Disease prevention in separating adverse selection equilibria

David Crainich

CNRS (LEM, UMR 8179) and Iéseg School of Management, Lille

Abstract

The paper examines self-insurance decisions under three adverse selection equilibria: the pooling equilibrium, the separating Rothschild-Stiglitz equilibrium and the separating Miyazaki-Spence equilibrium. We first show that adverse selection equilibria do not lead to optimal self-insurance efforts when diseases affect both the individuals' wealth and quality of life. When diseases have no impact on individuals' quality of life, we indicate that self-insurance efforts maximize the social welfare in case separating equilibria prevail. In this last case, the opportunity to make better informed self-insurance decisions brought be the development of genetic testing are exploited even if a regulation prohibiting insurers' access to genetic information applies.

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Introduction

Whether genetic test results should be made available to insurance companies is the most debated economic issue related to the development of genetic testing. Making genetic information disclosed to insurers should lead to genetic discrimination in the health insurance market since the individuals revealed at high-risk by the test could potentially not afford insurance contracts (or at least pay expensive insurance premia). On the other hand, adverse selection equilibria (which lead to the underinsurance of some individuals) prevail if the information remains private. A large literature has been dedicated to this specific problem (see Hoy and Ruse (2005) for an overview of the issue). Meanwhile, another topic related to the development of genetic testing has been overlooked: do individuals take advantage of the benefits brought by predisposition tests[1] which should lead to better informed prevention decisions? Ehrlich and Becker (1972) indicate that optimal self-protection efforts (that reduce the probability of the loss) and self-insurance efforts (that reduce the size of the loss in case it occurs) depend both on the probability of disease and on the insurance coverage individuals purchase. This implies that a better allocation of resources can be achieved if individuals make prevention decisions based on their own probabilities of disease and not on the average probability of disease in the population. This also suggests that the information regime in the health

[1] Predisposition tests provide individual information about the probability of disease.

insurance market - insofar as it influences insurance choices - may distort prevention decisions from their optimal levels.

The literature dedicated to the analysis of prevention decisions under adverse selection equilibria mainly addresses the incentives to seek the genetic information in order to make better informed prevention decisions. Doherty and Posey (1998) establish the conditions under which the information on the death probability (which allows to high-risk individuals to better adjust the level of self-protection actions) has a positive social value. Using a similar framework (high-risk individuals have the opportunity to reduce their probability of disease through self-protection actions), Hoel and Iversen (2002) determine the extent to which compulsory and private health insurance lead to inefficiency in the use of genetic testing. Filipova and Hoy (2009) examine how private and public insurance regimes exploit the opportunity to better calibrate prevention efforts through genetic information. The latter opportunity is also analyzed in Barigozzi and Henriet (2011) who compare different regulation of the information in the health insurance market.

In case this insurance coverage is constrained (because asymmetric adverse selection prevail for instance), the optimality of self-insurance decisions may thus be questioned since prevention and insurance decisions are related. This is the issue we analyse in our model which includes various motives leading individuals to undertake self-insurance actions. We introduce the fact that self-insurance actions may be implemented in order: 1) to reduce the pain and discomfort related to a disease; 2) to reduce the financial consequences of the disease in case individuals are not fully insured and; 3) to reduce the insurance premium (in case self-insurance efforts can be observed and thus condition the terms of the insurance contract). As a special case of the point 1), we suppose that the disease only has financial consequences. Using this framework, we examine whether two information regimes (the strict prohibition of the use of genetic information for insurance purposes and the *laissez-faire* approach) are such that individuals make the optimal use of the genetic information under three adverse selection equilibria: the pooling equilibrium (see Wilson (1977)), the separating Rothschild-Stiglitz equilibrium (see Rothschild and Stiglitz (1976)) and the separating Miyazaki-Spence equilibrium (see Miyazaki (1977) and Spence (1978)).

We first highlight that the influence of the information regime on the optimality of self-insurance decisions depends on whether diseases have an impact on the individuals' quality of life and on the type of adverse selection equilibria prevailing in the market. Optimal self-insurance actions are shown to be implemented by all the individuals only under the *laissez-faire* information regime when diseases affect individuals' wealth and their quality of life. In case the quality of life is not affected by the disease, regulations that prohibit the use of genetic tests results for insurance purpose also lead to optimal self-insurance decisions when separating equilibria (both of the Rothschild-Stiglitz or of the Miyazaki-Spence type) prevail.

The paper is organized as follows. The model is described in section 2. Optimal self-insurance efforts are characterized in section 3. Full information self-insurance efforts are examined in section 4. The rest of the paper is dedicated to adverse selection equilibria since we analyze the pooling equilibrium (section 5), the Rothschild-Stiglitz separating equilibrium (section 6) and the Miyazaki-Spence separating equilibrium (section 7). Section 8 concludes.

2. The model

Individuals' preferences are represented by the utility function $u(w,h)$ where w and h respectively denotes individuals' wealth and quality of life. Utility is increasing ($u_1(w,h)>0$ and $u_2(w,h)>0$) and concave ($u_{11}(w,h)>0$ and $u_{22}(w,h)>0$) in both arguments of the utility function[2]. No *a priori* sign is assumed about the cross derivative of the utility function[3]. Individuals are expected utility maximizers. They are endowed with an initial wealth w. Their quality of life in the absence of disease is denoted by H .

Individuals are identical in every respect except in their probability of being sick. The probability of disease of the high-risks (who represent a proportion λ of the population) is denoted by p_H while that of the low-risks (who represent a proportion $1-\lambda$ of the population) is denoted by p_L ($p_H > p_L$). Predisposition tests perfectly sort individuals into low- and high-risk groups, allowing them to make decisions according to their own probability of disease. We assume that individuals' informational status cannot be observed. This assumption allows us to be sure that individuals always perform the test (see Doherty and Thistle (1996)).

In case of disease, individuals follow a treatment. To reduce the severity of the disease, individuals have the opportunity to implement self-insurance efforts (denoted by n) before the appearance of the disease. Self-insurance efforts reduce both the cost of the treatment (denoted by $L(n)$) and the health deterioration in case of disease (denoted by $M(n)$). The cost of the treatment and the health

[2] First and second derivatives of the utility function with respect to the first argument (wealth) are respectively denoted by u_1 and u_{11} . First and second derivatives of the utility function with respect to the second argument (quality of life) are respectively denoted by u_2 and u_{22} .

[3] Empirical evidences suggest that health status modifies the marginal utility of wealth (see among others Viscusi and Evans (1990), Evans and Viscusi (1991) and Finkelstein et al. (2011)).

deterioration both fall at a decreasing rate with self-insurance efforts ($L'(n)<0$ and $M'(n)<0$; $L''(n)>0$ and $M''(n)>0$). The unitary cost of self-insurance is denoted by α. Throughout the paper, we will assume as a special case that the disease only affects individuals' wealth. Self-insurance actions only lower the cost of the treatment under this particular specification ($M=0$).

Insurance contracts are sold in competitive markets. They specify a premium and an indemnity paid in case of disease. Self-insurance efforts are supposed to be observed by insurers[4]. As a result, the premium and the indemnity are contingent to self-insurance actions. They are respectively denoted by $raL(n)$ and $aL(n)$ where r denotes the price per unit of coverage and where the insurance coverage that individuals buy is denoted by a. Competition forces insurance companies to charge actuarially fair insurance premia ($r=p_L$ and $r=p_H$ for the low- and high-risks respectively). Insurers define the structure of insurance contracts at stage 1, *i.e.* they offer a menu of contracts for each self-insurance decision. At stage 2, individuals simultaneously make self-insurance and insurance decisions (they choose a contract among the offer made). Individuals make self-insurance efforts and choose an insurance coverage at stage 2 given that the insurance premium and indemnity are respectively given by raL and aL (where L is the average cost of treatment). Insurance companies are supposed to monitor the total amount of insurance that individuals buy. Finally, insurance companies make non-static expectations about the policy offers made by other firms. This implies that an equilibrium exists in the health insurance market.

3. Optimal self-insurance efforts

The optimal prices per unit of coverage, insurance purchase and self-insurance efforts[5] made by each individuals' type are defined through the maximization of the utilitarian social welfare function SW.

$$\begin{aligned}SW=(1-\lambda)[(1-p_L)u(w-\alpha n_L-r_La_LL(n_L),H)+p_Lu(w-\alpha n_L-r_La_LL(n_L)-(1-a_L)L(n_L),H-M(n_L))]\\+\lambda[(1-p_H)u(w-\alpha n_H-r_Ha_HL(n_H),H)+p_Lu(w-\alpha n_H-r_Ha_HL(n_H)-(1-a_H)L(n_H),H-M(n_H))]\end{aligned}$$

This welfare function implies that individuals make decisions behind the veil of ignorance and act as expected utility maximizers. Doing so, we capture both the fear that individuals have towards the (ex-ante) risk of being revealed as being a "bad" risk by the test (*i.e.* the concern for genetic

[4] Barigozzi and Henriet (2010) note that "secondary prevention which allows early curative actions (and hence a low cost of treatment) are generally observable and verifiable by a third party". Besides, some indicators may reveal health-related behaviors (smoking behavior can be detected using imaging techniques, physical activity can be deduced from membership to a sporting club,…).

[5] The optimal values of the variables are indicated by a star superscript. The subscripts H and L are associated to the high- and low-risk individuals respectively.

discrimination) and their desire to take advantage of the opportunities to make informed decisions (*i.e.* the concern for efficiency).

This maximization program must meet the usual constraint ($0 \le r_L \le 1$ and $0 \le r_H \le 1$, $0 \le a_L \le 1$ and $0 \le a_H \le 1$, $n_L \ge 0$ and $n_H \ge 0$) as well as the following resource constraint:

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

We show in appendix A that the optimal self-insurance efforts (denoted n_L^* and n_H^*) are defined, for the low- and high-risks respectively by Eqs. (1) and (2).

For the low-risks:

$$\begin{cases} (-\alpha - p_L L'(n_L^*))[(1-p_L)u_1(D_L, H - M(n_L^*) + p_L u_1(C_L, H)] - p_L M'(n_L^*) u_2(., H - M(n_L^*)) = 0 & \text{if } u_{12} < 0 \ (1) \\ (-\alpha - p_L L'(n_L^*)) u_1(D_L, H - M(n_L^*)) - p_L M'(n_L^*) u_2(., H - M(n_L^*)) = 0 & \text{if } u_{12} \ge 0 \ (2) \end{cases}$$

For the high-risks:

$$\begin{cases} (-\alpha - p_H L'(n_H^*))[(1-p_H)u_1(D_H, H - M(n_H^*) + p_H u_1(C_H, H)] \\ \qquad - p_H M'(n_H^*) u_2(D_H, H - M(n_H^*)) = 0 & \text{if } u_{12} < 0 \quad (3) \\ (-\alpha - p_H L'(n_H^*)) u_1(D_H, H - M(n_H^*)) - p_H M'(n_H^*) u_2(D_H, H - M(n_H^*)) = 0 & \text{if } u_{12} \ge 0 \quad (4) \end{cases}$$

Optimality requires that individuals implement self-insurance efforts as long as the sum of the expected financial benefit (reduction in the expected cost of the treatment) and the expected health benefit (reduction in the expected severity of the disease) of the effort exceeds its financial cost. It is interesting to note that the optimal self-insurance efforts depend on the level of the individuals' health and wealth since the cost of self-insurance is weighted by the marginal utility of wealth while its marginal expected benefit is weighted by the marginal utility of wealth and health. Besides, since the interaction between wealth and health defines the optimal insurance coverage (see Rey (2003)) that in turn determines the wealth levels in both states of the world, the self-insurance decision rule depends on this interaction (as shown in the Eqs. (1) to (4)).

Individuals purchase full insurance ($a_H = a_L = 1$) in case $u_{12} \ge 0$ (see Mossin (1968) and Rey (2003)) and the financial cost of self-insurance is weighted by the unique marginal utility of wealth ($u_1(D_i, H - M(n_i^*)) = u_1(C_i, H)\,; i = H, L$) since the insurance coverage is set so as to make wealth equal in the disease and in the no-disease case. When individuals purchase partial insurance coverage (this happens when $u_{12} < 0$; see Rey (2003)), wealth in the disease and in the no-disease state are different and the financial cost of self-insurance is weighted by the expected utility of wealth ($(1-p_i)u_1(F_i, H) + p_i u_1(G_i, H - M(n_i^*))$; $i = H, L$).

We show in the appendix A that the optimal prices per unit of insurance that each group pays must be such that the wealth levels are made equal between each individual if $u_{12} = 0$. In contrast, the high-risk (resp. low-risks) group should be wealthier than the low-risk (resp. high-risk) group in case $u_{12} < 0$ (resp. $u_{12} > 0$). This result can be explained in the following way. If $u_{12} < 0$, an extra unit of wealth has more impact on the marginal utility in the disease state than on the marginal utility in the healthy state. Since the high-risks are characterized by a higher probability of being sick, they should obtain more wealth. Using the same reasoning, the price per unit of insurance the low-risks (resp. high-risks) pay is such that low-risk individuals should be wealthier than high-risk ones if $u_{12} > 0$.

If the treatment perfectly restores patients' health (so that $M = 0$ which implies that self-insurance efforts have no effect on patients' health $M'(n) = 0$), Eqs. (2) and (4) indicate that the optimal self-insurance efforts are defined by:

Low-risk individuals: $\alpha = -p_L(n_L^*)$ (5)

High-risk individuals: $\alpha = -p_H(n_H^*)$ (6)

In this case, optimality requires that individuals make self-insurance efforts as long as the efforts' cost is lower than the reduction in insurance premia they can obtain. Since the disease has no effect on the quality of life and since individuals are fully insured, their only incentive to make self-insurance efforts is to reduce their insurance premium.

4. Full information self-insurance efforts

As indicated by Crocker and Snow (2000), competition in the health insurance market forces insurance companies to sell type-specific contracts at fair odds. In the absence of information asymmetry, individuals thus maximize (according to their type) the following expected utility:

$$EU_i = [(1-p_i)u(w - \alpha n_i - p_i a_i L(n_i), H) + p_i u(w - \alpha n_i - p_i a_i L(n_i) - (1-a_i)L(n_i), H - M(n_i))]$$

subject to the constraints: $0 \le a_i \le 1$ and $n_i \ge 0$ ($i = L, H$).

As indicated in the previous section, individuals' demand for insurance coverage depends on the relationship between wealth and health ($a_L^{FI} = a_H^{FI} = 1$ if $u_{12} \le 0$ and $a_L^{FI} < 1$ and $a_H^{FI} < 1$ if $u_{12} > 0$) and that the self-insurance efforts (denoted n_L^{FI} and n_H^{FI}) are defined, for the low- and high-risks ($i = L, H$) by Eqs. (7) and (8)[6]:

$$\begin{cases} (-\alpha - p_i L'(n_i^{FI}))[(1-p_i)u_1(F_i, H) + p_i u_1(G_i, H - M(n_i^{FI}))] - p_i M'(n_i^{FI}) u_2(G_i, H - M(n_i^{FI})) = 0 \text{ if } u_{12} < 0 & (7) \\ (-\alpha - p_i L'(n_i^{FI})) u_1(F_i, H - M(n_i^{FI})) - p_i M'(n_i^{FI}) u_2(F_i, H - M(n_i^{FI})) = 0 \quad \text{if } u_{12} \ge 0 & (8) \end{cases}$$

with $F_i = w - \alpha n_i^{FI} - p_i a_i^{FI} L(n_i^{FI})$ and $G_i = w - \alpha n_i^{FI} - p_i a_i^{FI} L(n_i^{FI}) - (1 - a_i^{FI}) L(n_i^{FI})$.

Although the self-insurance efforts defined by (7) and (8) are not the ones defined by (1) and (2) for the low-risks and by (3) and (4) for the high-risks (the wealth distribution among individuals and states of the world being different, the marginal costs and benefits are not weighted by the same marginal utilities), it is interesting to note that individuals, *given the insurance premia that define the wealth levels*, make optimal self-insurance decisions. This can be seen by rewriting the social welfare function with p_L and p_H replacing r_L and r_H respectively and noticing that the optimal self-insurance efforts correspond to (7) and (8) in that case. Therefore, besides the gap it creates between the insurance premia individuals must pay in the high- and low-risk situation, the *laissez-faire* regime does not distort self-insurance actions from their optimal levels.

When the disease has no impact on the quality of life, it is straightforward to see that low- and high-risk individuals make the optimal full-information efforts respectively defined by (5) and (6), *i.e.* $n_L^{FI} = n_L^*$ and $n_H^{FI} = n_H^*$.

5. Self-insurance efforts in the pooling equilibrium

When a pooling equilibrium prevails in the health insurance market, a unique insurance contract is sold and high-risk individuals, in order to hide their risk-type, make the self-insurance efforts the low-risks do (remember that this effort can be observed by the insurers). The insurance and self-insurance decisions are defined by the low-risk individuals who maximize the following expected utility:

$$EU_p = [(1-p_L)u(w - \alpha n - p_M aL(n), H) + p_L u(w - \alpha n - p_M aL(n) - (1-a)L(n), H - M(n))]$$

[6] The values of the variables at the full information equilibrium are indicated by the superscript FI.

subject to the following constraint: $0 \le a \le 1$ and $n \ge 0$.

We show in appendix C that the self-insurance efforts the low-risk do is defined by[7]:

$$\begin{cases} (-\alpha - p_M L'(n^P))u_1(K, H - M(n^P)) - p_M M'(n^P)u_2(K, H - M(n^P)) = 0 \quad \text{if } a_L < 1 & (9) \\ (-\alpha - p_M L'(n^P))[(1-p_L)u_1(G,H) + p_L u_1(K, H - M(n^P))] \\ \qquad - p_L M'(n^P)u_2(K, H - M(n^P)) = 0 \quad \text{if } a_L = 1 & (10) \end{cases}$$

with: $G = w - \alpha n - p_M aL(n)$ and $K = w - \alpha n - p_M aL(n) - (1-a)L(n_i)$.

The self-insurance effort defined by (9) is the one individuals make when the insurance demand is not constrained, *i.e.* when $a^P < 1$. This occurs either when $u_{12} \ge 0$ and when u_{12} is not too negative. The threshold defining the (negative) value u_{12} below which the insurance coverage is partial depends on the difference between p_M and p_L (and thus on the initial difference between p_H and p_L and on the proportion of high- and low-risk individuals in the population). Whatever the insurance coverage, the self-insurance efforts defined by (9) and (10) are not optimal.

When the disease only affects the individuals' wealth, the self-insurance effort made by each type of individual is defined by:

$$\alpha = -p_M(n^P) \qquad (10)$$

In that case, it is interesting to note that individuals, despite the information they have on their probability to contract the disease, implement the self-insurance they would do in the absence of genetic information (*i.e.* with decisions based on the average probability of disease in the population). Therefore, the regulation that prohibits the use of genetic information for health insurance purpose does not lead to better targeted self-insurance decisions.

6. Self-insurance efforts in the Rothschild-Stiglitz equilibrium

In case the Rothschild-Stiglitz separating equilibrium prevails, insurance companies offer a set of contracts such that each individual purchase a contract designed for his/her own type. High- and low-risks individuals pay actuarially fair insurance premia (with a unit cost of insurance being equal to p_H and p_L respectively) but low-risk individuals cannot purchase the full-insurance contract (otherwise, the high-risk would also buy it). Contracts thus act as self-selection mechanisms, the high-risk do not hide their risk-type and it is straightforward, since the information is provided to the insurers, to

[7] The values of the variables at the pooling equilibrium are indicated by the superscript P.

show that the high-risks' demand for self-insurance is defined – according to the interaction between wealth and health - by (3) or (4) (with $i = H$). As a result, the high-risks self-insurance actions are optimal.

Low-risk individuals choose among the contracts offered by insurance companies in order to maximize the following expected utility:

$$EU_L^{RS} = [(1-p_L)u(w-\alpha n - p_L aL(n), H) + p_L u(w-\alpha n - p_L aL(n) - (1-a)L(n), H - M(n))]$$

This maximization is subject to the usual constraints ($0 \le a \le 1$ and $n \ge 0$) as well as the following incentive compatibility constraint (which states that the contract is not be purchased by high-risks individuals).

$$\begin{aligned}(1-p_H)u(w-\alpha n_H^{FI} - p_H a_H^{FI} L(n_H^{FI}), H) + p_H u(w-\alpha n_H^{FI} - p_H a_H^{FI} L(n_H^{FI}) - (1-a_H^{FI})L(n_H^{FI}), H - M(n_H^{FI})) \\ \ge (1-p_H)u(w-\alpha n - p_L aL(n), H) + p_H u(w-\alpha n_L - p_L aL(n) - (1-a)L(n), H - M(n))\end{aligned}$$

We show in appendix D that the low-risks' demand for self-insurance is given by[8]:

$$(-\alpha - p_L L'(n_L^{RS}))u_1(R, H - M(n_L^{RS})) - p_L M'(n_L^{RS})u_2(R, H - M(n_L^{RS})) = 0 \qquad (11)$$

with $R = w - \alpha n_L^R - p_L a_L^R L(n_L^R) - (1-a_L^R)L(n_L^R)$.

The first thing interesting to note is that the low-risks' self-insurance efforts do not depend on the interaction between health and wealth (*i.e.* the sign of u_{12}). No matter their preferences towards wealth and health, they are not offered full-insurance contracts in order to prevent the high-risks to buy a contract designed for them.

The self-insurance decision made by the low-risks at the separating equilibrium is not optimal, even if we take the insurance coverage that defines the wealth levels as given. This can be demonstrated by rewriting the social welfare function with a_L^R instead of a_L and checking that the low-risks' optimal self-insurance effort does not correspond to that defined by (11). That is, beside the already well know effect of the information asymmetry on the insurance coverage, legislation banning the use of genetic information for rate-making purpose distorts self-insurance actions from their optimal levels.

[8] The values of the variables at the Rothschild-Stiglitz equilibrium are indicated by the superscript RS .

However, when the disease has no impact on the individuals' quality of life, we notice from (11) that the low-risk individuals also make the optimal self-insurance effort defined by Eq (5), *i.e.* $n_L^{RS} = n_L^*$ (besides the fact that $n_H^{RS} = n_H^*$).

7. Self-insurance efforts in the Miyazaki-Spence equilibrium

In the Miyazaki-Spence model, insurance companies do not necessarily break even on each insurance contract but on the aggregate (see Miyazaki (1977) and Spence (1978)). Doing so, they offer to the high-risks more than actuarially fair insurance premia ($r_H < p_H$) that are counterbalanced by the less than actuarially fair insurance premia offered to the low-risks ($r_L > p_L$) and make zero profit on their portfolios of contracts. Compared to the Rothschild-Stiglitz case (under which high- and low-risk individuals pay p_H and p_L respectively, *i.e.* actuarially fair insurance premia), high-risk individuals are more willing to accept the contract designed for them, which allows the low-risks to benefit from a higher insurance coverage (and thus to accept less-than-actuarially fair contracts). This equilibrium holds if the proportion of high-risks is sufficiently small. If this proportion is large, the Rothschild-Stiglitz separating equilibrium prevails.

Insurance companies offer contracts to low-risk individuals who choose among these contracts in order to maximize the following expected utility (the endogenous variables are: a_L, a_H, n_L, n_H, r_L and r_H).

$$EU_L^{MS} = (1-p_L)u(w-\alpha n_L - r_L a_L L(n_L), H) + p_L u(w-\alpha n_L - r_L a_L L(n_L) - (1-a_L)L(n_L), H - M(n_L))$$

This maximization is subject to the following incentive compatibility constraint (which states that the contract must not be purchased by high-risks individuals).

$$\begin{aligned}&(1-p_H)u(w-\alpha n_H - r_H a_H L(n_H), H) + p_H u(w-\alpha n_H - r_H a_H L(n_H) - (1-a_H)L(n_H), H - M(n_H))\\ &\quad \geq (1-p_H)u(w-\alpha n_L - r_L a_L L(n_L), H) + p_H u(w-\alpha n_L - r_L a_L L(n_L) - (1-a_L)L(n_L), H - M(n_L))\end{aligned}$$

Insurance companies are also supposed to breakeven on the average contract sold. The following constraint must thus also hold.

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

The usual constraints ($0 \leq a_L \leq 1$, $0 \leq a_H \leq 1$, $0 \leq r_L \leq 1$, $0 \leq r_H \leq 1$, $n_L \geq 0$ and $n_H \geq 0$) also apply.

We show in appendix E that the self-insurance efforts made by the low- and high-risks are respectively given by[9]:

$$(-\alpha - p_L L'(n_L^{MS}))u_1(T_L, H - M(n_L^{MS})) - p_L M'(n_L^{MS})u_2(T_L, H - M(n_L^{MS})) = 0 \quad (11)$$
$$(-\alpha - p_L L'(n_H^{MS}))u_1(T_H, H - M(n_H^{MS})) - p_H M'(n_H^{MS})u_2(T_H, H - M(n_H^{MS})) = 0 \quad (12)$$

with $T_i = w - \alpha n_i - r_i a_i L(n_i) - (1-a_i)L(n_i)$ ($i = H, L$).

At the Miyazaki-Spence equilibrium, the high-risks make optimal self-insurance efforts that can be explained as follows. In any separating equilibrium, insurance companies offer the best feasible contracts to each type of individuals in order to attract the low-risks while giving to the high-risks the incentives to purchase a contract designed for them. The contracts sold to the high-risks must increase their expected utility without being too costly. Therefore, even if the price per unit of insurance (which is more then actuarially fair: $r_H < p_H$) would lead the high-risks - had they the opportunity to do so - to make less than the optimal self-insurance effort, insurance companies specify contracts that make them implement the optimal level of self-insurance defined by. Doing so, savings are made in order to reduce the insurance premiums r_L and/or r_H .

As in the Rothschild-Stiglitz equilibrium, low-risks individuals do not make the optimal self-insurance efforts. If we write the social welfare function replacing a_L by a_L^{MS} , the self-insurance efforts low-risk individuals should make do not correspond to (12). These efforts are however optimal for high-risk individuals. Therefore, at the Miyazaki-Spence equilibrium, the prohibition to use genetic tests results for insurance purpose also distorts self-insurance actions from their optimal levels.

Again, in case the disease does not the individuals' quality of life, Eq. (12) indicates that low-risk individuals also make the optimal self-insurance effort defined by Eq (5), *i.e.* $n_L^{MS} = n_L^*$ (besides the fact that $n_H^{MS} = n_H^*$).

8. Conclusion.

Diseases are seldom the only consequence of the individuals' genetic predisposition but rather the result of the genetic-environment interaction. When making health decisions, individuals consider both the elements that cannot be modified (their genetic predisposition) and those that individuals can change (prevention decisions). Besides, health decisions under uncertainty result from a wealth-health trade-off. This is the framework that we use in this paper in order to evaluate regulations that

[9] The values of the variables at the Miyazaki-Spence equilibrium are indicated by the superscript MS .

prohibits the use of genetic information for the insurance purpose. More precisely, we evaluate whether adverse selection equilibria resulting from these regulations have the potential to reap the benefits resulting from the development of genetic testing by leading individual to optimal self-insurance decisions.

We first show that low-risk individuals do not exploit the opportunities offered by the development of genetic testing under this information regime in case diseases have an effect on the individuals' wealth and on their quality of life (only high-risk individuals exploit these opportunities at the separating equilibria). When diseases only affect individuals' wealth (*i.e.* when treatments perfectly restore patients' health), the opportunity to implement better targeted self-insurance efforts are exploited by each type of individuals in case separating equilibria prevail in the insurance market.

Of course, these results must be taken cautiously. First, among the limits of our analysis, we only considered self-insurance actions that can be observed by insurance companies (this is hardly the case for all of them). In the same way, our results would not necessarily hold if we had considered self-protection actions instead of self-insurance ones. Therefore, our conclusions cannot be generalized to every kind of prevention actions. Second, these results do not imply that the *laissez-faire* information regime is more desirable than regulations prohibiting the use of genetic tests results by insurers. The former introduces differences (that risk averse individuals dislike *ex-ante*) between wealth in the disease and in the no-disease state. This weakness is not necessarily compensated by the optimality of insurance and self-insurance decisions that prevail under this information regime.

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Appendix A: Social optimum

The Lagrangian L characterizes the constrained maximization of SW (the endogenous variables are: a_L, a_H, n_L, n_H, r_L, r_H, β_1, β_2 and β_3).

$$\begin{aligned}\text{Max } L = &(1-\lambda)[(1-p_L)u(w-\alpha n_L - r_L a_L L(n_L), H) + p_L u(w-\alpha n_L - r_L a_L L(n_L) - (1-a_L)L(n_L), H - M(n_L))] \\ &+\lambda[(1-p_H)u(w-\alpha n_H - r_H a_H L(n_H), H) + p_L u(w-\alpha n_H - r_H a_H L(n_H) - (1-a_H)L(n_H), H - M(n_H))] \\ &+\beta_1(1-a_L) + \beta_2(1-a_H) + \beta_3[(1-\lambda)(r_L - p_L)a_L L(n_L) + \lambda(r_H - p_H)a_H L(n_H)]\end{aligned}$$

The notations $C_i = w - \alpha n_i - r_i a_i L(n_i)$ and $D_i = w - \alpha n_i - r_i a_i L(n_i) - (1-a_i)L(n_i)$ $(i = L, H)$ are used.

The first-order conditions related to this program are:

$$\frac{\partial L}{\partial a_L} = (1-\lambda)L(n_L)[-r_L(1-p_L)u_1(C_L, H) + p_L(1-r_L)u_1(D_L, H-M(n_L)) + \beta_3(r_L - p_L)] - \beta_1 \le 0$$

$$a_L \ge 0,\ a_L \frac{\partial L}{\partial a_L} = 0 \qquad \text{(A1)}$$

$$\frac{\partial L}{\partial a_H} = \lambda L(n_H)[-r_H(1-p_H)u_1(C_H, H) + p_H(1-r_H)u_1(D_H, H-M(n_H)) + \beta_3(r_H - p_H)] - \beta_2 \le 0$$

$$a_H \ge 0,\ a_H \frac{\partial L}{\partial a_H} = 0 \qquad \text{(A2)}$$

$$\frac{\partial L}{\partial n_L} = (1-p_L)(-\alpha - r_L a_L L'(n_L))u_1(C_L, H) + p_L(-\alpha - r_L a_L L'(n_L) - (1-a_L)L'(n_L))u_1(D_L, H-M(n_L))$$

$$- p_L M'(n_L))u_2(D_L, H-M(n_L)) + \beta_3(r_L - p_L)a_L L'(n_L) \le 0; n_L \ge 0;\ n_L \frac{\partial L}{\partial n_L} = 0 \qquad \text{(A3)}$$

$$\frac{\partial L}{\partial n_H} = (1-p_H)(-\alpha - r_H a_H L'(n_H))u_1(C_H, H) + p_H(-\alpha - r_H a_H L'(n_H) - (1-a_H)L'(n_H))u_1(D_H, H-M(n_H))$$

$$- p_L M'(n_H))u_2(D_H, H-M(n_H)) + \beta_3(r_H - p_H)a_H L'(n_H) \le 0; n_H \ge 0;\ n_H \frac{\partial L}{\partial n_H} = 0 \qquad \text{(A4)}$$

$$\frac{\partial L}{\partial r_L} = [-(1-p_L)u_1(C_L, H) - p_L u_1(D_L, H-M(n_L)) + \beta_3]a_L L(n_L) \le 0; r_L \ge 0,\ a_L \frac{\partial L}{\partial r_L} = 0 \qquad \text{(A5)}$$

$$\frac{\partial L}{\partial r_H} = [-(1-p_H)u_1(C_H, H) - p_H u_1(D_H, H-M(n_H)) + \beta_3]a_H L(n_H) \le 0; r_H \ge 0,\ a_H \frac{\partial L}{\partial r_H} = 0 \qquad \text{(A6)}$$

$$\frac{\partial L}{\partial \beta_1} = 1 - a_L \ge 0; \beta_1 \ge 0,\ \beta_1 \frac{\partial L}{\partial \beta_1} = 0 \qquad \text{(A7)}$$

$$\frac{\partial L}{\partial \beta_2} = 1 - a_H \ge 0; \beta_2 \ge 0,\ \beta_2 \frac{\partial L}{\partial \beta_2} = 0 \qquad \text{(A8)}$$

$$\frac{\partial L}{\partial \beta_3} = \lambda(r_L - p_L)a_L L(n_L) + (1-\lambda)a_H(r_H - p_H)L(n_H) \ge 0; \beta_3 \ge 0,\ \beta_3 \frac{\partial L}{\partial \beta_3} = 0 \qquad \text{(A9)}$$

We obtain $\beta_3 = (1-p_L)u_1(C_L,H) + p_L u_1(D_L,H-M(n_L)) = (1-p_H)u_1(C_H,H) + p_H u_1(D_H,H-M(n_L))$ from (A5) and (A6). The introduction of the first equality in (A1) leads us to the following condition: $(1-\lambda)p_L(1-p_L)[u_1(D_L,H-M(n_L)-u_1(C_L,H)]-\beta_1 \le 0$ (this inequality is denoted by (A10)). To obtain the optimal value of a_L, we separately consider the various interactions that wealth and health can have in the utility function. Let us first suppose that $u_{12}=0$. If $a_L<1$, then $u_1(D_L,H-M(n_L)>u_1(C_L,H)$ and $\beta_1=0$ (in order to meet (A7)), hence (A10) cannot be met. In contrast, (A10) is respected if $a_L=1$ (that implies $u_1(D_L,H-M(n_L)=u_1(C_L,H)$) is combined with $\beta_1=0$. We now assume that $u_{12}<0$. It implies $u_1(D_L,H-M(n_L)>u_1(C_L,H)$ if $a_L<1$. But since $a_L<1$ imposes $\beta_1=0$ in order to meet (A7), the condition (A10) cannot be met. The only option to have the condition (A10) respected if $u_{12}<0$ is to combine $a_L=1$ (that implies $u_1(D_L,H-M(n_L)>u_1(C_L,H)$) with $\beta_1>0$. We finally turn to the case $u_{12}>0$. The condition (A10) can be met under two scenarios: a) $a_L=1$ (that implies $u_1(D_L,H-M(n_L)<u_1(C_L,H)$) combined with $\beta_1\ge 0$ and; b) $\beta_1=0$ combined with $a_L(<1)$ set so that $u_1(D_L,H-M(n_L)=u_1(C_L,H)$. Among these two cases, the second is preferred since it maximizes *SW*. Therefore, either $a_L=1$ or $a_L\le 1$ is associated to $u_1(D_L,H-M(n_L)=u_1(C_L,H)$. In the first case, setting $a_L=1$ with (A3) leads to the optimal level of self-insurance defined by Eq. (1) whereas the combination of $u_1(D_L,H-M(n_L)=u_1(C_L,H)$ with (A3) leads to the optimal level of self-insurance defined by Eq. (2). Using Eqs. (A2) and (A4), it can similarly be shown that the self-insurance effort the high-risks should make in order to maximize *SW* is defined (3) if by $u_{12}\le 0$ and by (4) if $u_{12}\ge 0$.

In any case, the values of r_L and r_H are set in order to make the expected marginal utility of both groups equal. In case $u_{12}=0$, this implies that the wealth levels in the four states of the word (being at high- or low-risk associated with being healthy and sick) are made equal, that is: $r_L^* = \dfrac{\alpha(n_H^*-n_L^*)+r_H^* L(n_H^*)}{L(n_L^*)}$. When $u_{12}<0$, $a_L=a_H=1$ and the marginal expected utilities can only be made equal among both groups if the wealth level of the high-risk is higher than that of the low risks ($C_L=D_L<C_H=D_H$). In the same way, optimality requires that the low-risks have more wealth than the high-risks ($C_L=D_L>C_H=D_H$) when $u_{12}>0$.

Appendix B: Full information self-insurance efforts

The constrained maximisation program is given by ($i = L, H$):

$$\text{Max } L_i = (1-p_i)u(w-\alpha n_i - p_i a_i L(n_i), H) + p_i u(w-\alpha n_i - p_i a_i L(n_i) - (1-a_i)L(n_i), H - M(n_i)) + \beta_4(1-a_i)$$

The notations: $E_i = w-\alpha n_i - p_i a_i L(n_i)$ and $F_i = w - \alpha n_i - p_i a_i L(n_i) - (1-a_i)L(n_i)$ are used.

The first-order conditions related to this program are ($i = L, H$):

$$\frac{\partial L_i}{\partial a_i} = (1-\lambda)\, p_i(1-p_i)L(n_i)[u_1(F_i, H-M(n_i)) - u_1(E_i, H)] - \beta_4 \le 0, a_i \ge 0,\ a_i \frac{\partial L_i}{\partial a_i} = 0 \quad \text{(B1)}$$

$$\frac{\partial L_i}{\partial n_i} = (1-p_i)(-\alpha - p_i a_i L'(n_i))u_1(E_L, H) + p_i(-\alpha - p_i a_i L'(n_i) - (1-a_i)L'(n_i))u_1(F_L, H-M(n_i))$$
$$- p_i M'(n_i))u_2(F_L, H-M(n_i)) \le 0, n_i \ge 0,\ n_i \frac{\partial L_i}{\partial n_i} = 0 \quad \text{(B2)}$$

$$\frac{\partial L_i}{\partial \beta_4} = 1 - a_i \ge 0; \beta_4 \ge 0,\ \beta_4 \frac{\partial L_i}{\partial \beta_4} = 0 \quad \text{(B3)}$$

From (B1) and (B3) we know that either $a_i = 1$ (combined with $\beta_4 \ge 0$) or $a_1 \le 1$ (combined with $\beta_4 = 0$ and with $u_1(D_i, H - M(n_i) = u_1(C_i, H)$). The first case occurs when $u_{12} < 0$ and, introducing $a_i = 1$ in (B2), we obtain the demand for self-insurance defined by the Eq. (7). The second case occurs when $u_{12} \ge 0$ and the self-insurance effort defined by the Eq. (8) is obtained by introducing $u_1(D_i, H - M(n_i) = u_1(C_i, H)$ in (B2).

Appendix C: Pooling equilibrium

The pooling equilibrium is characterized by:

$$\text{Max } L_3 = (1-p_L)u(w-\alpha n - p_M aL(n), H) + p_L u(w - \alpha n - p_M aL(n) - (1-a)L(n), H - M(n) + \beta_5(1-a)$$

The following notation is used: $G = w - \alpha n - p_M aL(n)$ and $K = w - \alpha n - p_M aL(n) - (1-a)L(n_i)$.

The first-order conditions related to this program are:

$$\frac{\partial L_3}{\partial a} = -p_M(1-p_L)L(n)u_1(G,H) + p_L(1-p_M)L(n)u_1(K, H-M(n)) - \beta_5 \le 0, a \ge 0,\ a\frac{\partial L_3}{\partial a} = 0 \quad \text{(C1)}$$

$$\frac{\partial L_3}{\partial n} = (1-p_L)(-\alpha - p_M aL'(n))u_1(G,H) + p_L(-\alpha - p_M aL'(n) - (1-a)L'(n))u_1(K, H-M(n))$$
$$- p_L M'(n))u_2(K, H-M(n)) \le 0, n \ge 0,\ n\frac{\partial L_3}{\partial n} = 0 \quad \text{(C2)}$$

$$\frac{\partial L_3}{\partial \beta_5} = 1 - a \ge 0, \beta_5 \ge 0,\ \beta_5 \frac{\partial L_3}{\partial \beta_5} = 0 \quad \text{(C3)}$$

Note first that $a=1$ or $a<1$ according to the relationship between wealth and health (*i.e.* according to the sign of u_{12}) and to the difference between . If $u_{12}\geq 0$ or if u_{12} is negative but not too small, the maximization of the objective function is achieved with $a<1$ which leads to $\beta_5=0$. Assuming that interior solutions prevail ($a>0$ and $n>0$) , we combine $\frac{\partial L_3}{\partial a}=0$ and $\frac{\partial L_3}{\partial n}=0$ to define the self-insurance effort by (9). If u_{12} is sufficiently negative, $a=1$ even if price per unit of insurance the low-risks pay is based on the average probability of disease. Inserting $a=1$ in (C3), we obtain the self-insurance effort defined by (10).

Appendix D: Rothschild-Stiglitz equilibrium

The Rothschild and Stiglitz equilibrium is characterized by:

$$\begin{aligned}\text{Max } L_4 &= (1-p_L)u(w-\alpha n_L - p_L a_L L(n_L),H)+p_L u(w-\alpha n_L - p_L a_L L(n_L)-(1-a_L)L(n_L),H-M(n_L))\\ &+\beta_6(1-a_L)+\beta_7[(1-p_H)u(w-\alpha n_H^{FI}-p_H a_H^{FI}L(n_H^{FI}),H)+p_H u(w-\alpha n_H^{FI}-p_H a_H^{FI}L(n_H^{FI})-(1-a_H^{FI})L(n_H^{FI}),H-M(n_H^{FI}))\\ &-(1-p_H)u(w-\alpha n_L-p_L a_L L(n_L),H)-p_H u(w-\alpha n_L - p_L a_L L(n_L)-(1-a_L)L(n_L),H-M(n_L))]\end{aligned}$$

The following notation is used: $Q=w-\alpha n-p_L aL(n)$ and $R=w-\alpha n-p_L aL(n)-(1-a)L(n_i)$. The first-order conditions related to this program are:

$$\begin{aligned}\frac{\partial L_4}{\partial a_L} &= -p_L(1-p_L)L(n_L)u_1(Q,H)+p_L(1-p_L)L(n)u_1(R,H-M(n_L))-\beta_6\\ &+\beta_7[p_L(1-p_H)L(n_L)u_1(Q,H)-p_H(1-p_L)L(n)u_1(R,H-M(n_L))]\leq 0, a_L\geq 0, a_L\frac{\partial L_4}{\partial a_L}=0 \qquad \text{(D1)}\end{aligned}$$

$$\begin{aligned}\frac{\partial L_4}{\partial n_L} &= (1-p_L)(-\alpha-p_L aL'(n_L))u_1(Q,H)+p_L(-\alpha-p_L aL'(n_L)-(1-a)L'(n_L))u_1(R,H-M(n_L))-p_L M'(n_L))u_2(R,H-M(n_L))\\ &+\beta_7[-(1-p_H)(-\alpha-p_L aL'(n_L))u_1(Q,H)-p_H(-\alpha-p_L aL'(n_L)-(1-a)L'(n_L))u_1(R,H-M(n_L))\\ &+p_H M'(n_L))u_2(R,H-M(n_L))]\leq 0, n_L\geq 0, n_L\frac{\partial L_4}{\partial n_L}=0 \qquad \text{(D2)}\end{aligned}$$

$$\frac{\partial L_4}{\partial \beta_6}=1-a_L\geq 0, \beta_6\geq 0, \beta_6\frac{\partial L_4}{\partial \beta_6}=0 \qquad \text{(D3)}$$

$$\begin{aligned}\frac{\partial L_4}{\partial \beta_7} &= (1-p_H)u(w-\alpha n_H^{FI}-p_H a_H^{FI}L(n_H^*),H)+p_H u(w-\alpha n_H^{FI}-p_H a_H^{FI}L(n_H^{FI})-(1-a_H^{FI})L(n_H^{FI}),H-M(n_H^{FI}))\\ &-(1-p_H)u(w-\alpha n_L-p_L a_L L(n_L),H)-p_H u(w-\alpha n_L-p_L a_L L(n_L)-(1-a_L)L(n_L),H-M(n_L))])\geq 0, \beta_7\geq 0, \beta_7\frac{\partial L_4}{\partial \beta_7}=0 \quad \text{(D4)}\end{aligned}$$

Note first that the self-selection constraint (D4) is not met if $a_L=1$ (high-risk individuals prefer the contract designed for the low-risks). Therefore: $a_L<1$. This implies $\beta_6=0$ (from (D3)). Since we assume interior solutions (*i.e.*: $a_L>0$ and $n_L>0$), we can combine $\frac{\partial L}{\partial a_L}=0$ and $\frac{\partial L}{\partial n_L}=0$ to define the low-risks demand for self-insurance as given by Eq. (10).

Appendix E: the Miyazaki-Spence equilibrium

$$\begin{aligned}\text{Max } L_5 &= (1-p_L)u(w-\alpha n_L - r_L a_L L(n_L), H) + p_L u(w-\alpha n_L - r_L a_L L(n_L) - (1-a_L)L(n_L), H - M(n_L)) \\ &+\beta_8(1-a_L) + \beta_9(1-a_H) + \beta_{10}[(1-\lambda)(r_L - p_L)a_L L(n_L) + \lambda(r_H - p_H)a_H L(n_H)] \\ &+\beta_{11}[(1-p_H)u(w-\alpha n_H - r_H a_H L(n_H), H) + p_H u(w-\alpha n_H - r_H a_H L(n_H) - (1-a_H)L(n_H), H - M(n_H)) \\ &-(1-p_H)u(w-\alpha n_L - r_L a_L L(n_L), H) - p_H u(w-\alpha n_L - r_L a_L L(n_L) - (1-a_L)L(n_L), H - M(n_L))]\end{aligned}$$

The following notation is used: $S_i = w - \alpha n_i - r_i a_i L(n_i)$ and $T_i = w - \alpha n_i - r_i a_i L(n_i) - (1-a_i)L(n_i)$. The first-order conditions related to this program are:

$$\begin{aligned}\frac{\partial L_5}{\partial a_L} &= -r_L(1-p_L)L(n_L)u_1(S_L,H) + p_L(1-r_L)L(n_L)u_1(T_L, H-M(n)) - \beta_8 + \beta_{10}(1-\lambda)(r_L - p_L)L(n_L) \\ &+\beta_{11}[r_L(1-p_H)L(n_L)u_1(S_L,H) - p_H(1-r_L)L(n_L)u_1(T_L,H-M(n_L))] \le 0, a_L \ge 0,\ a_L\frac{\partial L_5}{\partial a_L} = 0 \qquad \text{(E1)}\end{aligned}$$

$$\begin{aligned}\frac{\partial L_5}{\partial a_H} &= -\beta_9 + \beta_{10}\lambda(r_H - p_H)L(n_H) \\ &+\beta_{11}[-r_H(1-p_H)L(n_H)u_1(S_H,H) + p_H(1-r_H)L(n_H)u_1(T_H,H-M(n_H))] \le 0, a_H \ge 0,\ a_H\frac{\partial L_5}{\partial a_H} = 0 \qquad \text{(E2)}\end{aligned}$$

$$\begin{aligned}\frac{\partial L_5}{\partial n_L} &= (1-p_L)(-\alpha - r_L a_L L'(n_L))u_1(S_L,H) + p_L(-\alpha - r_L a_L L'(n_L) - (1-a_L)L'(n_L))u_1(T_L,H-M(n_L)) \\ &- p_L M'(n_L))u_2(T_L,H-M(n_L)) + \beta_{10}(1-\lambda)(r_L - p_L)a_L L'(n_L) \\ &+\beta_{11}[-(1-p_H)(-\alpha - r_L a_L L'(n_L))u_1(S_L,H) - p_H(-\alpha - r_L a_L L'(n_L) - (1-a_L)L'(n_L))u_1(T_L,H-M(n_L)) \\ &+p_H M'(n_L))u_2(T_L,H-M(n_L))] \le 0, n_L \ge 0,\ n_L\frac{\partial L_5}{\partial n_L} = 0 \qquad \text{(E3)}\end{aligned}$$

$$\begin{aligned}\frac{\partial L_5}{\partial n_H} &= \beta_{10}\lambda(r_H - p_H)a_H L'(n_H) \\ &+\beta_{11}[(1-p_H)(-\alpha - r_H a_H L'(n_H))u_1(S_H,H) + p_H(-\alpha - r_H a_H L'(n_H) - (1-a_H)L'(n_H))u_1(T_H,H-M(n_H)) \\ &- p_H M'(n_H))u_2(T_H,H-M(n_H))] \le 0, n_H \ge 0,\ n_H\frac{\partial L_5}{\partial n_H} = 0 \qquad \text{(E4)}\end{aligned}$$

$$\begin{aligned}\frac{\partial L_5}{\partial r_L} &= a_L L(n_L)[-(1-p_L)u_1(S_L,H) - p_L u_1(T_L,H-M(n_L) + \beta_{10}(1-\lambda) \\ &+\beta_{11}((1-p_H)u_1(S_L,H) + p_H u_1(T_L,H-M(n_L)))] \ge 0,\ r_L \ge 0, r_L\frac{\partial L_5}{\partial r_L} = 0 \qquad \text{(E5)}\end{aligned}$$

$$\frac{\partial L_5}{\partial r_H} = a_H L(n_H)(\beta_{10}\lambda p_H - \beta_{11}[(1-p_H)u_1(S_H,H) + p_H u_1(T_H,H-M(n_H))]) \ge 0, r_H \ge 0,\ r_H\frac{\partial L_5}{\partial r_H} = 0 \qquad \text{(E6)}$$

$$\frac{\partial L_5}{\partial \beta_8} = 1 - a_L \ge 0, \beta_8 \ge 0,\ \beta_8\frac{\partial L_5}{\partial \beta_8} = 0 \qquad \text{(E7)}$$

$$\frac{\partial L_5}{\partial \beta_9} = 1 - a_H \ge 0, \beta_9 \ge 0,\ \beta_9\frac{\partial L_5}{\partial \beta_9} = 0 \qquad \text{(E8)}$$

$$\frac{\partial L_5}{\partial \beta_{10}} = (1-\lambda)(r_L - p_L)a_L L(n_L) + \lambda(r_H - p_H)a_H L(n_H) \ge 0, \beta_{10} \ge 0,\ \beta_{10}\frac{\partial L_5}{\partial \beta_{10}} = 0 \qquad \text{(E9)}$$

$$\frac{\partial L_5}{\partial \beta_{11}} = (1-p_H)u(S_H,H) + p_H u(T_H, H-M(n_H)) - (1-p_H)u(S_L,H) - p_H u(T_L, H-M(n_L)) \geq 0,$$

$$\beta_{11} \geq 0,\ \beta_{11}\frac{\partial L_5}{\partial \beta_{11}} = 0 \qquad \text{(E10)}$$

We suppose that interior solutions prevail in the choice variable (*i.e.* we assume that $a_i > 0$, $n_i > 0$, $r_i > 0$ for $i = H, L$). Let us first consider the high-risk individuals. From (E8) we either have $a_H = 1$ and $\beta_9 \geq 0$ or $a_H < 1$ and $\beta_9 = 0$. We begin by examining the first case which happens when u_{12} is sufficiently negative. From (E6) we have $\beta_{10}\lambda p_H = \beta_{11}[(1-p_H)u_1(S_H,H) + p_H u_1(T_H, H-M(n_H))]$ that implies $(-\alpha - p_H L'(n_H))[(1-p_H)u_1(T_H, H-M(n_H) + p_H u_1(S_H,H)] - p_H M'(n_H)u_2(T_H, H-M(n_H^*)) = 0$ (which defines the self-insurance effort the high-risks make when $u_{12} < 0$) when it is inserted in (E4). We now examine the second case. Again, from (E6) we have $\beta_{10}\lambda p_H = \beta_{11}[(1-p_H)u_1(S_H,H) + p_H u_1(T_H, H-M(n_H))]$. Inserting the last equality in (E2) and (E4) we respectively obtain $\beta_{10}\lambda = \beta_{11}u_1(T_H, H-M(n_H))$ and $\beta_{10}\lambda(-\alpha - p_H a_H L'(n_H)) - \beta_{11}p_H(1-a_H)L'(n_H)u_1(T_H, H-M(n_H)) - p_H M'(n_H)u_2(T_H, H-M(n_H)) = 0$. Combining these two equalities, we define the self-insurance effort the high-risks make by: $(-\alpha - p_H L'(n_H))u_1(T_H, H-M(n_H)) - p_H M'(n_H)u_2(T_H, H-M(n_H)) = 0$.

Let us examine now the self-insurance efforts made by the low-risk individuals. Note first that $a_L = 1$ can be ruled out at the equilibrium since high-risk individuals would then prefer the contract offered to the low-risks. This implies $\beta_8 = 0$ from (E8).

From (E5), we obtain :

$$\beta_{10}(1-\lambda) = (1-p_L)u_1(S_L,H) + p_L u_1(T_L, H-M(n_L)) - \beta_{11}[(1-p_H)u_1(S_L,H) + p_H u_1(T_L, H-M(n_L))] \qquad \text{(E16)}$$

Inserting (E16) into (E1), we obtain after simplifications :

$$\frac{\beta_{11}p_H - p_L}{\beta_{11}(1-p_H) - (1-p_L)} = \frac{p_L u_1(S_L,H)}{(1-p_L)u_1(T_L, H-M(n_L))}$$

Inserting (E16) into (E3) we have:

$$\frac{\beta_{11}p_H - p_L}{\beta_{11}(1-p_H) - (1-p_L)} = \frac{(-\alpha - p_L a_L L'(n_L))u_1(S_L,H)}{(\alpha + p_L a_L L'(n_L) + (1-a_L)L'(n_L))u_1(T_L, H-M(n_L)) + M'(n_L))u_2(T_L, H-M(n_L))}$$

From the last two expressions, we obtain after simplifications self-insurance effort made by the low-risks defined by the Eq. (12).