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**Conference Paper**

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Beiträge zur Jahrestagung des Vereins für Socialpolitik 2010: Ökonomie der Familie - Session: Asymmetric Information and Risk, No. C8-V1

**Provided in Cooperation with:**

Verein für Socialpolitik / German Economic Association

*Suggested Citation:* Schumacher, Heiner; Kesternich, Iris (2010) : Pain, Precautions and Present-biased Preferences: A Theory of Health Insurance, Beiträge zur Jahrestagung des Vereins für Socialpolitik 2010: Ökonomie der Familie - Session: Asymmetric Information and Risk, No. C8-V1, Verein für Socialpolitik, Frankfurt a. M.

This Version is available at:

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# Pain, Precautions and Present-biased Preferences: A Theory of Health Insurance

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February 2010

## Abstract

We develop an insurance market model where consumers (i) exhibit present-biased preferences, and (ii) suffer from physical pain in case of (health-) damage. They can exert preventive effort to reduce the probability of damage. Sophisticated consumers correctly anticipate their effort and purchase full insurance. Naive consumers overestimate their future effort, purchase no insurance and end up with less effort than sophisticated ones. We allow consumers to differ in their wealth and risk preferences. Our model can explain why in some insurance markets there is a negative correlation between risk and insurance and a positive correlation between insurance and wealth.

**Keywords:** Insurance Markets, Moral Hazard, Hyperbolic Discounting, Sophistication

**JEL classification codes:** D82, D91, G22

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# 1 Introduction

Human beings can greatly influence their health and medical risk. The WHO estimates that 30% of the 7.9 million cancer deaths in 2007 could have been avoided, for instance, by reducing tobacco use, improving diets, exercising and lowering alcohol consumption.<sup>1</sup> The very same preventive measures also help to decrease the risk of many other diseases like heart attacks, strokes or mental disorders. However, a healthy lifestyle is not always compatible with our short-term interests. The problem is that its benefits accrue in the future whereas the costs are immediate. An extensive literature documents that people often overemphasize immediate costs relative to gains in the future, which leads to time-inconsistent behavior.<sup>2</sup> Gallup, for instance, reports that 74% of smokers would like to give up smoking, but only 4% to 7% of quit attempts are successful.<sup>3</sup>

Health per se is a valuable good. Even though technical progress constantly amplifies the possibilities to restore health, good reasons exist to avoid health damage. Medical drugs and treatments are expensive. Maybe more importantly, disease is painful and its treatment discomfoting. Consider again the example of cancer: While there exist several options for treatment (chemotherapy, radiation therapy or surgery) each one has adverse effects. Furthermore, they do not guarantee success. Even with treatment, the patient has to fear premature death. Thus, even if all medical bills are paid by insurance companies, incentives remain to engage in preventive efforts.

In this paper, we analyze a competitive insurance market with ex-post moral hazard where each consumer can exert costly preventive effort to reduce the risk of damage. In the spirit of our discussion above, we extend standard insurance theory by two aspects. First, consumers have present-biased preferences. This will be modeled by adopting the  $(\beta, \delta)$ -preferences from Laibson (1997). Following O'Donoghue and Rabin (1999, 2001) we assume that there are two types of consumers, naive and sophisticated ones. Naive consumers do not understand their self-control problem and act as if they are not exposed to the present bias in future periods. Sophisticated consumers know that they are exposed to the present bias and can undertake steps to manage it. Second, consumers suffer from physical pain in case of damage. Thus, even if a consumer has full insurance coverage, she still has an incentive to reduce the risk of health damage. Pain will be represented by a state dependent utility function.<sup>4</sup>

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<sup>1</sup>See [www.who.int/cancer/en](http://www.who.int/cancer/en).

<sup>2</sup>Ainslie (1992, 2001) and Laibson et al. (2007) provide empirical evidence, Strotz (1955), Phelps and Pollak (1968), Laibson (1997), O'Donoghue and Rabin (1999) provide formal models and economic implications.

<sup>3</sup>See Bryan et al. (2009).

<sup>4</sup>Pain can also be interpreted as a drop in "health capital", a concept introduced by Grossman (1972)

Our model can explain several empirical observations in insurance markets while mitigating some problems of the previous literature. We show that equilibria might exhibit a negative correlation between risk and insurance coverage. This negative correlation has been observed in many markets for supplementary and private health insurance.<sup>5</sup> In our model, a consumer's risk is endogenously determined through his effort choice. We assume that the marginal gains from effort decrease such that present-biased consumers never exert full preventive effort (that is, consumers will always engage in some unhealthy behaviors). When choosing an insurance contract, sophisticated consumers correctly assess the effort they are going to exert in the future. Insurance companies know the consumers' effort technology and can charge fair rates. Naive consumers overestimate their future efforts. They perceive the rates that are fair for sophisticated consumers as unfair. If they are not too risk-averse, they prefer to remain uninsured. However, when naive consumers reach the first period where they have to exert effort, they postpone preventive efforts to the future. Consequently, they may end up with less total effort provision than sophisticated consumers.

We can allow for substantial heterogeneity in wealth and risk preferences. Due to pain, consumers have an incentive to exert effort even if they are fully insured. In many circumstances, it does not pay off for sophisticated consumers to purchase only partial insurance in order to commit to even higher effort provision. In this case, the optimal contract is a full insurance contract given that it is available at a fair premium. Insurance firms can offer this contract as it is not purchased by naive consumers. While an optimal partial insurance contract would depend on the exact shape of the utility function, this is not the case for a full insurance contract that liberates consumers from any financial risk. We therefore can derive equilibria where the sophistication of consumers completely determines their demand for insurance. Note that this is different from previous insurance models with ex-post moral hazard. In these models, consumers cannot be fully insured, otherwise the incentives for preventive effort vanish.

This feature of our model can be used to rationalize phenomena that are at odds with models that explain the negative correlation property with heterogeneous risk preferences (like DeMeza and Webb 2001). Empirical studies often find a positive relationship between wealth (or income) and insurance. In general, it is assumed that individuals exhibit decreasing absolute risk aversion. Therefore, more wealthy individuals should demand less insurance. In our model, equilibria exhibit a positive correlation between wealth

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and used frequently in the health economics literature.

<sup>5</sup>See Bolhaar et al. (2008), Buchmueller et al. (2008) and Fang et al. (2008). Furthermore, Cawley and Philipson (1999) find a negative relationship between insurance coverage and the unit price in the life insurance market.

and insurance if there is also a positive correlation between wealth and sophistication. Furthermore, if the correlation between risk aversion and sophistication is zero, then also the correlation between risk aversion and insurance is zero in these equilibria. This might explain why some empirical studies find little evidence that heterogeneous risk preferences cause the negative correlation between risk and insurance.

Our model shows that the moral hazard problem *per se* might not be the primary source of inefficient allocations in insurance markets. Instead, the inability of consumers to correctly anticipate future behavior leads to an inefficiently low demand for insurance. There is considerable scope for policy interventions. A social planner might tax unhealthy and subsidize healthy behaviors in order to help consumers to exert more effort and to increase their expected self 0 utility. This can have several positive effects on welfare. All consumers would exert more preventive effort, such that insurance premia and the risk of suffering from pain decrease. Furthermore, expected effort may then equal realized effort for naive consumers. This would enable firms to offer insurance contracts that are fair to both sophisticated and naive consumers and that are also perceived as fair by both groups. In contrast, the effect of compulsory insurance on welfare is ambiguous in our framework.

We consider a number of extensions. In particular, it is shown that equilibria with negative correlation can exist if there is a small fraction of individuals who are not exposed to the present bias, or if consumers differ continuously in their degree of sophistication and some of them are pessimistic about their present bias. Furthermore, there also can be equilibria in our model with zero or positive correlation between insurance and risk. In particular, this happens if the marginal costs of effort are either very high or very low such that naive consumers do not postpone efforts to the future. Finally, we discuss what could happen if consumers have access to a commitment device (other than underinsurance) or if they underestimate the health risks they are exposed to.

The rest of the paper is organized as follows: the next Section summarizes the related literature. Section 3 introduces the model, derives our main results, discusses their properties and policy implications. In Section 4, we consider extensions and robustness checks. The last Section concludes.

## 2 Related Literature

The positive correlation property between risk and insurance coverage is the most extensively tested property in the empirical insurance literature.<sup>6</sup> However, unlike predicted

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<sup>6</sup>For an overview, see Cohen and Siegelman (2010).

by insurance theory with asymmetric information (Rothschild and Stiglitz 1976 and Chiappori et al. 2006) there are numerous studies finding either zero or negative correlation. This has triggered several theoretical papers addressing the question why there can be a negative correlation. De Meza and Webb (2001) consider a model of a competitive insurance market with moral hazard and adverse selection on risk preferences. They show that for certain parameter values there are separating equilibria where “bold” consumers purchase no insurance and do not exert preventive effort, while “timid” consumers purchase partial coverage and exert effort. Sonnenholzner and Wambach (2009) demonstrate that the same results may be obtained if consumers differ in their time preferences instead of risk preferences. Netzer and Scheuer (forthcoming) provide a somewhat opposing argument: patient consumers accumulate more wealth, become less risk-averse and therefore purchase less insurance. If there is a positive correlation between risk and patience, equilibria exhibit a negative correlation between risk and insurance. Jullien et al. (2007) show that in a monopolistic insurance market with asymmetric information on risk preferences equilibria may emerge where insurance protection is not correlated with risk. In contrast to these papers, we derive equilibria in a perfectly competitive insurance market where insurance demand and preventive effort are fully determined by the consumers’ sophistication. By introducing physical pain, we can allow for heterogeneous risk preferences.

Few papers have applied behavioral theories to analyze insurance markets. Sandroni and Squintani (2007) augment the model by Rothschild and Stiglitz (1976) by overconfident consumers who underestimate their risk. They show that compulsory insurance may make low-risk consumers worse off compared to the competitive equilibrium. In Koufopoulos (2008) overconfident consumers do not exert preventive effort and purchase less insurance than fully rational consumers who exert some effort. We discuss the relationship of our approach to overconfidence at a later stage. Finally, Ericson (2009) pursues a completely different approach. He explains the negative correlation by the presence of consumers with relatively high expected claims who learn to “game the system”, i.e. to get more service out relatively low insurance coverage.

This article also complements the literature on contracting with time-inconsistent consumers. DellaVigna and Malmendier (2004) analyze how firms in a competitive market can exploit individuals that are partially naive. In their model, firms make positive (negative) profits out of contracts with naive (sophisticated) consumers. Eliaz and Spiegler (2006) consider a screening problem where some consumers are sophisticated and some are (partially) naive. There, sophistication is interpreted as the ability to forecast a change in future preferences. Again, naive consumers purchase exploitative contracts in equilibrium. Heidues and Köszegi (forthcoming) show that credit card firms can exploit any consumer who is not perfectly sophisticated. To the best of our knowledge, we are the first ones who

analyze insurance markets with present-biased consumers. Firms are not able to exploit naiveté in our model, rather they try to avoid contracts with naive consumers as they exert less preventive effort than sophisticated ones.

### 3 Pain, Precautions and Present-biased Preferences

#### 3.1 Framework

We consider a dynamic setup with periods  $t \in \{0, 1, 2, 3\}$ . In period 0, insurance companies offer insurance contracts to consumers. In periods 1 and 2, consumers can exert preventive effort in order to reduce their risk of damage. Finally, damage occurs and transfers are made between insurance companies and consumers in period 3.

Let  $\mathbf{U}^2$  be the set of twice continuously differentiable utility functions  $U : \mathbb{R}_+ \rightarrow \mathbb{R}$  with  $U' > 0$  and  $U'' < 0$ . Let  $A_U$  be the Arrow-Pratt degree of absolute risk aversion of a function  $U$ . There is a continuum of consumers of mass one. Each consumer  $i \in [0, 1]$  is characterized by her type  $\zeta(i) \in \{S, N\}$  (that will be explained below), her utility function over monetary outcomes  $U_i \in \mathbf{U}^2$  and her wealth  $W_i$ .  $U_i$  and  $W_i$  are private information of consumer  $i$ . Each consumer  $i$  faces the risk of health damage in period 3. In the event of health damage the consumer loses an amount of  $d < W_i$ . Additionally, there are non-monetary costs of health damage. If an agent suffers from damage, her utility decreases by an amount of  $\bar{U}$ , which represents physical pain.<sup>7</sup>

In period 0, each consumer can purchase an insurance contract  $(\lambda, y)$  from a company, where  $y$  is the premium and  $(\lambda - 1)y$  the net-payout in case of a damage. The insurance market is competitive with free entry and at least two insurance companies.<sup>8</sup> In period 0, all companies make irrevocable offers. Consumers then apply for at most one contract. If more than one contract is optimal for a consumer, she chooses each optimal contract with equal probability. We exogenously rule out overinsurance.<sup>9</sup> The contract space is therefore given by

$$\mathbf{C} = \{(\lambda, y) \in \mathbb{R}_+^2 \mid \lambda y \leq d\}. \quad (1)$$

In each period  $t \in \{1, 2\}$ , consumers can exert preventive effort  $e_t \in [0, 1]$ . A plan  $(e_1, e_2)$  describes for each period the effort a consumer exerts. Total effort is given by  $\bar{e} = e_1 + e_2$

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<sup>7</sup>In the Appendix, we demonstrate that equilibria with negative correlation between risk and insurance may exist even if  $\bar{U} = 0$ . However, to obtain this result we have to assume that  $U$  and  $W$  are uniform among consumers.

<sup>8</sup>Instead of price-quantity competition, we also could consider price competition. In this case, all of our results would remain valid.

<sup>9</sup>This assumption is justified empirically and rules out that consumers gain by exaggerating the loss.

and determines the probability of damage  $\pi(\bar{e})$ . Let  $\pi(\bar{e})$  be continuously differentiable. We assume that preventive effort reduces the probability of damage and that returns to effort weakly decrease, i.e.  $\pi'(\bar{e}) < 0$  and  $\pi''(\bar{e})$  weakly increases for all  $\bar{e} \in [0, 2]$ . The marginal costs of effort in period  $t$  are given by  $c_t(e_t)$ , where  $c_t(e_t)$  weakly increases in  $e_t$ . We denote  $\mathbf{c} = (c_1, c_2)$ .

All consumers have present-biased preferences.<sup>10</sup> As costs of effort are immediate while their benefits occur in the future, each consumer faces an intrapersonal conflict of interest. To model this conflict, we use  $(\beta, \delta)$ -preferences with  $\delta = 1$ . There are two types  $\zeta$  of consumers: sophisticated consumers  $S$  and naive ones  $N$ . Sophisticated consumers foresee future self-control problems and take them into account when choosing a plan. Naive ones ignore the fact that in future periods they are exposed to the present bias. These consumers may therefore change their plan in later periods. In period 0, the expected utility of consumer  $i$  from an insurance contract  $(\lambda, y)$  and plan  $(e_1, e_2)$  is

$$\begin{aligned} & \beta\pi(e_1 + e_2) (U_i(W_i - d + (\lambda - 1)y) - \bar{U}) \\ & + \beta(1 - \pi(e_1 + e_2)) U_i(W_i - y) - \beta \left( \int_0^{e_1} c_1(\tilde{e}_1) d\tilde{e}_1 + \int_0^{e_2} c_2(\tilde{e}_2) d\tilde{e}_2 \right). \end{aligned} \quad (2)$$

In a period  $t \in \{1, 2\}$ , consumer  $i$ 's expected utility from choosing plan  $(e_1, e_2)$  is

$$\begin{aligned} & - \int_0^{e_t} c_t(\tilde{e}_t) d\tilde{e}_t + \beta\pi(e_1 + e_2) (U_i(W_i - d + (\lambda - 1)y) - \bar{U}) \\ & + \beta(1 - \pi(e_1 + e_2)) U_i(W_i - y) - \mathbf{1}_{t=1} \beta \int_0^{e_2} c_2(\tilde{e}_2) d\tilde{e}_2, \end{aligned} \quad (3)$$

where  $\mathbf{1}$  is the indicator function. The collection of parameters and functions that determine preventive effort in the absence of financial risk is given by

$$\Gamma = (\mathbf{c}, \beta, \pi, \bar{U}). \quad (4)$$

We call  $\Gamma$  the ‘‘effort technology’’. Throughout the paper we assume that the effort technology is uniform among consumers and common knowledge among firms and consumers. Let  $\bar{c}(\Gamma)$  be defined by

$$-\bar{c}(\Gamma) - \pi'(2)\bar{U} = 0. \quad (5)$$

In the following, we restrict attention to  $\Gamma$ 's where  $c_t(e_t) \leq \bar{c}(\Gamma)$  for all  $e_t \in [0, 1]$  and  $t \in \{1, 2\}$ . This ensures that a consumer without the present-bias would exert effort 1 in

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<sup>10</sup>In Section 4.1, we will discuss what happens if there is a positive mass of consumers who do not exhibit the present bias.



both periods even if she is fully insured. Define by  $\Upsilon (M_L, M_H, A_L, A_H)$  the set of wealth levels and utility functions  $(W, U) \in (d, \infty) \times \mathbf{U}^2$  for which it holds that

$$U(W) - U(W - d) \in [M_L, M_H] \text{ and } A_U([W - d, W]) \subset (A_L, A_H). \quad (6)$$

The first restriction in (6) limits the maximal loss in utility due to the monetary costs of health damage. By varying  $M_L$  ( $M_H$ ), we can change the minimal (maximal) ratio between the loss of utility due to the monetary costs and the loss of utility due to pain. In the following, we take  $M_L$  and  $M_H$  with  $0 < M_L < M_H$  as given. The second restriction in (6) confines the level of risk aversion in the interval  $[W - d, W]$ . Let  $c_H(\Gamma)$  and  $c_N(\Gamma)$  be given by

$$-c_H(\Gamma) - \beta\pi'(0) (\bar{U} + M_H) = 0, \quad (7)$$

$$-c_N(\Gamma) - \beta\pi'(1) (\bar{U} + M_H) = 0. \quad (8)$$

The interpretation is as follows. If the marginal costs of effort exceed  $c_H(\Gamma)$ , then a consumer with present-biased preferences will not exert any effort, even if she has no insurance and has not exerted any effort before. If the marginal costs of effort exceed  $c_N(\Gamma)$  in period 1 and a consumer with present-biased preferences expects to exert effort 1 in period 2, then she will not exert any effort in the present period even if she has no insurance coverage. Note that

$$c_N(\Gamma) < c_H(\Gamma) < \bar{c}(\Gamma) \quad (9)$$

if  $\beta$  is sufficiently small and  $-\pi'(0) > -\pi'(1)$ . Define for given  $\Gamma$

$$e_t(c) = \max \{ \tilde{e} \in [0, 1] \mid c_t(e_t) \leq c \text{ for all } e_t < \tilde{e}, c_t(e_t) > c \text{ for all } e_t > \tilde{e} \}. \quad (10)$$

Thus,  $e_t(c)$  represents the highest level of effort  $\tilde{e}$  such that for all levels of effort below (above)  $\tilde{e}$  marginal costs are lower or equal to (higher than)  $c$ .

### 3.2 Equilibria with negative correlation

We now analyze the effects of present-biased preferences and pain on insurance market equilibria. Let us start with the decisions of sophisticated consumers. If consumer  $i$  has purchased insurance contract  $(\lambda, y)$  and realizes plan  $(e_1, e_2)$ , then in period  $t \in \{1, 2\}$  the marginal gains from additional effort is given by

$$-c_t(e_t) - \beta\pi'(e_1 + e_2) (\bar{U} + U_i(W_i - y) - U_i(W_i - d + (\lambda - 1)y)). \quad (11)$$

This helps to understand the following definition:

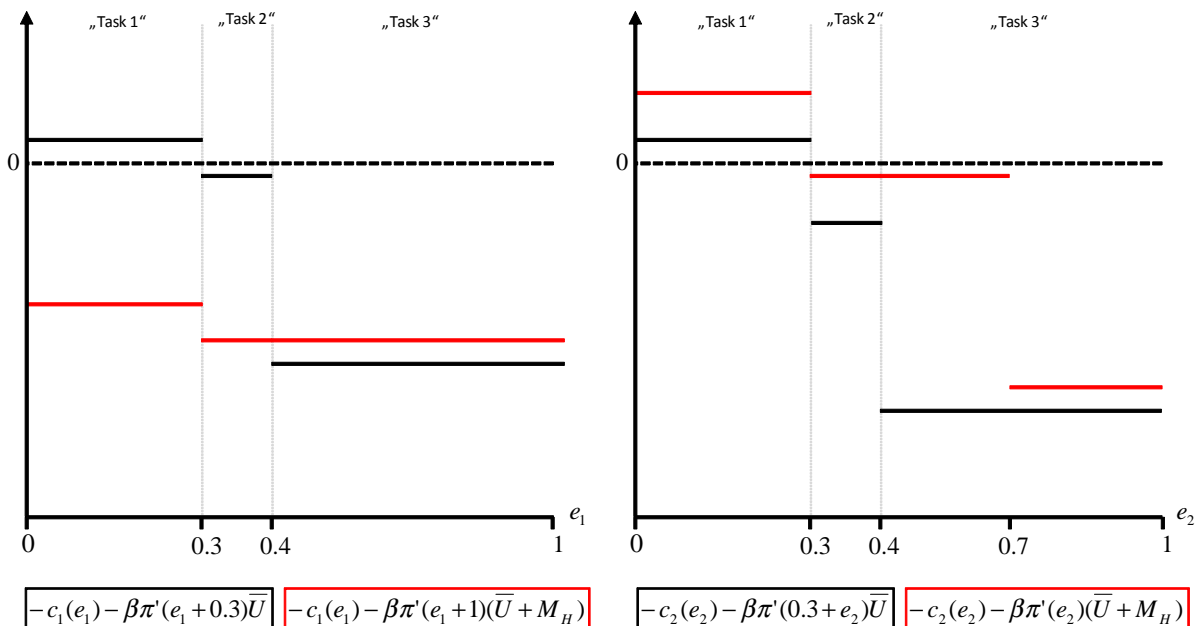


Figure 1: Effort technology with property  $\mathbf{A}(0.05, 0.3, 0.3)$

**Definition 1**  $\Gamma$  has property  $\mathbf{A}(\omega, e_1^*, e_2^*)$  if for  $t \in \{1, 2\}$

$$-c_t(e_t) - \beta\pi'(e_1^* + e_2^*)\bar{U} > 0 \text{ for all } e_t \in [0, e_t^*], \quad (12)$$

$$-c_t(e_t) - \beta\pi'(0)\bar{U} < -\omega \text{ for all } e_t \in (e_t^*, 1]. \quad (13)$$

$\Gamma$  has property  $\mathbf{A}(e_1^*, e_2^*)$  if additionally  $c_t(e_t) > c_H(\Gamma)$  for all  $e_t \in (e_t^*, 1]$  and  $t \in \{1, 2\}$ .

$\mathbf{A}(\omega, e_1^*, e_2^*)$  and  $\mathbf{A}(e_1^*, e_2^*)$  imply that there is a discontinuity in the marginal gains from effort. An intuition behind this discontinuity is that consumers can accomplish several “tasks” for which marginal costs and effectiveness differ. Such tasks can be, for example, healthy nutrition, physical exercises or low alcohol consumption. A consumer might have low marginal costs for the first task, intermediate marginal costs for the second task and probably very high marginal costs for the last task, such that she will not stay away from alcohol even if she has no insurance at all. An increase in preventive effort may also require a change in habits, which usually causes substantial discomfort. Figure 1 represents an effort technology that has property  $\mathbf{A}(0.05, 0.3, 0.3)$ .<sup>11</sup>

If  $\Gamma$  has property  $\mathbf{A}(\omega, e_1^*, e_2^*)$ , then sophisticated consumers who purchase full insurance will exert preventive effort  $e_1^*$  in period 1 and  $e_2^*$  in period 2. Furthermore, if  $\omega > 0$ ,

<sup>11</sup>In particular, Figure 1 shows an effort technology where  $c_1(e_1) = 1.5$  for all  $e_1 \in [0, 0.3]$  and  $c_1(e_1) = 1.65$  otherwise;  $c_2(e_2) = 1.5$  for all  $e_2 \in [0, 0.3]$  and  $c_1(e_1) = 1.85$  otherwise;  $\beta = 0.5$ ;  $\pi(0) = 0.8$ ,  $\pi(0.7) = 0.52$ ,  $\pi(2) = 0.26$ ,  $\pi$  is linear on the intervals  $[0, 0.7]$  and  $(0.7, 2]$ ;  $M_H = 1$ ;  $\bar{U} = 8$ .

then sophisticated consumers will choose the same preventive effort as long as the financial risk they are exposed to (i.e. if they have only partial insurance) is sufficiently small. Nevertheless, they might prefer partial insurance contracts in order to commit themselves to higher effort. By purchasing less coverage, marginal gains from effort increase. In Figure 1, a sophisticated consumer could commit to accomplish “Task 2” if she purchases less insurance (and would thus exert effort 0.4 instead of 0.3 in period 1).

Assume that  $\Gamma$  is such that the effort a sophisticated consumer exerts under full coverage is close to the effort she would exert under no insurance protection (i.e.  $e_t^*$  is close to  $e_t(c_H(\Gamma))$ ,  $t \in \{1, 2\}$ ). In this case, the additional effort the consumer would exert after purchasing partial insurance instead of full coverage is small. For example, if a consumer could commit to effort  $e_1^{**}$  (in Figure 1,  $e_1^{**} = 0.4$ ) by purchasing no insurance, then gains from additional effort are small if  $e_1^{**} - e_1^*$  is small. For risk-averse consumers underinsurance is costly. Thus, if the commitment effect through underinsurance is small and insurance is offered at fair rates, sophisticated consumers will purchase full coverage.

Let us now analyze the behavior of naive consumers. An immediate consequence of (5) is that naive consumers believe in period  $t \in \{0, 1\}$  that they will exert effort 1 in all future periods. This has two effects: first, they never exert more effort than  $e_1(c_N(\Gamma))$  in period 1. If  $\Gamma$  has property  $\mathbf{A}(\omega, e_1^*, e_2^*)$  and  $e_1(c_N(\Gamma)) < e_1^*$ , then in period 1 naive consumers without insurance exert less effort than sophisticated consumers with full insurance. Observe that under the effort technology of Figure 1, naive consumers would not exert any effort in period 1. If additionally  $e_2^*$  is sufficiently close to  $e_2(c_H(\Gamma))$ , then the same holds for total preventive effort exerted by naive consumers. Second, naive consumers assume in period 0, that their probability of damage equals  $\pi(2)$ , regardless of whether they purchase insurance or not. Therefore, contracts that are fair for sophisticated consumers are perceived as unfair by naive consumers. Given that consumers are not too risk-averse, naive consumers will then prefer to remain uninsured. Consequently, we get equilibria with negative correlation:

**Proposition 1** *Suppose that  $\Gamma$  has property  $\mathbf{A}(\omega, e_1^*, e_2^*)$  for  $\omega > 0$  and  $(e_1^*, e_2^*) \in (0, 1)^2$ ,  $(W_i, U_i) \in \Upsilon(M_L, M_H, A_L, A_H)$  for all  $i \in [0, 1]$  and  $c_H(\Gamma) < \bar{c}(\Gamma)$ . If  $A_H$  is sufficiently small,  $A_H > A_L > 0$ ,  $e_1(c_N(\Gamma))$  and  $e_t(c_H(\Gamma)) - e_t^*$  are sufficiently small for  $t \in \{1, 2\}$ , then in each equilibrium (i)  $S$  ( $N$ ) purchase full insurance (no insurance) and (ii)  $S$  exert more effort than  $N$ .*

**Proof.** See Appendix. ■

Full insurance is no longer the best insurance protection for sophisticated consumers if the marginal gains from effort are continuous in  $e_1$  and  $e_2$ . Recall that individuals are

risk-neutral if they face no uncertainty in their monetary wealth. If marginal gains are continuous, then, by a small decrease in insurance protection, consumers could commit to higher effort provision. Due to a positive  $\bar{U}$ , this would have a positive first order effect. The corresponding decrease in utility through an increase in financial risk is of second order. Thus, sophisticated consumers would maximize expected utility in period 0 through purchasing only partial insurance.

If  $\Gamma$  has property  $\mathbf{A}(e_1^*, e_2^*)$ , then sophisticated consumers anticipate that there is no opportunity to trade-off insurance protection and effort. This enables us to drop the lower bound on risk aversion and we obtain a simplified version of Proposition 1:

**Corollary 1** *Suppose that  $\Gamma$  has property  $\mathbf{A}(e_1^*, e_2^*)$  for  $(e_1^*, e_2^*) \in (0, 1)^2$ ,  $(W_i, U_i) \in \Upsilon(0, M_H, 0, A_H)$  for all  $i \in [0, 1]$  and  $c_H(\Gamma) < \bar{c}(\Gamma)$ . If  $A_H$  and  $e_1(c_N(\Gamma))$  are sufficiently small, then in each equilibrium (i)  $S$  ( $N$ ) purchase full insurance (no insurance) and (ii)  $S$  exert more effort than  $N$ .*

The equilibrium outcomes in Proposition 1 and Corollary 1 obtain even if consumers differ in their risk preferences and wealth. To get a sense for how many  $(U, W)$  combinations we can allow for, we provide a numerical example where the effort technology  $\Gamma^*$  has property  $\mathbf{A}(0.3, 0.3)$ .

**Example 1.** *Let  $\Gamma^*$  be as follows:  $c_t(e_t) = 1.5$  for all  $e_t \in [0, 0.3]$  and  $c_t(e_t) = 1.8$  otherwise,  $t \in \{1, 2\}$ ;  $\beta = 0.5$ ;  $\pi(0) = 0.8$ ,  $\pi(0.9) = 0.45$ ,  $\pi(2) = 0.2$ , where  $\pi$  is linear on the intervals  $[0, 0.9]$  and  $(0.9, 2]$ ;  $\bar{U} = 8$ . Note that  $\pi$  and  $\bar{U}$  imply  $\bar{c}(\Gamma^*) \approx 1.82$  (thus, naive consumers will assume in period 0 that they exert effort 2). From  $\beta$ ,  $\pi$  and  $\bar{U}$  we get  $c_N(\Gamma^*) \approx 1.02$  and  $c_H(\Gamma^*) = 1.75$ . If*

$$U_i(W_i) - U_i(W_i - d) \leq 1 \quad (14)$$

for all  $i \in [0, 1]$ , then naive consumers do not exert preventive effort in period 1, regardless of their insurance coverage. On the contrary,  $\Gamma^*$  is such that sophisticated consumers always exert  $e_1 = e_2 = 0.3$ . For them, the fair insurance contract with full coverage is given by  $\left(\frac{1}{\pi(0.6)}, d\pi(0.6)\right)$ . For simplicity, we assume that each consumer  $i$  has the following DARA utility function:

$$U_i(w) = w^{1-\gamma_i}. \quad (15)$$

From the proof of Proposition 1 we get that a sufficient condition for a naive consumer  $i$  not to purchase a contract  $\left(\frac{1}{\pi(0.6)}, y\right)$  is given by

$$\left(\frac{W_i - d}{W_i}\right)^\gamma > \frac{1 - \pi(0.6)}{\pi(0.6)} \frac{\pi(2)}{1 - \pi(2)}. \quad (16)$$

One can check that both (14) and (16) hold for each consumer  $i$  if  $d = 1.5$ ,  $W_i \in [2.5, \infty)$  and  $\gamma_i \in [0.3, 1]$ . In this case, we have  $A_{U_i}(W_i) \in (0, 0.4)$ .

### 3.3 Properties of equilibria with negative correlation

In the equilibria of Proposition 1, optimal insurance protection is fully determined by the sophistication of consumers. Risk aversion does not play a role, as insurance is fair for sophisticated consumers and perceived as unfair by naive consumers. This can be used to rationalize several correlations that are incompatible with insurance market models that explain the negative correlation property with heterogeneous risk preferences.

We first look at the relationship between wealth (or income) and insurance protection. It is generally assumed that most individuals exhibit decreasing absolute risk aversion. Individuals with more wealth should be less risk-averse and therefore purchase less insurance. However, empirically, insurance demand is increasing in wealth (or income). Studies using aggregate and microdata on insurance demand show that insurance is a normal good.<sup>12</sup> In our model, a positive correlation between wealth and insurance protection can be rationalized if we assume that there is a positive correlation between sophistication and wealth.<sup>13</sup>

**Corollary 2** *Suppose that  $Cov(W_i, 1_{\zeta(i)=S}) > 0$ ,  $\Gamma$  has property  $\mathbf{A}(\omega, e_1^*, e_2^*)$  for  $\omega > 0$  and  $(e_1^*, e_2^*) \in (0, 1)^2$ ,  $(W_i, U_i) \in \Upsilon(M_L, M_H, A_L, A_H)$  for all  $i \in [0, 1]$  and  $c_H(\Gamma) < \bar{c}(\Gamma)$ . If  $A_H$  is sufficiently small,  $A_H > A_L > 0$ ,  $e_1(c_N(\Gamma))$  and  $e_t(c_H(\Gamma)) - e_t^*$  are sufficiently small for  $t \in \{1, 2\}$ , then in each equilibrium (i)  $S$  ( $N$ ) purchase full insurance (no insurance), (ii)  $S$  exert more effort than  $N$ , and (iii) we have a positive correlation between wealth and insurance.*

Another relationship that seems unclear is the one between risk aversion and insurance protection. Bolin et al. (2010) and Fang et al. (2009) find little evidence that heterogeneous risk preferences explain the negative correlation between risk and insurance. Furthermore, Fang et al. (2009) find that cognitive ability and financial numeracy

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<sup>12</sup>Beenstock et al. (1988) show that property-liability is a superior good by using a panel dataset on the country-level. Foncel and Treich (2007) use microdata containing both information on individuals' wealth and car insurance purchases. Their results suggest that insurance is a normal good. In studies on insurance demand in supplementary health insurance and long-term care insurance, individuals with more income buy more insurance coverage, see Bolhaar et al. (2008), Buchmueller et al. (2008), Fang et al. (2006) and Finkelstein and McGarry (2006).

<sup>13</sup>See Bryan et al. (2009), chapter 5.2, for a summary of studies that analyze the correlation between long run life outcomes and the management of self-control problems.

are major sources of the negative correlation. However, other studies find a positive correlation between risk aversion and insurance coverage.<sup>14</sup> In our model, we again can use the relationship between risk aversion and sophistication to rationalize any correlation between risk and insurance demand:

**Corollary 3** *Suppose that  $Cov(A_{U_i}(W_i), 1_{\zeta(i)=S}) = \alpha$ ,  $\Gamma$  has property  $\mathbf{A}(\omega, e_1^*, e_2^*)$  for  $\omega > 0$  and  $(e_1^*, e_2^*) \in (0, 1)^2$ ,  $(W_i, U_i) \in \Upsilon(M_L, M_H, A_L, A_H)$  for all  $i \in [0, 1]$  and  $c_H(\Gamma) < \bar{c}(\Gamma)$ . If  $A_H$  is sufficiently small,  $A_H > A_L > 0$ ,  $e_1(c_N(\Gamma))$  and  $e_t(c_H(\Gamma)) - e_t^*$  are sufficiently small for  $t \in \{1, 2\}$ , then in each equilibrium (i)  $S$  ( $N$ ) purchase full insurance (no insurance), (ii)  $S$  exert more effort than  $N$ , and (iii) the correlation between absolute risk aversion and insurance is  $\alpha$ .*

### 3.4 Policy Implications

Following the literature, we take the consumers' self 0 preferences as those relevant for social welfare maximization.<sup>15</sup> If we do so, then in the equilibria analyzed so far, both types of consumers do not act in their best interests. Due to the present-bias, both naive and sophisticated consumers exert too little effort. Additionally, naive consumers do not purchase enough insurance coverage.

As in Gruber and Köszegi (2001), the government could undertake measures to improve welfare. By taxing unhealthy behavior ("sin taxes", see also O'Donoghue and Rabin 2006) or subsidizing a healthy lifestyle it could shift the consumers' incentives to more effort provision. Assume that the government can directly manipulate the cost functions  $c_1$  and  $c_2$  to  $\tilde{c}_1$  and  $\tilde{c}_2$ . In our framework, there would be efficient (i.e. full) effort provision if under these new cost functions it holds that

$$-\tilde{c}_t(e_t) - \beta\pi'(2)\bar{U} > 0 \quad (17)$$

for  $e_t \in [0, 1]$  and  $t \in \{1, 2\}$ . Observe that in this case, the expected effort would equal the realized provision for both naive and sophisticated consumers. Consequently, both would purchase a full insurance contract  $(\lambda^*, y^*)$  with  $\lambda^* = \frac{1}{\pi(2)}$ . Government intervention can therefore have two effects in our framework: encouraging more effort provision and increasing insurance demand.

An alternative policy intervention in insurance markets is compulsory insurance. Recall that compulsory insurance can lead to a pareto-improvement in the Rothschild and

<sup>14</sup>Recent empirical studies find that engaging all kind of risky behavior, whether it is drinking, gambling, smoking or gambling is negatively correlated with different types of insurance demand, while individuals who exhibit more cautious behavior (preventive measures or seat-belt use) demand more insurance (Buchmueller et al. 2008, Cutler et al. 2008, Finkelstein and McGarry 2006).

<sup>15</sup>For an in-depth discussion of this issue, see Bernheim and Rangel (2005).

Stiglitz (1976) setting if there are few high risks. Sandroni and Squintani (2007) show that this no longer holds if there are sufficiently many overconfident consumers. In our case, things are ambiguous. Assume that the government forces all consumers to purchase full coverage at prices that guarantee zero profits to insurance companies. Full insurance might cause naive consumers to exert even less effort. In this case, sophisticated consumers would have to subsidize naive ones. However, if the effort technology is such that both sophisticated and naive agents exert the same effort, regardless of their insurance protection (we will find this situation in Section 4.3), then compulsory insurance leads to a pareto-improvement as naive agents get the coverage they should have.

## 4 Robustness and Extensions

### 4.1 Consumers without present-biased preferences

Would the equilibria of the previous Section survive if there was a positive measure of consumers without present-bias preferences (henceforth “normal consumers”)? In our model, normal consumers face the same tradeoff as naive consumers in period 0. However, for them the planned effort equals the realized effort in periods 1 and 2. Given that (5) holds, they exert effort 1 in both periods, regardless of their insurance protection. Consider an assessment where naive consumers are not willing to purchase insurance contracts that are fair for sophisticated consumers and where sophisticated consumers purchase full insurance. Firms could additionally offer a contract that is chosen both by naive and normal consumers. This would imply a cross-subsidization of naive consumers by normal ones. The former group of consumers provides relatively little effort, while the latter group exerts full effort. If this contract is purchased by many naive consumers and only by few normal consumers, then firms offering it earn negative profits. This would always happen if (i) the distribution of consumers over  $(U, W)$  combinations is the same in the populations of naive and normal consumers, and (ii) the share of naive consumers is large relative to the share of normal consumers.<sup>16</sup> Therefore, our equilibria can persist if there is a small fraction of consumers without present-biased preferences.

### 4.2 Partially naive and pessimistic consumers

Up to now we assumed that there are only two degrees of sophistication, full sophistication and pure naiveté. In this Subsection, we discuss to what extent our results survive if we assume that there are also partially naive consumers, i.e. consumers who understand

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<sup>16</sup>We did not define this distribution explicitly. However, if we assume that there is a finite number of possible utility functions, then this is clearly possible.

that they exhibit present-biased preferences, but who do not anticipate the full extent to which they are biased. Let each consumer  $i$  have a prior belief  $\hat{\beta}_i$  about her future time preferences. If consumer  $i$  is sophisticated (naive), then  $\hat{\beta}_i = \beta$  ( $\hat{\beta}_i = 1$ ). If  $\hat{\beta}_i \in (\beta, 1)$ , we call consumer  $i$  partially naive. Let  $F(\hat{\beta})$  be the cumulative distribution over  $\hat{\beta}$ .

In general, heterogeneity in the level of sophistication is difficult to handle in our model. Consider, for example, consumers with belief  $\hat{\beta}$  close to  $\beta$ . Depending on  $\Gamma$ , these consumers may overestimate in period 0 the effort they are going to exert in the future. Thus, they will perceive any fair premium for them as unfair, such that at this premium only a partial insurance contract is optimal for them. Nevertheless, they might still exert enough effort such that firms can sell them a partial insurance contract that generates positive profits in expectation. This contract then depends on the exact shape of the utility function  $U$ . Nevertheless, we can find  $\Gamma$  such that equilibria with negative correlation exist even if we allow for heterogeneity in sophistication.

**Definition 2**  $\Gamma$  has property  $\mathbf{D}(e_1^*, e_2^*)$  if there are  $c_L^*, c_H^*, \pi_L^*, \pi_H^*$  with  $c_L^* > \beta c_H^*$ ,  $c_L^* > c_N(\Gamma)$ ,  $c_H^* > c_H(\Gamma)$  such that  $c_t(e_t) = c_L^*$  for  $t \in \{1, 2\}$  and all  $e_t \in [0, e_t^*]$ ,  $c_t(e_t) = c_H^*$  otherwise,  $\pi'(\bar{e}) = \pi_H^*$  for all  $\bar{e} \in [0, e_1^* + e_2^*]$ ,  $\pi'(\bar{e}) = \pi_L^*$  for all  $\bar{e} \in (e_1^* + e_2^*, 2]$ ,  $-c_L^* - \beta\pi_H^*\bar{U} > 0$ , and for all  $\hat{\beta} \in [\beta, 1]$

$$-c_L^* - \hat{\beta}\pi_L^*(\bar{U} + M_H) \leq -c_H^* - \hat{\beta}\pi_H^*\bar{U}. \quad (18)$$

If  $\Gamma$  has property  $\mathbf{D}(e_1^*, e_2^*)$ , consumers exert effort of at most  $e_1^*$  in period 1 and  $e_2^*$  in period 2. Those who are relatively sophisticated ( $\hat{\beta}$  is close to  $\beta$ ), anticipate that and would purchase a full insurance contract  $(\lambda^*, y^*)$  with  $\lambda^* = \frac{1}{\pi(e_1^* + e_2^*)}$ . Those who are relatively naive ( $\hat{\beta}$  is close to 1) perceive such a contract as unfair as they assume to exert full preventive effort in both periods. Given that they are not too risk-averse, these consumers therefore prefer to remain uninsured if only contracts  $(\lambda^*, y) \in \mathbf{C}$  are offered. Consumers with intermediate values of  $\hat{\beta}$  might want to purchase only partial insurance in order to commit to higher effort provision. However, partial insurance contracts with  $\lambda = \lambda^*$  will not be sold by firms. A consumer who assumes to exert more effort than  $e_2^*$  in period 2, will postpone any effort in period 1 (due to  $c_L^* > \beta c_H^*$ ) and ends up exerting total effort of  $e_2^*$  only. This in turn implies negative expected profits out of partial insurance contracts  $(\lambda^*, y)$ . Nevertheless, firms might offer partial insurance contracts  $(\lambda^{**}, y) \in \mathbf{C}$  with  $\lambda^{**} = \frac{1}{\pi(e_2^*)}$ . All consumer who purchase these contracts exert no effort in period 1 and end up with total effort  $e_2^*$ . We therefore get:

**Proposition 2** Suppose that  $\Gamma$  has property  $\mathbf{D}(e_1^*, e_2^*)$  with  $e_1^* \in (0, 1)$  and  $e_1^* + e_2^* < 1$ ,  $\hat{\beta}_i \in [\beta, 1]$ ,  $(W_i, U_i) \in \Upsilon(0, M_H, 0, A_H)$  for all  $i \in [0, 1]$ ,  $F(\hat{\beta})$  is continuously increasing



on  $(\beta, 1)$  and  $c_H(\Gamma) < \bar{c}(\Gamma)$ . If  $A_H$  is sufficiently small, then in each equilibrium we have a negative correlation between risk and insurance protection.

**Proof.** See Appendix. ■

We also may allow for consumers who are pessimistic about their present bias. If consumer  $i$  is pessimistic, then  $\hat{\beta}_i < \beta$ . Assume now that  $F(\hat{\beta})$  is continuously increasing on  $(0, 1)$ . Pessimistic consumers may underestimate the effort they are going to exert in the future. For example, if  $\hat{\beta}_i$  is sufficiently close to 0 and  $\Gamma$  has property  $\mathbf{D}(e_1^*, e_2^*)$  for  $e_1^*, e_2^* > 0$ , then they assume in period 0 that they exert no effort at all. In fact, they exert effort  $e_1^*$  and  $e_2^*$ . Such a consumer will perceive any fair contract as a bargain, i.e. she would be ready to pay a higher price for it. Due to perfect competition, pessimistic consumers purchase the same insurance contracts as sophisticated consumers in equilibrium. Thus, we have:

**Corollary 4** *Suppose that  $\Gamma$  has property  $\mathbf{D}(e_1^*, e_2^*)$  with  $e_1^* \in (0, 1)$  and  $e_1^* + e_2^* < 1$ ,  $\hat{\beta}_i \in [0, 1]$ ,  $(W_i, U_i) \in \Upsilon(0, M_H, 0, A_H)$  for all  $i \in [0, 1]$ ,  $F(\hat{\beta})$  is continuously increasing on  $(0, 1)$  and  $c_H(\Gamma) < \bar{c}(\Gamma)$ . If  $A_H$  is sufficiently small, then in each equilibrium we have a negative correlation between risk and insurance protection.*

### 4.3 Other types of equilibria

We have seen under what circumstances equilibria will exhibit a negative correlation between insurance coverage and risk. In the following, we show that there also can be (i) equilibria with zero correlation between insurance coverage and risk or (ii) equilibria with positive correlation between insurance coverage and risk. In particular, these equilibria arise if the effort technology is such that naive consumers do not postpone effort to the future, i.e. if the marginal costs of effort are either very high or very low. The proofs of Proposition 3 and Proposition 4 below use the same arguments as the one of Proposition 1 and are therefore omitted.

The first type of equilibria arises if sophisticated and naive consumers exert the same preventive efforts, but purchase different insurance contracts. Let  $c_L(\Gamma)$  be given by

$$-c_L(\Gamma) - \beta\pi'(1) (\bar{U} + M_L) = 0. \quad (19)$$

A naive consumer without insurance coverage is ready to exert effort up to  $e_1(c_L(\Gamma))$  in period 1. The following definition will be important for equilibria with the zero-correlation property:

**Definition 3**  $\Gamma$  has property  $\mathbf{Z}(e_1^*, e_2^*)$  if  $c_1(e_1) < c_L(\Gamma)$  for all  $e_1 \in [0, e_1^*]$ ,

$$-c_t(e_t) - \beta\pi'(e_1^* + e_2^*)\bar{U} > 0 \quad (20)$$

for all  $e_t \in [0, e_t^*]$ , and  $c_t(e_t) > c_H(\Gamma)$  for all  $e_t \in (e_t^*, 1]$ ,  $t \in \{1, 2\}$ .

Let  $\Gamma$  have property  $\mathbf{Z}(e_1^*, e_2^*)$ . Sophisticated consumers will exert preventive effort  $e_1^*$ ,  $e_2^*$ , regardless of the insurance protection they have purchased. Thus, a full insurance contract  $(\lambda^*, y^*)$  with  $\lambda^* = \frac{1}{\pi(e_1^* + e_2^*)}$  maximizes their expected utility and generates zero-profits for companies.  $\mathbf{Z}(e_1^*, e_2^*)$  also ensures that naive consumers exert the same preventive effort as sophisticated ones. Note that, compared to property  $\mathbf{A}(\omega, e_1^*, e_2^*)$ , property  $\mathbf{Z}(e_1^*, e_2^*)$  requires a larger distance between  $c_t(e_t^*)$  and  $\inf \{c_t(e_t^* + \varepsilon) \mid \varepsilon > 0\}$ , i.e. the minimal marginal costs at effort levels consumers will not exert in equilibrium. In period 0, naive consumers assume that they will exert full preventive effort and therefore perceive the contract  $(\lambda^*, y^*)$  as unfair. Thus, we get:

**Proposition 3** Suppose that  $\Gamma$  has property  $\mathbf{Z}(e_1^*, e_2^*)$  for  $(e_1^*, e_2^*) \in [0, 1]^2$ ,  $(W_i, U_i) \in \Upsilon(M_L, M_H, 0, A_H)$  for all  $i \in [0, 1]$  and  $c_H(\Gamma) < \bar{c}(\Gamma)$ . If  $A_H$  is sufficiently small, then in each equilibrium (i)  $S$  ( $N$ ) purchase full insurance (no insurance) and (ii)  $S$  exert the same effort as  $N$ .

Our model can therefore rationalize equilibria with no correlation between insurance coverage and actual risk. A number of studies report that the hypothesis of zero-correlation cannot be rejected in several markets, see Cawley and Philipson (1999), Chiappori and Salanie (2000), Dionne et al. (2001) and Finkelstein and McGarry (2006).

We also can find effort technologies such that in equilibrium there is a positive correlation between insurance coverage and risk. We thereby provide an alternative explanation for the positive correlation property.

**Definition 4**  $\Gamma$  has property  $\mathbf{B}(\omega, e_1^*, e_2^*, e_2^{**})$  for  $e_2^* < e_2^{**}$  if

$$-c_1(e_1) - \beta\pi'(e_1^* + e_2^*)\bar{U} > 0 \text{ for all } e_1 \in [0, e_1^*], \quad (21)$$

$$-c_1(e_1) - \beta\pi'(e_1^* + e_2^*)(\bar{U} + M_H) < 0 \text{ for all } e_1 \in (e_1^*, 1], \quad (22)$$

$$c_1(e_1) < c_L(\Gamma) \text{ for all } e_1 \in [0, e_1^*], \quad (23)$$

$$-c_2(e_2) - \beta\pi'(e_1^* + e_2^{**})(\bar{U} + M_L) > 0 \text{ for all } e_2 \in [0, e_2^{**}], \quad (24)$$

$$c_2(e_2) > c_H(\Gamma) \text{ for all } e_2 \in (e_2^{**}, 1] \quad (25)$$

and

$$-c_2(e_2) - \beta\pi'(e_1^* + e_2^*)\bar{U} \begin{cases} > 0 & \text{for all } e_2 \in [0, e_2^*] \\ < -\omega & \text{for all } e_2 \in (e_2^*, 1] \end{cases}. \quad (26)$$

Let  $\Gamma$  have property  $\mathbf{B}(\omega, e_1^*, e_2^*, e_2^{**})$  for  $e_2^* < e_2^{**}$ . The conditions in (21) to (23) ensure that both sophisticated consumers with full insurance, and naive consumers without coverage exert effort  $e_1^*$  in period 1. Property  $\mathbf{B}(\omega, e_1^*, e_2^*, e_2^{**})$  again requires a larger distance between  $c_1(e_1^*)$  and  $\inf \{c_1(e_1^* + \varepsilon) \mid \varepsilon > 0\}$ , than  $\mathbf{A}(\omega, e_1^*, e_2^*)$ . Conditions (24) to (26) imply that in period 2 sophisticated consumers with full insurance exert effort  $e_2^*$  and naive consumers without coverage exert effort  $e_2^{**}$ . Furthermore, if  $\omega > 0$  and  $e_2^{**}$  is sufficiently close to  $e_2^*$ , then it does not pay off for risk-averse sophisticated consumers to underinsure in order to commit to higher effort provision. We then get:

**Proposition 4** *Suppose that  $\Gamma$  has property  $\mathbf{B}(\omega, e_1^*, e_2^*, e_2^{**})$  for  $\omega > 0$  and  $(e_1^*, e_2^*) \in (0, 1)^2$ ,  $(W_i, U_i) \in \Upsilon(M_L, M_H, A_L, A_H)$  for all  $i \in [0, 1]$  and  $c_H(\Gamma) < \bar{c}(\Gamma)$ . If  $A_H$  is sufficiently small,  $A_H > A_L > 0$ ,  $e_2^*$  is sufficiently close to  $e_2^{**}$ , then in each equilibrium (i)  $S$  ( $N$ ) purchase full insurance (no insurance) and (ii)  $S$  exert less effort than  $N$ .*

## 4.4 Overconfidence

An alternative explanation for equilibria with negative correlation is overconfidence. Overconfident consumers underestimate their risk of damage. Koufopoulos (2008) constructs insurance market equilibria where overconfident consumers purchase less insurance and exert less effort than rational consumers. There exists substantial evidence that many people are overconfident on several issues (like, for example, driving).<sup>17</sup> For health risks, evidence is somewhat mixed.<sup>18</sup>

In principle, overconfidence and present-biased preferences can reinforce each other in our model, in particular, if naive consumers also underestimate their risk of health damage. However, it is not entirely clear how to interpret overconfidence in a framework with preventive effort. Observe that consumers can be overconfident on any value  $\pi(\bar{e})$ ,  $\bar{e} \in [0, 1]$ . If a consumer believes that she has in general a very low risk of being affected by disease, she will neither purchase insurance, nor will she exert much preventive effort. However, a consumer might also be overconfident on the impact of preventive measures. Such a consumer then may purchase no insurance, but exert more effort than consumers who hold correct beliefs about their risk and effort technology. Therefore, the effects of overconfidence on the correlation between risk and insurance in equilibrium can go in any direction.

Finally, we believe that overconfidence is relatively easy to reduce compared to naiveté

<sup>17</sup>See Koufopoulos (2008) and Sandroni and Squintani (2007) for a brief overview.

<sup>18</sup>For example, while Sutton (1998) reports that people underestimate the health risks of smoking, Viscusi (1990) finds that people overestimate the effect of smoking on the risk of being affected by lung-cancer.

about future time preferences. There are countless initiatives by private, national and international institutions that educate people on health risks and preventive measures (such as anti-smoking and anti-drug initiatives). As long as poor information is a major source of bad decisions, these programs are beneficial. Nevertheless, as our model shows, health behavior and insurance demand can differ among consumers with the same risk and effort technology even if all of them are perfectly informed about risks and preventive measures.

## 4.5 Commitment Devices

A major concern in the construction of our model was that sophisticated consumers could choose underinsurance in order to commit to higher effort in the future. An implicit assumption was that underinsurance is the only commitment device available to consumers. We know that this is not the case. Bryan et al. (2009) provides a recent survey that reports many examples: long-term contracts can be used to commit to the desired attendance rate at a health club (Della Vigna and Malmendier 2006); self-imposed financial penalties for a failure to quit smoking or to avoid sugary foods may help to overcome addictive behavior (Giné et al. 2009 and Trope and Fischbach 2000); buying only small units instead of buying in bulk may help to lower the consumption of unhealthy food (Wertenbroch 1998). “Soft commitments”, i.e. commitment devices that involve only psychological costs, could also be used as an additional source of motivation. Well-known examples are “new year’s resolutions”, deadlines or individual goals.<sup>19</sup>

Through commitment, consumers could make unhealthy behaviors more costly. Assume that in our framework consumers can enter into such an arrangement in period  $\tau - 1$  to install a punishment if a certain effort level is not reached in period  $\tau$ . This commitment device may or may not create costs in period  $\tau - 1$ . Naive consumers assume that they will exert full preventive effort in all periods. Therefore, they will never make use of this arrangement. Sophisticated consumers understand the value of the commitment device. If its costs are sufficiently small or even zero (as in the case of soft commitments), then they will use it. In terms of our model, this can have several effects. First, sophisticated consumers exert even more effort than naive ones compared to the case when there is no commitment device available. Second, sophisticated consumers might purchase full insurance in equilibrium even if the marginal gains from effort are continuous. If the commitment device is costless, then its use is more attractive for consumers than to choose partial coverage in order to commit to more effort. However, if the commitment device is too powerful, then this could harm the existence of our equilibria. To see why, assume

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<sup>19</sup>See Koch and Nafziger (2008) for a theoretical study and a summary of the psychological literature.

that through its use, sophisticated consumers could commit to exert full effort. A fair insurance contract  $(\lambda, y)$  would take this into account, such that  $\lambda = \frac{1}{\pi(2)}$ . But then even naive consumers perceive the contract offers as fair and are ready to purchase it.

## 5 Conclusion

In this paper, we developed a theory of (health-) insurance that explains why in equilibrium there can be a negative correlation between risk and insurance coverage. After purchasing a contract from a competitive insurance market, consumers could exert preventive effort to reduce the risk of (health-) damage. Unlike previous models, we assumed that (i) consumers exhibit present-biased preferences and (ii) suffer from physical pain in the case of damage. The latter feature gives consumers an incentive to reduce the risk of damage even if they are fully insured. There were both naive consumers (who are not aware of the present-bias) and sophisticated consumers (who perfectly anticipate the present bias). We showed that under quite general conditions sophisticated consumers purchase full insurance, while naive consumers overestimate their preventive efforts, purchase no insurance and end up with less effort than sophisticated ones. As the demand for insurance in equilibrium depends only on consumers' sophistication, we could allow for considerable heterogeneity in risk preferences. We therefore could derive equilibria with a negative correlation between risk and insurance and a positive correlation between insurance and wealth. In our model, a social planner could increase welfare substantially by taxing (subsidizing) unhealthy (healthy) behaviors. This would not only help consumers to exert more preventive effort, but it would also enable firms to offer contracts that are both fair and perceived as fair by naive consumers.

Our results might help in solving the puzzle of why in some insurance markets we observe positive correlation between risk and coverage, while in others we observe negative correlation. After a recent review of the empirical literature by Cohen and Siegelman (2010) and recent empirical papers of supplementary health insurance, those markets where the occurrence of damage is associated with physical pain and discomfort (life insurance and supplementary health insurance) are characterized by negative correlation between risk and insurance coverage, while those markets where damage is only a matter of (insurable) financial loss (annuities and crop insurance) are characterized by a positive correlation between risk and coverage. The articles reviewed by Cohen and Siegelman further find inconclusive results for the correlation present in automobile insurance and positive correlation in long-term care insurance, while Finkelstein and McGarry (2006) find negative correlation in long-term care insurance. Recent papers that find negative correlation in supplementary health insurance are Bolhar et al. (2008) for private health

insurance in Ireland, Buchmueller et al. (2008) for private health insurance in Australia, and Fang et al. (2008) for Medigap policies.

We did not discuss the role of private information in our model, even though it is a major issue in insurance market theory. In fact, there were several variables in our model that were private information of consumers: risk preferences, wealth and (in Section 4.2) the belief about the present-bias. However, we assumed that the effort technology (that included the risk of damage) was uniform among consumers. Therefore, we did not consider a model of multidimensional screening (as, for example, Smart 2000). Future work may approach this issue. We conjecture that equilibria can be constructed where sophisticated consumers with low risk still purchase more insurance and exert more effort than naive consumers with high risk. A screening model will also be necessary if one drops the assumption of competitive markets. A monopolistic insurance company might want to offer different contracts to (sophisticated) consumers with relatively high valuation for insurance and to (sophisticated) consumers who are close to risk-neutral.

## 6 Appendix

### 6.1 Equilibria with negative correlation between risk and insurance when $\bar{U} = 0$

We show by example that equilibria with negative correlation can exist in our framework even if  $\bar{U} = 0$ . Let all consumers have the same utility function  $U \in \mathbf{U}^2$  and the same level of wealth  $W$ . The effort technology is denoted by  $\hat{\Gamma} = (\mathbf{c}, \beta, \pi)$ . Let  $\hat{c}_H(\hat{\Gamma})$  and  $\hat{c}_N(\hat{\Gamma})$  be given by

$$-\hat{c}_H(\hat{\Gamma}) - \pi'(0) \beta (U(W) - U(W - d)) = 0, \quad (27)$$

$$-\hat{c}_N(\hat{\Gamma}) - \pi'(1) \beta (U(W) - U(W - d)) = 0. \quad (28)$$

The expected utility of a consumer's self 0 for a given plan  $(e_1, e_2)$  and insurance contract  $(\lambda, y)$  is given by

$$\begin{aligned} EU(e_1, e_2, \lambda, y) &= \pi(e_1 + e_2)U(W - d + (\lambda - 1)y) + (1 - \pi(e_1 + e_2))U(W - y) \\ &\quad - \int_0^{e_1} c_1(\tilde{e}_1) d\tilde{e}_1 - \int_0^{e_2} c_1(\tilde{e}_2) d\tilde{e}_2. \end{aligned} \quad (29)$$

Let  $U, W, d, \hat{\Gamma}$  and  $e^* < 1$  be such that (i)  $\pi'(\bar{e}) = \hat{\pi}_H$  for all  $\bar{e} \in [0, 1)$ ,  $\pi'(\bar{e}) = \hat{\pi}_L$  for all  $\bar{e} \in [1, 2]$ , where  $\hat{\pi}_H > \hat{\pi}_L$ , (ii)

$$EU(e^*, 0, 0, 0) > U(W - d\pi(0)), \quad (30)$$

$$EU(1, 1, 0, 0) > U(W - d\pi(e^*)), \quad (31)$$

(iii)  $c_1(e_1) = \bar{c}_L > \hat{c}_N(\hat{\Gamma})$  for all  $e_1 \in [0, e^*]$  with

$$-\bar{c}_L - \beta \hat{\pi}_H (U(W) - U(W - d)) > 0, \quad (32)$$

(iv)  $c_1(e_1) = \bar{c}_H > \hat{c}_H(\hat{\Gamma})$  for all  $e_1 \in (e^*, 1]$ ,  $c_2(e_2) = \bar{c}_H$  for all  $e_2 \in [0, 1]$ . The assumptions in (iii) and (iv) ensure that  $N$  who did not purchase insurance never exert effort. Define  $\lambda^* = \frac{1}{\pi(e^*)}$ . Let  $y^*$  be given by

$$-\bar{c}_L - \beta \hat{\pi}_H (U(W - y^*) - U(W - d + (\lambda^* - 1)y^*)) = 0. \quad (33)$$

The assumption in (32) ensures that this value exists and that  $y^* < d\pi(e^*)$ . The inequality in (30) ensures that  $S$  prefer this contract to any other contract that guarantees zero profits to insurance companies. If

$$-\bar{c}_H - \hat{\pi}_L (U(W - y^*) - U(W - d + (\lambda^* - 1)y^*)) > 0, \quad (34)$$

then  $N$  assume in period 0, that they exert effort 2 even if they purchase contract  $(\lambda^*, y^*)$ . Furthermore, if

$$\pi(2)U'(W - d)(\lambda^* - 1) - (1 - \pi(2))U'(W) < 0, \quad (35)$$

then  $N$  prefer to remain uninsured as long as only contract  $(\lambda^*, y^*)$  is offered. (31) and (35) ensure that there is no contract that would be purchased by  $N$  and that guarantees zero-profits for insurance firms. Now, if all the assumptions from above hold, then one can easily show that in each equilibrium (i)  $S$  purchase the partial insurance contract  $(\lambda^*, y^*)$ , while  $N$  remain uninsured, and (ii)  $S$  exert effort  $e^*$ , while  $N$  do not exert effort. It remains to provide an example for  $U$ ,  $W$ ,  $d$ ,  $\hat{\Gamma}$  and  $e^*$  that satisfy all of these assumptions.

**Example 2.** Choose

$$U(w) = \frac{1}{1 - \gamma} w^{1 - \gamma} \quad (36)$$

with  $\gamma = 0.1$ ,  $W = 10$  and  $d = 5$ . For  $\hat{\Gamma}$  we select  $e^* = 0.3$ ,  $\bar{c}_L = 0.4$ ,  $\bar{c}_H = 0.62$ ,  $\pi(0) = 0.9$ ,  $\pi'(\bar{e}) = \hat{\pi}_H = 0.5$  for all  $\bar{e} \in [0, 1)$ , and  $\pi'(\bar{e}) = \hat{\pi}_L = 0.5$  for all  $\bar{e} \in (1, 2]$ . Using (27) and (28) we calculate that  $\hat{c}_H(\hat{\Gamma}) \approx 0.61$  and  $\hat{c}_N(\hat{\Gamma}) \approx 0.31$ . One can check that with these values the inequalities in (30), (31) and (32) are satisfied. For  $(\lambda^*, y^*)$  we get  $\approx (1.33, 1.32)$ . With this, we can calculate that the inequalities in (34) and (35) are also satisfied.

## 6.2 Proof of Proposition 1

We first show that all  $S$  purchase a full insurance contract if  $e_t^*$  sufficiently close to  $e_t(c_H(\beta, \pi))$ ,  $t \in \{1, 2\}$ . Define  $\pi^* = \pi(e_1^* + e_2^*)$  and let  $(\lambda^*, y^*)$  be a full insurance contract with  $\lambda^* = \frac{1}{\pi^*}$

and  $y^* = d\pi^*$ . Recall that a sophisticated consumer who purchased this contract exerts efforts  $e_1^*$  and  $e_2^*$ . The insurance company that sold the contract earns zero-profits in expectation. As  $\omega > 0$ , a sophisticated consumer deviates from the plan  $(e_1^*, e_2^*)$  only if she purchased a contract  $(\lambda^{**}, y^{**}) \in \mathbf{C}$  with less than full coverage, i.e.  $y^{**} < \frac{d}{\lambda^{**}}$ . Let  $(e_1^{**}, e_2^{**})$  be an optimal plan for a sophisticated consumer who purchased such a contract  $(\lambda^{**}, y^{**})$ , where  $\lambda^{**} = \frac{1}{\pi^{**}}$  and  $\pi^{**} = \pi(e_1^{**} + e_2^{**})$ . Observe that if  $e_t(c_H(\Gamma)) - e_t^* \leq \varepsilon$ , then we have  $e_t^{**} - e_t^* < \varepsilon$ ,  $t \in \{1, 2\}$ , which, by the continuity of  $\pi$ , implies that for some function  $\rho(\varepsilon)$  it holds that  $|\pi^{**} - \pi^*| < \rho(\varepsilon)$ , where  $\rho(\varepsilon) \rightarrow 0$  for  $\varepsilon \rightarrow 0$ . The expected utility from contract  $(\lambda^*, y^*)$  and plan  $(e_1^*, e_2^*)$  exceeds the one from contract  $(\lambda^{**}, y^{**})$  and plan  $(e_1^{**}, e_2^{**})$  in period 0 if

$$\begin{aligned} & U_i(W_i - y^*) - \pi^* \bar{U} - \left( \int_0^{e_1^*} c_1(\tilde{e}_1) d\tilde{e}_1 + \int_0^{e_2^*} c_2(\tilde{e}_2) d\tilde{e}_2 \right) \\ & > \pi^{**} (U_i(W_i - d + (\lambda^{**} - 1)y^{**}) - \bar{U}) + (1 - \pi^{**}) U_i(W_i - y^{**}) \\ & \quad - \left( \int_0^{e_1^{**}} c_1(\tilde{e}_1) d\tilde{e}_1 + \int_0^{e_2^{**}} c_2(\tilde{e}_2) d\tilde{e}_2 \right). \end{aligned} \quad (37)$$

This inequality is implied by

$$U_i(W_i - y^*) - \pi^* \bar{U} \geq \pi^{**} (U_i(W_i - d + (\lambda^{**} - 1)y^{**}) - \bar{U}) + (1 - \pi^{**}) U_i(W_i - y^{**}). \quad (38)$$

We show that the loss in expected utility in period 0 due to underinsurance has a lower bound. Define

$$EU(\pi^{**}, \lambda^{**}, y^{**}) = \pi^{**} U_i(W_i - d + (\lambda^{**} - 1)y^{**}) + (1 - \pi^{**}) U_i(W_i - y^{**}) \quad (39)$$

and derive

$$\frac{\partial EU(\pi^{**}, \lambda^{**}, y^{**})}{\partial y^{**}} = (1 - \pi^{**}) (U_i'(W_i - d + (\lambda^{**} - 1)y^{**}) - U_i'(W_i - y^{**})). \quad (40)$$

Observe that

$$\begin{aligned} & \pi^{**} U_i(W_i - d + (\lambda^{**} - 1)y^{**}) + (1 - \pi^{**}) U_i(W_i - y^{**}) \\ & = U_i(W_i - d\pi^{**}) - (1 - \pi^{**}) \\ & \quad \times \int_0^{d\pi^{**} - y^{**}} [U_i'(W_i - d + (\lambda^{**} - 1)(y^{**} + \xi)) - U_i'(W_i - (y^{**} + \xi))] d\xi. \end{aligned} \quad (41)$$

We can estimate

$$\begin{aligned} \frac{U_i'(W_i)}{U_i'(W_i - d)} & = \frac{U_i'(W_i - d) + \int_0^d U_i''(W_i - d + \xi) d\xi}{U_i'(W_i - d)} > 1 + \int_0^d \frac{U_i''(W_i - d + \xi)}{U_i'(W_i - d + \xi)} d\xi \\ & = 1 - \int_0^d A_{U_i}(W_i - d + \xi) d\xi > 1 - A_H d. \end{aligned} \quad (42)$$



If  $U_i \in \Upsilon(M_L, M_H, A_L, A_H)$ , then

$$-U_i''(W_i - d + \xi) \geq A_L U_i'(W_i) \quad (43)$$

for all  $\xi \in [0, d]$  and

$$-U_i'(W_i - d) \geq \frac{M_L}{d}. \quad (44)$$

Using (42), (43) and (44) we get

$$-U_i''(W_i - d + \xi) \geq A_L(1 - A_H d) \frac{M_L}{d}. \quad (45)$$

for all  $\xi \in [0, d]$ . Consequently, we have

$$\begin{aligned} & \int_0^{d\pi^{**}-y^{**}} [U_i'(W_i - d + (\lambda^{**} - 1)(y^{**} + \xi)) - U_i'(W_i - (y^{**} + \xi))] d\xi \\ & \geq -A_L(1 - A_H d) \frac{M_L}{d} \int_0^{d\pi^{**}-y^{**}} (d - \lambda^{**}(y^{**} + \xi)) d\xi \\ & = A_L(1 - A_H d) \frac{M_L}{d} (d - \lambda^{**}y^{**}). \end{aligned} \quad (46)$$

We use (41) and (46) to see that (38) is implied by

$$U_i(W_i - y^*) - \pi^* \bar{U} \geq U_i(W_i - d\pi^{**}) - (1 - \pi^{**}) A_L(1 - A_H d) \frac{M_L}{d} (d - \lambda^{**}y^{**}) - \bar{U}\pi^{**}. \quad (47)$$

Thus, if  $e_t^*$  sufficiently close to  $e_t(c_H(\Gamma))$ ,  $t \in \{1, 2\}$ , a sophisticated consumer  $i$  prefers contract  $(\lambda^*, y^*)$  to any other contract that can generate at least zero-profits for firms. Now observe that for  $e_1(c_N(\Gamma)) \rightarrow 0$  ( $e_t^* \rightarrow e_t(c_H(\Gamma))$ ) the effort exerted by  $N$  in period 1 (period 2) converges to 0 (to the same value as for  $S$ ). Thus, if  $e_1(c_N(\Gamma))$  is sufficiently close to 0 and  $e_2^*$  sufficiently close to  $e_2(c_H(\Gamma))$ , then  $N$  exert less effort than  $S$  who purchased full coverage. Next, we show that if  $A_H$  is not too large,  $N$  prefer to remain uninsured whenever only contracts  $(\lambda, y)$  with  $\lambda = \frac{1}{\pi^*}$  are offered. Recall that in period 0 these consumers assume that their probability of damage equals  $\pi(2) < \pi^*$ . A sufficient condition for a naive consumer  $i$  not to choose a contract  $(\frac{1}{\pi^*}, y)$  is that

$$\frac{\partial EU(\pi(2), \frac{1}{\pi^*}, 0)}{\partial y^{**}} < 0. \quad (48)$$

This inequality is equivalent to

$$\frac{1 - \pi^*}{\pi^*} < \frac{1 - \pi(2)}{\pi(2)} \frac{U_i'(W_i)}{U_i'(W_i - d)}. \quad (49)$$

Note from (42) that the inequality in (49) holds if  $A_H$  is not too large. If  $N$  exert less effort than  $S$  and do not purchase any contract  $(\frac{1}{\pi^*}, y)$ , then insurance companies cannot sell any contract to  $N$  that guarantees them at least zero profits. From this the result follows immediately.

### 6.3 Proof of Proposition 4

Let  $c_L^*$ ,  $c_H^*$ ,  $\pi_L^*$ ,  $\pi_H^*$  be the values for which  $\Gamma$  has property  $\mathbf{D}(e_1^*, e_2^*)$ . Let  $\hat{\beta}_L$  and  $\hat{\beta}_H$  be defined by

$$-c_H^* - \hat{\beta}_L \pi_H (\bar{U} + M_H) = 0, \quad (50)$$

$$-c_H^* - \hat{\beta}_H \pi_L \bar{U} = 0. \quad (51)$$

$\mathbf{D}(e_1^*, e_2^*)$  ensures that consumers exert effort of at most  $e_1^* + e_2^*$ . Assume that in period 0 insurance companies offer the full insurance contract  $(\lambda^*, y^*)$  with  $\lambda^* = \frac{1}{\pi(e_1^* + e_2^*)}$  and  $y^* = d\pi(e_1^* + e_2^*)$ , and partial insurance contracts  $(\lambda^{**}, y)$  with  $\lambda^{**} = \frac{1}{\pi(e_1^*)}$  and  $y \in (0, d\pi(e_1^*))$ . If consumer  $i$  has  $\hat{\beta}_i \in [\beta, \hat{\beta}_L)$ , then she anticipates that she will exert effort  $e_1^*$  in period 1 and  $e_2^*$  in period 2, regardless of her insurance protection. Therefore, it is optimal for her to purchase full insurance. If consumer  $i$  has  $\hat{\beta}_i \in (\hat{\beta}_H, 1]$ , then she assumes that she will exert full effort in both periods, regardless of her insurance protection. Therefore, she perceives all contracts as unfair. Given that  $A_H$  is small enough, then she will never purchase any insurance contract. We now show that firms earn zero profits out of consumers with  $\hat{\beta} \in (\hat{\beta}_L, \hat{\beta}_H)$ . If consumer  $i$  would purchase contract  $(\lambda^{**}, y)$  and

$$-c_H^* - \hat{\beta}_i \pi_L (\bar{U} + U_i(W_i - y) - U_i(W_i - d + (\lambda^{**} - 1)y)) < 0, \quad (52)$$

then, due to the assumption in (18), she anticipates that she will realize plan  $(e_1^*, e_2^*)$ . She also knows that she would realize this plan if she had purchased  $(\lambda^*, y^*)$ , which would have been strictly better for her. If consumer  $i$  purchases  $(\lambda^{**}, y)$  and

$$-c_H^* - \hat{\beta}_i \pi_L (\bar{U} + U_i(W_i - y) - U_i(W_i - d + (\lambda^{**} - 1)y)) \geq 0, \quad (53)$$

then she will not exert any effort in period 1. To see why, recall that consumer  $i$ 's self 1 maximizes (3) and that  $c_L^* > \beta c_H^*$ . Therefore, she postpones in period 1 any effort to period 2. Consequently, she ends up with total effort  $e_2^*$ . It follows that those consumers who purchase a contract  $(\lambda^*, y^*)$  exert effort  $e_1^* + e_2^*$ , and those who purchase a contract  $(\lambda^{**}, y)$  exert effort  $e_2^*$ . By going through similar steps one can show that firms cannot offer any other contract that is purchased by a positive mass of consumers and that generates positive profits. As  $F(\hat{\beta})$  is continuous, there is no positive mass of consumers with exactly the same  $\hat{\beta}$ . Thus, the behavior of consumers with  $\hat{\beta} \in \{\hat{\beta}_L, \hat{\beta}_H\}$  does not influence the firms' profits.

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