simply reflects a hypothetical starting point to allow us to develop an understanding of scenarios in which the schedules $s^*(\rho)$ and $\widehat{s}(\rho)$ may intersect, giving rise to the possibility that, conditional on having a GT, one risk type over-utitilizes surveillance while another type under-utilizes surveillance. We are not so concerned with the initial situation (i.e., whether untested individuals over or under-utilize surveillance).

Assumption 2: Before a genetic test is conducted, the private demand for and the socially optimal level of surveillance coincide, that is $\hat{s}(\rho^0) = s^*(\rho^0)$. Thus, for ρ^0 it holds that $TC'(s^*(\rho^0)) = 0$, and hence, $\frac{C'(s^*(\rho^0))}{C^{DL}-C^{DE}} = \frac{\Phi'(s^*(\rho^0))}{\kappa_L-\kappa_E}$.

First we develop the intuition and some graphs to understand two different patterns in how $\widetilde{s}, s^*$, and $\widehat{s}$ change as ρ changes. Recall that, at a given value of ρ (probability of disease), if the per capita financial cost of health care is falling in s at the privately optimal level of surveillance ($s = \widehat{s}$), then the consumer is under-utilitizing s and the cost-minimizing level of s exceeds the privately optimal level as well as the socially optimal level of surveillance (i.e., $\widetilde{s} > s^* > \widehat{s}$ - see Figure 7). Therefore, if starting from a position ($\rho = \rho^0$) in which these three levels of surveillance are equal it is the case that use of surveillance is, at the margin, relatively ineffective in reducing the financial savings from early detection while being relatively costly to provide, then an increase in ρ will induce a relatively small increase in $\widetilde{s}$. Thus, this enhances the likelihood that the corresponding increase in the privately optimal choice of surveillance ($\widehat{s}$) will be larger than the increase in $\widetilde{s}$, leaving one in a position of $\widetilde{s} < s^* < \widehat{s}$ for $\rho > \rho^0$ and vice versa for $\rho < \rho^0$. In other words, the schedule $\widetilde{s}(\rho)$ will be flatter than the schedule $\widehat{s}(\rho)$, which in turn implies it is also flatter than the schedule $s^*(\rho)$. This possibility is illustrated in Figure 10. The corresponding case for surveillance being relatively effective in reducing financial savings from early detection while being relatively inexpensive to provide - at the margin - is illustrated in Figure 11. The formal requirements for these two cases are described below.

Insert Figure 10 about here.

Insert Figure 11 about here.

Case 1: Surveillance is ineffective and costly at the margin (In this scenario we assume that $p^{ED\prime}(s)$ and $p^{ED\prime\prime}(s)$ are small enough for all s; and $C'(s)$ and $C''(s)$ are large enough for all s, such that the following inequality holds**).** Suppose that the marginal financial costs of surveillance increase in the probability of disease:

$$\frac{d}{d\rho}(\frac{\partial TC}{\partial s}) = \frac{\partial^2 TC}{\partial s \partial \rho} + \frac{\partial^2 TC}{\partial s^2}\frac{ds}{d\rho} > 0 \text{ for all } \rho, \tag{41}$$

where

$$\frac{\partial^2 TC}{\partial s \partial \rho} = -p^{ED\prime}(s)(C^{DL} - C^{DE}) < 0, \tag{42}$$

$$\frac{\partial^2 TC}{\partial s^2} = C''(s) - \rho p^{ED\prime\prime}(s)(C^{DL} - C^{DE}) > 0, \tag{43}$$

and $\frac{ds}{d\rho} > 0$ by assumption. The indirect effect of the probability of disease on the marginal costs of surveillance ($\frac{\partial^2 TC}{\partial s^2}\frac{ds}{d\rho}$), which is positive, is stronger than the direct effect ($\frac{\partial^2 TC}{\partial s \partial \rho}$), which is negative. For this relationship to hold, the costs of surveillance and the probability of early detection must be strongly curved in the level of surveillance ($C''(s), |p^{ED\prime\prime}(s)| >> 0 \ \forall s$).

Together with assumption 2, this implies that $TC'(s^*(\rho)) < 0$ for small values of ρ, including ρ^L, and $TC'(s^*(\rho)) > 0$ for high values of ρ, including ρ^H. As was shown above, this is equivalent to a situation, where $\frac{C'(s^{L*})}{C^{DL}-C^{DE}} < \frac{\Phi'(s^{L*})}{\kappa_L - \kappa_E}$ and $\frac{C'(s^{H*})}{C^{DL}-C^{DE}} > \frac{\Phi'(s^{H*})}{\kappa_L - \kappa_E}$, and $\hat{s}^H > s^{H*}$ and $\hat{s}^L < s^{L*}$ hold respectively (high risks overinvest in surveillance, low risks under-invest in surveillance).

Case 2: Surveillance is effective and inexpensive at the margin. Suppose that the marginal costs of surveillance decrease in the probability of disease, $\frac{d}{d\rho}(\frac{\partial TC}{\partial s}) = \frac{\partial^2 TC}{\partial s \partial \rho} + \frac{\partial^2 TC}{\partial s^2}\frac{ds}{d\rho} < 0$ for all ρ. This time the direct effect of the probability of disease on the marginal costs of surveillance, which is negative, must exceed the positive indirect effect. For this relationship to hold, the costs of surveillance and the probability of early detection must be almost linear in the level of surveillance ($C''(s), p^{ED\prime\prime}(s) \approx 0 \ \forall s$). Together with assumption 2 this implies that $TC'(s^*(\rho)) > 0$ for small values of ρ, including ρ^L, and $TC'(s^*(\rho)) < 0$ for high values of ρ, including ρ^H. In this case, the financial marginal cost-benefit ratio is small for high probabilities of disease and large for low probabilities of disease, $\frac{C'(s^{L*})}{C^{DL}-C^{DE}} > \frac{\Phi'(s^{L*})}{\kappa_L - \kappa_E}$ and $\frac{C'(s^{H*})}{C^{DL}-C^{DE}} < \frac{\Phi'(s^{H*})}{\kappa_L - \kappa_E}$, and $\hat{s}^H < s^{H*}$ and $\hat{s}^L > s^{L*}$ (high risks under-invest in surveillance, low risks overinvest in surveillance).

The above analysis explains the relationship between the (financial) cost minimizing, privately optimal, and socially optimal levels of surveillance as a function of some known or perceived probability of disease. Clearly there is a tension in that the socially optimal

level of surveillance may be either lower or higher than the privately optimal choice of individuals when insurance plans allow any desired level of surveillance by consumers and this cost is borne by the insurance pool. In the case of over-utilization, this source of inefficiency can be avoided if the insurance provider can ration or tax through coinsurance payments the use of surveillance. Solutions to under-utilization perhaps create a more subtle problem. One could create financial incentives for consumers to increase their utilization of surveillance by taxing (through coinsurance) the financial cost of treating disease since this is greater for late detection than for early detection. Of course, this creates a conflict with the risk reducing property of full insurance and this applies to surveillance levels as well in the ex post scenario of genetic testing given the different utilization rates implied by that. Moreover, our results demonstrate that the relationship between over or under-utilization of surveillance and the variation in the probability of disease across genotypes is not a simplistic one. The same coinsurance rate or even the same sign of an implicit tax (subsidy) on surveillance can vary depending on the probability of disease and such flexible instruments may not be politically feasible. Moreover, the issue becomes significantly more complex if one were to allow for other sources of heterogeneity across individuals (e.g., differences in the function $\Phi(s)$ or the value of $[\kappa_L - \kappa_E]$). We leave these questions for future research.

However, if the socially optimal levels of s can be obtained by way of some instruments that do not create any loss of utility due to the introduction of risk-bearing costs, then a costless genetic test will always improve welfare (at least weakly) in the case of community rating. This follows simply because the social planner always has the option of maintaining the same level of surveillance as before genetic tests are taken for both risk types. This would imply the same expected financial costs and health benefits/costs due to the information. In the case of the financial costs being unchanged this is due to risk pooling (community rating) while the health benefits/costs of surveillance are linear in the probability of disease. Thus, any alterations in the risk-type specific level of surveillance that could improve average welfare, if possible, would be undertaken by the social planner (or by the insurance provider). In the case of risk-rating, only some of these arguments would apply. Under risk rating the health benefits/costs due to information about ρ are also linear, and so the lottery on ρ induced by genetic testing does not directly reduce expected welfare of individuals, leaving open the possibility of improved health benefits and these could potentially be properly weighed by a social planner against the cost implications of changing the surveillance levels ex post to a genetic test. However, under risk rating it is implicit that risk types will face different prices for insurance even if ex post (risk-type specific) surveillance levels did not change from that used by everyone before the genetic test occurred. Therefore, since premium risk is an inevitable consequence of

genetic testing even when efficient ex post levels of surveillance can be enforced it does not follow that a costless genetic test will be welfare improving in the case of risk rating. Of course, individuals have the choice not to take the genetic test and so the option doesn't reduce welfare either.

3 Impact of genetic testing on prevention

In this section we simply outline the changes to the model for surveillance required to represent the decision to take preventive measures that are both financially costly from the insurance provider's perspective and physiologically costly from the individual's perspective. An example would be the use of prophylactic mastectomy or chemoprevention (e.g., tamoxifen) sometimes taken by individuals who are sufficiently highly predisposed to breast cancer.[22] The model is very similar to that for surveillance but of course the interpretation is quite different. Moreover, the structure imposed on the model is different and has different motivation. We keep the basic framework of the model in the previous section except that this time we are interested in how the level of prevention changes the probability of getting the disease at all.

Prevention may be either observable by the health care provider (surgery, therapy) or unobservable (lifestyle). We focus on observable medical preventions, which we denote by $m \in [\underline{m}, \overline{m}]$. The probability of disease is a function of the level of prevention $\rho(m)$,with $\rho'(m) < 0, \rho''(m) > 0$.

We regard the level of surveillance as fixed and summarize the financial costs of treatment, which is assigned in case of disease, as C^D, and the non-financial, physiological cost of disease as κ. Note that in terms of the model on surveillance, we could set $C^D = p^{ED}C^{DE} + (1 - p^{ED})C^{DL}$ and $\kappa = p^{ED} \cdot \kappa_E + (1 - p^{ED}) \cdot \kappa_L$ and include a second decision, that of surveillance represented by s in the previous model. Alternatively, one can see that consideration of only one or the other decision variable m or s allows for recognizing the similarity in the two models through the relationships $m \equiv s$ with $\rho(m) \cdot \kappa \equiv \rho\left[p^{ED}(s)\kappa_E + (1 - p^{ED}(s))\kappa_L\right] = \rho\left[-p^{ED}(s)[\kappa_L - \kappa_E] + \kappa_L\right]$ in which case properties of the function $\rho(m)$ play a similar role to properties of the function $p^{ED}(s)$. A similar relationship can be drawn between the functions $TC(s)$ and $TC(m)$. Thus, the expected utility of individuals with probability of disease $\rho(m)$ is

$$EU(m) = u(y - TC(m)) - \rho(m) \cdot \kappa - \Phi(m)$$

where

$$TC(m) = \rho(m) \cdot C^D + C(m)$$

[22] See, for example, Anderson, et al. (2006) for a discussion of possible preventive strategies suggested for women with a BRCA1 or BRCA2 mutation.

are the financial health care costs which are incurred per capita to the health care provider. $C(m)$ is the financial cost of prevention, where $C'(m) > 0, C''(m) > 0$. $\Phi(m)$, with $\Phi'(m) > 0, \Phi''(m) > 0$, is the non-financial (physiological) cost of prevention incurred by the consumer.

Before a GT is conducted, the perceived probability of disease for a given level of prevention m is the same from the viewpoint of all individuals and the health care provider, and we denote it by $\rho^0(m)$. As before, a genetic test classifies individuals into two risk groups - negatives and positives - which have probabilities of disease $\rho^L(m)$ and $\rho^H(m)$ respectively. Thus, for the same level of prevention m, the population average probability of disease can be written as $\rho^0(m) = \eta_L \rho^L(m) + \eta_H \rho^H(m)$, where η_L is the proportion of tested negatives, and $\rho^H(m) > \rho^0(m) > \rho^L(m)$.

Let the probabilities of disease for low risks and high risks be

$$\rho^L(m) = \rho^0(m) - \frac{e \cdot \varepsilon(m)}{\eta_L} \tag{44}$$

$$\rho^H(m) = \rho^0(m) + \frac{e \cdot \varepsilon(m)}{\eta_H}, \tag{45}$$

where e is the precision of the test, and $\varepsilon(m) > 0$ reflects the difference in the effect of the level of prevention on the probabilities of disease for the two risk types.

Further, we assume that $\varepsilon(m)$ is such, that the second order conditions hold for tested positives and tested negatives. Specifically, we assume that, after a GT is conducted, both for tested positives and tested negatives the probability of disease is decreasing and convex in the level of prevention, i.e. $\rho^{H\prime}(m) < 0, \rho^{H\prime\prime}(m) > 0$ and $\rho^{L\prime}(m) < 0, \rho^{L\prime\prime}(m) > 0$ for all m. With the above specifications this is equivalent to

$$\begin{aligned} \rho^{H\prime}(m) &= \underbrace{\rho^{0\prime}(m)}_{<0} + \underbrace{\frac{e \cdot \varepsilon'(m)}{\eta_H}}_{?} < 0, \\ \rho^{H\prime\prime}(m) &= \underbrace{\rho^{0\prime\prime}(m)}_{>0} + \underbrace{\frac{e \cdot \varepsilon''(m)}{\eta_H}}_{?} > 0 \end{aligned} \tag{46}$$

and

$$\begin{aligned} \rho^{L\prime}(m) &= \underbrace{\rho^{0\prime}(m)}_{<0} - \underbrace{\frac{e \cdot \varepsilon'(m)}{\eta_L}}_{?} < 0, \\ \rho^{L\prime\prime}(m) &= \underbrace{\rho^{0\prime\prime}(m)}_{>0} - \underbrace{\frac{e \cdot \varepsilon''(m)}{\eta_L}}_{?} > 0. \end{aligned} \tag{47}$$

The difference between the probabilities of disease of positives and negatives, for the same level of prevention m, is

$$\rho^H(m) - \rho^L(m) = \frac{e \cdot \varepsilon(m)}{\eta_L \eta_H}.$$

For $e = 1$ (perfect precision of the test) those probabilities of disease can be regarded as the true probabilities of disease of high risks and low risks, for $e < 1$ (imperfect precision) they are simply the average probabilities of disease for tested positives and tested negatives.

With these specifications, the effects of the rate of false positives and false negatives cannot be analyzed separately. Instead, the precision of the test e is used to reflect both a smaller rate of false negatives and a smaller rate of false positives.[23] Thus, for a given population, average probability of disease before a genetic test is conducted is $\rho^0(m)$, a bigger difference between the observed probabilities of disease, or a more precise test in general (i.e. with both a lower rater of false positives *and* false negatives) is reflected by a larger e.

From an individual's perspective the level of prevention has no effect on health care costs $\frac{\partial TC(m)}{\partial m} = 0$. The private choice of prevention $\widehat{m}$ is found as the solution to

$$FOC : -\rho'(m) \cdot \kappa = \Phi'(m)$$

where

$$SOC : -\rho''(m) \cdot \kappa - \Phi''(m) < 0.$$

For the socially optimal level of prevention m^*, for which the effect on health care costs is taken into account, it holds that

$$FOC^* : u'(y - TC(m)) \cdot (-\frac{\partial TC(m)}{\partial m}) - \rho'(m) \cdot \kappa - \Phi'(m) = 0$$

where

$$\frac{\partial TC(m)}{\partial m} = \rho'(m) \cdot C^D + C'(m).$$

For the second order condition we get

$$SOC^* : u''(y - TC(m))(-\frac{\partial TC(m)}{\partial m})^2 + u'(y - TC(m))(-\frac{\partial^2 TC(m)}{\partial m^2}) - \rho''(m) \cdot \kappa - \Phi''(m) < 0,$$

where

$$\frac{\partial^2 TC(m)}{\partial m^2} = \rho''(m) \cdot C^D + C''(m) > 0 \text{ for all } m.$$

[23] This is similar to the characterization of the difference between safety techonologies in Hoy (1989). One could introduce a two parameter characterization that allows for separate treatment of false positives and false negatives, but this would be an unnecessary complication.

A comparison of the first order conditions for the the private choice of prevention and the socially optimal level shows that

Lemma 1: $m^* \lesseqgtr \widehat{m} \Leftrightarrow \frac{\partial TC(m)}{\partial m}|_{m^*} = \rho'(m^*) \cdot C^D + C'(m^*) \gtreqless 0.$

As we did for the model of surveillance, we can derive similar relationships between the privately optimal level of prevention, $\widehat{m}$, the cost minimizing level of prevention, $\widetilde{m}$, and the socially optimal level of prevention, m^*, as well as between the pattern of over and under use of prevention for different informations sets (i.e., knowledge of $\rho^0(m)$, $\rho^H(m)$, and $\rho^L(m)$). The only complication from a modeling perspective is that the difference in genetic types for the model of surveillance represents a straightforward difference in probability of disease, with $\rho^H > \rho^L$, while to model genome specific prevention we need a difference in functions, $\rho^H(m) > \rho^L(m)$ where the relationship between $\rho^{H\prime}(m)$ and $\rho^{L\prime}(m)$ is important and may vary across multifactorial genetic diseases.[24] Due to the strong similarity in results we do not repeat the same exercises but simply note that the possibility of over and under prevention is possible as well as the possibility of a rich set of patterns of over and under prevention being generated by genetic testing. Thus, attention should be paid by either public or private insurance systems to correct for such inefficiencies due to moral hazard considerations and the instruments required may seem horizontally inequitable in that the optimal policy may imply that one group face a tax (through coinsurance payments) on surveillance or preventive activities while another group may face a subsidy. Such possibilities may seem more likely or palatable in a private insurance regime.

4 Conclusions

In this paper we have considered the implications on two aspects of behaviour - surveillance or monitoring to improve the chances of early detection of disease onset and preventive actions to reduce the probability of onset - and how these change as a result of the acquisition of information from genetic tests. In this setting information from genetic tests has the potential to improve the targeting of these actions and hence improve expected welfare (health outcomes) for individuals. However, we also presume that insurers, whether public or private, naively allow individuals to choose their privately optimal levels of surveillance or preventive actions.[25] If insurance is privately provided and no community rating reg-

[24] Multifactorial genetic diseases are those for which both genes and environment (including possibly medications, surgery, etc.) interact to generate a probability of disease or degree of severity of disease.

[25] Barros, Machado, and Sanz-de-Galdeano (2008) provide some evidence that use of sruveillance (blood and urine tests in their case) is higher for those covered by 'extra' health insurance. This is suggestive, but not necessarily conclusive, evidence that insurance coverage may induce inefficient use of such services. It may of course be that those without extra insurance are under utilizing surveillance. The possibility

ulations are in place, premium risk can in some circumstances create a disincentive to obtain socially valuable genetic information that would otherwise be acquired if publicly provided insurance were in place. On the other hand, however, it is possible in a public insurance regime that since the cost of insurance is independent of risk status, and hence also independent of whether one has taken a genetic test, in a public insurance regime individuals may voluntarily take a genetic test even when it leads to a reduction in welfare for all. This possibility will not happen in a private insurance regime with risk-rating provided individuals can demonstrate that they have not taken the relevant genetic test.

There is also a further interaction between the moral hazard implications of under or over utilization of surveillance or preventive technologies. If insurance plans in either private or public regimes accommodate all private demands for costly surveillance or prevention activities, then obtaining genetic information can worsen the efficiency loss of such activities and lead to foregone welfare improvements, and in the public insurance regime even lead to a pareto worsening of welfare. This turns out to be possible when the equilibrium schedule of the per capita cost of providing health care is strictly convex in the probability of disease in the case of surveillance, with an analogous result also applying but with a more complex interpretation in the case of prevention. Alternatively, if insurers are able to enforce first-best choices of these activities, then costless genetic tests always improve welfare under public insurance (or under private insurance with effective commuting rating regulations) but premium risk can impede such opportunities under private insurance. From this perspective, our paper demonstrates how the pattern of under or over use of these activities can develop differently according to risk type under genetic testing and so provide guidance on how to determine or measure the extent to which private demands vary from socially efficient demands.

Many countries have compulsory public and/or private insurance plans with prohibitions on risk-rating of premiums and so our analysis of the tension between privately versus socially optimal and surveillance provides some guidance for administration of such programs in regards to attempts to effect appropriate private decision making as well as helping to provide some building blocks for appropriate cost-benefit calculations for the introduction of possible genetic tests for various segments of the population. There are admittedly few countries with health insurance regimes in which both compulsory full coverage insurance applies in combination with no restrictions on rate making (i.e., no community rating regulations). For example, Australia's optional private health insurance sector faces community rating requirements except for age of consumer. The health insurance scenario in the United States is perhaps the closest to that of our private in-

of using taxes and/or subsidies to effect efficient levels of screening and prevention is investigated in a different context in Byrne and Thompson (2001).

surance model, although the majority of private insurance holders obtain their insurance through employee plans and so are often well insulated from risk-rating effects as long as they don't change employment status. Moreover, although there are substantial numbers of individuals in the US who purchase private health insurance individually, interestingly on May 21, 2008 President Bush signed the so-called GINA bill (Genetic Information Nondiscrimination Act) into law after about 10 years in the making. This bill prohibits insurance companies from using genetic test results as a means of rate-making for health insurance as well as excluding firms from using such information for employment decisions. However, this paper provides some insight into the problems of such community rating regulations for sending appropriate signals to individuals to obtain genetic tests in comparison to the case had private insurers been continued to be allowed to use genetic test results for pricing health insurance. Moreover, regulations and insurance programs may change in the future and so such a comparison is still worthwhile.[26]

Several directions for future research include, among others, (1) allowing for heterogeneous preferences regarding the health benefits and costs of surveillance and prevention activities, (2) explicitly introducing second-best instruments such as coinsurance on either surveillance (prevention) costs or treatment costs, and (3) introducing asymmetric information regarding whether a genetic test has been taken.

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[26] As noted in Wagstaff et al. (1999, p. 269), "It is well known that during the last decade or so, there has been a shift in many OECD countries away from public sources of finance (for health care) to private sources." If insurance continues to fall under a community rating regulation, however, the risk premium issues identified here would vanish although risk selection issues might arise.

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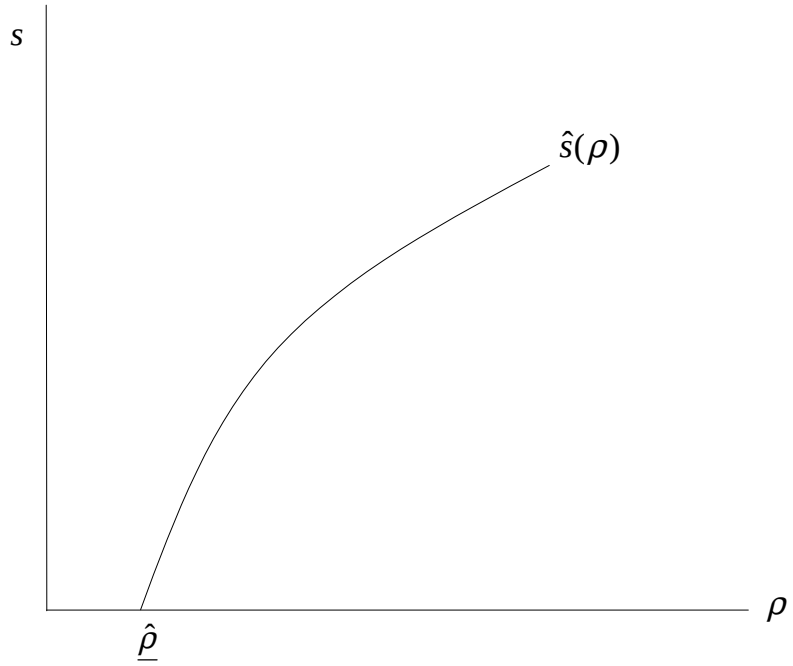
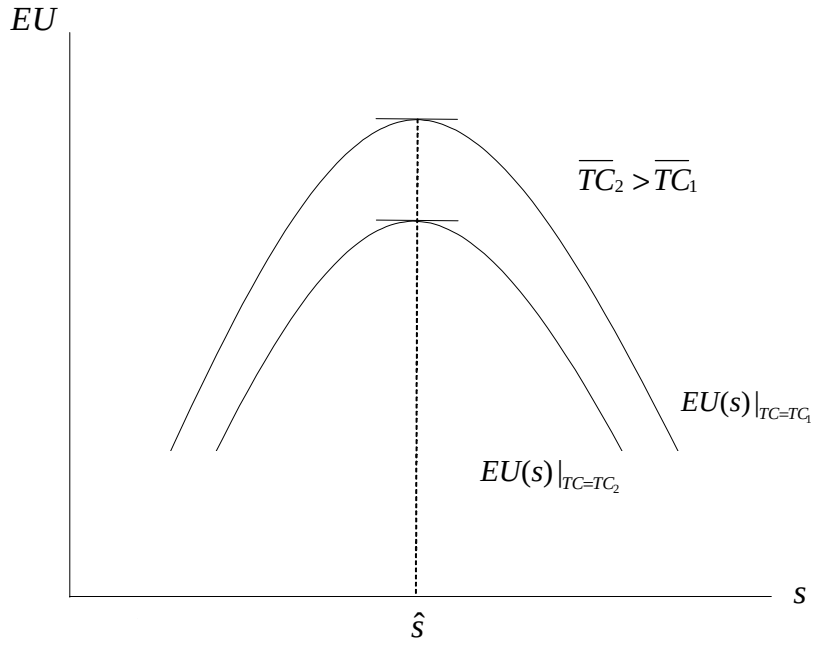


Figure 1:



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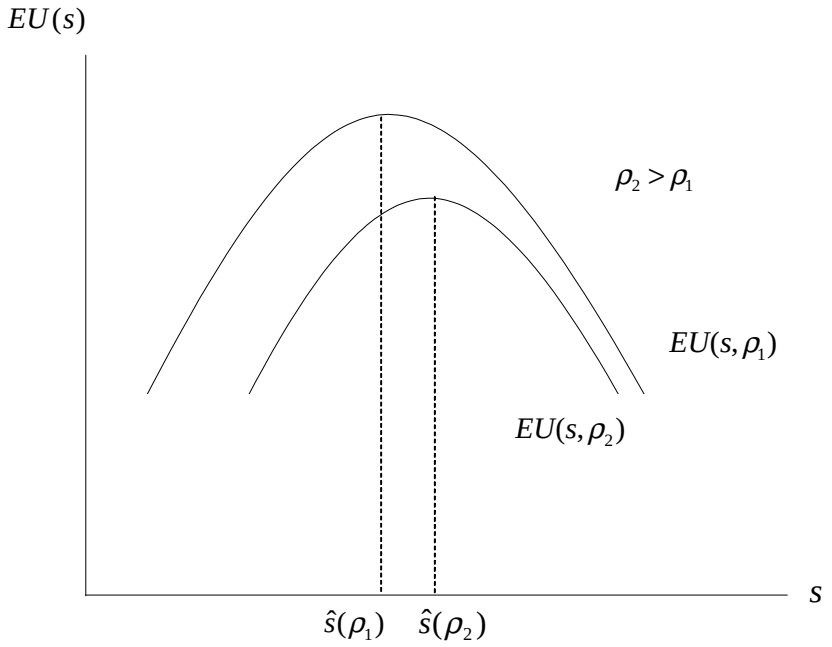

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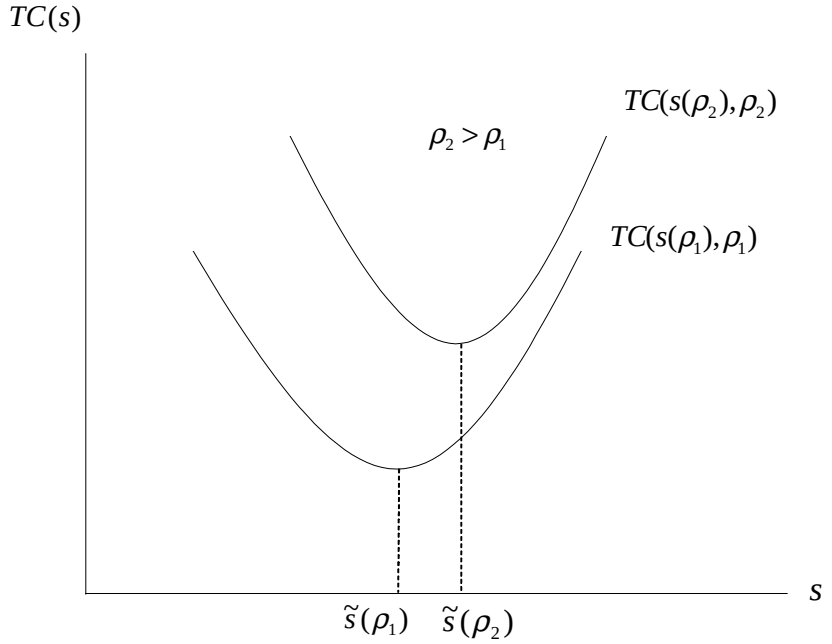

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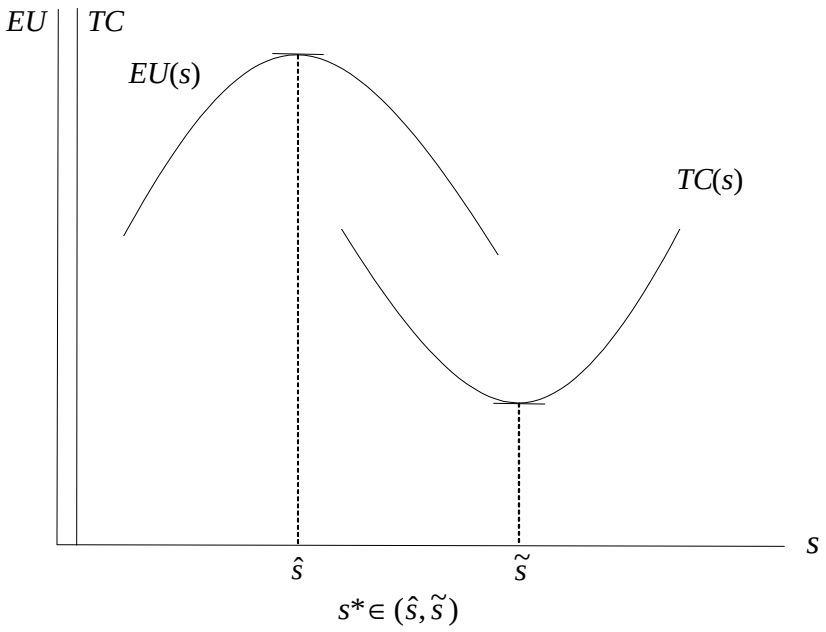

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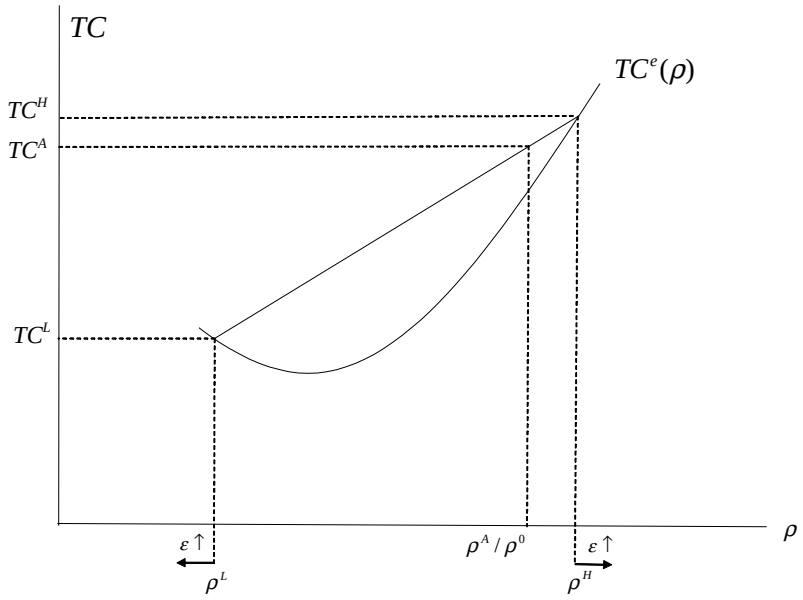

Figure 6: Necessary Condition for (simultaneously):
Community Rating ⇒ GT reduces welfare
Risk Rating ⇒ GT increases welfare

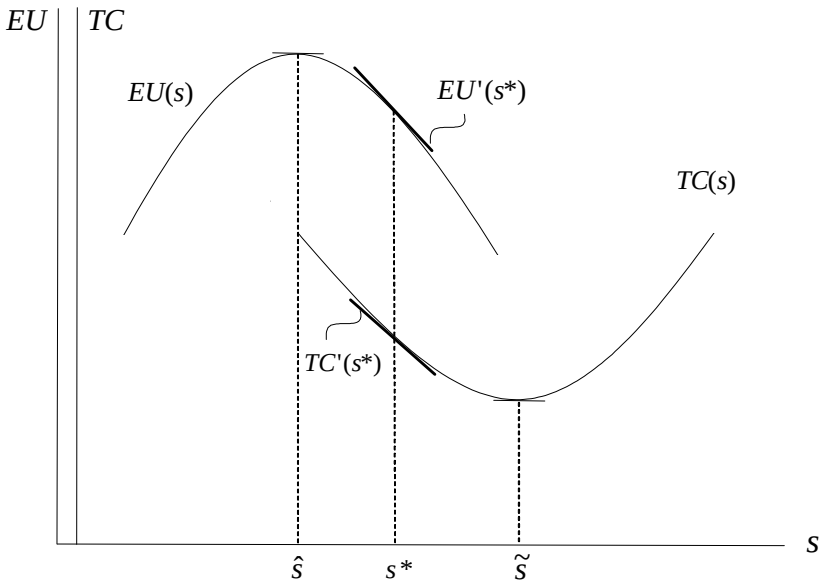

Figure 7: Underutilization of Surveillance

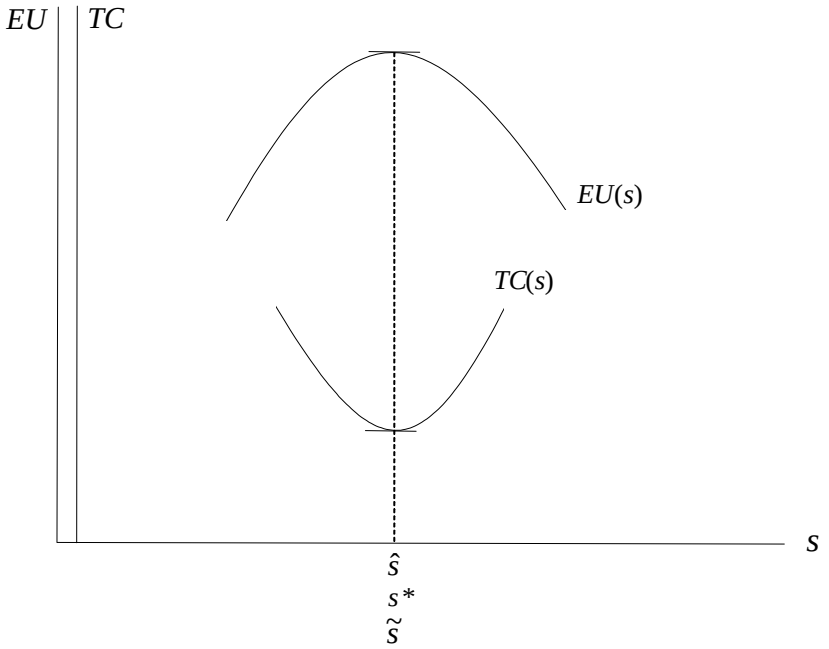

Figure 8: Appropriate Utilization

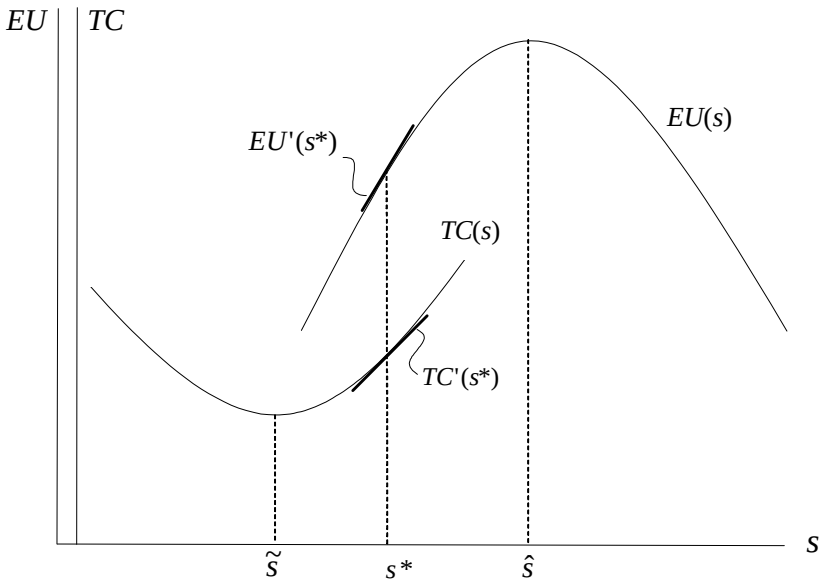

Figure 9: Overutilization of Surveillance

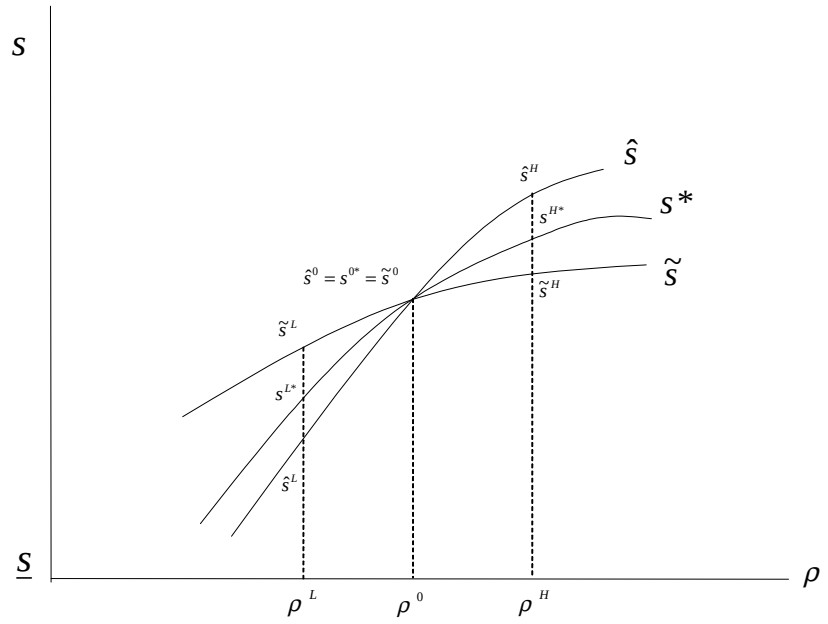

Figure 10: Surveillance ineffective and costly at the margin

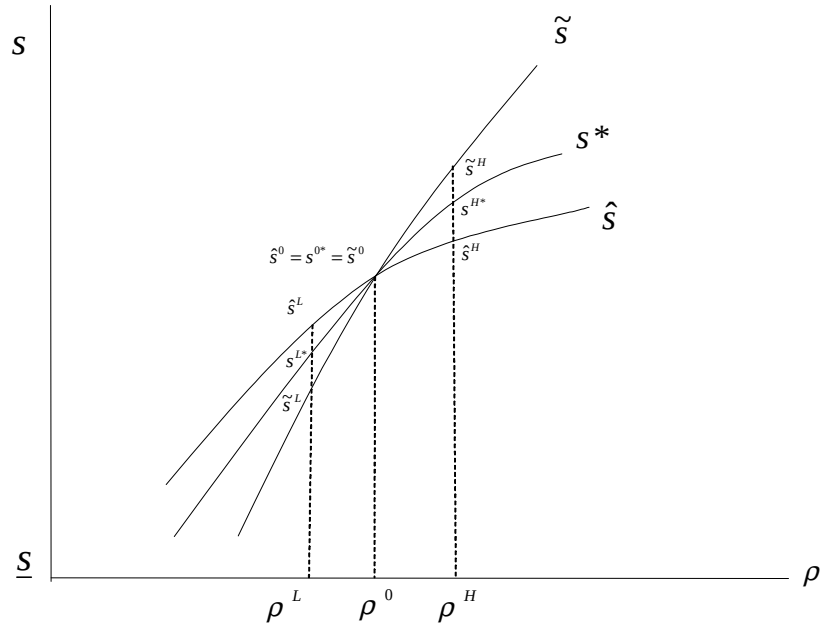

Figure 11: Surveillance effective and inexpensive at the margin