Disease prevention in separating adverse selection equilibria

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Abstract

Predisposition genetic testing offers the opportunity to better target prevention actions by providing personalized information on the probability to develop a given disease. In this paper, we analyze the way genetic information modifies the intensity of prevention actions reducing the financial and health consequences of diseases. Specifically, we determine the extent to which individuals adjust their prevention actions to the available genetic information when insurers cannot use test results for rate-making purposes, hence resulting in adverse selection equilibria in the health insurance market. We show that individuals exploit the information provided by genetic tests when either Rothschild-Stiglitz or Miyazaki-Spence separating equilibria occur. In contrast individuals behave as if they did not have the genetic information when Wilson pooling equilibria prevail.

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Introduction

Whether genetic information should be made available to insurance companies is the most controversial economic issue related to the development of genetic testing. Disclosing genetic information to insurers should lead to discrimination in health insurance markets as individuals revealed at high-risk by a test could potentially not afford insurance contracts. On the other hand, adverse selection equilibria – that prevail if the genetic information remains private – result in sub-optimal insurance coverage for some agents. A large literature has been dedicated to this specific problem (see Hoy and Ruse (2005) for an overview of the issue). Meanwhile, another question related to the development of genetic testing and to the regulation of the information on the health insurance market has been quite overlooked: to what extent do individuals make use of predisposition tests (*i.e.* genetic tests providing information about the probability of disease) in order to target prevention actions in adverse selection equilibria? Ehrlich and Becker (1972) indicate that self-protection and self-insurance efforts (*i.e.* actions reducing respectively the probability of a loss and the size of a loss) depend on the baseline probability of loss and on their insurance coverage. A better allocation of resources can thus 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. However, this also suggests that the information regime in the health insurance market - insofar as it influences insurance coverage - may distort prevention decisions from their optimal levels.

The literature dedicated to the effects of genetic testing on 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) show that information on mortality probability has a positive social value if high-risk individuals can reduce their death probability through self-protection actions, if some individuals are initially informed about their baseline probability of death and if insurers do not know individuals' informational status and risk-type. 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. Specifically, they show that the likelihood that efficient genetic tests are not exploited is higher among agents only covered by compulsory health insurance while the opposite is more likely to occur (*i.e.* non-efficient genetic testing are taken) among agents purchasing a large amount of voluntary insurance coverage on the top of the compulsory one. Barigozzi and Henriet (2011) compare the effect of four different regulations of the information in the health insurance market (*Laissez-faire*, disclosure duty[1], consent law[2] and strict prohibition) on the propensity to take genetic tests offering the opportunity to make better informed self-insurance decisions and conclude that the disclosure duty approach maximizes social welfare.

More recent papers have instead focused on the welfare effects of genetic testing in the presence of moral hazard. Bardey and De Donder (2014) examine the 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) examine the conditions under which (possibly imperfect) genetic testing improve the targeting of surveillance (*i.e.* activities increasing the probability of early detection of potential diseases). In their settings, individuals benefit from a public health insurance scheme potentially leading to moral hazard issues in the use of surveillance actions. The authors show that if genetic testing leads to better targeted surveillance actions, the interaction between information and moral hazard is such that it may reduce social welfare (even if the test is costless). Finally, Peter, Richter and Thistle (2016) compare four information regimes in the health insurance market (disclosure duty, consent law, code of conduct[3] and strict prohibition) in a model where genetic information allow better inform self-protection actions that are not necessarily observed by insurers. In this context they confirm the result Barigozzi and Henriet (2011) obtained for observable self-insurance actions: namely, that the disclosure duty regime dominates the other information regimes.

The literature on the topic highlights that when insurance coverage is constrained, the optimality of prevention decisions may be questioned as prevention and insurance are related. This is the issue we examine in this paper that proposes a natural extension of Crainich (2017) who compares the intensity of self-insurance actions in various adverse selection equilibria. Crainich (2017) as well as the above-mentioned contributions share the important common hypothesis that diseases affect only one aspect

[1] Under the disclosure duty regime insurers are allowed to use the results of existing tests but not to require additional tests.
[2] Under consent law, individuals have the opportunity to disclose test results to insurers but are not forced to do so.
[3] Information regime under which insurers have no access to individuals' tests results but know whether tests have been taken.

of well-being (most of time wealth[4]). In the present work, we assume that individuals' preferences are represented by bi-dimensional utility functions depending on wealth and health and that diseases affects both dimension of welfare. As a consequence, our model integrates several motives to perform self-insurance efforts: 1) reducing pain and discomfort related to disease; 2) reducing the insurance premium since prevention is assumed to be observable and thus to condition the terms of the insurance contract; 3) reducing the financial consequences of the disease for individuals who are not fully covered by the insurance contract. These three reasons to preform self-insurance actions are analyzed while taking into account an important aspect of bi-dimensional utility functions depending on wealth and health indicated by the literature in health economics: the marginal utility of wealth is not independent of the health state so that preferences cannot be represented by additive utility functions. However, there is no consensus about the way health affects the marginal utility of wealth. As a matter of fact, while some papers (Viscusi et Evans (1990), Sloan et al. (1998), Carthy et al. (1999) and, more recently, Finkelstein, Luttmer et Notowidigdo (2013) ou Gyrd-Hansen (2016)) provide empirical evidence that health increases the marginal utility of wealth, the opposite conclusion is reached in other contributions (Evans and Viscusi (1991), Lilliard and Weiss (1998) et Edwards (2008)). The way health influences the marginal utility of wealth actually seems to critically depend on diseases characteristics[5]. As a result we make no *a priori* assumption about the interaction between health and wealth.

Using this framework, we show that both the *laissez-faire* approach and the strict prohibition of genetic test results for insurance purposes does not prevent individuals from using genetic information when making self-insurance decisions if Rothschild-Stiglitz or Miyazaki-Spence separating equilibria prevail. In contrast, individuals do not use the available genetic information when there is a pooling equilibrium in the health insurance market.

The paper is organized as follows. The model is described in section 2. We first describe the purchase of insurance and the demand for self-insurance in the absence of genetic information (section 3). Optimal self-insurance efforts are characterized in section 4. Full information self-insurance efforts are examined in section 5. The rest of the paper is dedicated to adverse selection equilibria since we analyze the pooling equilibrium (section 6), the Rothschild-Stiglitz separating equilibrium (section 7) and the Miyazaki-Spence separating equilibrium (section 8). Section 9 concludes.

2. The model

Individuals' preferences are represented by the utility function $u(w,h)$ where w and h respectively denotes individuals' wealth and health. Utility is increasing ($u_1(w,h)>0$ and $u_2(w,h)>0$) and concave

[4] Filipova-Neumann and Hoy (2017) consider the health effects of the disease but there is no money/health trade-off in individuals' decision-making as they are perfectly covered through compulsory health insurance.
[5] See Finkelstein, Luttmer and Notowidigdo (2013) for a summary of this topic.

($u_{11}(w,h) > 0$ and $u_{22}(w,h) > 0$) in both arguments of the utility function[6]. No assumption is made about the sign of the cross derivative of the utility function. Individuals are expected utility maximizers. They are endowed with an initial wealth w. Their health status in the absence of disease is *h*.

Individuals are identical in every respect except in their probability of being sick. The probability of disease of the high- and low-risks (who respectively represent a proportion λ and $1-\lambda$ of the population) is respectively denoted by p_H an p_L ($p_H > p_L$). This characteristic is initially unknown by individuals but can be revealed through a costless genetic test. The average probability of disease is denoted $p_M = (1-\lambda)p_L + \lambda p_H$.

In case of disease, individuals follow a treatment. To reduce the severity of the disease, individuals have the opportunity to implement self-insurance actions (denoted by n) before the appearance of the disease. Self-insurance actions include programs, such as the use of mammograms or colonoscopies, allowing early detections of diseases onset, and thus more effective treatments. These actions 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 deterioration both fall at a decreasing rate with the intensity of self-insurance actions ($L'(n) < 0$ and $M'(n) < 0$; $L''(n) > 0$ and $M''(n) > 0$). The unitary cost of self-insurance is denoted by α.

Insurance contracts are sold in competitive markets. They specify a premium and an indemnity paid in case of disease. We suppose that self-insurance efforts can be observed by insurers. While this assumption is not necessarily realistic for all type of prevention action, it seems appropriate for the surveillance actions allowing the early detection of diseases[7]. As a result, the insurance premium and 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. Individuals cannot purchase more than full coverage ($0 \leq a \leq 1$). 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) knowing that the insurance premium and indemnity are respectively given by raL and aL (where L is the average cost of treatment). 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.

[6] 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 first argument (wealth) are respectively denoted by u_2 and u_{22}.

[7] Note however that even for non-surveillance actions, the development of mobile applications and connected objects make this assumption progressively more realistic. For instance, telemedicine technologies allow insurers to check how often policyholder suffering from sleep apnea syndrome are connected to a respiratory machine which use reduces the risk associated to several diseases (cardiovascular diseases, depression,…).

3. No genetic information

Suppose first that individuals have no access to the genetic information. In that case, they make insurance and self-insurance decisions based on the average probability of disease in the population (p_M). The equilibrium is defined by the values of a, n and r maximizing the expected utility $EU_1 = (1-p_M)u(w-\alpha n - raL(n), H) + p_M u(w - \alpha n - raL(n) - (1-a)L(n), H - M(n))$ given the constraints $0 \leq a \leq 1$ and $raL(n) \geq p_M aL(n)$.

This optimization program corresponds to the following Lagrangian:

$$Z_1 = (1-p_M)u(A_M) + p_M u(B_M) + \beta_1[1-a]$$

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

This first-order conditions associated to this program are given by:

$$\frac{\partial Z_1}{\delta a} = -p_M(1-p_M)u_1(A_M) + p_M(1-p_M)u_1(B_M) - \beta_1 \leq 0; a \geq 0; a\frac{\partial Z_1}{\delta a} = 0$$

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

$$\frac{\partial Z_1}{\delta \beta_1} = 1 - a \geq 0; \beta_1 \geq 0; \beta_1\frac{\partial Z_1}{\delta \beta_1} = 0$$

The equilibrium intensity of self-insurance depends on the insurance coverage purchased by individuals. As indicated by Rey (2003), when diseases have financial and non-financial consequences, individuals buy less than full insurance (resp. more than full insurance; resp. full insurance) if the marginal utility of wealth rises with health *i.e.* if $u_{12} > 0$ (resp. falls with health *i.e.* if $u_{12} < 0$; resp. does not change with health *i.e.* if $u_{12} < 0$). However, since individuals cannot purchase more than full coverage ($a \leq 1$), the purchase of insurance is defined by a corner solution, so that the marginal utility of wealth in the disease and in the no disease case are not equal when $u_{12} < 0$.

We thus obtain - depending on the sign of u_{12} - three different cases:

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

$$\left(-\alpha - p_M L^{'}(n)\right)[(1-p_M)u_1(A_M) + p_M u_1(B_M)] - p_M M^{'}(n)u_2(B_M) = 0$$

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

$$\left(-\alpha - p_M L^{'}(n)\right)u_1(B_M) - p_M M^{'}(n)u_2(B_M) = 0$$

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

$$\left(-\alpha - p_M L^{'}(n)\right)u_1(B_M) - p_M M^{'}(n)u_2(B_M) = 0$$

Note first that the self-insurance decision is similar in cases 2) and 3) which both reflect an interior solution in the purchasing of insurance leading to the same marginal utility of wealth in the disease and in the no disease case. Note also that in the three cases, the condition defining the demand for self-insurance is such that the marginal cost of the effort (the unit cost α weighted by the marginal utility of wealth) is equal to the sum of its marginal benefits (*i.e*. the reduction in the financial consequences of the disease also weighted by the marginal utility of wealth and the reduction in the health consequences of the disease weighted by the marginal utility of health).

4. Optimal self-insurance efforts

The optimal prices per unit of coverage, insurance purchase and self-insurance efforts[8] made by each individuals' type are defined through the maximization of the utilitarian social welfare function SW . This 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 discrimination) and their desire to take advantage of the opportunities to make informed decisions (*i.e.* the concern for efficiency).

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

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:

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

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

[8] 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.

and wealth. The cost of self-insurance is weighted by the marginal utility of wealth while its marginal expected benefits (*i.e.* the reduction in the cost of treatment and that in the severity of disease) are respectively weighted by the marginal utility of wealth and health. Besides, since the interaction between wealth and health defines the optimal insurance coverage 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)). Specifically,

In case $u_{12} < 0$ individuals would like to purchase more than full insurance but cannot since $0 \le a_L \le 1$ and $0 \le a_H \le 1$. They are thus constraint to purchase full insurance ($a_H = a_L = 1$) that does not allow they to make equal the marginal utility of wealth in the two states of the world (loss and no loss). As a result, the financial cost of self-insurance is weighted by the expected marginal utility of wealth ($(1-p_i)u_1(F_i, H) + p_i u_1(G_i, H - M(n_i^{FI}))$; $i = H, L$). In contrast, purchasing partial or full insurance is an interior solution when $u_{12} \ge 0$, so that individuals equalize the marginal utility of wealth in the disease and the no-disease case. Therefore, the financial cost of self-insurance is weighted by a unique marginal utility of wealth ($u_1(D_i, H - M(n_i^*))$; $i = H, L$) in that case.

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 receive 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 $u_{12} > 0$.

5. Full information self-insurance efforts

In the absence of information asymmetry, individuals 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 $n_i \ge 0$ ($i = L, H$).

It is straightforward to show that 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-risk individuals ($i = L, H$) by Eqs. (7) and (8):

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

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 levels of 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), individuals adjust their self-insurance actions to their probability of disease (i.e. the benefits of self-insurance are weighted by their own probability of disease).

Finally, note that making the genetic information public is in general not sufficient for the implementation of adjusted self-insurance decisions since individuals may well choose not to take the genetic information. Crocker and Snow (1992) have shown that risk-averse individuals - in the absence of prevention actions and if the informational status is observable to insurers - prefer to pay the average insurance premium with certainty rather than the uncertainty of being categorized at low- or high-risk. In that case, the genetic test is taken and the optimal self-insurance efforts are implemented if the benefits resulting from better informed self-insurance actions more than counterbalance the aversion for the classification risk *i.e.* if:

$$\begin{gathered}(1-p_M)u(w - p_M a_M L(n_M), h) + p_L u\big(w - p_M a_M L(n_M) - (1-a_M)L(n_M), h - M(n_M)\big) < \\ (1-\lambda)\Big[(1-p_L)u(w - p_L a_L^{FI} L(n_L^{FI}), h) \\ + p_L u\Big(w - p_L a_L^{FI} L(n_L^{FI}) - (1-a_L^{FI})L(n_L^{FI}), h - M(n_L^{FI})\Big)\Big] \\ +\lambda[(1-p_H)u(w - p_H a_H^{FI} L(n_H^{FI}), h) + p_H u(w - p_H a_H^{FI} L(n_H^{FI}) - (1-a_H^{FI})L(n_H^{FI}), h - M(n_H^{FI}))]\end{gathered}$$

where a_M and n_M respectively denote the insurance coverage and the intensity of the self-insurance action in the absence of genetic information. In the opposite case, insurer maximize individuals' expected utility by offering contracts based on the average probability of disease and individuals makes self-insurance decisions according to that probability.

If we suppose instead that insurers cannot observe policyholders' informational status, individuals learn their risk type (Doherty and Thistle (1996)) even if the above inequality does not hold and agents perform self-insurance actions adjusted to their individual probability of disease.

6. 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:

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

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:

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

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 defined when the insurance demand is not constrained, *i.e.* when $a_L < 1$. 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 is defined by:

$$\alpha = -p_M(n^P) \tag{10}$$

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). The regulation that prohibits the use of genetic information for health insurance purpose is – when pooling equilibria prevail– not effective since it leads individuals to make the self-insurance efforts they would make in the absence of genetic information. Individuals also have no incentives to take the test at this equilibrium.

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

In case the Rothschild and Stiglitz (1976) 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 do not purchase full coverage 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 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 must 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:

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

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 demand for self-insurance is not explained by the interaction between health and wealth (*i.e.* the sign of u_{12}). This is due to the fact that low-risk individuals do not choose their insurance coverage (which is partial) at the separating equilibrium. 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 the low-risks.

The self-insurance decision made by individuals at the separating equilibrium is not optimal as it does not correspond to the levels defined by (1) and (2) for the low-risks and (3) and (4) for the high-risks. However, despite the fact that the low-risk agents do not obtain the insurance coverage maximizing their expected utility, they make self-insurance decisions according to the own probability of disease, i.e. they exploit the information provided by genetic testing.

8. 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 ($r_H < p_H$) which 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 actuarially fair insurance premia, *i.e.* p_H and p_L respectively), 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).

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

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 low-risks' demand for self-insurance is given by:

$$(-\alpha - p_L L'(n_L^{MS}))u_1(R, H - M(n_L^{MS})) - p_L M'(n_L^{MS})u_2(R, H - M(n_L^{MS})) = 0 \qquad (12)$$

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

As in the Rothschild-Stiglitz case, the self-insurance decision made by the low-risks at the separating equilibrium is not optimal as it does not correspond to the levels defined by (1) and (2) for the low-risks and (3) and (4) for the high-risks. However, in is interesting to note that individuals make self-insurance decisions according to the own probability of disease despite the fact that: 1) low-risk agents do not obtain the insurance coverage maximizing their expected utility; 2) individuals (whether high- or low-risks) do not pay an insurance premium based on the own probability of disease. At the Miyazaki-Spence equilibrium, individuals thus exploit the information provided by genetic testing despite the distortions existing in the health insurance market.

9. 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 take into account both the components 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 prohibits the use of genetic information for the purpose of insurance underwriting.

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.

In the paper, we show that the opportunities offered by the development of genetic testing are unexploited under this information regime when pooling equilibria prevail in the health insurance market When separating equilibria – either in the form of Rothschild-Stiglitz or Miyazaki-Spence – occur, the opportunity to implement better targeted are exploited since individuals adjust their prevention efforts according to the information provided by genetic tests.

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Appendix A: Social optimum

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

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 $\beta_1 \geq 0$ 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 $a_L \leq 1$ 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 $u_{12} \leq 0$ and by (4) if $u_{12} \geq 0$.

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 ($i = L, H$):

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

$$\frac{\partial L_i}{\partial n_i} = (1-p_i)(-\alpha - p_i a_i L'(n_i)) u_1(E_L, H) + p_i(-\alpha - p_i a_i L'(n_i) - (1-a_i) L'(n_i)) u_1(F_L, H - M(n_i))$$

$$- p_i M'(n_i)) u_2(F_L, H - M(n_i)) \leq 0, n_i \geq 0, \; n_i \frac{\partial L_i}{\partial n_i} = 0 \qquad \text{(B2)}$$

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

From (B1) and (B3) we know that either $a_i = 1$ (combined with $\beta_4 \geq 0$) or $a_1 \leq 1$ (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 $u_{12} \geq 0$ 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:

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

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

The first-order conditions related to this program are:

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

$$\frac{\partial L_3}{\partial n} = (1-p_L)(-\alpha - p_M a L'(n)) u_1(G, H) + p_L(-\alpha - p_M a L'(n) - (1-a) L'(n)) u_1(K, H - M(n))$$

$$- p_L M'(n)) u_2(K, H - M(n)) \leq 0, n \geq 0, \; n \frac{\partial L_3}{\partial n} = 0 \qquad \text{(C2)}$$

$$\frac{\partial L_3}{\partial \beta_5} = 1 - a \geq 0, \beta_5 \geq 0, \; \beta_5 \frac{\partial L_3}{\partial \beta_5} = 0 \qquad \text{(C3)}$$

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:

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

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

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

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

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 Myiazaki-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:

$$\frac{\partial L_5}{\partial a_L} = -r_L(1-p_L)L(n_L)u_1(S_L, H) + p_L(1-r_L)L(n_L)u_1(T_L, H-M(n)) - \beta_8 + \beta_{10}(1-\lambda)(r_L - p_L)L(n_L)$$

$$+\beta_{11}[r_L(1-p_H)L(n_L)u_1(S_L,H) - p_H(1-r_L)L(n_L)u_1(T_L, H-M(n_L))] \leq 0, a_L \geq 0,\ a_L \frac{\partial L_5}{\partial a_L} = 0 \qquad \text{(E1)}$$

$$\frac{\partial L_5}{\partial a_H} = -\beta_9 + \beta_{10}\lambda(r_H - p_H)L(n_H)$$

$$+\beta_{11}[-r_H(1-p_H)L(n_H)u_1(S_H,H) + p_H(1-r_H)L(n_H)u_1(T_H, H-M(n_H))] \leq 0, a_H \geq 0,\ a_H \frac{\partial L_5}{\partial a_H} = 0 \qquad \text{(E2)}$$

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

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

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

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

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

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

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

$$\frac{\partial L_5}{\partial \beta_{11}} = (1-p_H)u(S_H,H) + p_H u(T_H, H-M(n_H)) - (1-p_H)u(S_L,H) - p_H u(T_L, H-M(n_L)) \geq 0,$$
$$\beta_{11} \geq 0,\ \beta_{11} \frac{\partial L_5}{\partial \beta_{11}} = 0 \qquad \text{(E10)}$$

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).