Disease prevention in adverse selection equilibria

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1. Objective

Are the benefits related to the development of predisposition tests (*i.e.,* tests providing individuals with better information about their probability of developing a disease) exploited when the use of genetic information for rate-making purposes is prohibited ?

Personalized health-related information can potentially improve welfare through better-targeted disease prevention actions. However:
1) insurance and prevention decisions are related (Ehrlich and Becker, 1972)
2) information asymmetry leads to suboptimal insurance coverage (Rothschild and Stiglitz, 1976 and Wilson, 1977)

To what extent do individuals make use of predisposition tests in order to target prevention actions in adverse selection equilibria?

Genetic information and prevention decisions with moral hazard and adverse selection:

Doherty and Posey (1998): High risk individuals have the opportunity to perform self-protection actions (*i.e.,* to reduce the probability of the loss); conditions under which information on the baseline probability of loss has a positive private and social value.

Hoel and Iversen (2002): how decisions conditional to: 1) the insurers access to the genetic information and; 2) the mix of compulsory and private health insurance lead to economic inefficiencies in the use of genetic testing.

Peter, Richter and Thistle (2014): individuals' decision to perform a genetic test allowing informed self-protection in four different forms of regulation of the genetic information in health insurance markets.

Bardey and De Donder (2014): relationship between the value of the genetic test and both the efficiency and the cost of the self-protection actions that cannot be observed by insurers.

Filipova-Neumann and Hoy (2017): welfare implications of (possibly imperfect) genetic tests that improve the targeting of surveillance (activities increasing the probability of early detection of potential diseases).

Genetic information and prevention decisions with adverse selection:

Barigozzi and Henriet (2011): individuals’ decision to perform a genetic test allowing informed self-insurance actions (*i.e.,* actions reducing the extent of the loss) in four different forms of regulation of the genetic information in health insurance markets.

Crainich (2017) determine the intensity of self-insurance efforts in the whole set of equilibria possibly arising in an insurance market when insurers are denied access to genetic information known by policyholders.

Self-insurance actions reducing both the financial and health consequences of diseases (bi-dimensional utility function depending on wealth and health).

The empirical literature indicates that improved health either increases (see among others Viscusi and Evans (1990), Sloan et al. (1998), Carthy et al. (1999), Finkelstein, Luttmer and Notowidigdo (2013), Gyrd-Hansen (2016)) or reduces (Evans and Viscusi (1991), Lilliard and Weiss (1998), Edwards (2008)) the marginal utility of wealth.

We determine the extent to which individuals target self-insurance actions according to predisposition test results (*i.e.*, adjust prevention actions to their probability of disease) in various adverse selection equilibria.

2. The model

Expected utility maximizing individuals

Utility depends on wealth (w) and health (h), therefore: $u(w,h)$.

Utility is increasing and concave with respect to wealth and health:
$u_1(w,h) > 0; u_{11}(w,h) < 0; u_2(w,h) > 0; u_{22}(w,h) < 0;$

No a priori assumption is made about the sign of $u_{12}(w,h)$

Individuals develop (with a probability p) a disease that has financial and health consequences (respectively denoted by L and M).

Consequences of the disease can be mitigated through self-insurance:

n: intensity of self-insurance actions

α: unit cost of self-insurance

$L(n)$: financial consequence of the disease (with $L'(n) < 0$ and $L''(n) > 0$)

$M(n)$: health consequence of the disease (with $M'(n) < 0$ and $M''(n) > 0$)

Self-insurance actions include programs allowing early detections of diseases onset, and thus more effective treatments (such as the use of mammograms or colonoscopies).

Contracts covering the financial consequences of the disease are sold by perfectly competitive insurance companies. Self-insurance actions can be observed by insurers: contracts are contingent on the intensity of self-insurance.

$R = raL(n)$: insurance premium with a = insurance coverage ($0 \leq a \leq 1$)

r= insurance price (cost per € covered)

$I = aL(n)$: insurance indemnity

A genetic test (perfect and costless) is available. Insurers do not know individuals' informational status: the test is taken by individuals (Doherty and Thistle, 1996).

The test sorts the population into 2 groups:

- the high-risks (prob. of disease: p_H; proportion of the population: λ)
- the low-risks (prob. of disease : p_L; proportion of the population : 1- λ)

with $p_H > p_L$

The average probability of disease is denoted: $p_M = (1 - \lambda)p_L + \lambda p_H$

Adverse selection equilibria

Insurance companies make non-static expectations about the policy offers made by other firms

Insurers make non-negative profits on each contract (*i.e.,* there is no cross-subsidization between the contracts).

1. Rothschild and Stiglitz (1976) separating equilibrium (λ sufficiently high)
2. Wilson (1977) pooling equilibrium (λ sufficiently low)

Insurance companies make non-negative profits on the average contract sold (*i.e.,* there might be some degree of cross-subsidization between the contracts)

1. Rothschild and Stiglitz (1976) separating equilibrium (λ sufficiently high)
2. Miyazaki (1977) and Spence (1978) separating equilibrium (λ sufficiently low)

	Non-negative profits on each contract	**Non-negative profits on the average contract**
Low proportion of high-risks	**Wilson (1977)** pooling equilibrium: partial insurance; contracts based on the average probability of disease	**Miyazaki (1977) and Spence (1978)** separating equilibrium: full-insurance for HR, partial insurance for LR; cross subsidization
High proportion of high-risks	**Rothschild and Stiglitz (1976)** separating equilibrium: full-insurance for HR, partial insurance for LR; no-cross subsidization	**Rothschild and Stiglitz (1976)** separating equilibrium: full-insurance for HR, partial insurance for LR; no-cross subsidization

3. Genetic tests are not available

Individuals make insurance and self-insurance decisions according to the average probability of disease (p_M).

The equilibrium is defined by the values of a, n and r maximizing the expected utility (EU_1).

$$EU_1 = (1 - p_M)u(A_M) + p_M u(B_M)$$

with: $A_M = (w - \alpha n - raL(n), H);$

$B_M = (w - \alpha n - raL(n) - (1 - a)L(n), H - M(n))$

Constraints: $0 \leq a \leq 1$; $raL(n) \geq p_M aL(n)$

$$Z_1 = (1 - p_M)u(A_M) + p_M u(B_M) + \beta[1 - a]$$

with: $A_M = (w - \alpha n - p_M a L(n), H);$

$B_M = (w - \alpha n - p_M a L(n) - (1 - a)L(n), H - M(n))$

First-order conditions

$$\frac{\delta Z_1}{\delta a} = -p_M(1 - p_M)u_1(A_M) + p_M(1 - p_M)u_1(B_M) - \beta \leq 0; a \geq 0; a\frac{\delta Z_1}{\delta a} = 0$$

$$\frac{\delta Z_1}{\delta n} = (-\alpha - p_M a L'(n)[(1 - p_M)u_1(A_M) + p_M u_1(B_M)] + p_M[-L'(n)(1 - a)u_1(B_M) - M'(n)u_2(B_M)] \leq 0; n \geq 0; n\frac{\delta Z_1}{\delta n} = 0$$

$$\frac{\delta Z_1}{\delta \beta} = (1 - a) \geq 0; \beta \geq 0; \beta\frac{\delta Z_1}{\delta \beta} = 0$$

3. No genetic testing

The solution of the program depends on the sign of u_{12}:

if $u_{12} < 0$: $a = 1$, $\beta_1 > 0$ (corner solution) and n is defined by:

$$\big(-\alpha - p_M L'(n)\big)[(1 - p_M)u_1(A_M) + p_M u_1(B_M)] - p_M M'(n) u_2(B_M) = 0$$

if $u_{12} = 0$: $a = 1$, $\beta_1 = 0$ (interior solution) and n is defined by:

$$\big(-\alpha - p_M L'(n)\big)u_1(B_M) - p_M M'(n) u_2(B_M) = 0$$

if $u_{12} > 0$: $a < 1$, $\beta_1 = 0$ (interior solution) and n is defined by:

$$\big(-\alpha - p_M L'(n)\big)u_1(B_M) - p_M M'(n) u_2(B_M) = 0$$

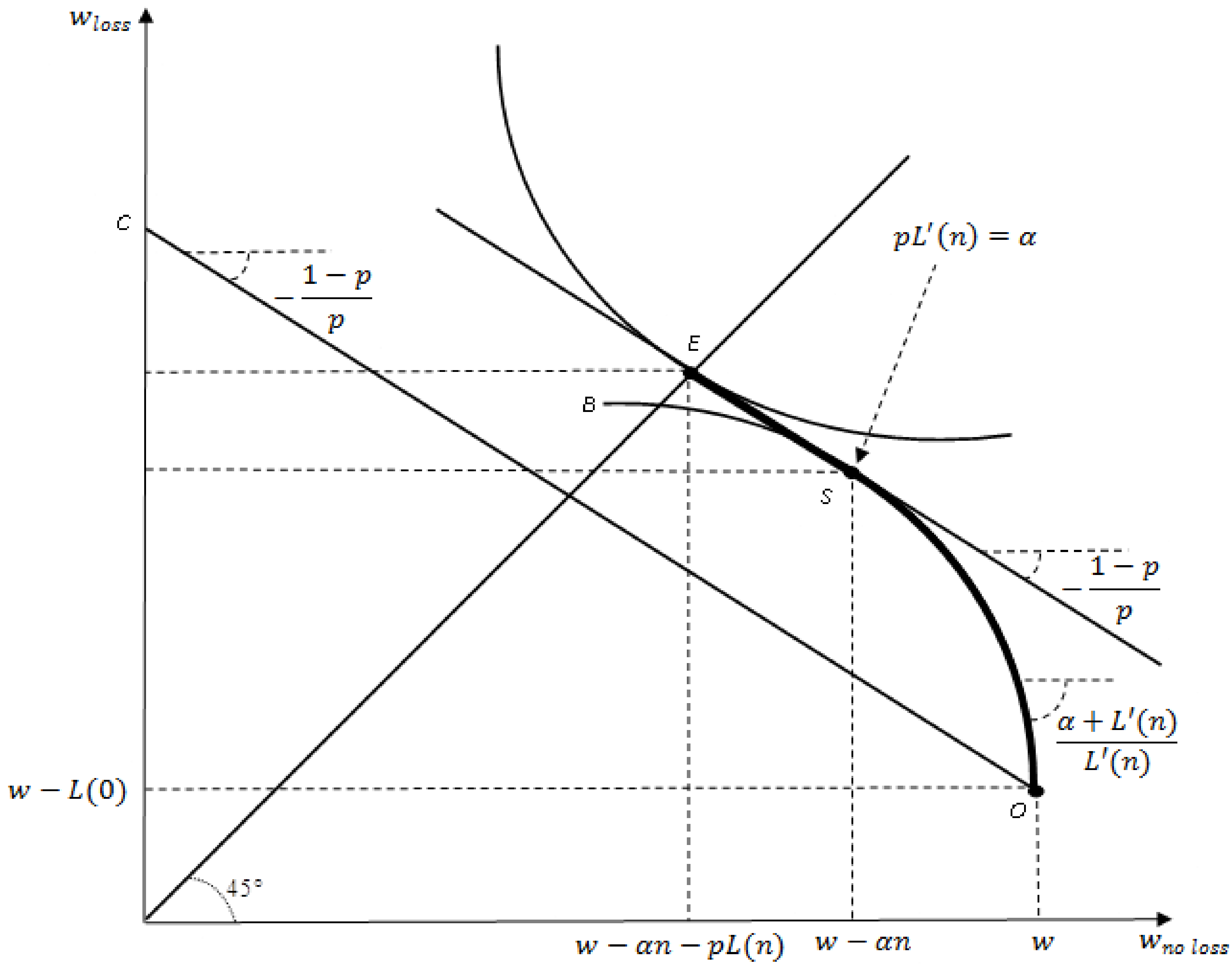
3. No genetic testing

Suppose diseases only have financial consequences

When insurance is available at fair-odds, it reallocates wealth from the no-disease to the disease state at no cost (unchanged expected wealth). Risk averse individuals purchase full insurance contracts (Mossin, 1968).

Self-insurance reallocates wealth from the no-disease to the disease state while changing the expected wealth. It is performed as long as it increases expected wealth. The self-insurance decision rule is:

$$\alpha = -p_M L'(n)$$


w_{loss}
C
$-\frac{1-p}{p}$
$pL'(n) = \alpha$
E
B
S
$-\frac{1-p}{p}$
$\frac{\alpha + L'(n)}{L'(n)}$
$w - L(0)$
O
45°
$w - \alpha n - pL(n)$
$w - \alpha n$
w
$w_{no\ loss}$

Suppose diseases have financial and health consequences but that self-insurance has no impact on the health consequence of the disease ($M'(n) = 0$).

Individuals purchase (Rey 2003):

- less than full insurance if the marginal utility of wealth rises with health
- more than full insurance if the marginal utility of wealth falls with health
- full insurance if the marginal utility of wealth does not change with health

The self-insurance decision rule is:

$$\alpha = -p_M L'(n)$$

When diseases have financial and health consequences and when self-insurance mitigates the health consequences of the disease ($M'(n) < 0$):

Individuals have an additional incentive to preform self-insurance actions.

The marginal cost of self-insurance($-\alpha - p_M L'(n) < 0$) weighted by the marginal utility of wealth is equal to its marginal benefit ($-p_M M'(n) > 0$) weighted by the marginal utility of health.

4. Genetic tests are available

4.1 Social optimum

Maximization of the social welfare function SW:

$$SW = (1-\lambda)[(1-p_L)u(A_L) + p_L u(B_L)] + \lambda[(1-p_H)u(A_H) + p_H u(B_H)]$$

with:

$$A_L = (w - \alpha n_L - r_L a_L L(n_L), H);$$

$$B_L = (w - \alpha n_L - r_L a_L L(n_L) - (1-a_L)L(n_L), H - M(n_L))$$

$$A_H = (w - \alpha n_H - r_H a_H L(n_H), H);$$

$$B_H = (w - \alpha n_H - r_H a_H L(n_H) - (1-a_H)L(n_H), H - M(n_H))$$

Decision variables: r_L; r_H; a_L; a_H; n_L; n_H

Constraints: $0 \leq r_L \leq 1; 0 \leq r_H \leq 1; 0 \leq a_L \leq 1; 0 \leq a_H \leq 1$

$$(1-\lambda)(r_L - p_L)a_L L(n_L) + \lambda(r_H - p_H)a_H L(n_H) \geq 0$$

The optimal insurance coverage depends on the effect of health on the marginal utility of wealth:

$$a_i^* \leq 1 \text{ if } u_{12} \geq 0 \text{ and } a_i^* = 1 \text{ if } u_{12} < 0 \; (i = L, H)$$

The values of r_L^* and r_H^* are such that:

if $u_{12} > 0$: r_L^* and r_H^* are selected so that wealth in the high-risk state is higher;

if $u_{12} < 0$: r_L^* and r_H^* are selected so that wealth in the low-risk state is higher;

if $u_{12} = 0$: $r_L^* L(n_L^*) + \alpha n_L^* = r_H^* L(n_H^*) + \alpha n_H^*$ (same wealth in each state);

The intensity of self-insurance actions is defined by (for $i = L, H$):

If $u_{12} < 0$: $\left(-\alpha - p_i L'(n_i^*)\right)[(1 - p_i) u_1(A_i^*) + p_i u_1(B_i^*)] - p_i M'(n_i^*) u_2(B_i^*) = 0$

if $u_{12} \geq 0$: $\left(-\alpha - p_i L'(n_i^*)\right) u_1(B_i^*) - p_i M'(n_i^*) u_2(B_i^*) = 0$

4.2. *Laissez-faire*

Individuals make decisions and insurance companies offer contracts based on the (true) probability of disease: $\hat{r}_L = p_L$ and $\hat{r}_H = p_H$

The insurance coverage depends on how the marginal utility of wealth is affected by health:

$$\hat{a}_i \leq 1 \text{ if } u_{12} \geq 0 \text{ and } \hat{a}_i = 1 \text{ if } u_{12} < 0 \ (i = L, H)$$

The intensity of self-insurance actions is defined by (for $i = L, H$)

If $u_{12} < 0:\ \left(-\alpha - p_i L'(\hat{n}_i)\right)\left[(1-p_i)u_1\left(\hat{A}_i\right) + p_i u_1\left(\hat{B}_i\right)\right] - p_i M'(\hat{n}_i)u_2\left(\hat{B}_i\right) = 0$

If $u_{12} \geq 0:\ \left(-\alpha - p_i L'(\hat{n}_i)\right)u_1\left(\hat{B}_i\right) - p_i M'(\hat{n}_i)u_2\left(\hat{B}_i\right) = 0$

Although the levels of self-insurance efforts in the *Laissez-faire* regime are not the ones maximizing social welfare ($\hat{A}_i \neq A_i^*$ and $\hat{B}_i \neq B_i^*$), individuals target self-insurance efforts according to predisposition test results.

4.3. Pooling equilibrium

A unique insurance contract - based on the average probability of disease - is sold to policyholders. It results from the low-risks' decision: high-risks purchase the same insurance contract and perform the same self-insurance effort.

$$Z_2 = (1 - p_L)u(A_M) + p_L u(B_M) + \beta[1 - a]$$

with: $A_M = (w - \alpha n - p_M aL(n), H);$

$$B_M = (w - \alpha n - p_M aL(n) - (1 - a)L(n), H - M(n))$$

$$\frac{\delta Z_2}{\delta n} = -p_M(1 - p_L)u_1(A_M) + p_L(1 - p_M)u_1(B_M) - \beta \leq 0; a \geq 0; a\frac{\delta Z_2}{\delta a} = 0$$

$$\frac{\delta Z_2}{\delta n} = (-\alpha - p_M aL'(n)[(1 - p_L)u_1(A_M) + p_L u_1(B_M)]$$
$$+p_L[-L'(n)(1 - a)u_1(B_M) - M'(n)u_2(B_M)] \leq 0; n \geq 0; n\frac{\delta Z_1}{\delta n} = 0$$

$$\frac{\delta Z_2}{\delta \beta} = (1 - a) \geq 0; \beta \geq 0; \beta\frac{\delta Z_2}{\delta \beta} = 0$$

We rule out the corner solution (*i.e.,* we suppose that low-risk individual are not sufficiently correlation averse to purchase full insurance at less than odds: $a^p < 1$)

The intensity of self-insurance actions is defined by (for $i = L, H$):

$$\left(-\alpha - p_M L'(n^p)\right)u_1(B_P) - p_M M'(n^p)u_2(B_P) = 0$$

Despite they have the genetic information, the low-risks apply the same decision rule than in the absence of testing: they do not target self-insurance efforts according to predisposition test results.

4.4. Separating equilibrium (Rothschild & Stiglitz)

Two contracts are offered: they specify a premium and an insurance coverage associated to each self-insurance effort. At the equilibrium (achieved if the proportion of high-risks is sufficiently high), the contracts act as a self-selection mechanism.

Both individuals types purchase actuarially fair insurance contracts. Compared to the *laissez-faire* case, low-risk individuals purchase less insurance while high-risks receive the same contract.

The intensity of self-insurance actions performed by high-risk agents corresponds to that performed at the *laissez-faire* equilibrium.

The contract offered to low-risk individuals maximizes

$$Z_3 = (1 - p_L)u(A_{RS}) + p_L u(B_{RS})$$

with: $A_{RS} = (w - \alpha n - p_L a L(n), H)$;

$B_{RS} = (w - \alpha n - p_L a L(n) - (1 - a)L(n), H - M(n))$

Decision variables: $a_L; n_L$

Constraint: $\widetilde{EU}_H > (1 - p_H)u(A_{RS}) + p_H u(B_{RS})$

where $\widetilde{EU}_H$ is the expected utility the high-risks obtain at the *laissez-faire* equilibrium

The self-insurance effort performed by low-risk individuals is given by:

$$\left(-\alpha - p_L L'\left(n_L^{RS}\right)\right) u_1(B_{RS}) - p_L M'\left(n_L^{RS}\right) u_2(B_{RS}) = 0$$

Low-risk individuals target self-insurance efforts according to predisposition test results.

The self-insurance efforts are not those defined at the social optimum since $u_1(.)$ and $u_2(.)$ are evaluated at B_{RS}, *i.e.* the wealth level in case of loss at the Rothschild-Stiglitz equilibrium.

4.4. Separating equilibrium (Miyazaki and Spence)

Two contracts are offered: they specify a premium and an insurance coverage associated to each self-insurance effort.

At the equilibrium (achieved if the proportion of high-risks is sufficiently low), the contracts act as a self-selection mechanism.

Insurance companies do not necessarily price each contract at its expected cost but instead make losses on some contracts that are counterbalanced by profits made on others: $r_L > p_L$ and $r_H < p_H$

The subsidization of the high-risks by the low-risks can be beneficial for both groups: low-risk individuals may benefit from a higher insurance coverage as the subsidy provides to the high risks more incentives to purchase a contract that is designed for them.

The contract offered to low-risk individuals maximizes

$$Z_4 = (1 - p_L)u(A_L) + p_L u(B_L)$$

with: $A_L = (w - \alpha n - r_L aL(n), H)$;

$$B_L = \left(w - \alpha n - r_L aL(n) - (1 - a)L(n), H - M(n)\right)$$

$$A_H = (w - \alpha n_H - r_H a_H L(n_H), H);$$

$$B_H = (w - \alpha n_H - r_H a_H L(n_H) - (1 - a_H)L(n_H), H - M(n_H))$$

Decision variables: $r_L;\ r_H;\ a_L;\ a_H;\ n_L;\ n_H$

Constraints:

$$0 \le r_L \le 1; 0 \le r_H \le 1; 0 \le a_L \le 1; 0 \le a_H \le 1$$

$$(1 - \lambda)(r_L - p_L)a_L L(n_L) + \lambda(r_H - p_H)a_H L(n_H) \ge 0$$

$$(1 - p_H)u(A_H) + p_H u(B_H) \ge (1 - p_H)u(A_L) + p_H u(B_L)$$

The self-insurance effort performed by low- and high-risk individuals are respectively given by:

$$\left(-\alpha - p_L L'\left(n_L^{MS}\right)\right) u_1(B_L) - p_L M'\left(n_L^{MS}\right) u_2(B_L) = 0$$

$$\left(-\alpha - p_H L'\left(n_H^{MS}\right)\right) u_1(B_H) - p_H M'\left(n_L^{MS}\right) u_2(B_H) = 0$$

High- and low-risk individuals exploit the genetic information as they target self-insurance efforts according to predisposition test results.

The intensities of self-insurance actions are not those defined at the social optimum since $u_1(.)$ and $u_2(.)$ are evaluated at B_{MS}, *i.e.* the wealth level in case of loss at the Myiazaki-Spence equilibrium.

5. Discussion

Interesting results are obtained when disease have financial and health effects but when self-insurance actions do not reduce the latter ($L'\,(n) < 0$; $M'(n) = 0$): the optimal intensity of self-insurance ($-\alpha - p_i L'(n_i) = 0$; $i = L, H$) are performed in the Laissez-faire regime, the Rothschild-Stiglitz equilibrium and the Miyazaki-Spence equilibrium. The personalized information is not exploited in the pooling equilbrium ($-\alpha - p_M L'(n) = 0$).

What happens when self-insurance actions cannot be observed?

6. Conclusion

When insurers have no access to the genetic information, individuals do not adjust self-insurance actions to their probability of disease in case the pooling equilibrium occurs (insurance companies breakeven on each contract and the proportion of high-risk individuals in the population is low).

Individuals exploit the genetic information in the other adverse selection equilibria, *i.e.* if the proportion of high-risk individuals in the population is high or if – whatever the proportion of high-risks in the population – insurance companies breakeven on the average contract sold.

There is empirical evidence (Browne (1992)) of adverse selection and of cross-subsidization from the low to the high risks in the health insurance market. Besides, Browne and Doerpinghaus (1993, 1994) indicate that low- and high-risk policyholders purchase similar insurance policies. These works suggest thus that the Wilson pooling equilibria prevail.