ADVERSE SELECTION IN TERM LIFE INSURANCE PURCHASING DUE TO THE BRCA1/2 GENETIC TEST AND ELASTIC DEMAND

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ABSTRACT

Consumer groups fear that the use of genetic testing information in insurance underwriting might lead to the creation of an underclass of individuals who cannot obtain insurance; thus, these groups want to ban insurance companies from accessing genetic test results. Insurers contend that such a ban might lead to adverse selection that could threaten their financial solvency. To investigate the potential effect of adverse selection in a term life insurance market, a discrete-time, discrete-state, Markov chain is used to track the evolution of 12 closed cohorts of women, differentiated by family history of breast and ovarian cancer and age-at-issue of a 20-year annually renewable term life insurance policy. The insurance demand behavior of these women is tracked, incorporating elastic demand for insurance. During the 20-year period, women may get tested for BRCA 1/2 mutations. Each year, the insurer calculates profits/losses to date and expected future benefit payouts which determines the following year's premium schedule. At the end of each policy year, women can change their life insurance benefit, influenced by their testing status and premium changes. Adverse selection could result from differentiated (i) benefits following test results; (ii) lapse rates according to test results; and (iii) reactions to price increases. It is concluded that with realistic estimates of behavioral parameters, adverse selection should be a manageable problem for insurers.

INTRODUCTION

The initial phase of the human genome project was completed in 2000. Researchers hope that the sequencing of the human genome will allow them to develop new drugs and therapies, and to identify genetic risk factors for a variety of conditions. At the same time, many fear that the human genome map may open a new frontier for potential discrimination, particularly in insurance. Senators James Jeffords and Tom Daschle stated that "misuse of genetic testing could create a new underclass: the genetically less fortunate" (Jeffords and Daschle, 2001). In many countries, an intense legislative and lobbying activity, reminiscent of the debate over access to HIV tests in the 1980s, is taking place that could shape the environment of underwriting in life and health insurance. Consumer groups, fearing discrimination and the creation of a class of uninsurable individuals, want insurers and employers prevented from gaining access to medical information obtained through genetic testing.

In opposition to these views, insurance companies point to the risk of adverse selection. With over 1,100 genetic conditions identified and over 800 genetic tests offered, they fear that policyholders may gain a financial advantage through insurance purchase decisions, from genetic information known to them but not revealed to insurers.[1] Insurers claim that without a level playing field a death spiral of increasing premiums and decreasing portfolio size may threaten their financial solvency. They emphasize the positive implications of DNA testing for annuitants and the benefits of early diagnosis. They discuss the ethics and inconsistency of prohibiting the use of genetic tests while allowing other medical tests and family history to be used for underwriting purposes. Actuaries in the United States voice their concerns through bodies such as the American Academy of Actuaries; by means of Issue Briefs, articles, and Capitol Hill

[1] More information about specific genetic conditions and genetic tests can be obtained from the National Institutes of Health, National Library of Medicine, www.genetests.org.

briefings, Congress is urged to proceed with extreme caution when it considers legislation aimed at preventing genetic discrimination for insurance.

Both sides, consumer groups and the insurance industry, recognize that the predictive information obtained from genetic tests could be relevant to the actuarial calculations used by insurers in establishing policies and premiums. At issue is whether the use of such information by insurers in underwriting is justified on economic and market grounds to overcome social concerns.

The word “discrimination” is often used neutrally by economists to reflect the ability to distinguish among groups, but the same word is used by the public to reflect socially unfair ways of classifying groups. In the economic sense, is adverse selection a sufficiently plausible threat that discrimination based on genetic test results is justified? On average, in the US, women live longer than men and Caucasian-Americans live longer than African-Americans. Both of these differences in life expectancy could be used to establish lower term life insurance premiums for women and Caucasian-Americans compared to men and African-Americans. Insurance companies typically charge lower premiums for women than for men, but they do not charge lower premiums for Caucasian-Americans than for African-Americans. This is not because discrimination by sex is actuarially more important than discrimination by race, but because discrimination by race is not socially tolerated. To that end, the use of race as an underwriting factor for insurance is prohibited in all states. In Montana alone, the use of gender in rating for any type of insurance is illegal. If in these cases, failure to discriminate by race or gender led to sufficient adverse selection - for example, if the protected groups overpurchased life insurance as a result, raising premiums to a level that drove the other groups from the market - the balance

between socially intolerable discrimination and actuarially fair discrimination might shift in the other direction.

In the debate about whether insurers should be allowed to use genetic testing results in underwriting, the actuarial profession can contribute by designing models to analyze adverse selection and quantify its impact, thereby generating a more informed discussion. Several recent articles have been published, estimating the potential impact of the test for a BRCA1/2 mutation on the term insurance and critical illness markets, and of the test for specific alleles of the ApoE gene that may predispose one to Alzheimer's Disease on long-term care insurance (Subramanian et al, 1999; MacDonald and Pritchard, 2000, 2001; MacDonald et al, 2003). These models all rely on the assumption of inelastic demand. Those articles model insurance purchase behavior following a genetic test, but do not account for the fact that policyholders may elect to reduce their coverage following the price increases resulting from adverse selection. This research introduces elastic demand for term insurance into the analysis. A discrete-state, discrete-time, Markov chain is used to follow the evolution of twelve cohorts of women, differentiated by age at issue and family history of breast and ovarian cancer. All women own term insurance at time 0. Policyholders can get tested for BRCA1/2 mutations and, after receiving the test results, either change their face amount or lapse their policy. The adverse selection that results forces insurance carriers to raise premium levels. Marshall's Law of Demand, resulting in a constant price elasticity of demand, models the reaction of policyholders when confronted with premium increases.

The paper proceeds as follows. First, current regulatory and underwriting procedures in various countries are discussed, to illustrate the diversity of country response to insurer use of genetic tests results. The elastic demand Markov model is described next and the estimation

procedure for all parameters is described. Results and sensitivity analyses are then presented, followed by our concluding remarks.

CURRENT REGULATORY CONDITIONS

Insurance companies are concerned about being restricted from access to genetic tests taken by their potential and current customers. The questions that regulation needs to address are:

(i) Should insurers be permitted to reflect in their rates the information provided by genetic tests?

(ii) Should insurers be permitted to require applicants to disclose the results of genetic tests taken prior to the application for insurance?

(iii) Should insurers be permitted to require applicants to take genetic tests prior to consideration of the application?

Regulatory authorities also need to provide a definition of "genetic information" and "genetic test." A genetic test can be defined in a narrow way as a chemical test involving examination of the constitution of a gene or chromosome, or in a much larger way that would include examination of family history.

The answers to these questions have led to four major types of laws, which can be classified as follows (Berberich and Fischer, 1999; Bartram et al, 2000; Regenauer, 2000; Breyer, 2001; Doble, 2001). Under a *Laissez Faire* approach, insurers have full freedom to request new tests and the disclosure of existing tests, and to incorporate test results in

underwriting and rating.[2] This is practiced in Australia, Canada, Japan, Ireland, Portugal and Spain. Through *Disclosure Duty*, applicants have to disclose the results of existing tests, at the insurer's request, but cannot be required to take additional tests; this approach is used in Germany, New Zealand and the UK. By *Consent Law*, applicants are not required to divulge genetic tests results. If they do, insurers may use this information; this approach exists in the Netherlands and Switzerland. In Austria, Belgium, Denmark, France, Italy, and Norway, under *Strict Prohibition*, insurers cannot request genetic tests, cannot require applicants to provide existing tests results, and cannot use any genetic information in underwriting and rating.

In the absence of (or in addition to) legislation, three approaches have been used by insurers' associations. Through a *Voluntary Agreement*, the Swedish Insurance Federation and the state have agreed that no genetic tests can be made a condition for issuance or modification of a life insurance policy. In addition, the results of tests taken prior to the application will not be considered in the risk assessment, unless the sum insured exceeds 15 times an inflation-adjusted base amount ($62,000 in 1999). In Germany, Finland, Greece, the Netherlands, Switzerland, and the UK, insurers have adopted a voluntary *Moratorium* on the use of genetic tests. The moratorium may apply to all life insurance policies (Germany) or to all policies with a sum insured under a given limit (Netherlands, UK). Finally, in Australia and South Africa, insurers' associations have put together *Guidelines* or a *Code of Conduct*. The Life, Investment and Superannuation Association of Australia passed a position paper "Genetic Testing and Life Insurance" that was accepted as an underwriting guide in 1997. These guidelines specify that insurers (i) will not initiate any genetic test; (ii) may request that existing test results be made

[2] Legislative activity concerning the regulation of genetics in insurance is proceeding at such a fast pace that some of the information in this introduction may have become obsolete by the time this article is published.

available for risk classification; (iii) will not use tests as a basis for preferred underwriting; and (iv) will not use test results in the assessment of relatives of the tested individual. In a May 2003 report, the Australian Law Reform commission recommended that the insurance industry should be required to adopt a range of improved consumer protection policies with respect of the use of genetic information (including family history) for underwriting purposes. New laws and guidelines should ensure that genetic information is only used in an actuarially sound matters, that industry education about genetics is improved, and that complaints-handling processes are extended to cover underwriting decisions.

In the UK, the Association of British Insurers introduced a Code of Practice on Genetics in 1997, which enforced a ban on insurers asking anyone to take a genetic test (Daykin et al, 2003). Results from seven specific tests, approved by a genetics advisor, must be disclosed and can be taken into account.[3] Genetic test outcomes cannot be used to underwrite another member of the family. More importantly, a moratorium was imposed on the use of genetic tests for life insurance policies with a sum insured not exceeding £100,000 sold in connection with a mortgage. In the UK, mortgage-based life insurance is common and considerably reduces the potential for adverse selection, since the sum insured is limited to the price of the house; over-insurance is unlikely.

In 1997, the British government set up a Genetics and Insurance Committee charged with assessing requests from insurers to be allowed to use specific genetic tests for specific policies. The Committee ruled that a test could be approved if medical and actuarial evidence demonstrates that a positive test result implies an extra mortality exceeding 50% or an extra

[3] The seven tests are for the following conditions: Huntington's disease, hereditary breast cancer, familial adenomatous polyposis, myotonic dystrophy, early-onset Alzheimer's disease, multiple endocrine neoplasia, and hereditary motor and sensory neuropathy.

morbidity exceeding 25%. In 2000, the Committee approved the Huntington's disease test for policies not covered by the existing moratorium.

In 2001, a major British insurer was forced to admit that it had been using unapproved tests in underwriting, in violation of the code of conduct (Kite, February 8, 2001). Following this disclosure, the House of Commons Science and Technology Select Committee issued a report strongly critical of the industry, concluding that self-regulation by insurers is not working, and that some companies are trying to set up a "genetic ghetto." The Human Genetics Commission recommended that the government place a moratorium on the use of genetic test results. During that moratorium, the Commission would investigate the use of family history in underwriting. In October 2001, the insurance industry and the government reached an agreement on a five-year moratorium on access to genetic test results for all life insurances policies with a sum insured not exceeding £500,000, with no link to mortgages. During the moratorium, the government and insurance industry will fund research by independent experts on the use of family history and explore risk pooling so that those with adverse genetic test results will be able to access affordable insurance post-moratorium. In such an arrangement, policyholders would be insured by the risk pool and companies would share in the pool's experience. At the 2002 UK Forum for Genetics and Insurance, some insurance companies, mentioning the poor experience of the diabetes pool, expressed their belief that risk pooling may not be a viable idea due to high administrative costs.

In the United States, Wisconsin became in 1991 the first state to pass a law barring insurers from using existing genetic test information and requesting new tests from health insurance applicants. Other states have followed suit, periodically revising their laws to adapt to advances in genetic testing. A vast majority of states now prohibits the use of genetic test results

for health insurance risk classification and pricing. Far fewer states have regulated life insurance. In Missouri and Minnesota, insurers may not require individuals to take a genetic test, may not base rates on any test result and may not refuse to insure based on genetic traits. In Florida and North Carolina, no insurer may refuse to issue a life policy because the insured person has the sickle-cell trait. Several states require informed consent before submitting to a genetic test, and confidentiality of results. In many of these states, insurers also cannot request genetic information from family members. Interestingly, several states have laws whereby insurers may not use genetic test results "unless the applicant's medical history and condition and claims experience or actuarial projections establish that substantial differences in claims are likely to result from the genetic condition." This provision would allow insurers to invest in and use medical studies to calculate the mortality risks associated with a particular test and justify its use for future premium determination. At the federal level, Congress is currently debating the "Genetic Nondiscrimination in Health Insurance and Employment Act" (HR 602/S 318). This bill places restrictions on insurers, banning the use of genetic information in underwriting health insurance; it does not however address the use of genetic testing results in life insurance underwriting.

DESCRIPTION OF MODEL

To model the degree of potential adverse selection to an insurer, a discrete-state, discrete-time, Markov chain is used to track the insurance purchase and genetic testing behavior of different cohorts of women over a 20-year period. At time 0, 1,000 healthy women of the same age, untested for BRCA1/2 gene mutation, are insured for an amount of $100,000 under an annually renewable term insurance policy, with the premium paid at the beginning of each year

and benefit paid at the end of the year of death. Three ages at time 0 are considered: 30, 40, and 50, along with four different family histories: no family history (No FH) of breast (BC) or ovarian (OC) cancer, one first-degree relative (a mother or a sister) with onset of BC between the ages of 20 and 30 (1FDR-BC), two first-degree relatives with onset of BC between 20 and 30 (2FDR-BC), and one first-degree relative with OC (1FDR-OC). This leads to a total of 12 cohorts. These cohorts are closed: there are no new entrants into the group after time 0.

The adoption of a discrete-time Markov chain rather than a continuous-time model reflects the belief that insurance decisions are usually taken at the end of the policy year, just before renewal. Policyholders rarely cancel a policy in the middle of the year; rather, they lapse after receiving the renewal invoice. Policyholders with an elastic demand for insurance react to price increases when they learn about them through the renewal notice.

Each year, the initial cohort reduces through the combined effect of three decrements: policy lapse, death, and test for BRCA1/2 mutations. Lapses take place at the end of the year and are final: once her policy has lapsed, a woman does not reenter the cohort later on. Deaths and tests take place during the year; a uniform distribution of decrements in each year of age is assumed both for deaths and tests, to model the competing interaction between these two decrements. Within a particular policy year, women who undergo a BRCA test receive the result (positive or negative). As the test for the BRCA is believed to be very accurate, with sensitivity and specificity exceeding 99%, testing errors (false positives and false negatives) are not considered (Myriad Genetic Laboratories, 2003). Tested women then constitute their own sub-cohort, from which lapses and deaths occur over the remainder of the 20-year period. The insurer is not allowed to learn about any genetic testing results.

At the end of each policy year, all women make their insurance decision for the following

year: they can change their benefit amount or let the policy lapse. This decision is influenced by their testing status/outcome and the prices faced for insurance. When all decisions are taken, an adverse selection process may begin to develop at the expense of the insurer. Three factors contribute to this process:

(i) Differentiated lapsing rates: women testing positive are expected to lapse at a lower rate than untested women; women testing negative may exhibit a higher lapsing rate.

(ii) Differentiated benefits: women testing positive are more likely to increase their benefit; women testing negative may reduce their benefit. It is assumed that women may increase their benefit without having to provide medical evidence of insurability.

(iii) Women who test positive may be more likely to accept a premium increase than women who are untested or who test negative. Facing an increase, they may decrease their benefits less than others.

The insurer, being prevented from accessing genetic test results, does not know which of its insureds has tested and, more importantly, who has tested positive. A combination of the factors listed above may lead to total observed death benefits being higher than expected since the insurer prices these women corresponding to their family history. Consequently, the company must raise premiums for the following year. Not knowing who among the policyholders have tested, the company must continue to price all contracts using family history and thus must increase the premiums in each cohort by the same percentage. Since insurers have access to family history information, each of the twelve cohorts is assumed to constitute a separate rating cell; price increases are calculated for each cell separately.

In practice, insurers may follow a variety of pricing strategies: they may simply react to adverse mortality experience by attempting to recoup their losses or they may try to anticipate

future mortality trends by developing an actuarial model to forecast future losses. Such a model could incorporate the downward time trend in mortality rates, adverse selection increase factors, behavioral reactions of policyholders to price increases, changes in the demographic composition of the portfolio, and anticipated investment experience. The retroactive pricing approach is considered here because it maximizes the adverse selection effect. It is assumed that, each year, the insurer calculates its cumulative losses since time 0. These losses are spread among the remaining customers of the rating cell through a uniform premium increase per benefit dollar. The company does not recoup every single lost dollar, as policyholders continue to modify their insurance purchase behavior through lapses and benefit changes. The company is always one step behind; it changes its premiums based on past customer behavior, but does not anticipate the fact that this behavior constantly changes as a result of pricing decisions.

Elastic demand is incorporated into the consumers' demand system. Behavioral changes in benefits as a result of price increases is modeled using Marshall's Law of Demand, linking the price P of an economic good to its quantity sold Q through the relationship:

$$P^{\lambda} Q = A \tag{1}$$

where A is a constant. Parameter λ is the (constant) price elasticity of demand:

$$\lambda = -\frac{dQ/Q}{dP/P} \tag{2}$$

At the end of a policy year, a woman who remains untested reacts to an annual premium change according to the price elasticity $\lambda_{untested}$, determining her insurance benefit for the next policy year.

For a woman who gets tested during policy year t, the insurance benefit demanded for year $t+1$ is solely influenced by this test result. For each test outcome, the relative degree of

change in the woman's known death risk depends on the information known to her prior to testing, specifically her family history. This relative change in risk level then influences the quantity of insurance demanded. This (constant) risk elasticity of demand with respect to health risk, δ, is defined as

$$\delta = \frac{dQ/Q}{dR/R} \tag{3}$$

where *R* denotes the woman's family history health risk – her 20-year probability of death given her family history of BC or OC. $\delta_{(+)}$ denotes the risk elasticity after the shock of a positive test that doubles the death risk, while $\delta_{(-)}$ denotes the risk elasticity after a negative test that halves the death risk.

The insurance benefit demanded in year *t+2* and each year after will be determined using Marshall's law of demand with a price elasticity parameter corresponding to the woman's test status, $\lambda_{positive}$ or $\lambda_{negative}$. Thus, three different price elasticities of demand are estimated for the model, with the relationship $\lambda_{positive} < \lambda_{untested} < \lambda_{negative}$, reflecting the expected level of responsiveness to benefit changes. Summarizing, a woman who tests positive in year 5 modifies her insurance benefit according to a price elasticity $\lambda_{untested}$ at times 1 to 4, a risk elasticity $\delta_{(+)}$ at time 5, and a price elasticity $\lambda_{positive}$ at times 6 to 19 (unless she decides to lapse at some intermediate time). In our model, if a woman gets tested in year *t*, the insurance decision made for year *t+1* is influenced only by her risk elasticity corresponding to the test result; the amount of insurance benefit demanded in *t+1* is not simultaneously affected by her price elasticity of demand. We use this as each woman's decision-making approach; a recently obtained result of a genetic test overwhelmingly affects the woman's thoughts and subsequent insurance strategy thus any premium change for year *t+1* would be accepted in full.

Each year, premiums increase because of (i) increased mortality due to age, and (ii) adverse selection. To identify the increase due to adverse selection alone, it is assumed that policyholders do not reduce their benefits in response to the portion of the price increase due to normal mortality changes. Sensitivity analyses will be performed on the various parameter estimates to investigate the variability of our results.

PARAMETER ESTIMATION

The model requires the estimation of many parameters. Annual probabilities of death for the different ages at issue, family histories, and test results are required to set premiums and determine expected and observed benefit payouts. These death probabilities were obtained in Lemaire et al (2000). Probabilities to test positive according to family history (0.40 for women with 2 FDR with BC, 0.15 with 1 FDR with BC, 0.08 with 1 FDR with OC, 0.005 with no family history) were derived in Subramanian et al (1999). These estimates are based upon initial findings of relatively high penetrance for BRCA1/2 mutations among linkage families. Although it was believed in the late 1990s that these estimates may be inflated by the selection of highly penetrant families for inclusion in linkage analysis, the most recent evidence suggests that the risk of breast and ovarian cancer associated with BRCA1/2 mutations is not much lower in the population as compared to just high-risk families (Berg, 2002; Brose et al, 2002; Antoniou, 2003). Given the controversy that surrounds the exact BRCA1/2 risk, we chose to base our analyses on early, slightly higher, estimates, as this conservative approach assumes the greatest impact of testing on cancer risk and will provide the highest estimate of adverse selection. An annual effective rate of 5% is used for discounting. The annual testing rate is set at a

conservatively high 5%. While currently a very small proportion of women are getting tested, this situation could change if the cost of the test substantially drops from the current $2,760.

Price and risk elasticities were estimated by means of a questionnaire completed by 48 individuals working in the health care industry, 18 males and 30 females. Respondents were sorted into three age groups: under 36, 36-45, above 45. Each was asked 15 life insurance coverage questions, as illustrated in the Appendix. In each question, 10 possible life insurance amounts were presented, ranging from no coverage to $1,500,000. A premium for each amount was given. On the first question, respondents were asked how much insurance they would buy given their current health level and benchmark premiums obtained from a leading insurer. As expected, older individuals selected higher benefit amounts. The average benefit was $200,400 in the "under 36" age group, $446,667 in the "36-45" group, and $523,077 in the "over 45" group. Males selected much higher benefits than females: $433,889 v. $274,000, for an overall average of $333,958. In the next four questions, respondents were asked to select benefit amounts under different pricing scenarios, holding their mortality risk level constant. The premiums for the different insurance benefit amounts were varied from one-half to two and a half times benchmark premiums. These first five questions measured respondents' price sensitivity of demand for term life insurance, holding mortality risk constant. Answers to these questions were used to estimate $\lambda_{untested}$.

In questions 6 to 10, a hypothetical situation was presented in which respondents were told their risk of death had doubled after the result of a special blood test. In question 6, the same set of possible life insurance benefit amounts and premiums was offered as in question 1, at these benchmark premiums; respondents were asked to choose their desired benefit amount given this higher death risk level. In the next four questions, premium schedules were varied in

the same way as in questions 2 to 5; these questions were used to estimate $\lambda_{positive}$, the price elasticity of demand for term insurance under the high death risk scenario. Questions 11 to 15, used to estimate $\lambda_{negative}$, followed the same format, but represented a situation in which the death risk was halved after the blood test. Respondents exhibited a high degree of inertia in the presence of a test result that halves the death risk; 71.25% did not change their benefit, with little variation across gender. The average benefit change was not significantly different from 0. This emphasizes that, for most people, term insurance is an essential purchase driven by family need; the amount of insurance purchased is fairly independent of the mortality risk and the annual premium. Respondents reacted more to a doubling of the death risk; in this situation, only 48.33% did not change their benefits (61.11% of males v. 40.67% of females). The average benefit increase was a highly significant $145,600. Males increased their benefit by an average $115,000, females by an average $164,000.

First, the price elasticity coefficient for untested women $\lambda_{untested}$ was estimated through a stacked cross-section regression analysis performed on all questionnaire responses to questions 1 through 5. The regression used the percentage change in benefit as the dependent variable and the percentage change in premium as the exogenous price variable. For each individual, four observations were recorded, the changes in selected benefit from question 1 to questions 2 to 5 respectively. Maximum likelihood estimation with an error components error structure was used to allow for correlation across observations drawn from the same individual. Regression equations were of the form

$$\%(\Delta \text{ Benefit}) = \lambda \%(\Delta \text{ Premium}) + \beta (\text{Control Variables}) + \mu \quad (4)$$

where the error term included a fixed effect for each individual and independent and identically distributed error terms. Dummy variables for demographic characteristics, such as age, sex, and

income of the respondents, were included in the regression. The overall price elasticity coefficient λ was estimated at 0.6579; this estimate was robust across all categories of respondents and insensitive to changes in age, gender, education level, income, or marital status.

Pauly et al (2003) also estimate the price elasticity of demand for annually renewable term life insurance, using two sets of data: the January 1997 data set sold by CompuLife that contains firm-level premium data for term contracts from all major companies in the US market, and the 1997 US Buyer's Study sold by LIMRA International that consists of a random sample of policies bought by the customers of over 35 life insurance companies. Their regression analyses suggest that the price elasticity of demand for annually renewable term insurance ranges from 0.3 to 0.5, depending on the dataset and the control variables used.

Table 1 compares annually renewable term insurance to common goods and services in terms of price elasticities. It shows that consumers consider term insurance to be an important good in their lives. It is more inelastic than everyday use goods such as shoes and kitchen appliances and only slightly more elastic than tobacco, a product that is not only highly addictive, but in addition shows little substitution effect across brands.

[Table 1 about here]

A similar regression analysis on all fifteen questions, using death risk level dummies to allow price elasticity to change across risk scenarios, provided estimates of the three price elasticities $\lambda_{positive}$, $\lambda_{untested}$, and $\lambda_{negative}$, that are not significantly different. Although there is some evidence that average benefit levels change across risk scenarios, the data do not support the hypothesis that $\lambda_{positive} < \lambda_{untested} < \lambda_{negative}$. Thus, in our benchmark model, both $\lambda_{positive}$ and $\lambda_{negative}$ are set equal to 0.6579.

To obtain estimates for the risk elasticity of demand, attention was focused on an individual's responses to questions 1 and 6, which used the same premium pricing schedule. Question 1 asked the respondent to indicate the desired level of benefit given current death risk; in question 6, the death risk was hypothesized to be doubled. For each respondent, a risk elasticity of demand was determined by calculating the percentage change in benefit given this doubling of health risk in the question; these individual elasticities were then averaged across all respondents to determine $\delta_{(+)}$. An estimate for $\delta_{(-)}$ was calculated in a similar manner, using responses to questions 1 and 11. $\delta_{(+)}$ and $\delta_{(-)}$ were estimated at 0.9851 and 0.1279, respectively.

As stated above, the estimate for $\delta_{(+)}$ was obtained assuming a death risk increase of 100%. The results of a positive test for BRCA1/2 mutations do not exactly result in the death risk being doubled. Rather, the degree of change in known health risk depends upon the woman's family history and age. Table 2 presents the change in mortality risk following a genetic test, for the 12 cohorts of women. These probabilities were derived in Lemaire et al (2000). They show that, for instance, a 30-year old woman with 2FDR-BC who tests positive experiences a 56.1% increase in death risk. A linearity assumption was used to interpolate/extrapolate the risk elasticity parameters for women in each cohort, both for positive and negative tests.

[Table 2 about here]

Lapse rates that are differentiated according to test results are introduced. LIMRA (1996) reports average lapse rates for annually renewable term insurance policies of 15% during policy year 1, 14.8% during year 2, 12.4% during years 3-5, 9.4% during years 6-10, and 6.5% during

years 11+. These lapse rates do not vary much by age at issue. With these rates, out of one thousand issued policies, only 151.75 remain in force after 20 years. To correspond with this figure, for untested women, a constant lapse rate of 13.4% is adopted in our model for years 1-5; a rate of 7.5% is used for years 6-20. These rates lead to the same total number of lapses as the LIMRA rates. From the questionnaire, it is observed that no respondents selected a $0 benefit, thus lapsing, after learning of a positive or negative test result. This can be interpreted, for this sample, as the initial purchase of insurance serving to fulfill a basic financial need rather than a hedge against future dramatic changes in health. However, one of the primary adverse selection concerns is that women who test negative for a mutation are more likely to lapse their insurance policy than women who test positive. Following this, as a conservative approach, lapse rates for our benchmark model are set at 2% for women who test positive; for women who test negative, the lapse rate is set at 9.5%.

RESULTS

For each of the twelve cohorts, premiums collected and benefits paid year by year were tracked and term insurance benefits were changed according to elasticity parameters. The model is first run using the parameters estimates listed above. As the model conveys, the change in benefits in response to a BRCA test result widely varies across cohorts, as the significance of a test result depends on family history. For women age 30 at the beginning of year 1 with no family history of BC or OC, the prior probability of having the BRCA mutation is only 0.5%; a negative test hardly carries any information, while a positive test brings disastrous news and a huge shock. Consequently, the selected benefit -if the test is taken in year 1- only decreases by 0.12% if the test turns out to be negative, and increases by 173.07% for a positive result. For

women age 30 in the 2FDR-BC cohort, the probability of a gene mutation is 40%. The outcome of the test conveys significant information, either way. Women testing positive increase their benefit by 55.26%, women testing negative decrease their benefit by 5.61%, the highest figure among all cohorts. For other family histories, benefit increases following a positive test range between 33.87% (2FDR-BC, age 50) and 173.07% (No FH, 30), corresponding to the amount of information revealed by a positive test. Benefit decreases following a negative test range between 0.05% (no FH, age 50) and 5.61% (2FDR-BC, age 30).

Table 3 summarizes the evolution of the cohort of women age 30 at the beginning of year 1, whose family history is 2FDR-BC. Beginning at time 2 and continuing thereafter, the insurer increases premiums, reacting to the aggregate effect of women getting tested and changing their insurance benefit, untested women who reduce their insurance benefit because of price increases, and women who lapse. Annual and cumulative premium increases are depicted in Figure 1. After 20 years, the cumulative premium increase, which we also interpret as cumulated adverse selection, reaches 29.28%. The degree of information provided by the BRCA test for this family history renders this case as one of the worst possible scenarios for potential adverse selection; however, with our benchmark parameter estimates, there is clearly no "adverse selection death spiral". After seven years of escalating premium increases, the adverse selection process tapers off, as the portfolio runs out of insured women available to be tested. After 20 years, 798 policies have lapsed, 20 policyholders have died, and only 51 women remain insured and untested.

[Table 3 about here]

[Figure 1 about here]

For other cohorts, cumulated adverse selection ranges from ranges from 0.62% (no FH, age 50) to 40.44% (1FDR-BC, age 30). The 12 cohorts are then pooled into a single portfolio in which each cohort of age and family history is weighted by its respective likelihood in the population. These weights were determined using observed age-at-issue of term insurance policies obtained from LIMRA, and probabilities for given family histories derived from fertility rates published the National Center for Health Statistics (2000). The evolution of premium increases for the portfolio are tracked; these increases are also reported in Table 3. It is observed that the overall cumulative premium increase due to adverse selection reaches only 4.23%. This is a very modest figure. Despite uncertainties in the estimation of all parameters, it appears very likely that adverse selection in term life insurance following a ban on the use of the BRCA genetic test should not be a major source of concern to insurers.

To examine the degree of potential adverse selection due to genetic testing for BRCA1/2 mutations, the sensitivity of our results to the behavioral assumptions was then explored. The results presented here for the sensitivity analysis explore the 2FDR-BC, age 30 case, one that has so far exhibited a high degree of adverse selection. Recall that the benchmark value of the main elasticity parameter, $\lambda_{untested}$, was estimated at 0.6579 and because estimates of $\lambda_{positive}$ and $\lambda_{negative}$ were not found to be significantly different from $\lambda_{untested}$, the values for these two parameters were also set at 0.6579. The values for all three parameters are varied from 0.30 to 1.00 and the 20-year cumulative premium increases were then calculated. Keeping all other assumptions constant, we find remarkably that cumulated adverse selection is quite insensitive to changes in price elasticities; it remains at approximately 29.3% in the 2FDR-BC, age 30, case.

Next, keeping $\lambda_{untested}$ at the benchmark 0.6579, the range between $\lambda_{positive}$ and $\lambda_{negative}$ was expanded by setting these price elasticities equal to 0.00 and 1.00, respectively. Thus, under

this scenario, women at a higher than average risk do not reduce their insurance benefit in the face of price increases while women at a lower than average risk are completely responsive to price changes. We found that the adverse selection cost here is 31.70%.

We then kept all price elasticities at their initial levels and varied the two risk elasticities of demand. These two parameters $\delta_{(+)}$ and $\delta_{(-)}$ convey the level of benefit change after a test which results in doubling or halving the death risk; the initial estimates for these parameters were 0.9851 and 0.1279. $\delta_{(+)}$ was varied from 0.50 to 1.00; $\delta_{(-)}$ from 0.00 to 0.50. In Figure 2, the gradual increase in cumulated adverse selection is depicted in the 2 FDR-BC age 30 case; the cumulative premium increase approaches 32.19% in the most extreme case.

[Figure 2 about here]

To examine the incremental effect of lapsing, all lapse rates were kept at their benchmark levels; all price and risk elasticities were set at zero. In this scenario, women do not change their insurance benefits year to year; they either remain at $100,000 throughout their insured life or lapse their policies. It was observed that adverse selection from lapsing forces the insurer to institute a 18.07% premium increase over 20 years. We then return the price and risk elasticities to their benchmark values and set only the two lapse rates after testing to be zero. Thus, the lapse rates for untested women remain at the rates estimated from the LIMRA data. So, in this scenario, regardless of whether a woman tests positive or negative, she does not lapse her policy for the rest of the time period. We find that the 20-year adverse selection cost, which would be solely due to price and risk elasticities of demand, is 11.33%. Then, these lapse rates after testing are gradually increased. It is observed that the greater the disparity between the lapse rate after a positive test and lapse rate after a negative test, the greater the adverse selection costs.

Our model introduces three sources for adverse selection: differentiated benefits following test results, differentiated lapse rates after testing, and different reactions to price increases. Focusing on the 2 FDR-BC, age 30, case, one of the cohorts that has the highest potential for adverse selection, at our benchmark parameter estimates, we calculated cumulated adverse selection costs to be 29.28% after 20 years. The impact of differentiated lapsing rates was estimated at 18.07% while the impact of price and risk elasticities was found to be 11.33%. Given that differentiated reactions following premium increases were found to be negligible, we conclude that adverse selection costs come mainly from benefit changes following the shock of a test, and to varying lapsing rates after testing. The price elasticity of demand has a minimal impact on adverse selection costs.

DISCUSSION

In our analysis, performed with conservative behavioral assumptions, we found that potential adverse selection due to BRCA1/2 testing should not result in a significant cost to term life insurers, as our point estimate of the cumulative effect of adverse selection after 20 years only amounted to 4.23%. This cost is likely to be offset by the overall decrease in mortality rates, and the decline in breast and ovarian cancer mortality due to better prevention, detection and treatment techniques.

Many other genetic tests are now available. Among the most common are tests for familial adenomatous polyposis, myotonic dystrophy, early-onset Alzheimer's disease, multiple endocrine neoplasia, and hereditary motor and sensory neuropathy. Probabilities to develop the disease after a positive test are generally smaller than with BRCA1/2 mutations; thus their impact on life expectancy is likely to be smaller. Consequently, a similar model, specifically

developed for other genetic diseases, will surely lead to smaller estimates of the cost of adverse selection.

We conclude that as long as current testing conditions prevail (few highly predictive genetic tests available, low testing rate due to high cost), adverse selection due to genetic testing could be a manageable problem for insurance companies. This conclusion is valid only in the term life insurance market; models to study the impact of genetic testing and adverse selection in health and long term care insurance, which require different inputs on morbidity and treatment, are currently being developed.

These conclusions could change if advances in genetics lead to the development of an inexpensive test that would simultaneously investigate many common genetic diseases. The availability of such a test may be several years away, which provides some time for actuarial research to further investigate the consequences of new tests. In the presence of huge uncertainties concerning the future of genetic testing, a limited-time moratorium on the use of genetic tests by insurers, a policy implemented in many European countries, could make sense.

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Appendix

Survey Questionnaire

After answering questions concerning employment, gender, marital status, years of education completed, number of people depending on their financial support, and annual household income, respondents were requested to imagine that they currently have no personal life insurance, through their employer or otherwise, and that they are contemplating purchasing a 10-year term life policy for themselves. After explanations about the policy, respondents had in question 1 to select one benefit amount and annual premium, given their current health conditions. For the 36-45 age group, premium and benefits are provided in Table 4. In subsequent questions, premiums and health conditions were varied, keeping the same benefit levels.

Table 4

Question 1, age group 36-45

Given your current health and the basic premiums listed below, how much personal life insurance would you buy?	
Annual Premium	Benefit Amount
No purchase	0
$160	$100,000
$250	$200,000
$340	$300,000
$430	$400,000
$520	$500,000
$610	$600,000
$745	$750,000
$970	$1,000,000
$1,420	$1,500,000

Table 1

Short-run Price Elasticity of Demand of Several Goods

GOOD	ELASTICITY
Electricity	0.13
Rental housing	0.18
Water	0.20
Telephone	0.26
Eyeglasses	0.37
Jewelry and watches	0.41
Tobacco products	0.46
Term Insurance	0.66
Kitchen appliances	0.67
Movie tickets	0.87
Shoes	0.91
Shoe cleaning and repair	1.31
China, glassware, tableware	1.54
Restaurant meals	2.27

Source: Houthaker & Taylor (1970) and this research

Table 2

Increase or Decrease of Death Risk following the Outcome of BRCA1/2 Testing

AGE	TEST	NO FH	1FDR-BC	2FDR-BC	1FDR-OC
30	Positive	+175.7%	+119.2%	+56.1%	+141.2%
40	Positive	+150.8%	+113.8%	+64.0%	+122.4%
50	Positive	+68.7%	+56.2%	+34.4%	+56.6%
30	Negative	-0.9%	-21.2%	-43.9%	-13.3%
40	Negative	-0.8%	-15.4%	-35.1%	-12.0%
50	Negative	-0.4%	-7.8%	-20.7%	-7.5%

Table 3

Cost of Adverse Selection. Age 30 at Time 0.

	2FDR-BC Cohort				Entire Portfolio	
Year t	Premiums Collected	Benefits Paid	Necessary % increase in Year t+1	Cumulative % increase by Year t+1	Necessary % increase in Year t+1	Cumulative % increase by Year t+1
1	72,753.53	76,391.21	0.0000	0.0000	0.0000	0.0000
2	72,189.43	76,013.04	0.2982	0.2982	0.0550	0.0550
3	72,610.20	76,815.27	0.7883	1.0889	0.1419	0.1973
4	73,774.40	78,357.47	1.2006	2.3025	0.2103	0.4094
5	75,464.41	80,411.34	1.5344	3.8723	0.2643	0.6782
6	77,529.53	82,814.59	1.7145	5.6532	0.2906	0.9765
7	83,236.97	88,869.05	1.6713	7.4189	0.2742	1.2607
8	89,072.01	95,135.38	1.7153	9.2615	0.2768	1.5501
9	94,994.19	101,468.18	1.7285	11.1500	0.2729	1.8378
10	100,938.77	107,801.72	1.7189	13.0606	0.2654	2.1198
11	106,851.24	114,081.59	1.6935	14.9753	0.2557	2.3937
12	112,685.97	120,262.16	1.6571	16.8806	0.2450	2.6580
13	118,404.73	126,305.12	1.6130	18.7659	0.2340	2.9120
14	123,975.41	132,178.18	1.5636	20.6230	0.2231	3.1558
15	129,370.84	137,854.07	1.5105	22.4450	0.2128	3.3895
16	134,567.93	143,309.60	1.4549	24.2265	0.2031	3.6137
17	139,546.83	148,524.90	1.3977	25.9628	0.1940	3.8289
18	144,290.33	153,482.84	1.3395	27.6500	0.1857	4.0356
19	148,783.28	158,168.43	1.2808	29.2849	0.1781	4.2346
20	153,012.27	162,568.46				

Figure 1

Annual and Cumulative % Premium Increases, 2FDR-BC, age 30

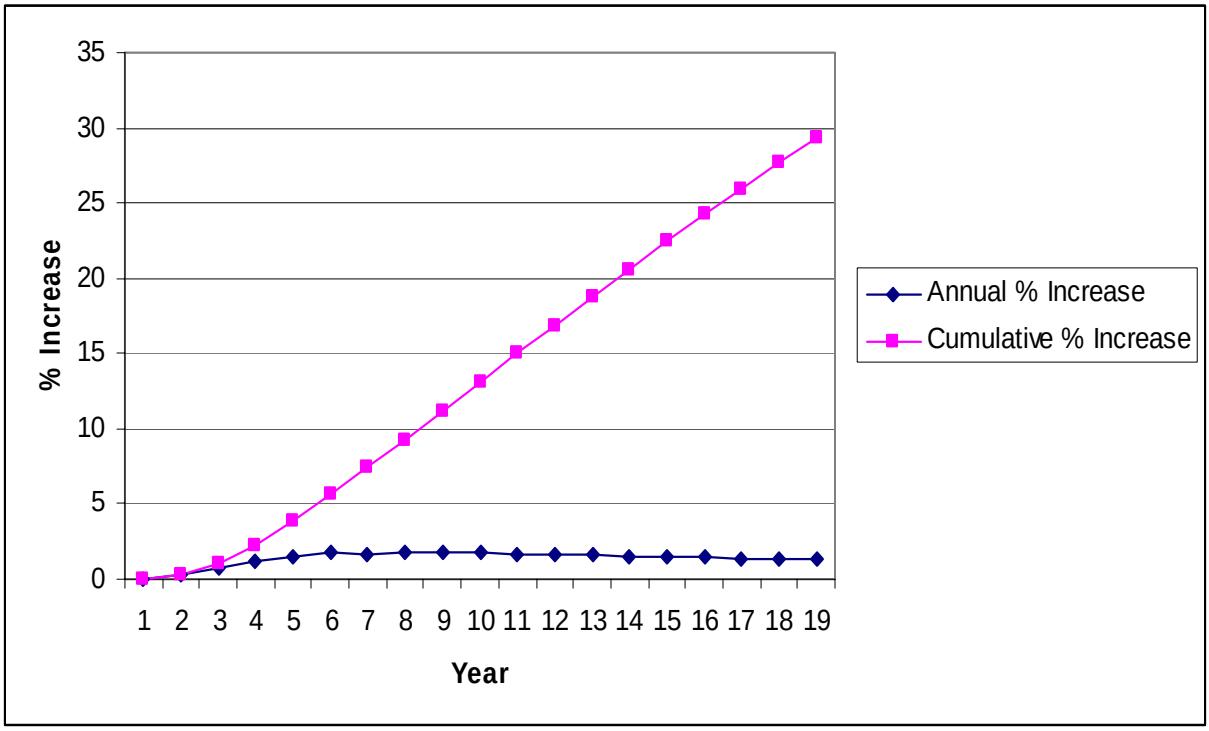

Figure 2

Cumulative % Premium Increases, 2FDR-BC, age 30. Varying Risk Elasticities of Demand