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Prevention incentives in long-term insurance contracts

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Abstract
Long-term insurance contracts are widespread, particularly in public health and the labor market. Such contracts typically involve monthly or annual premia which are related to the insured's risk profile. A given profile may change, based on observed outcomes which depend on the insured's prevention efforts. The aim of this paper is to analyze the latter relationship. In a two-period optimal insurance contract in which the insured's risk profile is partly governed by her effort on prevention, we find that both the insured's risk aversion and prudence play a crucial role. If absolute prudence is greater than twice absolute risk aversion, moral hazard justifies setting a higher premium in the first period but also greater premium discrimination in the second period. This result provides insights on the trade-offs between long-term insurance and the incentives arising from risk classification, as well as between inter- and intragenerational insurance.

1 | INTRODUCTION

Long-term insurance contracts are common, notably in public health and the labor market (e.g., unemployment insurance). One of their main features is the adjustment of premia in response to observed outcomes and the consequent evolution of risk profiles. The aim of this paper is to analyze the effect of this on an insured's preventive efforts.

The topic of risk classification (i.e., the use of observable characteristics to pool together individuals with similar risk exposure) has received significant attention in the literature (see Crocker & Snow, 2013, for a survey). Being analogous to price discrimination, it has raised equity issues (see, e.g., Dionne & Rothschild, 2014) that have recently been tackled by regulators.[1] The allocative efficiency resulting from information acquisition by insurance companies has also been explored (see Bond & Crocker, 1991; or Polborn, Hoy, & Sadanand, 2006).

In long-term insurance, however, risk classification is not only a response to hidden knowledge or adverse selection; it also relates to moral hazard, shaping incentives for prevention that can impact the insured's future risk profile. Accordingly, we study here optimal long-term insurance contracts under moral hazard, focusing on the evolution of premia and the impact of classification risk.

We do so using a two-period model of dynamic insurance with change in risk exposure during the life cycle. In the first period, agents are identically exposed to a risk and can invest in prevention. In the second period, agents can either be of high-risk or low-risk type. Prevention effort in the first period has the effect of lowering the probability of being high-risk (that is, the probability of having a high probability of falling ill, in the case of health insurance[2]) in the second period.

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When effort is observable and contractible, long-term insurance fully covers classification risk (high-risk and low-risk agents optimally pay the same premium). On the other hand, when effort is unobservable, the insurance offered during the second period depends on the risk type (which we assume to be observable and public information).[3] This generates classification risk.

We then highlight a trade-off between inter- and intragenerational insurance. Through the prepayment of premia (i.e., intergenerational insurance) agents can increase their (expected) wealth in the second period, in which classification risk occurs. This "precautionary mechanism" would therefore be favored by prudent agents. Indeed, prepayment can here be understood as a way to achieve "pain disaggregation." This terminology, introduced by Eeckhoudt and Schlesinger (2006), reflects the fact that prudent agents prefer to be richer in the state in which they face a risk.[4] However—because of risk aversion—to remain incentive compatible, the long-term insurance contract must involve a higher classification risk when agents are richer in the second period. The optimal choice of prepayment therefore depends on the relative influence of prudence and risk aversion.

This paper shows that the critical level of the ratio of absolute prudence (P, as introduced by Kimball, 1990) to absolute risk aversion (A) is actually 2. If P is greater than two times A, in response to future uncertainty an insured optimally transfers wealth in the second period (through prepayment) at the expense of a higher classification risk. In this case, moral hazard—through the unobservability of preventive efforts—increases the first-period premium (hence enhances intergenerational insurance). On the contrary, when $P < 2A$, the negative effect of prepayment on classification risk dominates and moral hazard decreases intergenerational insurance.

We also investigate the beneficial effect risk classification can have on preventive efforts. This corresponds, for example, to safe behavior or a "hygieno-dietetic" regime in the case of health insurance[5][6] or to training that reduces the probability of unemployment in the future. Public policy in Europe may benefit from insights into the trade-off between the generosity of unemployment insurance and incentives to train.

Finally, we prove that classification risk can be reduced by decreasing prevention costs, whatever the insured's preferences, or by increasing the effectiveness of prevention when agents are risk-neutral during the first period.

To deal with classification risk, which could make insurance unaffordable to most agents, Pauly, Kunreuther, and Hirth (1995) propose guaranteed renewable insurance policies involving a declining schedule of premia, whereas Cochrane (1995) recommends time-consistent insurance contracts involving severance payments. These proposals, however, rely on the assumption of a perfect market and can be ineffective if agents are too impatient or face borrowing constraints (Frick, 1998; Pauly, Nickel, & Kunreuther, 1998).

Our paper is not the first to introduce moral hazard in dynamic insurance contracts. Abbring, Heckman, Chiappori, and Pinquet (2003) use dynamic insurance contracts in their empirical study on the distinction between moral hazard and adverse selection, but they analyze moral hazard related to the probability of accident. An important difference is that, in our model, the effort exerted in the current period reduces the probability of being high-risk next period. In a two-period model similar to ours, Hendel and Lizzeri (2003) analyze to what extent the prepayment of premia (front-loading) can reduce classification risk when accounting for cream-skimming. They state that front-loading allows the reduction of both cream-skimming (low-risk agents are insured at their fair premium in the second period) and classification risk (agents of different types have the same insurance contract).[7] Through preventive effort, we add moral hazard to this model.[8]

This is also not the first work where the relationship between P and $2A$ turns out to matter. It has already been found to play a role in contexts like the opening of a new asset market (Gollier & Kimball, 1996), when there is uncertainty on the size (Gollier, Jullien, & Treich, 2000) or the probability of losses (Gollier, 2002), and under contingent auditing (Sinclair-Desgagné & Gabel, 1997). Below, we provide an intuitive and new interpretation of this relationship. It is now well-established that the inverse of marginal utility plays a preponderant role in models with moral hazard. Our paper underlines the influence of the degree of concavity of this function, which is captured by the difference between P and $2A$.

We present the model in the next section. The optimal dynamic contract under moral hazard is defined in Section 3 and general results of comparative statics are provided in Section 4. We discuss various extensions of our model and its possible policy implications in Section 5. Section 6 contains concluding remarks and directions for future research.

2 | THE MODEL

To analyze the impact of moral hazard on prepayment and classification risk, we build a two-generation model with change in risk exposure during the life cycle. We model the simplest two-period, two-type case and assume that (homogeneous) newborn agents can affect their second-period risk status through prevention.

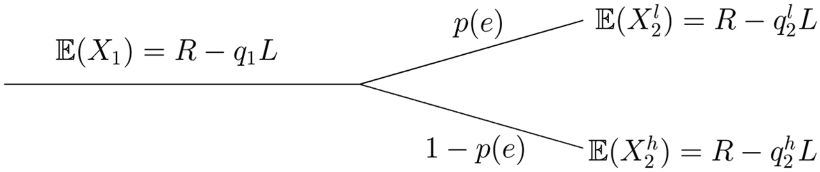

FIGURE 1 Income profile without insurance

Consider generations (of identical size) living for two periods $t = 1, 2$. In each period, all agents receive a sure revenue R. During the first period, all (young) individuals face the same risk, that is, the same probability q_1 of suffering a monetary loss L.[9] At $t = 2$, (old) agents may be of two types. Either, with probability p, they are low-risk type and face a probability of loss q_2^l or, with probability $1 - p$, they are high-risk type and suffer the loss with probability q_2^h, with $q_2^l < q_2^h$. At each period, we assume that two generations coexist (one composed of young agents and the other of older individuals).

Information about an agent's risk type is revealed at the beginning of the second period (for example, through medical check-ups) and is then public information. Young agents can exert a preventive effort that reduces the probability of becoming high-risk in the second period. This corresponds, in the case of health insurance, to efforts of primary prevention that aim at reducing risk factors associated with disease. For example, exercising and eating a balanced diet reduce the risk of high blood pressure or cholesterol, risk factors for cardiovascular diseases (see, e.g., Bacon, Sherwood, Hinderliter, & Blumenthal, 2004; Roberts, Vaziri, & Barnard, 2002; Varady & Jones, 2005). We assume that agents choose between two levels of prevention[10] $\underline{e}$ and $\overline{e}$ ($\underline{e} < \overline{e}$) leading, respectively, to probabilities of being low-risk $p(\underline{e}) \equiv \underline{p}$ and $p(\overline{e}) \equiv \overline{p}$, with $\underline{p} < \overline{p}$. Let us note $\Delta p \equiv \overline{p} - \underline{p}$.

Let X_i^j be the wealth of agents of type j in period i. In the absence of insurance, the income profile of a newborn agent can be schematized as in Figure 1.

During the first period, the utility function is separable in wealth and effort and the utility-cost of exerting a high effort of prevention is $\varphi \equiv \psi(\overline{e}) - \psi(\underline{e})$. We moreover assume time separability of preferences (to distinguish saving and insurance behavior).[11] Let $u(\cdot)$ (with $u'(\cdot) > 0$ and $u''(\cdot) \leq 0$) be the utility function of young agents and $v(\cdot)$ (with $v'(\cdot) > 0$ and $v''(\cdot) < 0$) be the utility function of both types of old agents.[12] Specifying different utility functions for the two periods allows us to isolate second-period risk preferences and to show that they are the ones at stake in our model. To illustrate our mechanism, we will sometimes assume that agents are risk-neutral during the first period (i.e., $u(\cdot)$ linear). This would simplify the model: because agents then have no reason other than prepayment to buy insurance at this stage, we can identify a first-period premium with prepayment.

To insure against this two-period risk, a mutual (or public) insurer offers young agents a long-term insurance contract, that is a contract specifying premium and coverage for both periods that depends on risk status in the second period.[13] The timing of the game is described in Figure 2.

Dynamic insurance contracts allow the insurer to use first-period premia to decrease the premium offered to high-risk agents when old (as shown in Hendel & Lizzeri, 2003).[14] However, when effort is unobservable and not contractible upon, the incentive to exert high preventive effort may be reduced.[15]

Note here that prepayment of premia can be related to precautionary saving, as it corresponds to an intertemporal transfer of wealth used to deal with future uncertainty. These two mechanisms, however, differ in a fundamental respect that is important

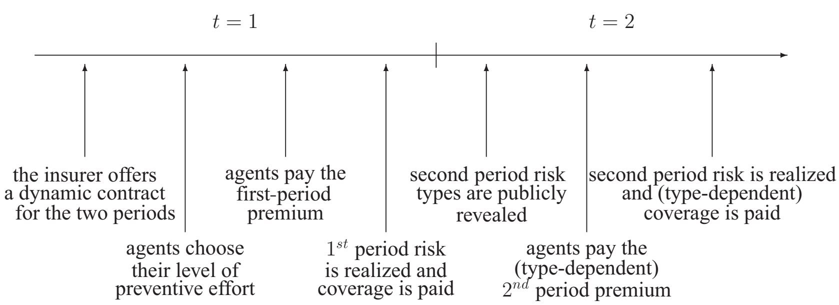

FIGURE 2 Timing of the game

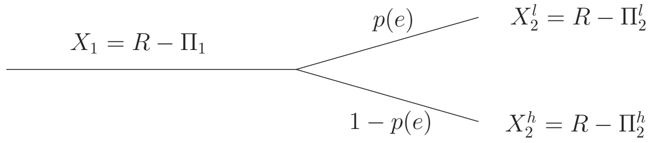

FIGURE 3 The income profile under the insurance contract

here. Whereas savings have the same return in every future state (thus hardly impacting classification risk), the insurer can choose to reallocate the prepaid premia differently across second-period types (thereby perhaps strongly impacting classification risk).

3 | THE OPTIMAL DYNAMIC CONTRACT

3.1 | The benchmark case of observable effort

It is easy to show, using the concavity of the utility function, that the dynamic insurance contract necessarily specifies complete insurance (in the sense that it provides an agent with the same wealth whether she suffers damage or not) once risk types are known.[16] A dynamic contract is therefore fully defined by a triplet $(\Pi_1, \Pi_2^l, \Pi_2^h)$ of premia corresponding, respectively, to the probabilities of loss q_1, q_2^l, and q_2^h. The coverage in all cases equals the amount of the loss L. Under such a dynamic insurance contract, the income profile of a newborn agent can then be summarized as in Figure 3.

The risk of being classified high-risk is then measured by the difference between the second-period premia.

Definition 1. The classification risk is defined as the risk of being classified high-risk by one's insurer and therefore paying a higher premium. In our two-type model with complete insurance in each state, this risk is simply measured by the spread between the premia paid by each type in the second period: $\Pi_2^h - \Pi_2^l$.

The insurer then seeks to maximize the expected utility of a young individual exerting an effort e:

$$u(R - \Pi_1) - \psi(e) + p(e)v\left(R - \Pi_2^l\right) + (1 - p(e))v\left(R - \Pi_2^h\right). \tag{1}$$

If the insurer is large enough, it can rely on the law of large numbers, and the zero-profit condition can be written as

$$\Pi_1 + p(e)\Pi_2^l + (1 - p(e))\Pi_2^h = \left[q_1 + p(e)q_2^l + (1 - p(e))q_2^h\right] L \equiv \mathbb{E}(L|e). \tag{2}$$

This states that the sum of premia collected (from young and old agents) covers (in expectation) the reimbursement of health costs. Recall here that we are considering a model with identical agents (that therefore exert the same preventive effort) and generations of identical size.

With observable effort, it is then optimal to set $\Pi_1{}^*$ and $\Pi_2^{l\,*} = \Pi_2^{h*} = \Pi_2^*$ such that $u'(R - \Pi_1^*) = v'(R - \Pi_2^*)$ and $\Pi_1^* = \mathbb{E}(L|e) - \Pi_2^*$. Then, there is no classification risk at the optimum and premia in both stages are decreasing in the level of preventive effort.[17] Therefore, for a low enough cost of effort φ,[18] the optimal contract without moral hazard specifies:

$$\begin{cases} e = \bar{e} \\ \Pi_2^{l\,*} = \Pi_2^{h*} \equiv \Pi_2^* \text{ with } v'\left(R - \Pi_2^*\right) = u'\left(R - \Pi_1^*\right) \\ \Pi_1^* = \bar{L} - \Pi_2^*, \end{cases} \tag{3}$$

where $\overline{L} \equiv \mathbb{E}(L|e = \overline{e})$.

Note here that we obtain the classical risk-smoothing result when utility functions are the same in both periods ($u(\cdot) \equiv v(\cdot)$): then $\Pi_1^* = \Pi_2^* = \frac{\bar{L}}{2}$. Risk-neutrality in the first period ($u(x) = x\ \forall x \in \mathbb{R}^+$) also simplifies the analysis as then the second-period premium is independent of the level of effort (it is obtained for $v'(R - \Pi_2^*) = 1$) and only the first-period premium adjusts through the zero-profit condition. We use this simplification below to analyze the optimal contract graphically.

3.2 | The optimal dynamic contract under moral hazard

Now, if prevention efforts are not observable, that is under moral hazard, agents have an incentive to exert the maximum level of effort only if the insurance contract satisfies

$$v\left(R-\Pi_2^l\right)-v\left(R-\Pi_2^h\right)\geq\frac{\varphi}{\Delta p}. \tag{4}$$

Therefore, the optimal contract producing an incentive to exert the high level of effort is the solution of

$$\max_{\Pi_1,\Pi_2^l,\Pi_2^h} u(R-\Pi_1)-\psi(\bar{e})+\bar{p}v\left(R-\Pi_2^l\right)+(1-\bar{p})v\left(R-\Pi_2^h\right) \tag{5}$$

$$\text{s.t.}\quad\begin{cases}\Pi_1+\bar{p}\Pi_2^l+(1-\bar{p})\Pi_2^h\geq\bar{L}\\ v(R-\Pi_2^l)-v(R-\Pi_2^h)\geq\frac{\varphi}{\Delta p}.\end{cases}$$

The contract solution of this program then represents the overall optimum if it provides agents with more expected utility than the optimal contract with low effort. We only focus in the following on the optimal incentive-compatible contract. We do not discuss the issue of the optimal level of effort, assuming that it is optimal for all agents to exert the maximum level of effort.[19]

The optimal dynamic contract under moral hazard then solves

$$\begin{cases}\frac{\bar{p}}{v'\left(R-\Pi_2^{l**}\right)}+\frac{1-\bar{p}}{v'\left(R-\Pi_2^{h**}\right)}=\frac{1}{u'(R-\Pi_1^{**})}\\ \Pi_1^{**}=\bar{L}-\bar{p}\Pi_2^{l**}-(1-\bar{p})\Pi_2^{h**}=\bar{L}-\mathbb{E}(\Pi_2^{**})\\ v(R-\Pi_2^{l**})-v(R-\Pi_2^{h**})=\frac{\varphi}{\Delta p}.\end{cases} \tag{6}$$

As shown in the next proposition, the shape of the inverse of marginal utility plays a preponderant role in our setting when analyzing the impact of moral hazard.

Proposition 1. *If the inverse of marginal utility ($1/v'$) is concave (respectively, convex) in the second period, moral hazard increases (respectively, reduces) prepayment (as then $\Pi_1^{**}>\Pi_1^*$, resp. $\Pi_1^{**}<\Pi_1^*$).*

Proof. See Appendix A.1. □

The condition $1/v'$ concave can be interpreted here in terms of prudence and risk aversion. It indeed corresponds to the index of absolute prudence $P\equiv\frac{-v'''(\cdot)}{v''(\cdot)}$, introduced by Kimball (1990), being everywhere greater than twice the index of absolute risk aversion $A\equiv\frac{-v''(\cdot)}{v'(\cdot)}$.

Because under observable effort agents have the same level of wealth in the second period whatever their type, moral hazard corresponds here to increased second-period uncertainty. Proposition 1 states that it leads to a decrease in first-period consumption (through an increase in the premium paid in the first stage) if $P\geq 2A$. This condition comes from the effect prepayment has on second-period premium. First, if agents are prudent ($P>0$), the increase in uncertainty would lead to an increase in prepayment (i.e., a decrease in first-period consumption) because of "precautionary motives" (or "pain disaggregation" as Eeckhoudt & Schlesinger, 2006, call it: see Section 1). This effect increases with the index of absolute prudence P (see Kimball, 1990). However, through the zero-profit condition, this would increase, in our setting, average wealth in the second period. Then, because of the concavity of the utility function, the optimal contract has to exhibit a higher classification risk (a higher spread between second-period premia) to remain incentive compatible.[20] This last effect goes against an increase in the first-period premium, and dominates if agents are "too risk averse" relative to their prudence. Proposition 1 states that this will be the case if $\frac{A}{P}\geq\frac{1}{2}$.

Now we turn to second-period premia.

Proposition 2. *Whatever the extent of prepayment when young, the unobservability of effort decreases the premium paid by low-risk agents and increases the one paid by high-risk agents when old ($\Pi_2^{l**}<\Pi_2^*<\Pi_2^{h**}$). Therefore, it increases classification risk.*

Proof. See Appendix A.2. □

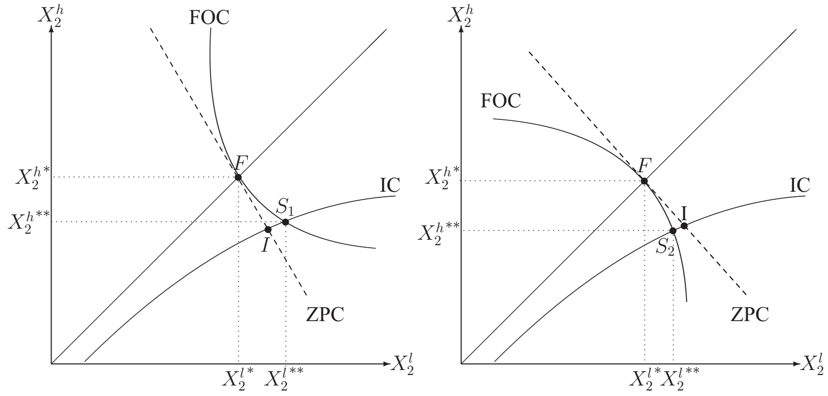

FIGURE 4 Second-period premia and the concavity/convexity of $1/v'$

Interestingly, Proposition 2 states that although the first-period premium can increase (respectively, decrease) with respect to the case of observable effort, it is never optimal to decrease (respectively, increase) second-period premia so much that both are higher (respectively, lower) under moral hazard than without. Because of consumption smoothing between the two periods, the optimal second-period premia are always set such that low-risk agents pay less than under observable effort, and high-risk pay more.

For the intuitions behind Propositions 1 and 2, it is useful to analyze the case of risk-neutrality in the first period. In this setting, the optimal contract under moral hazard solves[21]

$$\begin{cases} \frac{\bar{p}}{v'\left(R-\Pi_2^{l\,**}\right)} + \frac{1-\bar{p}}{v'\left(R-\Pi_2^{h\,**}\right)} = 1 \\ \Pi_1^{**} = \bar{L} - \bar{p}\Pi_2^{l\,**} - (1-\bar{p})\Pi_2^{h\,**} = \bar{L} - \mathbb{E}(\Pi_2^{**}) \\ v(R-\Pi_2^{l\,**}) - v(R-\Pi_2^{h\,**}) = \frac{\varphi}{\Delta p}, \end{cases} \tag{7}$$

so that the second-period premia are fully determined by the first-order condition and the incentive constraint. The zero-profit condition constraint then sets the premium paid when young depending on the expected second-period premium. This allows us to analyze the solution graphically, recalling $X_1 \equiv R - \Pi_1$, $X_2^l \equiv R - \Pi_2^l$, $X_2^h \equiv R - \Pi_2^h$ and studying the optimal premia in the plan (X_2^l, X_2^h). The shape of the first-order condition, the incentive constraint and the zero-profit condition, labeled, respectively FOC, IC, and ZPC in Figure 4, in the plan (X_2^l, X_2^h) are described in Appendix A.3.

Depending on the concavity of $1/v'$, moral hazard has different effects on second-period premia. First, whatever the concavity of $1/v'$, an "incentive" effect appears to lead to increased wealth for low-risk agents (decrease in Π_2^l) and decreased wealth for high-risk agents, relative to the complete information benchmark. Graphically, this corresponds to a move along ZPC line from point F to point I, and to what would happen if the first-period premium was set to Π_1^*. This effect is combined with a "risk preferences" effect—linked to prepayment—that depends on the concavity of $1/v'$. Indeed, if $1/v'$ is concave (figure on left) the "incentive" effect is coupled with a move to the northeast along the incentive constraint from point I to S_1. Therefore, when $1/v'$ is concave (i.e., when $P \geq 2A$), the "risk preferences" effect corresponds to a decrease in both second-period premia. This last effect moreover leads to the increase in prepayment described in Proposition 1, moving the line representing the zero-profit conditions upward. Indeed, in the plan (X_2^l, X_2^h), the zero-profit condition is represented by parallel lines of slope $\frac{1-p}{p}$ that determine Π_1 (see Appendix A.3).

The reverse effect (a move from I to S_2) holds when $1/v'$ is convex (figure on right). The "risk preferences" effect then corresponds to a decrease in both X_2^l and X_2^h (leading to the increase in X_1 found in Proposition 1). However, as the first-order condition is necessarily decreasing in the plan (X_2^l, X_2^h), the "incentive" effect dominates and Proposition 2 still holds.

This confirms our interpretation of the condition $P \geq 2A$. To be incentive compatible, the optimal contract has to involve classification risk (the move from F to I). To cope with this uncertainty, prudent agents are tempted to rely on prepayment increasing expected wealth in the second period (through the zero-profit condition, that is, a shift upward of the ZPC line). However, due to the concavity of the second-period utility function, a higher spread in premium would then be needed to remain incentive compatible. This prevents agent with high risk aversion, more precisely with $P < 2A$, from relying on prepayment.

This mechanism can also be understood as a trade-off between inter- and intragenerational insurance. Indeed, for the contract to be incentive compatible, either it must specify a small spread between wealth—that is, a small classification risk—when expected wealth is low in the second period; or it has to entail high classification risk when expected wealth is high. In the former case, intragenerational insurance is high and intergenerational insurance low, and vice versa in the latter case. We show that this trade-off between inter- and intragenerational insurance depends on the concavity of $1/v'$, that is, on the difference between prudence and twice risk aversion.

Note here that the very same mechanism holds with a concave utility function in the first period but, as shown in the proofs of Proposition 1 and 2, the relevant mechanism then goes through both the first order and the zero-profit conditions.

4 | COMPARATIVE STATICS: HOW TO REDUCE CLASSIFICATION RISK?

In this section, we analyze how the preventive technology can affect the optimal premia. By defining how it impacts classification risk, we are able to formulate some policy recommendations on how to deal with this kind of risk, a source of inequalities (see Dionne & Rothschild, 2014). We study the effect of changes in the cost of preventive effort φ and its effectiveness through $\overline{p}$.

4.1 | Changes in the cost of preventive effort

The cost of preventive effort appears to offer the first leverage for policymakers (using subsidies) or insurers (see examples in footnote 6). Our model allows us to analyze the impact of this cost φ on optimal premia and especially on classification risk, as summarized Proposition 3.

Proposition 3. *A decrease in the cost of prevention*

- *decreases classification risk*
- *decreases (respectively, increases) prepayment if* $1/v'$ *is concave (respectively, convex).*

Proof. See Appendix A.4. □

The effect on classification risk is quite straightforward. A decrease in the cost of prevention increases the incentive to exert the effort. The insurance contract can then exhibit a lower classification risk and remain incentive compatible. Therefore, a policymaker seeking to reduce the inequality resulting from classification risk should work on reducing the cost of prevention. By the same mechanism as for Proposition 1, this decreases (respectively, increases) prepayment if $1/v'$ is concave (respectively, convex). Graphically, an increase in φ corresponds to a downward shift of the incentive curve.

4.2 | Changes in the effectiveness of prevention

Let us now analyze the effect of a change in the probability of being low-risk when exerting the preventive effort. An increase in $\overline{p}$, keeping $\underline{p}$ constant, can be interpreted as an improvement in the effectiveness of prevention, for example, by investing in research on prevention. This suggests an important role for public policy on prevention. Comparative statics with respect to $\overline{p}$ are, however, complex due to an additional effect on the zero-profit condition. Assuming risk-neutrality in the first period (in order to get rid of this effect as explained above) still allows us to state the following proposition.

Proposition 4. *When agents are risk-neutral in the first period (i.e., if $u(\cdot)$ is linear), an increase in the probability of being low-risk in the second period when exerting the preventive effort decreases classification risk.*

Proof*: See Appendix A.5.*

When $u(\cdot)$ is linear, the second-period premia are fully determined by the first-order condition and the incentive constraint. Now, an increase in the probability of being low-risk for agents that exert preventive effort (maintaining this probability constant for agents that do not) increases the benefit of effort, making it easier to provide the incentive. The optimal contract can therefore lead to a lower welfare in the good state of nature and still be incentive compatible.

Through the incentive constraint, this implies a decrease in the second-period premium for risky agents. However, an increase in $\overline{p}$ also decreases the weight attached to this bad state in the objective function. This leads to a decrease in optimal wealth of high-risk agents. The outcome of these two effects is ambiguous. Still, it is possible to state that an increase in the probability of being low-risk decreases classification risk, meaning that the incentive effect dominates in that respect.

The effect on prepayment (i.e., on Π_1^{**}) is ambiguous. Indeed, in addition to the effects on second-period premia, an increase in $\overline{p}$ changes the shape of the zero-profit condition, both in terms of resources and in terms of costs. Then, besides the shape of $1/v'$, the effect of an increase in $\overline{p}$ depends on the relative position of second-period premia with respect to expected losses.

For the same reasons, the effect of $\overline{p}$ is ambiguous in the general case of concave utility functions in the first period, as then the zero-profit condition also impacts second-period premia.

In this sense, a decrease in the cost of prevention appears to have a clearer effect on classification risk than an increase in the effectiveness of prevention. Still, for our analysis to hold, prevention has to be efficient enough for the incentive contract to be preferred to the optimal contract with low effort.

5 | DISCUSSION AND POLICY IMPLICATIONS

Through the analysis of primary prevention effort in long-term insurance contracts, we have highlighted a trade-off between inter- and intragenerational insurance. To be incentive compatible, the optimal contract either entails low classification risk (i.e., high intergenerational insurance) and low prepayment (i.e., low intragenerational insurance), or high classification risk (low intergenerational insurance) and high prepayment (high intragenerational insurance).

Key to our analysis is the full information of risk status. As highlighted in Li, Bruen, Lantz, and Mendez (2015) in the case of hypertension (a risk factor for cardiovascular disease), the expansion of health insurance coverage allows for earlier detection and better treatment. This would however create classification risk that, as previously pointed out, creates equity issues. We claim here that long-term insurance, that is a combination of inter- and intragenerational insurance, can partly solve these issues.

Intragenerational health insurance generates moral hazard related to primary prevention (or health behavior), often called *ex ante* moral hazard. Several studies (see, e.g., Dave & Kaester, 2009; or De Preux, 2011) indeed find evidence of a decrease in primary prevention after obtaining Medicare, a national social insurance program for the elderly in the United States. We argue in this paper that intergenerational insurance can solve this issue through long-term insurance. Interestingly, recent evidence on the Patient Protection and Affordable Care Act seems to support this result. Simon, Soni, and Cawley (2016) find that the extension of Medicaid to nonelderly adults did not increase risky health behaviors. This is in keeping with our paper's policy implication, namely, that a combination of inter- and intragenerational insurance can induce an optimal level of prevention.

The model presented above in the case of health insurance moreover appears to be applicable to other insurance markets, with slight modifications. One application is life insurance, where the insurer offers protection against the risk of death and agents can reduce the probability of having a high probability of death in the second period by exerting preventive effort. If we assume *ad hoc* altruism (the indemnity paid to the beneficiary directly enters the insured's utility function), optimal insurance is complete in each state and is the solution of a program similar to (5). However, we need to include in this extension the fact that agents can die in the first period (that is the survival probability). As q_1 then represents the risk of death in period 1, only a portion $(1 - q_1)$ of a generation is still alive in period 2. However, all the above properties hold for life insurance with (*ad hoc*) altruistic agents (computations can be found in Bourlès, 2015).

With more amendments, our model also seems to be applicable to unemployment insurance. Consider unemployment insurance in our simple overlapping generation model. In their early life, all agents face the same probability of being unemployed (or have the same expected length of unemployment) and can invest in training effort e. Partially based on this effort, agents can then either be employed as a "skilled" (executive) or "unskilled" (nonexecutive) worker in the second period. We moreover assume (based on real economies) that the risk of unemployment is higher among unskilled than among skilled workers. Although the risk is then multiplicative, the observability of risk status (and the absence of asymmetric information regarding the probability of unemployment for each risk status) imply complete insurance in each state. We therefore end up with a problem very similar to (5) (see Bourlès, 2015, for the relevant program). Our analysis therefore contributes insights on optimal intra- and intergenerational employment insurance. This is particularly relevant in countries with extensive social employment insurance schemes. For example, employment benefit in France amounts to 75% of the last gross wage for the lowest wage bracket and about 57% for the highest, consistent with intragenerational insurance between skilled and unskilled workers. As these unemployment benefits are higher for workers above 50 years old, this intragenerational insurance moreover seems to be combined with an intergenerational insurance. In this application, our model reveals a trade-off between training effort and intergenerational insurance, and could inform the debate on the relative merits of generous unemployment benefits and training subsidization.

Finally, this trade-off between intergenerational insurance and incentives, as well as the role of risk preferences, seem to be at least partially extendable to a continuum of effort levels. As shown in the Appendix A.6, a part of Proposition 1 continues to hold in this case when agents are risk-neutral in the first period. Then, moral hazard decreases the expected premium paid in the second period if and only if $1/v'$ is concave. Provided that moral hazard decreases the optimal preventive effort, it also increases prepayment when prudence is greater than twice risk aversion. As explained in the previous section, the issue here is that changes in effort impact both revenue and cost in the zero-profit condition. Moreover, assuming a continuum of effort levels complicates the analysis, since unlike the two-level case, effort levels may be different with and without moral hazard.

6 | CONCLUSION

We highlight in this paper the role of prudence and risk aversion in long-term insurance contracts. Adding to the usual models an effort of prevention, we show that the concavity of the inverse of marginal utility (i.e., the difference between prudence, P, and twice risk aversion, A) plays a central role in defining the optimal level of prepayment (which can be understood as intergenerational insurance) and the optimal incentive-compatible classification risk. First, our analysis indicates that moral hazard always increases classification risk (relative to the complete information benchmark) and increases the first-period premium if $P \geq 2A$. This reveals the trade-off between prevention and (intergenerational) insurance that arises from future uncertainty.

It moreover appears that classification risk can be reduced by decreasing the cost of prevention or by increasing the effectiveness of prevention (when $P < 2A$). Therefore, if the objective is to make insurance more affordable to high-risk agents, the policymaker should try to make prevention cheaper and more effective.

It is left for future research to analyze to what extent this optimal long-term contract can withstand competition from companies offering spot (short-term) contracts. Hendel and Lizzeri (2003) pointed out that long-term insurance contracts are subject to lapsation in the second period. In the absence of severance payments, healthier agents may then leave the dynamic contract to go to a competing short-term (spot) insurer that offers actuarially fair premia. This will be the case if the optimal incentive premium for low-risk agents is higher than their expected costs. Therefore, the lower the premium offered to low-risk agents in the second period, the lower the incentive for healthy agents to lapse (and turn to the spot insurer). Preliminary work for specific utility functions (see Bourlès, 2015) suggests that the optimal long-term insurance is more likely to withstand competition from companies offering spot (short-term) contracts if it insures agents with a greater difference between absolute prudence and twice absolute risk aversion.

It would then be interesting to infer the value of $P - 2A$ for economic agents. The specification of the usual utility functions leads to conflicting results. It may therefore be necessary to use simple lotteries or resort to experiments to determine whether/when $P \geq 2A$. Applying the notion of "risk apportionment" (used in the case of additive risks by Eeckhoudt & Schlesinger, 2006) to multiplicative risks in simple lotteries, Eeckhoudt, Etner, and Schroyen (2009) provide a sufficient condition for P to be greater than $2A$. They offer simple conditions on preferences among lotteries for which the index of relative prudence is higher than 2 and the index of relative risk aversion is lower than 1.

NOTES

[1] Risk classification has been restricted by the Patient Protection and Affordable Care Act in 2010 in the United States and the EU has banned classification based on gender in 2012.

[2] In medical science, such efforts are referred to as "primary prevention." The U.S. Preventive Services Task Forces Guide to Clinical Preventive Services (2nd edition, 1996) defines primary prevention measures as "those provided to individuals to prevent the onset of a targeted condition." It includes in particular health behavior (exercising, eating a balanced diet) aimed at reducing risk factors associated with disease (Sharlin, 2014).

[3] In other words, we focus here on moral hazard (hidden actions) rather than on adverse selection (hidden information). This last case has been extensively studied in the literature (see, e.g., Bond & Crocker, 1991; or Polborn et al., 2006).

[4] Formally, Eeckhoudt and Schlesinger (2006) show that a prudent individual prefers the lottery $[-k; \tilde{\varepsilon}]$ over $[0; \tilde{\varepsilon} - k]$ $\forall\, k \in \mathbb{R}^+$ and $\forall$ zero-mean random variable $\tilde{\varepsilon}$.

[5] Health behaviors (exercising, balance diet, nonsmoking, etc.) indeed decrease the risk of high blood pressure or cholesterol, themselves risk factors for cardiovascular diseases.

[6] Insurance market initiatives show how attractive this kind of prevention is to insurers, and especially mutual insurers. In 2005 and 2007, respectively, French mutual insurers AGF and MAAF began to reimburse some food products designed to lower cholesterol. There was a similar initiative in 2005 by the Dutch insurer VGZ.

[7] Contrary to us, Hendel and Lizzeri (2003) allow for more than two risk types in the second period.

[8] This is partly done at the expense of the study of limited commitment. Although we discuss the issue of lapsation, we do not explicitly model the possibility for low-risk agents to exit the long-term insurance contract.

[9] We only model here the insurable part of the damage. Then, under complete insurance, agents have the same utility in both (loss/nonloss) states.

[10] We discuss the case of a continuum of effort levels in Section 5.

[11] Using incentive constraints prevents us from using Kreps–Porteus preferences, which would allow us to fully disentangle risk and time effects. However, the use of such nonexpected utility makes the problem untractable as it greatly complicates the writing of the incentive-compatible constraint.

[12] We assume there is no direct utility loss due to risk status. This notably ensures that the optimal contract does not entail any counterintuitive classification risk, where high-risk agents pay a lower premium than low-risk agents.

[13] The experienced reader will note that the following problem also fits in the case of competing insurance companies that do not seek to propose profitable one-period contracts. However, as illustrated in Geoffard (2000), premia of mutual insurers (in France) increase less with age than those of stock insurers. This seems to indicate that long-term contracts, as modeled here, are more likely to be offered by mutual insurers.

[14] A polar case of such a mechanism is genetic insurance—as proposed by Tabarrok (1994)—which corresponds to a complete insurance of classification risk and is therefore not optimal in presence of moral hazard.

[15] Contrary to Hendel and Lizzeri (2003), we do not allow agents to exit the contract (i.e., to lapse) once their second-period risk types are revealed. However, as noted in Hendel and Lizzeri (2003), lapsation is closely related to prepayment, as early payment of premia tends to lock agents into the contract. We discuss this issue in Section 6.

[16] This issue is more problematic in Hendel and Lizzeri (2003) who model life insurance and therefore specify a state- (alive/dead) dependent utility function.

[17] This can be seen by writing the first-order condition as $u'(R-\Pi_1^*) - v'(R-\mathbb{E}(L|e)+\Pi_1^*) = 0$ (respectively, $u'(R-\mathbb{E}(L|e)+\Pi_2^*) - v'(R-\Pi_2^*) = 0$) and noticing that $\mathbb{E}(L|e)$ is decreasing in e.

[18] If the cost of effort is too high, the optimal contract is achieved for $e = \underline{e}$ and unobservability of effort does not entail any moral hazard issue.

[19] In a static model, Jullien, Salanié, and Salanié (1999) give conditions under which more risk-averse agents optimally exert a higher effort of prevention.

[20] By allowing an unequal distribution of the prepaid premium between the two types in the second period, prepayment of premia appears to be more flexible than precautionary saving.

[21] Note here that the first-order condition of the program (7) is the same as in the standard moral hazard model (see Laffont & Martimort, 2002, chapter 4). Our model can indeed be viewed as a dynamic extension of the classic moral hazard problem.

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APPENDIX A

A.1 Proof of Proposition 1

Under observable effort, the optimal contract if defined by (3)

$$\begin{cases} \Pi_2^{l*} = \Pi_2^{h^*} \equiv \Pi_2^* \text{ with } v'(R-\Pi_2^*) = u'(R-\Pi_1^*) \\ \Pi_1^* = \bar{L} - \Pi_2^* \end{cases} \tag{A1}$$

and the second-period premia are fully determined by

$$\frac{u'(R-\bar{L}+\Pi_2^*)}{v'(R-\Pi_2^*)} = 1. \tag{A2}$$

Now, under moral hazard, the optimal contract solves (6)

$$\begin{cases} v(R-\Pi_2^{l\,**}) - v(R-\Pi_2^{h^{**}}) = \frac{\varphi}{\Delta p} \\ \frac{\bar{p}}{v'\left(R-\Pi_2^{l\,**}\right)} + \frac{1-\bar{p}}{v'\left(R-\Pi_2^{h^{**}}\right)} = \frac{1}{u'(R-\Pi_1{}^{**})} \\ \Pi_1^{**} = \bar{L} - \bar{p}\Pi_2^{l\,**} - (1-\bar{p})\Pi_2^{h^{**}} = \bar{L} - \mathbb{E}(\Pi_2^{**}). \end{cases} \tag{A3}$$

Taken together, the first two equations of this system give

$$\frac{\bar{p}}{v'\left(R-\Pi_2^{l\,**}\right)}+\frac{1-\bar{p}}{v'\left(R-\Pi_2^{h\,**}\right)}=\frac{1}{u'\left(R-\bar{L}-\mathbb{E}\left(\Pi_2^{**}\right)\right)}. \tag{A4}$$

Therefore, if $(1/v')$ is concave (respectively, convex), the optimal incentive contract under moral hazard satisfies $\frac{1}{v'(R-\mathbb{E}(\Pi_2^{**}))}\geq\frac{\bar{p}}{v'(R-\Pi_2^{l\,**})}+\frac{1-\bar{p}}{v'(R-\Pi_2^{h\,**})}=\frac{1}{u'(R-\overline{L}+\mathbb{E}(\Pi_2^{**}))}$ that is $\frac{u'(R-\overline{L}+\mathbb{E}(\Pi_2^{**}))}{v'(R-\mathbb{E}(\Pi_2^{**}))}\geq 1$ (respectively, $\frac{u'(R-\overline{L}+\mathbb{E}(\Pi_2^{**}))}{v'(R-\mathbb{E}(\Pi_2^{**}))}\leq 1$). The function $f(x)\equiv\frac{u'(R-\overline{L}+x)}{v'(R-x)}$ being decreasing with x for all $u(.)$ and $v(.)$ increasing and concave, we end up having $\mathbb{E}(\Pi_2^{**})\leq\Pi_2^*$, that is, $\Pi_1^{**}\geq\Pi_1^*$, when $(1/v')$ is concave; and $\mathbb{E}(\Pi_2^{**})\geq\Pi_2^*$, that is $\Pi_1^{**}\leq\Pi_1^*$, when $(1/v')$ is convex.

A.2 Proof of Proposition 2

By equation (A4), under moral hazard, second-period premia have to verify $g(\Pi_2^{l\,**},\Pi_2^{h\,**})=0$ with

$$g\left(\Pi_2^l,\Pi_2^h\right)\equiv\frac{\bar{p}}{v'\left(R-\Pi_2^l\right)}+\frac{1-\bar{p}}{v'\left(R-\Pi_2^h\right)}-\frac{1}{u'(R-\bar{L}+\bar{p}\Pi_2^l+(1-\bar{p})\Pi_2^h)}. \tag{A5}$$

Now, by (A2), under observable effort, the second-period premia are such that $g(\Pi_2^*,\Pi_2^*)=0$.

Moreover, because of the incentive constraint $\Pi_2^{l\,**}<\Pi_2^{h\,**}$. Therefore, $g(\Pi_2^l,\Pi_2^h)$ being decreasing in both arguments, we necessarily have $\Pi_2^{l\,**}<\Pi_2^*<\Pi_2^{h\,**}$.

A.3 Graphical analysis

- The incentive constraint (IC in Fig. 4).

The incentive constraint: $v(X_2^l)-v(X_2^h)=\frac{\varphi}{\Delta p}$ defines, in the plan (X_2^l,X_2^h), an increasing and concave curve below the 45° line. Moreover, the distance between the incentive constraint and the 45° line is increasing in X_2^l as the function $h(X_2^l)=X_2^l-v^{-1}(v(X_2^l)-\frac{\varphi}{\Delta p})$ is increasing in X_2^l when $v'(X_2^l)<v'[v^{-1}(v(X_2^l)-\frac{\varphi}{\Delta p})]=v'(X_2^h)$.

- The zero-profit condition (ZPC in Fig. 4).

The first-period wealth can be inferred graphically based on X_2^l and X_2^h using the zero-profit condition. We can indeed rewrite the zero-profit condition as $R-\Pi_1+\overline{p}(R-\Pi_2^l)+(1-\overline{p})(R-\Pi_2^h)=2R-\overline{L}$ that is as $\overline{p}X_2^l+(1-\overline{p})X_2^h=-X_1+2R-\overline{L}$. In the plan (X_2^l,X_2^h), the zero-profit condition can therefore be represented by parallel lines of slope $\frac{1-p}{p}$, upper lines corresponding to lower X_1's. The ZPC line in Figure 4 refers to the zero-profit condition for $X_2^l=X_2^h=X_2^*$.

- The first-order condition (FOC in Fig. 4).

The first-order condition can be written as $\frac{\overline{p}}{v'(R-\Pi_2^{l\,**})}+\frac{1-\overline{p}}{v'(R-\Pi_2^{h\,**})}=1$ when agents are risk-neutral in the first period. It therefore corresponds to a decreasing curve in the plan (X_2^l,X_2^h). As, by construction it is satisfied at first-best, this curve goes through point (X_2^*,X_2^*). It is finally tangent to the line $\overline{p}X_2^l+(1-\overline{p})X_2^h=X$ at (X_2^*,X_2^*) and convex (respectively, concave) when $1/v'$ is concave (respectively, convex).

A.4 Proof of Proposition 3

Differentiating the solution system (6) with respect to Π_1, Π_2^l, Π_2^h, and φ gives

$$\frac{d\Pi_2^l}{d\varphi}=\frac{-\frac{1-\bar{p}}{\Delta p}\left[\frac{-v''\left(R-\Pi_2^h\right)}{\left[v'\left(R-\Pi_2^h\right)\right]^2}+\frac{-u''(R-\Pi_1)}{[u'(R-\Pi_1)]^2}\right]}{\bar{p}v'\left(R-\Pi_2^h\right)\left[\frac{-v''\left(R-\Pi_2^l\right)}{\left[v'\left(R-\Pi_2^l\right)\right]^2}+\frac{-u''(R-\Pi_1)}{[u'(R-\Pi_1)]^2}\right]+(1-\bar{p})v'\left(R-\Pi_2^l\right)\left[\frac{-v''\left(R-\Pi_2^h\right)}{\left[v'\left(R-\Pi_2^h\right)\right]^2}+\frac{-u''(R-\Pi_1)}{[u'(R-\Pi_1)]^2}\right]}$$

$$<0$$

$$\frac{d\Pi_2^h}{d\varphi} = \frac{\frac{\bar{p}}{\Delta p}\left[\frac{-v''\left(R-\Pi_2^l\right)}{\left[v'\left(R-\Pi_2^l\right)\right]^2} + \frac{-u''(R-\Pi_1)}{[u'(R-\Pi_1)]^2}\right]}{\bar{p}v'\left(R-\Pi_2^h\right)\left[\frac{-v''\left(R-\Pi_2^l\right)}{\left[v'\left(R-\Pi_2^l\right)\right]^2} + \frac{-u''(R-\Pi_1)}{[u'(R-\Pi_1)]^2}\right] + (1-\bar{p})v'\left(R-\Pi_2^l\right)\left[\frac{-v''\left(R-\Pi_2^h\right)}{\left[v'\left(R-\Pi_2^h\right)\right]^2} + \frac{-u''(R-\Pi_1)}{[u'(R-\Pi_1)]^2}\right]} > 0$$

$$\frac{d\Pi_1}{d\varphi} = \frac{\frac{\bar{p}(1-p)}{\Delta p}\left[\frac{-v''\left(R-\Pi_2^h\right)}{\left[v'\left(R-\Pi_2^h\right)\right]^2} - \frac{-v''\left(R-\Pi_2^l\right)}{\left[v'\left(R-\Pi_2^l\right)\right]^2}\right]}{\bar{p}v'\left(R-\Pi_2^h\right)\left[\frac{-v''\left(R-\Pi_2^l\right)}{\left[v'\left(R-\Pi_2^l\right)\right]^2} + \frac{-u''(R-\Pi_1)}{[u'(R-\Pi_1)]^2}\right] + (1-\bar{p})v'\left(R-\Pi_2^l\right)\left[\frac{-v''\left(R-\Pi_2^h\right)}{\left[v'\left(R-\Pi_2^h\right)\right]^2} + \frac{-u''(R-\Pi_1)}{[u'(R-\Pi_1)]^2}\right]}.$$

Therefore, $\frac{d(\Pi_2^h-\Pi_2^l)}{d\varphi} > 0$ and $\frac{d\Pi_1}{d\varphi}$ is positive if $(1/v')$ is concave—as the ratio $-v''(.)/[v'(.)]^2$ is then decreasing—and Proposition 3 holds.

A.5 Proof of Proposition 4

Using (7), the solution with a linear $u(\cdot)$, comparative statics on changes in $\bar{p}$ gives

$$\begin{cases} \frac{d\Pi_2^l}{d\bar{p}} = \frac{v'\left(R-\Pi_2^h\right)\left[\frac{1}{v'\left(R-\Pi_2^l\right)} - \frac{1}{v'\left(R-\Pi_2^h\right)}\right] + (1-\bar{p})\frac{\varphi}{(\Delta p)^2}\frac{-v''\left(R-\Pi_2^h\right)}{\left[v'\left(R-\Pi_2^h\right)\right]^2}}{\bar{p}v'\left(R-\Pi_2^h\right)\frac{-v''\left(R-\Pi_2^l\right)}{\left[v'\left(R-\Pi_2^l\right)\right]^2} + (1-\bar{p})v'\left(R-\Pi_2^l\right)\frac{-v''\left(R-\Pi_2^h\right)}{\left[v'\left(R-\Pi_2^h\right)\right]^2}} \geq 0 \\ \frac{d\Pi_2^h}{d\bar{p}} = \frac{v'\left(R-\Pi_2^l\right)\left[\frac{1}{v'\left(R-\Pi_2^l\right)} - \frac{1}{v'\left(R-\Pi_2^h\right)}\right] - \bar{p}\frac{\varphi}{(\Delta p)^2}\frac{-v''\left(R-\Pi_2^l\right)}{\left[v'\left(R-\Pi_2^l\right)\right]^2}}{\bar{p}v'\left(R-\Pi_2^h\right)\frac{-v''\left(R-\Pi_2^l\right)}{\left[v'\left(R-\Pi_2^l\right)\right]^2} + (1-\bar{p})v'\left(R-\Pi_2^l\right)\frac{-v''\left(R-\Pi_2^h\right)}{\left[v'\left(R-\Pi_2^h\right)\right]^2}}, \end{cases}$$

which gives

$$\begin{aligned} \frac{d\left(\Pi_2^h-\Pi_2^l\right)}{d\bar{p}} &= \frac{\left[v'\left(R-\Pi_2^l\right) - v'\left(R-\Pi_2^h\right)\right]\left[\frac{1}{v'\left(R-\Pi_2^l\right)} - \frac{1}{v'\left(R-\Pi_2^h\right)}\right]}{\bar{p}v'\left(R-\Pi_2^h\right)\frac{-v''\left(R-\Pi_2^l\right)}{\left[v'\left(R-\Pi_2^l\right)\right]^2} + (1-\bar{p})v'\left(R-\Pi_2^l\right)\frac{-v''\left(R-\Pi_2^h\right)}{\left[v'\left(R-\Pi_2^h\right)\right]^2}} \\ &\quad - \frac{\frac{\varphi}{(\Delta p)^2}\left[\bar{p}\frac{-v''\left(R-\Pi_2^l\right)}{\left[v'\left(R-\Pi_2^l\right)\right]^2} + (1-\bar{p})\frac{-v''\left(R-\Pi_2^h\right)}{\left[v'\left(R-\Pi_2^h\right)\right]^2}\right]}{\bar{p}v'\left(R-\Pi_2^h\right)\frac{-v''\left(R-\Pi_2^l\right)}{\left[v'\left(R-\Pi_2^l\right)\right]^2} + (1-\bar{p})v'\left(R-\Pi_2^l\right)\frac{-v''\left(R-\Pi_2^h\right)}{\left[v'\left(R-\Pi_2^h\right)\right]^2}} \\ &\leq 0. \end{aligned}$$

A.6 Generalization to a continuum of effort levels

Let us now consider a model in which agents can choose their preventive effort among a continuum. This amounts to choosing $p \in [0, 1]$ at a cost $\psi(p)$ increasing and convex. Assuming risk-neutrality in the first period, the optimal contract under observable effort then solves

$$\max_{p,\Pi_1,\Pi_2^l,\Pi_2^h} \; R - \Pi_1 - \psi(p) + pv\left(R - \Pi_2^l\right) + (1-p)v\left(R - \Pi_2^h\right)$$

$$\text{s.t.} \quad \Pi_1 + p\Pi_2^l + (1-p)\Pi_2^h = \left[q_1 + pq_2^l + (1-p)q_2^h\right] L$$

and the solution is given by

$$\begin{cases} \Pi_2^{l*} = \Pi_2^{h^*} \equiv \Pi_2^* \\ v'(R - \Pi_2^*) = 1 \\ \psi'(p^*) = (q_2^h - q_2^l)L \\ \Pi_1^* = \left[q_1 + p^* q_2^l + (1-p^*)q_2^h\right] L - \Pi_2^*. \end{cases}$$

Under moral hazard on p, the program becomes

$$\max_{\Pi_1,\Pi_2^l,\Pi_2^h} \; R - \Pi_1 - \psi(p^{**}) + p^{**}v\left(R - \Pi_2^l\right) + (1-p^{**})v\left(R - \Pi_2^h\right)$$

$$\text{s.t.} \quad \begin{cases} \Pi_1 + p^{**}\Pi_2^l + (1-p^{**})\Pi_2^h = \left[q_1 + p^{**}q_2^l + (1-p^{**})q_2^h\right] L \\ \psi'(p^{**}) = v'\left(R - \Pi_2^l\right) - v\left(R - \Pi_2^h\right) \end{cases}$$

and

$$\begin{cases} \frac{p^{**}}{v'(R - \Pi_2^{l\,**})} + \frac{1-p^{**}}{v'(R - \Pi_2^{h**})} = 1 \\ \Pi_1^{**} = \left[q_1 + p^{**}q_2^l + (1-p^{**})q_2^h\right] L - \left[p^{**}\Pi_2^{l\,**} + (1-p^{**})\Pi_2^{l\,**}\right] \\ \psi'(p^{**}) = v'\left(R - \Pi_2^{l\,**}\right) - v\left(R - \Pi_2^{h**}\right). \end{cases}$$

Therefore, when $1/v'$ is concave (respectively, convex) $\mathbb{E}(\Pi_2^{**}) \leq \Pi_2^*$ (respectively, $\mathbb{E}(\Pi_2^{**}) \geq \Pi_2^*$). If moreover $p^{**} < p^*$, $\Pi_1^{**} > \Pi_1^*$ when $1/v'$ is concave (as $q_2^l < q_2^h$).