Adverse Selection in Insurance Contracting

Georges Dionne
HEC Montréal

Nathalie Fombaron
Université Paris X-Nanterre

Neil Doherty
University of Pennsylvania

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Abstract

In this survey we present some of the more significant results in the literature on adverse selection in insurance markets. Sections 1 and 2 introduce the subject and Section 3 discusses the monopoly model developed by Stiglitz (1977) for the case of single-period contracts extended by many authors to the multi-period case. The introduction of multi-period contracts raises many issues that are discussed in detail; time horizon, discounting, commitment of the parties, contract renegotiation and accidents underreporting. Section 4 covers the literature on competitive contracts. The analysis is more complicated because insurance companies must take into account competitive pressures when they set incentive contracts. As pointed out by Rothschild and Stiglitz (1976), there is not necessarily a Cournot-Nash equilibrium in the presence of adverse selection. However, market equilibrium can be sustained when principals anticipate competitive reactions to their behavior or when they adopt strategies that differ from the pure Nash strategy. Multi-period contracting is discussed. We show that different predictions on the evolution of insurer profits over time can be obtained from different assumptions concerning the sharing of information between insurers about individual's choice of contracts and accident experience. The roles of commitment and renegotiation between the parties to the contract are important. Section 5 introduces models that consider moral hazard and adverse selection simultaneously and Section 6 covers adverse selection when people can choose their risk status. Section 7 discusses many extensions to the basic models such as risk categorization, multidimensional adverse selection, symmetric imperfect information, reversed or double-sided adverse selection, principals more informed than agents, uberrima fides and participating contracts.

Keywords: Adverse selection, insurance markets, monopoly, competitive contracts, self-selection mechanisms, single-period contracts, multi-period contracts, commitment, contract renegotiation, accident underreporting, risk categorization, participating contracts.

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1 Introduction

In 1996, the European Group of Risk and Insurance Economists used its annual meeting to celebrate the 20th anniversary of the Rothschild and Stiglitz (1976) article "Equilibrium in Competitive Insurance Markets: An Essay in the Economics of Imperfect Information". At this meeting, many papers on adverse selection were presented and a subset of these presentations was published in a 1997 issue of the Geneva Papers on Risk and Insurance Theory.

One of these articles was written by Rothschild and Stiglitz (1997) themselves. Their main topic was the role of competition in insurance markets, with an emphasis on underwriting in a world with imperfect information. They argue that insurance competition using underwriting on preexisting conditions (such as genetic conditions) can limit the welfare benefits of insurance. In this survey, we concentrate on a subset of situations involving imperfect information in the insured-insurer relationship; we analyze situations of standard adverse selection where the insured has more information about his risk than the insurer. However, we will consider extensions where insurers learn on individual characteristics that are not known by the insureds. We will also consider the assumption that risks are endogenous to individuals.

Adverse selection can be a significant resource allocation problem in many markets. In automobile insurance markets, risk classification is mainly explained by adverse selection. In health insurance, different insurance policies or contracts are offered to obtain self-selection between different groups. In life insurance, the screening of new clients with medical exams is an accepted activity justified by asymmetric information between the insurer and the insured. These three resource allocation mechanisms can be complements or substitutes and adverse selection is not always a necessary condition for their presence. For example, in automobile insurance, we observe that insurers use risk classification and different deductible policies. Risk classification is usually justified by adverse selection, but the presence of different deductibles can also be explained by proportional transaction costs with different observable risks and by moral hazard. It is very difficult to verifying whether the presence of different deductibles is justified by residual adverse selection or not. Another empirical test would be to verify whether bonus-malus schemes or multiperiod contracts with memory are explained in various markets by the presence of moral hazard, by that of adverse selection or both. We shall not discuss these tests or these mechanisms in detail here; other chapters of this book are concerned with these issues (Chiappori, 2012, Dionne, 2012, and Dionne and Rothschild, 2011). Instead, we will review the major allocation mechanisms that can be justified by the presence of adverse selection. Emphasis will be placed on self-selection mechanisms in one-period contracting because a much of the early literature was devoted to this subject (on risk classification, see Crocker and Snow, 2012). We will also discuss some extensions of these basic models; particularly, the role of multi-period contracting will be reviewed in detail. Finally, we will discuss the more recent contributions that focus on the effect of modifying the basic assumptions of the standard models. In particular, we will see how introducing moral hazard in the basic Rothschild and Stiglitz (1976) model affects the conclusions about both the nature and the existence of an equilibrium. We will also introduce moral hazard in the monopoly model. Another subject will be insurance coverage when individuals can choose their risk status. Other extensions concern the consideration of multidimensional adverse selection (introduction of different risk averse individuals or different privately known initial wealth combined with differences in risk, multiple risks), the case where the insurer is more informed than the insured about loss probabilities (reversed adverse selection and even double-sided adverse selection, imprecise information about accident probabilities), adverse selection and uberrima fides and finally the consideration of participating contracts. This survey should be considered as an update of Dionne, Doherty and Fombaron (2000).

2 Basic assumptions and some fundamental results

Without asymmetric information and under the standard assumptions of insurance models that we shall use in this article (same attitude toward risk and same risk aversion for all individuals in all classes of risk, one source of risk, risk neutrality on the supply side, no transaction cost in the supply of insurance, no learning and no moral hazard), a Pareto optimal solution is characterized by full insurance coverage for all individuals in each class of risk. Each insured sets his optimal consumption level according to his certain wealth. No other financial institution is required to obtain this level of welfare. Both risk categorization and self-selection mechanisms are redundant. There is no need for multi-period insurance contracts because they are not superior to a sequence of one-period contracts. Finally, the two standard theorems of welfare economics hold and market prices of insurance are equal to the corresponding social opportunity costs.

In insurance markets, adverse selection results from asymmetric information between the insured (agent) and the insurer (principal). The insureds are heterogeneous with respect to their expected loss and have more information than the insurance company which is unable to differentiate between risk types. Naturally, the high-risk individual has no incentive to reveal his true risk which is costly for the insurer to observe. Pooling of risks is often observed in insurance markets. "In fact, however, there is a tendency to equalize rather than to differentiate premiums... This constitutes, in effect, a redistribution of income from those with a low propensity of illness to those with a high propensity..." (Arrow, 1963; p. 964). One major difficulty is that a pooling cannot be a Nash equilibrium.

Akerlof (1970) showed that if all insurers have imperfect information on individual risks, an insurance market may not exist, or if it exists, it may not be efficient. He proposed an explanation of why, for example, people over 65 have great difficulty in buying medical insurance "the result is that the average medical condition of insurance applicants deteriorates as the price level rises − with the result that no insurance sales may take place at any price" (1970; p. 492). The seminal contributions of Akerlof and Arrow have generated a proliferation of models on adverse selection. In this survey we shall, however, confine our attention to a limited subset. Many authors have proposed mechanisms to reduce the inefficiency associated with adverse selection, the "self-selection mechanism" in one-period contracts that induces policyholders to reveal hidden information by selection from a menu of contracts, (Rothschild and Stiglitz, 1976; Stiglitz, 1977; Wilson, 1977; Miyazaki, 1977; Spence, 1978; Hellwig, 1986), the "categorization of risks" (Hoy, 1982; Crocker and Snow, 1985, 1986, 2000), and "multi-period contracting" (Dionne, 1983; Dionne and Lasserre, 1985, 1987; Kunreuther and Pauly, 1985; Cooper and Hayes, 1987; Hosios and Peters, 1989; Nilssen, 1990; Dionne and Doherty, 1994; Fombaron, 1997b, 2000). All of them address private market mechanisms. In the first case, insurers offer a menu of policies with different prices and quantity levels so that different risk types choose different insurance policies. Pareto improvements for resource allocation with respect to the single-contract solution with an average premium to all clients can be obtained. In the second case, insurers use imperfect information to categorize risks and, under certain conditions, it is also possible to obtain Pareto improvements for resource allocation. In the third case, insurers use the information related to the past experience of the insured as a sorting device (i.e. to motivate high-risk individuals to reveal their true risk ex ante).

Before proceeding with the different models, let us comment briefly on some standard assumptions. We assume that all individuals maximize expected utility. The utility functions of the individuals in each risk group are identical, strictly concave and satisfy the von Neumann-Morgenstern axioms. Utility is time-independent, time-additive and state-independent. In many models there is no discounting but this is not a crucial issue. Individuals start each period with a given wealth, W, which is non-random. To avoid problems of bankruptcy, the value of the risky asset is lower than W. All risks in the individual's portfolio are assumed to be insurable. Income received in a given period is consumed in that period; in other words, there is no saving and no banking or lending. Insurers are risk neutral and maximize the value of their cash flows or profits. Insurers write exclusive insurance contracts and there are no transaction costs in the supply of insurance. Finally, the insureds are assumed to be unable to influence either the probabilities of accident or the damages due to accidents; this rules out any problem of moral hazard.

To simplify the presentation we explicitly assume that insurers are risk neutral. An equivalent assumption is that insurers are well diversified in the sense that much of their total risk is diversified by their own equity holders in the management of their personal portfolios. The presence of transaction costs would not affect the qualitative conclusions concerning the effects of adverse selection on resource allocation in insurance markets (see Dionne, Gouriéroux and Vanasse, 1999, for more details). However, proportional transaction costs (or proportional loadings) are sufficient to explain partial insurance coverage and their explicit introduction in the analysis would modify some conclusions in the reference models. For example, each individual in each class of risk would buy less than full insurance in the presence of full information and the introduction of adverse selection will further decrease the optimal coverage for the low-risk individuals. Consequently the presence of adverse selection is not a necessary condition to obtain different deductibles in insurance markets.

The presence of many sources of non-insurable risks or of many risky assets in individual portfolios is another empirical fact that is not considered in the models. As long as these risks are independent, the conclusions should not be affected significantly. However, the optimal portfolio and insurance decisions in the presence of many correlated risks and asymmetric information in one or in many markets is still an open question in the literature.

In reality, we observe that banks coexist with insurers that offer multi-period insurance contracts. The presence of saving and banking may change the conclusions obtained for multi-period contracts under asymmetric information. Particularly, it may modify accident reporting strategies and commitment to the contracts. However, with few exceptions (Allen, 1985, moral hazard; Dionne and Lasserre, 1987, adverse selection; Fudenberg, Holmstrom and Milgrom, 1986, moral hazard; Caillaud, Dionne and Jullien, 2000, insurance and debt with moral hazard), research on principal-agent relationships has not envisaged the simultaneous presence of several alternative types of assets and institutions (see Chiappori *et al*, 1994, for detailed discussion of different issues related to the effect of savings on the optimality of multi-period contracts).

The assumption of exclusive insurance contracting is discussed in Section 4 and some aspects of the discounting issues are discussed in Section 3. There remain the assumptions on the utility function. Although the theory of decision making under uncertainty has be challenged since its formal introduction by von Neumann and Morgenstern (Machina, 1987, 2012), it has produced very useful analytical tools for the study of optimal contracts such as optimal insurance coverage and the associated comparative statics, and the design of optimal contracts under moral hazard or the characterization of optimal insurance policies under adverse selection. In fact, few contributions use non-linear models in insurance literature (see however Karni, 1992; Gollier, 2000; Doherty and Eeckhoudt, 1995) and very few of these have addressed the adverse selection problem. In this survey we thus limit the discussion to the linear expected utility model. We also assume that utility functions are not function of the states of the world and that all individuals in all classes of risks have the same level of risk aversion. As we will see, some of these assumptions are not necessary to get the desired results but permit the discussion to focus on differences in the risk types.

3 Monopoly

3.1 Public information

There are two possible states of the world ($x \in \{n, a\}$); state (n), "no accident" having the probability $(1 - p_i)$ and state (a), "accident" having the probability $0 < p_i < 1$. Consumers differ only by their probability of accident. For simplicity, there are two types of risk in the economy ($i \in \{H, L\}$ for High and Low-risk) with $p_H > p_L$. Each consumer owns a risky asset with monetary value $D(x)$; $D(a) = 0$ in state (a) and $D(n) = D$ in state (n). Therefore the expected loss for a consumer of type i ($E_i D(x)$) is $p_i D$.

Under public information and without transaction cost, a risk neutral private monopoly[1] would offer insurance coverage (net of premium) (β_i) for an insurance premium (α_i) such that a consumer will be indifferent between purchasing the policy and having no insurance (Stiglitz, 1977). In other words, the private monopolist maximizes his total profit over α_i, β_i and λ_i:

Problem 1

$$\underset{\alpha_i,\ \beta_i,\ \lambda_i}{Max} \sum q_i \ \ ((1 - p_i)\ \ \alpha_i - p_i \beta_i) \tag{1}$$

under the individual rationality (or participating) constraints[2]

$$V(C_i \mid p_i) - V(C^0 \mid p_i) \geq 0 \qquad\qquad i = H, L \tag{2}$$

where $V(C_i \mid p_i)$ is the expected utility under the contract $C_i = \{\alpha_i, \beta_i\}$;

$$V(C_i \mid p_i) = p_i U(W - D + \beta_i) + (1 - p_i)\ U(W - \alpha_i);$$

$U(\cdot)$ is a twice differentiable, strictly increasing and strictly concave function of final wealth$(U'(\cdot) > 0, U''(\cdot) < 0)$;

W is non-random initial wealth;

C^0 denotes no insurance; $C^0 = \{0, 0\}$ and

$V(C^0 \mid p_i) \equiv p_i U(W - D) + (1 - p_i)\ U(W)$; $V(C^0 \mid p_i)$ is the reservation utility.

q_i is the number of policies sold to consumers of type i;

λ_i is a Lagrangian multiplier for constraint (2).

[1] For an analysis of several reasons why a monopoly behavior in insurance markets should be considered, see Dahlby (1987). For examples of markets with a monopoly insurer see D'Arcy and Doherty (1990) and Dionne and Vanasse (1992).

[2] For a detailed analysis of participation constraints, see Jullien (2000).

It is well known that full insurance, $\beta_i^* = D - \alpha_i^*$ (for $i = H, L$), is the solution to the above problem and that (2) is binding for both classes of risk, which means that

$$V(C_i^* \mid p_i) = V(C^0 \mid p_i) \qquad\qquad i = H, L$$

or

$$\alpha_i^* = p_i D + z_i^*,$$

where z_i^* is the maximum unit-profit (or the Arrow-Pratt risk premium) on each policy. In other words z_i^* solves $U(W - p_i D - z_i^*) = p_i U(W - D) + (1 - p_i)U(W)$.

The private monopoly extracts the entire consumer surplus. However, there is no efficiency cost associated with the presence of a monopoly because each individual buys full insurance as under perfect competition[3]. This is the classical result that Pareto efficient risk sharing between a risk-averse agent and a risk-neutral principal shifts all the risk to the principal. To sum up we can write:

Proposition 1 *In the presence of public information about insureds' underlying risk, an optimal contract between a private monopolist and any individual of type i is characterized by:*

a) full insurance coverage, $\beta_i^* = D - \alpha_i^*$*;*

b) no consumer surplus, $V(C_i^* \mid p_i) = V(C^0 \mid p_i)$*.*

Both solutions are shown at C_H^* and C_L^* in Figure 1 where C^0 is the "initial endowment" situation and where the vertical axis is wealth in the accident or loss state and the horizontal axis is wealth in the no-loss state.

Insert Figure 1 here.

Any point to the northwest of C^0 and below or on the 45° degree line represents the wealth of the insured with any contract where $\alpha_i \geq 0$ and $\beta_i \geq 0$. Because the monopoly solution implies no consumer surplus, it must lie on each risk type indifference curve passing through C^0. These indifference curves are strictly convex because $U(\cdot)$ is strictly concave by assumption.[4]

[3] As in the perfect discrimination case, the monopolist charges a price of insurance to each consumer equal to marginal cost. All potential consumer surplus is collected as monopoly profits so there is no dead weight loss. This result would not be obtained with a proportional loading.

[4] Since individuals of different types have the same degree of risk aversion, at each point in the figure, the absolute value of the slope of the high-risk indifference curve is lower than that of the low-risk individual. For example at point $C^0, U'(W)(1 - p_H)/U'(W - D)p_H < U'(W)(1 - p_L)/U'(W - D)p_L$. At equilibrium points C_H^* and C_L^*, the respective slopes (in absolute values) are $(1 - p_H)/p_H$ and $(1 - p_L)/p_L$. This is true because under full insurance, the insured of type i has $W - p_i D - z_i^*$ in each state.

3.2 Private information and single-period contracts

Under private information the insurer does not observe the individual's risk types[5], and must introduce mechanisms to ensure that agents will reveal this characteristic. Stiglitz (1977) extended the Rothschild-Stiglitz (1976) model to the monopoly case. In both contributions, price-quantity contracts[6] permit the separation of risks by introducing incentives for individuals to reveal their type. Low-risk individuals reveal their identity by purchasing a policy that offers limited coverage at a low unit price. Thus they trade off insurance protection to signal their identity. Formally, risk revelation is obtained by adding two self-selection constraints to Problem 1:

$$V\left(C_i \mid p_i\right) - V\left(C_j \mid p_i\right) \geq 0 \qquad \begin{array}{l} i, j = H, L \\ i \neq j \end{array} \tag{3}$$

Equation (3) guarantees that individual i prefers C_i to C_j. Let us use λ_{HL} and λ_{LH} for the corresponding Lagrangian multipliers where λ_{HL} is for the self-selection constraint of the H type risk and λ_{LH} is that for the L type. λ_{HL} and λ_{LH} cannot both be positive.[7] From Figure 1 it is easy to observe that, if the high-risk individuals are indifferent between both contracts ($\lambda_{HL} > 0$), the low-risk individuals will strictly prefer their own contracts ($\lambda_{LH} = 0$). Moreover, λ_{LH} cannot be positive when λ_{HL} is zero because this leads to a violation of (2). Therefore, a feasible solution can be obtained only when $\lambda_{HL} > 0$ and $\lambda_{LH} = 0$.

Figure 1 shows the solution to the maximization of (1) subject to (2) and (3) where low-risk individuals choose a positive quantity of insurance[8] $\beta_L^{**} > 0$ and high-risk individuals buy full insurance coverage ($\beta_H^{**} = \beta_H^{*}$). Separation of risks and profit maximization imply that $V(C_H^{**} \mid p_H) = V(C_L^{**} \mid p_H)$. As discussed above, it is clear that (2) and (3) cannot both be binding for the high-risk individuals when it is possible for the low-risks to buy insurance. In fact, Figure 1 indicates that C_H^{**} is strictly preferred to C_H^{*} which means that high-risk individuals get some consumer surplus when the monopolist sells insurance

[5] For models where neither the insurer nor the insured know the individuals' probabilities of accident, see Palfrey and Spatt (1985), Malueg (1988), Boyer, Dionne and Kihlstrom (1989), and De Garidel (2005).

[6] We limit our discussion to private market mechanisms. On public provision of insurance and adverse selection, see Pauly (1974) and Dahlby (1981).

[7] Technically the preference structure of the model implies that indifference curves of individuals with different risks cross only once. This single crossing property has been used often in the sorting literature (Cooper, 1984).

[8] There is always a separating equilibrium in the monopoly case. However, the good-risk individuals may not have any insurance coverage at the equilibrium. Property 4 in Stiglitz (1977) establishes that $C_L^{**} = \{0, 0\}$ when q_H/q_L exceeds a critical ratio of high to low-risk individuals where q_i is the proportion of individuals i in the economy. The magnitude of the critical ratio is function of the difference in accident probabilities and of the size of the damage. Here, to have $C_L^{**} \neq \{0, 0\}$, we assume that q_H/q_L is below the critical ratio.

to the low-risk individuals. In other words, the participation constraint (2) is not binding for the H individuals ($\lambda_H = 0$).

Another property of the solution is that good risk individuals do not receive any consumer surplus ($\lambda_L > 0$). However, as discussed above, they strictly prefer their contract to the contract offered to the bad risk individuals. In other words

$$V(C_L^{**} \mid p_L) = V(C^0 \mid p_L) \quad \text{and} \quad V(C_L^{**} \mid p_L) > V(C_H^{**} \mid p_L),$$

which means that the self-selection constraint is not binding for the low-risk individuals unlike the participation constraint.

In conclusion, one-period contracts with a self-selection mechanism increase the monopoly profits under private information compared with a single contract without any revelation mechanism, but do not necessarily correspond to the best risk allocation arrangement under asymmetric information. In particular, good risk individuals may not be able to buy any insurance coverage or, if they can, they are restricted to partial insurance. As we shall see in the next section, multi-period contracts can be used to relax the binding constraints and to improve resource allocation under asymmetric information. In summary

Proposition 2 *In the presence of private information, an optimal one-period contract menu between a private monopoly and individuals of types H and L has the following characteristics:*
a) $\beta_H^{**} = D - \alpha_H^{**}; \beta_L^{**} < D - \alpha_L^{**}$
b) $V(C_H^{**} \mid p_H) > V(C^0 \mid p_H); V(C_L^{**} \mid p_L) = V(C^0 \mid p_L)$
c) $V(C_H^{**} \mid p_H) = V(C_L^{**} \mid p_H); V(C_L^{**} \mid p_L) > V(C_H^{**} \mid p_L)$.

Proof. See Stiglitz (1977). ■

Stiglitz (1977) also considered a continuum of agent types and showed that some of the above results can be obtained under additional conditions. However, in general, the presence of a continuum of agent types affects the results.[9]

3.3 Multi-period insurance contracts

Multi-period contracts are often observed in different markets. For example, in many countries, drivers buy automobile insurance with the same insurer for many years and insurers use bonus-malus systems (or experience rating) to relate insurance premiums to the individual's past experience (Lemaire, 1985; Henriet and Rochet, 1986; Hey, 1985; Dionne and Vanasse, 1989, 1992, and Dionne *et al*, 2010). Long term contracting is also observed in labor markets, workers'

[9] In another context, Riley (1979a) shows that a competitive Nash equilibrium never exists in the continuum case (see also Riley, 1985).

compensation insurance, service contracts, unemployment insurance and many other markets. The introduction of multi-period contracts in the analysis gives rise to many issues such as time horizon, discounting, commitment of the parties, myopic behavior, accident underreporting, and contract renegotiation. These issues are discussed in the following paragraphs.

Multi-period contracts are set not only to adjust ex-post insurance premiums or insurance coverage to past experience, but also as a sorting device. They can be a complement or a substitute to standard self-selection mechanisms. However, in the presence of full commitment, ex-ante risk announcement or risk revelation remains necessary to obtain optimal contracts under adverse selection.

In Cooper and Hayes (1987), multi-period contracts are presented as a complement to one-period self-selection constraints. Because imperfect information reduces the monopolist's profits, the latter has an incentive to relax the remaining binding constraints by introducing contracts based on anticipated experience over time. By using price-quantity contracts and full commitment in long term contracts, Cooper and Hayes introduce a second instrument to induce self-selection and increase monopoly profits: experience rating increases the cost to high-risks from masquerading as low-risks by exposing them to second-period contingent coverages and premia.

Cooper and Hayes' model opens with a direct extension of the standard one-period contract presented above to a two-period world with full commitment on the terms of the contract. There is no discounting and all agents are able to anticipate the values of the relevant futures variables. To increase profits, the monopolist offers contracts in which premiums and coverages in the second period are function of accident history in the first period. Accidents are public information in their model. The two period contract C_i^2 is defined by:

$$C_i^2 = \{\alpha_i, \beta_i, \alpha_{ia}, \beta_{ia}, \alpha_{in}, \beta_{in}\}$$

where a and n mean "accident" and "no accident" in the first period and where α_{il} and $\beta_{il}(l = a, n)$ are "contingent" choice variables. Conditional on accident experience, the formal problem consists of maximizing two-period expected profits by choosing C_L^2 and C_H^2 under the following constraints:

$$V(C_i^2 \mid p_i) \geq 2V(C^0 \mid p_i) \tag{4.1}$$

$$V(C_i^2 \mid p_i) \geq V(C_j^2 \mid p_i) \qquad \begin{array}{l} i, j = H, L \\ i \neq j \end{array} \tag{4.2}$$

where

$$\begin{aligned} V(C_i^2|p_k) \quad \equiv \quad & p_k U(W-D+\beta_i)+(1-p_k)U(W-\alpha_i) \\ & +p_k \ \left[p_k U(W-D+\beta_{ia})+(1-p_k) \ U\left(W-\alpha_{ia}\right)\right] \\ & +(1-p_k) \ \left[p_k U\left(W-D+\beta_{in}\right)+(1-p_k) \, U\left(W-\alpha_{in}\right)\right] \\ & \qquad\qquad\qquad k=i,j \quad i,j=H,L \quad i\neq j. \end{aligned}$$

The above constraints show that agents are committed to the contracts for the two periods. In other words, the model does not allow the parties to renegotiate the contract at the end of the first period. Moreover, the principal is committed to a loss-related adjustment of the insurance contract in the second period negotiated at the beginning of the first period. The insured is committed, for the second period, to buy the coverage and to pay the premium chosen at the beginning of the first period. It is also interesting to observe from (4) that the decisions concerning insurance coverage in each period depend on the anticipated variations in the premiums over time. In other words, (4) establishes that variations in both premia and coverages in the second period are function of experience in the first period. Using the above model, Cooper and Hayes proved the following result:

Proposition 3 *In the presence of private information and full commitment, the monopoly increases its profits by offering an optimal two-period contract having the following characteristics :*

1) High-risk individuals obtain full insurance coverage in each period and are not experience rated

$\widehat{\alpha}_H = \widehat{\alpha}_{Hn} = \widehat{\alpha}_{Ha}, \ \widehat{\beta}_H = \widehat{\beta}_{Ha} = \widehat{\beta}_{Hn}$

where $\widehat{\beta}_H = D - \widehat{\alpha}_H$

2) Low-risk individuals obtain partial insurance with experience rating

$\widehat{\alpha}_{Ln} < \widehat{\alpha}_L < \widehat{\alpha}_{La}, \ \widehat{\beta}_{La} < \widehat{\beta}_L < \widehat{\beta}_{Ln}$

3) Low-risk individuals do not obtain any consumer surplus, and high-risk individuals are indifferent between the two contracts

$V\left(\widehat{C}_L^2 \mid p_L\right) = 2V\left(C^0 \mid p_L\right),$

$V\left(\widehat{C}_H^2 \mid p_H\right) = V\left(\widehat{C}_L^2 \mid p_H\right).$

Proof. See Cooper and Hayes (1987). ■

The authors also discuss an extension of their two-period model to the case where the length of the contract may be extended to many periods. They show that the same qualitative results as those in Proposition 3 hold with many periods.

Dionne (1983) and Dionne and Lasserre (1985, 1987) also investigated multi-period contracts in the presence of both adverse selection[10] and full commitment

[10] Townsend (1982) discussed multi-period borrowing-lending schemes. However, his mechanism implies a constant transfer in the last period that is incompatible with insurance in the presence of private information.

by the insurer. Their models differ from that of Cooper and Hayes in many respects. The main differences concern the revelation mechanism, the sorting device, commitment assumptions and the consideration of statistical information. Moreover, accidents are private information in their models. Unlike Cooper and Hayes, Dionne (1983) did not introduce self-selection constraints to obtain risk revelation. Instead risk revelation results from a Stackelberg game where the insurer offers a contract in which the individual has to select an initial premium by making a risk announcement in the first period. Any agent who claims to be a low-risk pays a corresponding low premium as long as his average loss is less than the expected loss given his declaration (plus a statistical margin of error to which we shall return). If that condition is not met, he is offered a penalty premium. Over time, the insurer records the agent's claims and offers to reinstate the policy at the low premium whenever the claims frequency become reasonable again.[11]

Following Dionne (1983) and Dionne and Lasserre (1985), the no-claims discount strategy consists in offering two full insurance premiums[12] ($F^1 = \{\alpha_H, \alpha_L\}$) in the first period and for $t = 1, 2, ...$

$$F^{t+1} \begin{cases} = \alpha_d \text{ if } \sum_{s=1}^{N(t)} \theta^s / N(t) < E_d D(x) + \delta_d^{N(t)} \\ = \alpha_k \text{ otherwise} \end{cases}$$

where

α_d is the full information premium corresponding to the declaration (d), $d \in \{H, L\}$

θ^s is the amount of loss in contract period $s, \theta^s \in \{0, D\}$

α_k is a penalty premium. α_k is such that $U(W - \alpha_k) < V(C_0 \mid p_H)$

$E_d D(x)$ is the expected loss corresponding to the announcement (d)

$\delta_d^{N(t)}$ is the statistical margin of error

$N(t)$ is the total number of periods with insurance; $N(t) \leq t$.

Therefore, from the construction of the model, $\sum_{s=1}^{N(t)} \theta^s / N(t)$ is the average loss claimed by the insured in the first $N(t)$ periods. If this number is strictly

[11] This type of "no-claims discount" strategy was first proposed by Radner (1981) and Rubinstein and Yaari (1983) for the problem of moral hazard (see also Malueg (1986) where the "good faith" strategy is employed). However, because the two problems of information differ significantly the models are not identical. First the information here does not concern the action of the agent (moral hazard) but the type of risk which he represents (adverse selection). Second, because the action of the insured does not affect the random events, the sequence of damage levels is not controlled by the insured. The damage function depends only on the risk type. Third, in the adverse selection model, the insured cannot change his declaration and therefore cannot depart from his initial risk announcement although he can always cancel his contract. Therefore, the stronger conditions used by Radner (1981) (robust epsilon equilibrium) and Rubinstein and Yaari (1983) ("long proof") are not needed to obtain the desired results in the presence of adverse selection only. The Law of the Iterated logarithm is sufficient.

[12] In fact their formal analysis is with a continuum of risk types.

less than the declared expected loss plus some margin of error, the insurer offers α_d. Otherwise he offers α_k. The statistical margin of error is used to avoid penalizing honest insureds too often. Yet it has to be small enough to detect those who try to increase their utility by announcing a risk class inferior to their true risk. From the Law of the Iterated Logarithm, one can show that

$$\delta_d^{N(t)} = \sqrt{2\gamma\sigma_d^2 \ \log \ \log \ N(t)/N(t)}, \quad \gamma > 1$$

where σ_d^2 is the variance of the individual's loss corresponding to the declaration (d) and $\delta_d^{N(t)}$ converges to zero over time (with arbitrary large values for $N(t)$).

Graphically, we can represent $E_d D(x) + \delta_d^{N(t)}$ in the following way:

Insert Figure 2 here.

As $N(t) \longrightarrow \infty, E_d D(x) + \delta_d^{N(t)} \longrightarrow E_d D(x)$.

Over time, only a finite number of points representing $(\Sigma\theta^s/N(t))$ will have a value outside the shaded area.

Proposition 4 below shows that the full information allocation of risks is obtainable using the no-claims discount strategy as $T \longrightarrow \infty$ and as long as the agents do not discount the future.[13]

Proposition 4 *Let i be such that:*

$$\alpha_i - E_i D(x) \geq 0 \text{ and } U(W - \alpha_i) \geq V(C^0 \mid p_i).$$

Then, when $T \longrightarrow \infty$, there exists a pair of optimal strategies for the individual of type i and the private monopoly having the following properties:

1) the strategy of the monopoly is a "no-claims discount strategy"; the strategy of insured i is to tell the truth about his type in period 1 and to buy insurance in each period;

2) the optimal corresponding payoffs are $\alpha_i^* - E_i D(x) = z_i^*$ and $U(W - \alpha_i^*) = V(C^0 \mid p_i), i = H, L$;

3) both strategies are enforceable.

Proof. See Dionne and Lasserre (1985). ∎

It is also possible to obtain a solution close to the public information allocation of risks in finite horizon insurance contracts. Dionne and Lasserre (1987)

[13] In general, introducing discounting in repeated games reduces the incentives of telling the truth and introduces inefficiency because players do not care for the future as they care for the current period. In other words, with discounting, players become less patient and cooperation becomes more difficult to obtain. See Sabourian (1989) and Abreu, Pearce and Stacchetti (1990) for detailed discussions of the discount factor issues in repeated contracts.

show how a trigger strategy with revisions[14] may establish the existence of an ε equilibrium. This concept of ε equilibrium is due to Radner (1981) and was also developed in the moral hazard context. Extending the definition to the adverse selection problem, Dionne and Lasserre (1987) defined an ε equilibrium as a triplet of strategies (principal, low-risk individual, high-risk individual) such that, under these strategies, the expected utility of any one agent is at least equal to his expected utility under public information less epsilon. In fact, the expected utility of the high-risk individual is that of the full information equilibrium.

As for the case of an infinite number of periods,[15] Dionne and Lasserre (1987) showed that it is in the interest of the monopolist (which obtains higher profits) to seek risk revelation by the insured rather than simply use the ex-post statistical instrument to discriminate between low-risk and high-risk agents. In other words, their second main result shows that it is optimal to use statistical tools not only to adjust, ex-post, insurance premiums according to past experience, but also, to provide an incentive for the insured to announce, ex- ante, the true class of risk he represents. Finally, they conclude that a multi-period contract with announcement dominates a repetition of one-period self-selection mechanisms (Stiglitz, 1977) when the number of periods is sufficiently large and there is no discounting. This result contrasts with those in the economic literature where it is shown that the welfare under full commitment is equal to that corresponding to a repetition of one-period contracts. Here, a multiperiod contract introduces a supplementary instrument (experience rating) that increases efficiency (Dionne and Doherty, 1994; Dionne and Fluet, 2000).

Another characteristic of Dionne and Lasserre's (1987) model is that low-risk agents do not have complete insurance coverage when the number of periods is finite; they chose not to insure if they are unlucky enough to be considered as high-risk individuals. However, they always choose to be insured in the first period and most of them obtain full insurance in each period. Finally, it must be pointed out that the introduction of a continuum of agent types does not create any difficulty in the sense that full separation of risks is obtained without any additional condition.

[14] Radner's (1981) contribution does not allow for revisions after the initial trigger. However, revisions were always present in infinite horizon models [Rubinstein and Yaari (1983), Dionne (1983), Radner (1985), Dionne and Lasserre (1985)]. A trigger strategy without revision consists in offering a premium corresponding to a risk declaration as long as the average loss is less than the reasonable average loss corresponding to the declaration. If that condition is not met, a penalty premium is offered for the remaining number of periods. With revisions, the initial policy can be reinstate.

[15] See also Gal and Landsberger (1988) on small sample properties of experience rating insurance contracts in the presence of adverse selection. In their model, all insureds buy the same contracts, and experience is considered in the premium structure only. They show that the monopoly's expected profits are higher if based on contracts that take advantage of longer experience. Fluet (1998) shows how a result similar to Dionne and Lasserre (1985) can be obtained in a one-period contract with fleet of vehicles.

In Dionne (1983) and Dionne and Lasserre (1985) there is no incentive for accident underreporting at equilibrium because there is no benefit associated with underreporting. When the true classes of risk are announced, insureds cannot obtain any premium reduction by underreporting accidents. When the number of periods is finite, matters are less simple because each period matters. In some circumstances, the insured has to evaluate the trade-off between increased premiums in the future and no coverage in the present. This is true even when the contract involves full commitment as in Dionne and Lasserre (1987). For example, the unlucky good risk may prefer to receive no insurance coverage during a particular period to pass a trigger date and have the opportunity to pay the full information premium as long as his average loss is less than the reasonable average loss corresponding to his class of risk.

We now address the incentive for policyholders to underreport accidents. The benefits of underreporting can be shown to be nil in a two-period model with full commitment and no statistical instrument when the contract cannot be renegotiated over time. To see this, let us go back to the two-period model presented earlier (Cooper and Hayes, 1987) and assume that accidents are now private information. When there is ex ante full commitment by the two parties to the contract one can write a contract where the net benefit to any type of agent from underreporting is zero. High-risk individuals have full insurance and no experience rating at equilibrium and low-risk individuals have the same level of expected utility whatever the accident reporting at the end of the second period. However, private information about accidents reduces insurers' profits compared with the situation where accidents are public information.

In all the preceding discussions it was assumed that the insurer can precommit to the contract over time. It was shown that an optimal contract under full commitment can be interpreted as a single transaction where the incentive constraints are modified to improve insurance possibilities for the low-risk individuals and to increase profits. Because there is full commitment and no renegotiation, accident histories are uninformative on the risk type. This form of commitment is optimal in Dionne (1983) and Dionne and Lasserre (1985): as in the Arrow-Debreu world, neither party to the contract can gain from renegotiation. However, in a finite horizon world, the role of renegotiation becomes important because self-selection in the first period implies that future contracts might be inefficient given the public information available after the initial period. When the good risks have completely revealed their type, it becomes advantageous to both parties − the insurer and the low-risk individuals − to renegotiate a full insurance contract for the second period. Although the possibilities of renegotiation improve welfare in the second period, they violate the ex-ante self-selection constraints and reduce ex-ante welfare. In other words, renegotiation limits the commitment possibilities and reduces parties' welfare ex-ante. For example, if the high-risk individuals anticipe renegotiation in the second period, they will not necessarily reveal their type in the first period (Dionne and Doherty, 1994).

Formally, we can interpret the possibility of renegotiation as adding a new constraint to the set of feasible contracts; unless parties can precommit to not renegotiate then contracts must be incentive compatible and renegotiation-proof (Dewatripont, 1989; Bolton, 1990; Rey and Salanié, 1996). To reduce the possibilities of renegotiation in the second period, the insurer that cannot commit to renegotiate after new information is revealed must set the contracts so that the insured type will not be perfectly known after the first period. This implies that the prospect of renegotiation reduces the speed of information revelation over time. In other words, the prospect of renegotiation can never improve the long term contract possibilities. In many circumstances, a sequence of one-period contracts will give the same outcome as a renegotiated-proof long term contract; in other circumstances a renegotiation-proof long-term contract dominates (when intertemporal and intertype transfers and experience rating are allowed, for example) (Hart and Tirole, 1988; Laffont-Tirole, 1987, 1990, 1993; Dionne and Doherty 1994; see the next section for more details).

Hosios and Peters (1989) present a formal model that rules out any renegotiation by assuming that only one-period contracts are enforceable.[16] They also discuss the possibility of renegotiation in the second period when this renegotiation is beneficial to both parties. Although they cannot show the nature of the equilibrium under this alternative formally, they obtain interesting qualitative results. For example, when the equilibrium contract corresponds to incomplete risk revelation in the first period, the seller offers, in the second period, a choice of contract that depends on the experience of the first period. Therefore accident underreporting is possible without commitment and renegotiation. This result is similar to that obtained in their formal model where they ruled out any form of commitment for contracts that last for more than one period. Only one-period contracts are enforceable. They show the following results.[17]

Proposition 5 *In absence of any form of commitment from both parties to the contract:*

1) Without discounting, separating equilibria do not exist; only pooling and semi-separating equilibria are possible.

2) Accident underreporting can now affect the seller's posterior beliefs about risk types and insurance buyers may fail to report accidents to avoid premium increases.

[16] On limited commitment see also Freixas, Guesnerie and Tirole (1985), Laffont and Tirole (1987) and Dionne and Fluet (2000).

[17] However, separating equilibria are possible with discounting because future considerations are less relevant. In a model with commitment and renegotiation, Dionne and Doherty (1994) obtain a similar result; when the discount factor is very low a separating equilibrium is always optimal in a two-period framework. Intuitively, low discount factors reduce the efficiency of using intertemporal transfers or rents to increase the optimal insurance coverage of the low-risk individuals by pooling in the first period. See Laffont and Tirole (1993) for a general discussion on the effect of discounting on optimal solutions in procurement when there is no uncertainty. See Dionne and Fluet (2000) for a demonstration that full pooling can be an optimal solution when the discount factor is sufficiently high and when there is no commitment. This result is due to the fact that, under no-commitment, the possibilities of rent transfers between the periods are limited.

Proof. See Hosios and Peters (1989). ■

This result implies that the insurer does not have full information on the risk types at the end of the first period; therefore, accidents reports become informative on the risk type contrary to the Cooper and Hayes model. However, the authors did not discuss the optimality of such two-period contract. It is not clear that a sequence of one-period contracts with separating equilibrium does not dominate their sequence of contracts.

4 Competitive contracts

We now introduce a competitive context. Competition raises many new issues in both static and dynamic environments. The two main issues that will be discussed here are 1) the choice of an adequate equilibrium concept and the study of its existence and efficiency properties, and 2) the nature of information between competitive insurers (and consequently the role of government in facilitating the transmission of information between insurance market participants, particularly in long-term relationships).

It will be shown that many well-known and standard results are a function of the assumption on how the insurers share the information about both the individual's choice of contracts and accident experience.

In a first step, the situation where no asymmetric information affects the insurance market is presented as a benchmark. After that, issues raised by adverse selection problem and the remedies to circumvent it are discussed.

4.1 Public information about an individual's characteristics

In a competitive market where insurance firms are able to discriminate among the consumers according their riskiness, we would expect insureds to be offered a menu of policies with a complete coverage among which they choose the one that corresponds with their intrinsic risk. Indeed, under competition, firms are now constrained to earn zero expected profits. When information on individual risk characteristics is public, each firm knows the risk type of each individual. The optimal individual contract is the solution to:

Problem 2

$$\underset{\alpha_i,\beta_i,\lambda_i}{Max}\, p_i U(W-D+\beta_i)+(1-p_i)U(W-\alpha_i)+\lambda_i[(1-p_i)\alpha_i-p_i\beta_i],\ i=H,L$$

where $(1-p_i)\alpha_i = p_i\beta_i$ is the zero-profit constraint.

As for the monopoly case under public information, the solution to Problem 2 yields full insurance coverage for each type of risk. However, contrary to a monopoly, the optimal solutions C_H^* and C_L^* in Figure 3 correspond to levels of consumer welfare greater than in the no-insurance situation (C^0). As already pointed out, the monopoly solution under public information also yields full insurance coverage and does not introduce any distortion in risk allocation. The difference between the monopoly and competitive cases is that in the former, consumer surplus is extracted by the insurer, while in the latter it is retained by both types of policyholder.

Under competition, a zero-profit line passes through C^0 and represents the set of policies for which a type i consumer's expected costs are nil for insurers. The value of its slope is equal to the (absolute) ratio $\frac{1-p_i}{p_i}$. Each point on the segment $[C^0C_i^*]$ has the same expected wealth for an individual of type i than that corresponding to C^0. The full information solutions are obtained when the ratio of slopes of indifference curves is just equal to the ratio of the probability of not having an accident to that of having an accident. To sum up,

Proposition 6 *In an insurance world of public information about insureds' riskiness, a one-period optimal contract between any competitive firm on market and any individual of type i* ($i = H, L$) *is characterized by:*
a) full insurance coverage, $\beta_i^* = D - \alpha_i^*$
b) no firm makes a surplus, $\pi\left(C_i^* \mid p_i\right) = 0$
c) consumers receive a surplus $V\left(C_i^* \mid p_i\right) > V\left(C^0 \mid p_i\right)$.

Characteristic b) expresses the fact that premiums are set to marginal costs and characteristic c) explains why individual participation constraints (2) are automatically satisfied in a competitive context. Consequently, introducing competitive actuarial insurance eliminates the wealth variance at the same mean or corresponds to a *mean preserving contraction.*

Insert Figure 3 here.

Under perfect information, competition leads to one-period solutions that are *first-best efficient*. This result does not hold when we introduce asymmetric information.

4.2 Private information and single-period contracts

In the presence of adverse selection, the introduction of competition may lead to fundamental problems with the existence and the efficiency of an equilibrium. When insurance firms cannot distinguish among different risk types, they lose money by offering the set of full information contracts (C_H^*, C_L^*) described above, because both types will select C_L^* (the latter contract requires a premium lower than C_H^* and in counterpart, also fully covers the incurring losses). Each insurer will make losses because the average cost is greater than the premium of C_L^*, which is the expected cost of group L. Under asymmetric information, traditional full information competitive contracts are not adequate to allocate risk optimally. Consequently, many authors have investigated the role of sorting devices in a competitive environment to circumvent this problem of adverse selection. The first contributions on the subject in competitive markets are by Akerlof (1970), Spence (1974), Pauly (1974), Rothschild and Stiglitz (1976) and Wilson (1977). The literature on competitive markets is now very large; it is not our intention here to review all contributions. Our selection of models was based on criteria that will be identified and explained at an appropriate point.[18]

A first division that we can make is between models of signaling (informed agents move first) and of screening (uninformed agents move first) (Stiglitz and Weiss, 1984). Spence (1974) and Cho and Kreps (1987) models are of the first type and are mainly applied to labor markets in which the workers (informed agents) move first by choosing an education level (signal). Then employers bid for the services of the workers and the latter select the more preferred bids. Cho and Kreps (1987) present conditions under which this three-stage game generates a Riley (1979a) single-period separating equilibrium.[19] Without restrictions (or criteria such as those proposed by Cho and Kreps (1987)) on out-of-equilibrium beliefs, many equilibria arise simultaneously, which limit the explanatory power of the traditional signaling models considerably.[20]

Although it may be possible to find interpretations of the signaling models in insurance markets, it is generally accepted that the screening interpretation is more natural. Rothschild and Stiglitz (1976) and Wilson (1977) introduced insurance models with a screening behavior. In Rothschild and Stiglitz's model only a two-stage game is considered. First, the uninformed insurer offers a menu of contracts to the informed customers, who choose among the contracts in the second stage.

Let us start with Rothschild and Stiglitz's (1976) model in which the insurers set premia with constant marginal costs. Each insurer knows the proportions of good risks and bad risks in the market but has no information on an individual's type. Moreover, each insurer cannot, by assumption, buy insurance from many

[18] See Cresta (1984) and Eisen (1989) for other analyses of problems of equilibria with asymmetric information.

[19] A Riley or reactive equilibrium leads to the Rothschild-Stiglitz separating equilibrium regardless of the number of individuals in each class of risk.

[20] Multiple equilibria are the rule in two-stage signaling models. However, when such equilibria are studied, the problem is to find at least one that is stable and dominates in terms of welfare. For a more detailed analysis of signaling models see the survey by Kreps (1989). On the notion of sequential equilibrium and on the importance of consistency in beliefs see Kreps and Wilson (1982).

insurers. Otherwise, the individual insurers would not be able to observe the individuals' total amount of insurance and would not be able to discriminate easily.[21] Each insurer observes all offers in the market. Finally, the insurer only needs to observe the claims he receives.[22]

Clearly, the properties of the equilibrium depend on how firms react to rival offers. In a competitive environment, it seems reasonable to assume that each insurer takes the actions of its rivals as given. The basic model by Rothschild and Stiglitz described in the following lines considers that firms adopt a (pure) Nash strategy. A menu of contracts in an insurance market is an equilibrium in the Rothschild and Stiglitz sense if a) no contract in the equilibrium set makes negative expected profits and b) there is no *other* contract added to the original set that earns positive expected profits.

Under this definition of the equilibrium, Rothschild and Stiglitz obtained three significant results:

Proposition 7 *When insurers follow a pure Cournot-Nash strategy in a two-stage screening game:*

a) A pooling equilibrium is not possible; the only possible equilibria are separating contracts.

b) A separating equilibrium may not exist.

c) The equilibrium, when it exists, is not necessarily a second-best optimum.

A pooling equilibrium is an equilibrium in which both types of risk buy the same contract. The publicly observable proportions of good-risk and bad-risk individuals are respectively q_L and q_H (with $q_H + q_L = 1$) and the average probability of having an accident is $\overline{p}$. This corresponds to line C^0F in Figure 4a. To see why the Nash definition of equilibrium is not compatible with a pooling contract, assume that C_1 in the figure is a pooling equilibrium contract for a given insurer. By definition, it corresponds to zero aggregate expected profits; otherwise, another insurer in the market will offer another pooling contract. Because of the relative slopes of the risk type indifference curves, there always exists a contract C_2 that will be preferred to contract C_1 by the low-risk individuals. The existence of contract C_2 contradicts the above definition of a Nash equilibrium. Consequently, if there exists an equilibrium, it has to be a separating one in which different risk-type consumers receive different insurance contracts.

[21] Jaynes (1978) and Hellwig (1988) analyze the consequences of relaxing this assumption. Specifically, they specify the conditions under which an equilibrium exists when the sharing of information about customers is treated endogenously as part of the game among firms. They also contend that it is possible to overcome Rothschild-Stiglitz's existence problem of an equilibrium if insureds cannot buy more than one contract. Finally, Hellwig (1988) maintains that the resulting equilibrium is more akin to the Wilson anticipatory equilibrium than to the competitive Nash equilibrium.

[22] This is a consequence of the exclusivity assumption. Because we consider static contracts, observing accidents or claims does not matter. This conclusion will not necessarily be true in dynamic models.

Insert Figure 4a here.
Insert Figure 4b here.

As for the monopoly case, the formal solution is obtained by adding to Problem 2 one self-selection constraint (3) that guarantees that individual i prefers C_i to C_j. By a similar argumentation to the one used in the determination of the optimal solution in the monopoly situation, it can be shown that only the self-selection constraint of the H risk type is binding at full insurance. Again the profit constraint is binding on each type so the problem is limited to finding an optimal contract to the low-risk individual because that of the high-risk individual corresponds to the full information case ($\alpha_H^{**} = \alpha_H^* = D - \beta_H^*$):

Problem 3

$$\underset{\alpha_L, \beta_L, \lambda_L, \lambda_{HL}}{Max} p_L U(W - D + \beta_L) + (1 - p_L)U(W - \alpha_L)$$

subject to the zero-profit constraint

$$(1 - p_L)\alpha_L = p_L \beta_L$$

and the self-selection constraint

$$U(W - \alpha_H^{**}) = p_H U(W - D + \beta_L) + (1 - p_H)U(W - \alpha_L).$$

At equilibrium, high-risk individuals receive full insurance because the low-risk self-selection constraint is not binding. The solution of Problem 3 implies that the low-risk type receives less than full insurance.[23] We can summarize the description of the separating equilibrium with the following proposition:

Proposition 8 *In the presence of private information, an optimal menu of separating one-period contracts between a competitive insurer and individuals of types H and L has the following characteristics:*
a) $\beta_H^{**} = D - \alpha_H^{**}$; $\beta_L^{**} < D - \alpha_L^{**}$
b) $V(C_i^{**} \mid p_i) > V(C^0 \mid p_i) \quad i = H, L$
c) $V(C_H^{**} \mid p_H) = V(C_L^{**} \mid p_H); \quad V(C_L^{**} \mid p_L) > V(C_H^{**} \mid p_L)$.

Graphically, C_H^{**} and C_L^{**} in Figure 4b correspond to a separating equilibrium. In equilibrium, high-risk individuals buy full insurance (C_H^{**}), while

[23] Partial coverage is generally interpreted as a monetary deductible. However, in many insurance markets the insurance coverage is excluded during a probationary period that can be interpreted as a sorting device. Fluet (1992) analyzed the selection of an optimal time-deductible in the presence of adverse selection.

low-risk individuals get only partial insurance C_L^{**}. [24] Each firm earns zero expected profit on each contract. This equilibrium has the advantage for the low-risk agents that their equilibrium premium corresponds to their actuarial risk and does not contain any subsidy to the high-risk individuals. However, a cost is borne by low-risk insureds in that their equilibrium contract delivers only partial insurance compared with full insurance in the full information case. Only high-risk individuals receive the first-best allocation. Finally, the separating equilibrium is not necessarily second-best optimal when it is possible to improve the welfare of individuals in each class of risk. We will revisit this issue.

The second important result from Rothschild and Stiglitz is that there are conditions under which a separating equilibrium does not exist. In general, there is no equilibrium if the costs of pooling are low for the low-risk individuals (few high-risk individuals or low q_H, which is not the case in Figure 4b becaue the line C^0F' corresponds to a value of q_H higher than the critical level q_H^{RS} permitting separating equilibria) or if the costs of separating are high (structure of preference). In the former case, given the separating contracts, the cost of sorting (partial insurance) exceeds the benefits (no subsidy) when profitable pooling opportunities exist. As already shown, however, a pooling contract cannot be an equilibrium. This negative result has prompted further theoretical investigations given that many insurance markets function even in the presence of adverse selection.

One extension of the existence of an equilibrium is to consider a mixed strategy in which an insurer's strategy is a probability distribution over a pair of contracts. Rosenthal and Weiss (1984) show that a separating Nash equilibrium always exists when the insurers adopt this strategy. However, it is not clear that such a strategy has any particular economic interpretation in insurance markets unlike in many other markets.[25] Another extension is to introduce a three-stage game in which the insurer may reject in the third stage the insured's contract choice made in the second stage. Hellwig (1986, 1987) shows that a pooling contract may correspond to a sequential equilibrium of the three-stage game or it can never be upset by a separating contract whenever pooling is Pareto preferred. Contrary to the Rothschild and Stiglitz two-stage model, the three-stage game always has a sequential equilibrium in pure strategies. The most plausible sequential equilibrium is pooling rather than sorting, while in a three-stage game in signaling models (Cho and Kreps, 1987) it is the pooling rather

[24] On the relationship between the coverage obtained by a low-risk individual under monopoly compared to that under the pure Nash competitive equilibrium, see Dahlby (1987). It is shown, for example, that under constant absolute risk aversion, the coverage obtained by a low-risk individual under monopoly is greater than, equal to, or less than that obtained under competition because the monopolist's expected profit on a policy purchased by low-risk individuals is greater than, equal to, or less than its expected profit on the policy purchased by high-risk individuals.

[25] See also Dasgupta and Maskin (1986) and Rothschild and Stiglitz (1997). On randomization to improve market functioning in the presence of adverse selection see Garella (1989) and Arnott and Stiglitz (1988).

the separating equilibria that lack robustness. As pointed out by Hellwig (1987), the conclusions are very sensitive to the details of game specification.[26]

Another type of extension that permits equilibria is to allow firms to consider other firms' behavior or reactions in their strategies and then to abandon the Nash strategy in the two-stage game. For example, Wilson (1977) proposes an anticipatory equilibrium concept where firms drop policies so that those remaining (after other firms anticipated reactions) at least break even. By definition, a Wilson equilibrium exists if no insurer can offer a policy such that this new policy 1) yields nonnegative profits and 2) remains profitable after other insurers have withdrawn all unprofitable policies in reaction to the offer. The resulting equilibrium (pooling or separation) always exists. A Wilson equilibrium corresponds to the Nash equilibrium when a separating equilibrium exists; otherwise, it is a pooling equilibrium such as C_1 in Figure 4a.[27] Finally, we may consider the Riley (1979) reactive equilibrium where competitive firms add new contracts as reaction to entrants. This equilibrium always corresponds to separating contracts.

Wilson also considers subsidization between policies, but Miyazaki (1977) and Spence (1977) develop the idea more fully. They show how to improve welfare of both classes of risk (or of all n classes of risk; Spence, 1977) with the low-risk class subsidizing the high-risk class. Spence shows that, in a model in which firms react (in the sense of Wilson) by dropping loss-making policies, an equilibrium always exists. In all the above models, each of the contracts in the menu is defined to permit the low-risk policyholders to signal their true risk. The resulting equilibrium is a break-even portfolio of separating contracts, and exists regardless of the relative value of q_H. The separating solution has no subsidy between policies when $q_H \geq q_H^{WMS}$. More formally we have

Proposition 9 *A Wilson-Miyazaki-Spence (WMS) equilibrium exists regardless of the value of q_H. When $q_H \geq q_H^{WMS}$, the WMS equilibrium corresponds to the Rothschild-Stiglitz equilibrium.*

One such equilibrium (C_3, C_4) is presented in Figure 5 for the case of two risk classes with cross-subsidization from the low to the high-risk group. The curve denoted by *frontier* in Figure 5 is the zero aggregate transfers locus defined such that the contract pairs yield balanced transfers between the risk-types, and the subset (C_3, Z) in bold is the set of contracts for the low-risk individuals that are second-best efficient. The derivation of the optimal contracts with transfers is obtained by maximizing the following program:

[26] See also Fagart (1996a) for another specification of the game. She extends the work of Rothschild and Stiglitz. Her paper presents a game where two principals compete for an agent, when the agent has private information. By considering a certain type of uncertainty, competition in markets with asymmetric information does not always imply a loss of efficiency.

[27] See Grossman (1979) for an analysis of the Wilson type equilibrium with reactions of insureds rather than reactions of sellers.

Problem 4

$$\underset{\alpha_L,\beta_L,t,s}{Max}\, p_L U(W - D + \beta_L - t) + (1 - p_L)U(W - \alpha_L - t)$$

subject to the non-negative aggregate profit constraint

$$q_L t \geq q_H s$$

the zero-profit constraint before cross-subsidization

$$(1 - p_L)\alpha_L \geq p_L \beta_L$$

the self-selection constraint

$$U(W - \alpha_H^{**} + s) \geq p_H U(W - D + \beta_L - t) + (1 - p_H)U(W - \alpha_L - t)$$

the positivity constraint

$$s \geq 0$$

where s and t are for subsidy and tax respectively.

When the positivity constraint is binding, (C_3, C_4) corresponds to the Rothschild-Stiglitz contracts (C_H^{**}, C_L^{**}) without cross-subsidization. When the positivity constraint holds with a strict inequality, the equilibrium involves subsidization from low-risks to high-risks.[28]

The Wilson-Miyazaki-Spence (WMS) equilibrium (C_3, C_4) solves this program if (C_3, C_4) is second-best efficient in the sense of Harris and Townsend (1981). An allocation is second-best efficient if it is Pareto-optimal within the set of allocations that are feasible and the zero-profit constraint on the portfolio.[29] In competitive insurance markets, Crocker and Snow (1985) prove the following proposition, which can be seen as an analogue with the welfare first theorem (Henriet and Rochet, 1991):

Proposition 10 *A Wilson-Miyazaki-Spence (WMS) equilibrium is second-best efficient for all values of* q_H.

Proof. See Crocker and Snow (1985).

Subsidization between different risk classes is of special interest for characterizing the notion of second-best optimality and simultaneously the shape of optimal redistribution in insurance markets. Indeed, the optimal allocation on these markets (given the incentive constraints imposed by adverse selection) involves cross-subsidization between risk types. Thus, the *second-best efficient*

[28] For a proof that the equilibrium can never imply subsidization from high-risk individuals to low-risk individuals, see Crocker and Snow (1985).

[29] See Crocker and Snow (1985,1986) for more details. See Lacker and Weinberg (1999) for a proof that a Wilson allocation is coalition proof.

contracts resulting from this redistribution are described for low-risk individuals by the frontier in bold in Figure 5 (see Crocker and Snow, 1985). It can be shown that a Rothschild and Stiglitz equilibrium is second-best efficient if and only if q_H is higher than some critical value q_H^{WMS}, [30] which is itself higher than the critical value q_H^{RS} permitting the existence of a Nash equilibrium. Then, as mentioned, a Nash equilibrium is not necessarily efficient. The same conclusion applies to the Riley equilibrium because it sustains the Rothschild and Stiglitz solution, regardless of the value of q_H. In the income-states space, the shape of this curve can be convex as shown in Figure 5 (Dionne and Fombaron, 1996) under some unrestrictive assumptions about utility functions. More precisely, some conditions about risk aversion and prudence indexes guarantee the strict convexity of the efficiency frontier: the insurance coverage β_L offered to low-risks is a convex function in the subscribed premium α_L. High-risks are offered a coverage β_H which is a linear function in the premium α_H. It is shown by Dionne and Fombaron (1996) that this frontier can never be strictly concave under risk aversion. At least a portion of the frontier must be convex.[31]

Insert Figure 5 here.

Despite the presence of non-convexities of this locus in the income-states space, the correspondence between optimality and market equilibrium is maintained (see Prescott and Townsend, 1984, for a general proof of this assertion, and Henriet and Rochet, 1986, for an analysis in an insurance context). Consequently, the conventional question about the possibility of achieving a second-best efficient allocation by a decentralized market does not arise. An analogue to the second optimality theorem holds for an informationally constrained insurance market (Henriet and Rochet, 1986): even though government cannot a priori impose risk-discriminating taxes on individuals, it can impose a tax on their contracts and thus generate the same effect as if taxing individuals directly (Crocker and Snow, 1986).

Another attempt of introducing some form of dynamics in a non-cooperative model was made by Asheim and Nilssen (1996). Their model allows insurers to make a second move after having observed the contracts that their applicants initially sign, under the restriction that this renegotiation is non-discriminating (a contract menu offered by an insurer to one of its customers has to be offered to all its customers). Such non-discriminating renegotiation weakens the profitability of cream-skimming, to the extent that the unique (renegotiation-proof) equilibrium of the game is the WMS outcome.

[30] On the relationship between risk aversion and the critical proportion of high-risks so that the Rothschild/Stiglitz equilibrium is second-best efficient, see Crocker and Snow (2008). Their analysis shows that, when the utility function U becomes more risk averse, the critical value of high-risks increases if U exhibits nonincreasing absolute risk aversion.

[31] For more general utility functions, the curvature can be both convex and concave in the premium but must necessarily be convex around the full insurance allocation under risk aversion. For more details, see Pannequin (1992) and Dionne and Fombaron (1996).

In contrast, Inderst and Wambach (2001) solve the non-existence problem by considering firms which face capacity constraints (due to limited capital for instance). Under the constraint that no single insurer can serve the whole market (implying that a deviating firm with a pooling contract cannot be assured of a fair risk selection), each customer receives in equilibrium his Rothschild-Stiglitz contract. However, the equilibrium is not unique. The same conclusion prevails if, instead of capacity constraints, the authors assume that firms face the risk of bankruptcy (or they are submitted to solvency regulation). In both contexts, more customers can make each policy less attractive to a potential insured.

Finally, as we will see in Section 7, another possibility to deal with equilibrium issues is to use risk categorization (see Crocker and Snow, 2012, and Dionne and Rothschild, 2011, for more detailed analyzes).

4.3 Multiperiod contracts and competition

The aspect of competition raises new technical and economic issues on multiperiod contracting. Indeed, the value of information affects the process of decision-making in a competitive insurance market considerably. Let us begin with Cooper and Hayes' (1987) analysis of two-period contracts with full commitment on the supply side.

4.3.1 Full commitment

Cooper and Hayes use the Nash equilibrium concept in a two-period game where the equilibrium must be separating.[32] They consider two different behaviors related to commitment on the demand side. First, both insurers and insureds commit themselves to the two-period contracts (without possibility of renegotiation) and second, the insurers commit to a two-period contract but the contract is not binding on insureds. We will refer these respective situations as contracts with *full commitment* and *with semi-commitment*, respectively. When competitive firms can bind agents to the two periods, it is easy to show that, in the separating solution, the contracts offered are qualitatively identical to that of the monopoly solution with commitment: high-risk agents receive full insurance at an actuarial price in each period while low-risk agents face price and quantity adjustments in the second period. Suppose that q_H is such that a Rothschild and Stiglitz equilibrium is second-best efficient. It can be shown that the two-period contract with full commitment dominates a repetition of Rothschild and Stiglitz contracts without memory. As for the monopoly case, this result is due

[32] In other words, they implicitly assume that the conditions to obtain a Nash separating equilibrium in a single-period contract are sufficient for an equilibrium to exist in their two-period model.

to the memory effect (see Chiappori *et al*, 1994 for a survey on the memory effect).

When the authors relax the strong commitment assumption in favor of semi-commitment, and consider that insureds can costlessly switch to other firms in the second period, they show that the presence of second-period competition limits but does not destroy the use of experience rating as a sorting device. The difference between the results with full commitment and semi-commitment is explained by the fact that the punishment possibilities for period-one accidents are reduced by the presence of other firms that offer single-period contracts in the second period.

The semi-commitment result was obtained by assuming that, in the second period, entrant firms offer single-period contracts without any knowledge of insureds' accident histories or their choice of contract in the first period. The new firms' optimal behavior is to offer Rothschild and Stiglitz separating contracts[33] to the market.[34] By taking this decision as given, the design of the optimal two-period contract by competitive firms with semi-commitment has to take into account at least one supplementary binding constraint (no-switching constraint) that reduces social welfare compared to full commitment. The formal problem consists of maximizing the low-risks' two-period expected utility by choosing C_H^2 and C_L^2 under the incentive compatibility constraints, the nonnegative intertemporal expected profit constraint and the *no-switching* constraints:

Problem 5

$$\max_{C_H^2, C_L^2} V(C_L^2 \mid p_L)$$

$$s.t.$$

$$V(C_i^2 \mid p_i) \geq V(C_j^2 \mid p_i) \qquad i, j = H, L,\ i \neq j$$

$$\pi(C_L \mid p_L) + [p_L \pi(C_{La} \mid p_L) + (1 - p_L)\pi(C_{Ln} \mid p_L)] \geq 0$$

$$V(C_{is} \mid p_i) \geq V(C_i^* \mid p_i) \qquad i = H, L \qquad s = a, n.$$

By the constraint of non-negative expected profits earned on the low-risks' multiperiod contract, this model rules out the possibility of insurers'offering cross-subsidizations between the low and the high-risks (and circumvent any problems of inexistence of Nash equilibrium). Because this constraint is obviously binding at the optimum, Cooper and Hayes allow only intertemporal transfers.

Using the above model, Cooper and Hayes proved the following results, summarized by Proposition 11:

[33] The Rothschild and Stiglitz contracts are not necessarily the best policy rival firms can offer. Assuming that outside options are fixed is restrictive. This issue is discussed in the next section.

[34] The authors limited their focus to separating solutions.

Proposition 11 *Under the assumption that a Nash equilibrium exists, the optimal two-period contract with semi-commitment is characterized by the following properties:*

1) High-risk individuals obtain full insurance coverage and are not experience rated: $V(C^*_{Ha} \mid p_H) = V(C^*_{Hn} \mid p_H) = V(C^*_H \mid p_H) = U(W - \alpha^*_H)$;

while low-risk individuals receive only partial insurance coverage and are experience rated: $V(C^*_{La} \mid p_L) < V(C^*_{Ln} \mid p_L)$;

2) High-risk agents are indifferent between their contract and that intended for low-risks, while low-risks strictly prefer their contract:
$V(C^{2*}_H \mid p_H) = V(C^{2*}_L \mid p_H)$ *and* $V(C^{2*}_L \mid p_L) > V(C^{2*}_H \mid p_L)$;

3) Both high and low-risks obtain a consumer surplus:
$V(C^{2*}_i \mid p_i) > 2V(C^0 \mid p_i)$, $i = H, L$;

4) The pattern of temporal profits is highballing on low-risks' contracts and flat on high-risks' ones:
$\pi(C^*_L \mid p_L) \geq 0 \geq [p_L\pi(C^*_{La} \mid p_L) + (1-p_L)\pi(C^*_{Ln} \mid p_L)]$
and $\pi(C^*_H \mid p_H) = \pi(C^*_{Ha} \mid p_H) = \pi(C^*_{Hn} \mid p_H) = 0.$

In other words, the presence of competition, combined with the agents' inability to enforce binding multiperiod contracts, reduces the usefulness of long term contracts as a sorting device and consequently, the potential gains of long term relationships. This conclusion is similar to that obtained in the monopoly case (in which the principal cannot commit on nonrenegotiation) because the no-switching constraints imposed by competition can be reinterpreted as rationality constraints in a monopolistic situation.

The fourth property in Proposition 11 means that, at equilibrium, firms make positive expected profits on old low-risk insureds (by earning positive profits on the low-risks' first period contract) and expected losses on new low-risk insureds (by making losses on the second-period contract of low-risks who suffered a first-period loss, greater than positive profits on the low-risks' contract corresponding to the no-loss state in the first period). In aggregate, expected two-period profits from low-risks are zero.

As in the monopoly situation, all the consumers self-select in the first period and only low-risk insureds are offered an experience-rated contract in the second period based on their accident history.[35] This arrangement provides an appropriate bonus for accident-free experience and ensures that low-risks who suffer an accident remain with the firm.[36] This temporal profit pattern, also called *highballing* by D'Arcy and Doherty (1990), was shown to contrast with

[35] But not on their contract choice.

[36] The corresponding expected utility of the low-risk individual who did not have an accident in the first period is strictly greater at equilibrium than that corresponding to the entrant one-period contract.

the *lowballing* predicted in dynamic models without commitment. In particular, D'Arcy and Doherty compare the results obtained by Cooper and Hayes under the full commitment assumption with those of the *lowballing* predicted by Kunreuther and Pauly (1985) in a price competition. With similar assumptions on commitment, Nilssen (1990) also obtains a *lowballing* prediction in the classic situation of competition in price-quantity contracts.

Although Cooper and Hayes were the first to consider a repeated insurance problem with adverse selection and full commitment, some assumptions are not realistic, namely the insurers' ability to commit to long term relationships. Indeed, because the first-period contract choices do reveal the individual risks, the initial agreement on the second-period contract could be renegotiated at the beginning of the second period (under full information) in a way that would improve the welfare of both parties. Consequently, the two-period contract with full commitment is Pareto-inefficient *ex post*, i.e. relative to the information acquired by insurers at that time. Recent articles in the literature have investigated other concepts of relationships between an insurer and its insureds, involving limited commitment: the *no-commitment* assumption represents the polar case of the full commitment situation (section 4.3.2) and the *commitment with renegotiation* appears to be an intermediate case between full commitment and no-commitment (section 4.3.3).

As a result of the strong hypotheses above, the literature obtains the same predictions as in the static model about the equilibrium existence issue[37] and about the self-selection principle. These predictions do not hold any longer when we assume limited commitment and/or endogenous outside options.

4.3.2 No-commitment

In this section, the attention is paid to competitive insurance models in which the contractual parties can commit only to one-period incentive schemes, i.e. where insurers can write short-term contracts, but not long-term contracts. The no-commitment is bilateral in the sense that each insured can switch to another company in period two if he decides to do so. Such situations are particularly relevant in liability insurance (automobile or health insurance for example) where long-term contracts are rarely signed. Despite this inability to commit, both parties can sign a first-period contract that should be followed by second-period contracts that are conditionally optimal and experience-rated. This sequence of one-period contracts gives rise to a level of intertemporal welfare lower than that of full commitment, but, in some cases, higher than in a repetition of static contracts without memory.

[37] Cross-subsidizations between risk types remain inconsistent with equilibrium, such that problems for equilibrium existence also exist in a multiperiod context.

Kunreuther and Pauly (1985) were the first to study a multiperiod model without commitment in a competitive insurance context. However, their investigation is not really an extension of the Rothschild and Stiglitz' analysis because the authors consider competition in price and not in price-quantity.[38] They argue that insurers are unable to write exclusive contracts; instead they propose that insurers offer pure price contracts only (Pauly, 1974). They also assume that consumers are myopic: they choose the firm that makes the most attractive offer in the current period. At the other extreme, the classic dynamic literature supposes that individuals have perfect foresight in the sense that they maximize the discounted expected utility over the planning horizon.

Despite the major difference in the assumption about the way insurers compete, their model leads to the same lowballing prediction as other studies, like the one developed by Nilssen (1990), using the basic framework of the Rothschild and Stiglitz model where firms compete by offering price-quantity contracts. Insurers make expected losses in the first period and earn expected profits on the policies they renew. This prediction of lock-in is due to the assumption that insurers do not write long-term contracts while, as we saw, Cooper and Hayes permitted long-term contracting. In Nilssen's model, an important result is to show that pooling contracts could emerge in dynamic equilibrium (pooling on the new insureds) when the ability to commit lacks in the relationships, which makes the cross-subsidizations compatible with equilibrium. Contrary to the Kunreuther and Pauly model, the absence of commitment does not rule out separation.

The program presented below (Problem 6) includes Nilssen's model as a particular case (more precisely, for both $x_H = 1, x_L = 0$ where $x_i \in [0;1]$ measures the level of separation of type i). In other words, we introduce strategies played by insureds in Nilssen's model, such that at equilibrium, semi-pooling can emerge in the first period, followed by separation in the second period. This technical process, also labeled *randomization*, serves to defer the revelation of information and thus encourages compliance with sequential optimality constraints required by models with limited commitment. It was used by Hosios and Peters (1989), as we saw, in a monopoly situation without commitment and by Dionne and Doherty (1994) in a competitive context with commitment and renegotiation.[39]

Solving the two-period model without commitment requires the use of the concept of Nash Perfect Bayesian Equilibrium (NPBE).[40] Given this notion of sequential equilibrium, we work backwards and begin by providing a description of the Nash equilibrium in the last period.

[38] They let insurers offer contracts specifying a per-unit premium for a given amount of coverage.

[39] On limited commitment and randomized strategies, see also Dionne and Fluet (2000).

[40] This concept implies that the set of strategies satisfies sequential rationality given the system of beliefs, and that the system of beliefs is obtained from both strategies and observed actions using Bayes' rule whenever possible.

In period 2, $\widehat{C_{ia}}$ and $\widehat{C_{in}}$ solve the following subprograms imposed by the constraints of sequential optimality, for $s \in \{a, n\}$ respectively where a means accident in the first period and n means no-accident:

Problem 6

$$\widehat{C_{is}} \in \arg\max \sum_{i=H,L} q_{is}(x_i)\pi(C_{is} \mid p_i)$$
$$s.t.$$
$$V(C_{is} \mid p_i) \geq V(C_{js} \mid p_i) \qquad i,j = H,L, \quad i \neq j$$
$$V(C_{is} \mid p_i) \geq V(C_i^{RS} \mid p_i) \qquad i = H,L$$

where posterior beliefs[41] are defined by

$$q_{ia}(x_i) = \frac{q_i p_i x_i}{\sum\limits_{k=H,L} q_k p_k x_k}$$
$$\text{and } q_{in}(x_i) = \frac{q_i(1-p_i)x_i}{\sum\limits_{k=H,L} q_k(1-p_k)x_k},\ i = H,L.$$

For given beliefs, the second-period optimization subprogram is similar, in some sense, to a single-period monopoly insurance model with adverse selection (Stiglitz 1977, in section 3.2) for a subgroup of insureds and where no-switching constraints correspond to usual participation constraints. In the absence of commitment and because of informational asymmetries between insurers, each informed firm can use its knowledge of its old insureds to earn positive profits in the second period. However, this profit is limited by the possibility that old insureds switch to another company at the beginning of the second period. Contrary to a rival company, a firm that proposes sets of contracts in the second period to its insureds can distinguish among accident-groups on the basis of past accident observations. Each company acquires over time an informational advantage relative to the rest of competing firms on the insurance market.

The PBE of the complete game is a sequence of one-period contracts $(C_i^*, C_{ia}^*, C_{in}^*)$ for every $i = H, L$, such that:

Problem 7

$$(C_i^*, C_{ia}^*, C_{in}^*) \in \underset{(C_i, C_{ia}, C_{in})}{\arg\max}\ V(C_L \mid p_L) + \delta[p_L V(\widehat{C_{La}} \mid p_L) + (1-p_L)V(\widehat{C_{Ln}} \mid p_L)]$$
$$s.t.$$
$$x_i(1+\delta)V(C_i^{RS}|p_i) + (1-x_i)[V(C_i|p_i) + \delta(p_i V(\widehat{C_{ia}}|p_i) + (1-p_i)V(\widehat{C_{in}}|p_i))]$$
$$\geq V(C_j|p_i) + \delta(p_i V(\widehat{C_{ja}}|p_i) + (1-p_i)V(\widehat{C_{jn}}|p_i))$$

[41] Put differently, $q_{ia}(x_i)$ and $q_{in}(x_i)$ are the probabilities at the beginning of the second period that, among the insureds having chosen the pooling contract in the first period, an insured belongs to the i-risk class if he has suffered a loss or no loss in the first period respectively.

$$\sum_{i=H,L} q_i(x_i)\pi(C_i|p_i) + \delta[\sum_{i=H,L} q_{ia}(x_i)\pi(\widehat{C_{ia}}|p_i) + \sum_{i=H,L} q_{in}(x_i)\pi(\widehat{C_{in}}|p_i)] \geq 0$$

where $\widehat{C_{La}}, \widehat{C_{Ln}}$ solve Problem 6 for $s = a, n$ respectively.

Problem 7 provides the predictions summarized in Proposition 12.

Proposition 12 *In the presence of private information, each company may increase the individuals welfare by offering two contracts, a sequence of one-period contracts and a multiperiod contract without commitment with the following characteristics:*

1) Both high and low-risk classes obtain partial insurance coverage in each period and are experience rated: $V(C^*_{ia} \mid p_i) \leq V(C^*_{in} \mid p_i),\ \ i = H, L;$

2) High-risk classes are indifferent between a mix of a sequence of Rothschild Stiglitz contracts and the multiperiod contract, also subscribed by low-risk individuals:
$x_H(1+\delta)V(C^{RS}_H \mid p_H) + (1-x_H)V(C^{2*}_H \mid p_H) = V(C^{2*}_L \mid p_H)$
and the low-risks strictly prefer the multiperiod contract:
$V(C^{2*}_L \mid p_L) > x_L(1+\delta)V(C^{RS}_L \mid p_L) + (1-x_L)V(C^{2*}_L \mid p_L)$, $x_L \in [0,1]$;

3) High and low-risk individuals obtain a consumer surplus:
$V(C^{2*}_i \mid p_i) > (1+\delta)V(C^0 \mid p_i),\ \ i = H, L;$

4) Aggregate expected profits earned on the multiperiod contract increase over time: $\sum\limits_{i=H,L} q_i(x_i)\pi(C^*_i \mid p_i) < \sum\limits_{i=H,L}\sum\limits_{s=a,n} q_{is}(x_i)\pi(C^*_{is} \mid p_i)$.

Concerning the existence property, it can be shown that a Nash Perfect Bayesian Equilibrium exists for some values of parameters (i.e. for every q_H such that $q_H \geq q^{NC}_H$ $(> q^{RS}_H)$ where NC is for no commitment). As a consequence, the existence property of equilibrium is guaranteed for a set of parameters smaller than in the static model. More importantly, this model exhibits a lowballing configuration of intertemporal profits (increasing profits over time; each firm earns a positive expected profit on its old customers because it controls information on past experience[42]), contrary to the highballing prediction resulting from models with full commitment.

Finally, particular attention could be paid to interfirm communication and the model could make the outside options endogenous to the information revealed over time. In Cooper and Hayes' and Nilssen's models and in most dynamic models, firms are supposed to offer the same contract to a new customer

[42] Cromb (1990) considered the effects of different precommitment assumptions between the parties to the contract on the value of accident history. Under fully binding contracts, the terms of the contract depend only on the number of accidents over a certain time horizon, while under other assumptions (partially binding and no binding) the timing of accidents becomes important.

(the outside option is C_i^{RS}), whatever his contractual path and his accident history. In other words, it is implicitly assumed that the information revealed by the accident records and by contractual choices does not become public.[43] However, this assumption is not very realistic with regard to the presence, in some countries, of a specific regulatory law that obliges insurers to make these data public.[44] This is the case in France and in most European countries for automobile insurance, where the free availability of accident records is a statutory situation. Consequently, models with endogenous outside options would be more appropriate to describe the functioning of the competitive insurance market in these countries. To evaluate the effects of a regulatory law about interfirm communication, let us consider the extreme situation in which insurers are constrained to make data records public, such that rival firms do have free access to all accident records. Formally, this amounts to replacing C_i^{RS} by C_i^{cc} in no-switching constraints of Problem 6 (C_i^{cc} is the best contract a rival uninformed company can offer to i-risk type at the beginning of period 2).

In other words, C_i^{cc} describes the switching opportunities of any insured i and depends on x_i). At one extreme case, when the first-period contracts are fully separating, the contract choice reveals individual risk-types to any insurer on the insurance market, and C_i^{cc} will be the first-best contract C_i^{FB}. If competing firms have identical knowledge about insureds risks over time, no experience rating is sustainable in equilibrium and allocative inefficiency results from dynamic contractual relationships. The "too large" amount of revealed information destroys efficiency and eliminates dynamic equilibria. In contrast, when rival firms do not have access to accident records, equilibrium involves experience-rating and dynamic contracts achieve second-best optimality, because informational asymmetries between competing firms make cross-subsidization compatible with the Nash equilibrium. As a consequence, insureds are always better off when accidents remain private information.[45] The next section is devoted to an analysis of multiperiod contracts under an intermediary level of commitment from insurers.

4.4 Commitment and renegotiation

Dionne and Doherty (1994) introduced the concept of renegotiation in long-term relationships in insurance markets. Here, the two-period contracts are considered where insureds can leave the relation at the end of the first period and the insurer is bound by a multiperiod agreement. It differs from Cooper and Hayes' model since the possibility of renegotiation. Indeed, insurers are allowed

[43] When an individual quits a company A and begins a new relationship with a company B, he is considered by the latter as a new customer on the insurance market.

[44] For a more detailed argumentation of information sharing, see Kunreuther and Pauly (1985), D'Arcy and Doherty (1990), and Dionne (2001).

[45] In a context of symmetric imperfect information (see section 7.3), de Garidel (2005) also finds that accident claims should not be shared by insurers.

to make a proposition of contract renegotiation with their insureds which can be accepted or rejected. In other words, parties cannot precommit to not make Pareto-improving changes based on information revealed at the end of the first period. As shown in Dionne and Doherty (1994), the Cooper and Hayes' solution is not renegotiation-proof. This means that sequential optimality fails because parties' objectives change over time. If renegotiation cannot be ruled out, the company and its insureds anticipate it, and this will change the nature of the contracts. Thus, to ensure robustness against renegotiation procedure described above, we must impose either the constraint of pooling in the first period or the constraint of full insurance for both types in the second period in addition to standard constraints in Cooper and Hayes' optimization program. The new program can be written as Problem 7 except for the second-period constraints imposed by sequential optimality. Indeed, renegotiation-proofness means that the second-period contracts are robust to Pareto-improving changes and not only for increasing the insurers' welfare. Consequently, second-period contracts cannot be solved as a subprogram that maximizes insurers' expected profits. In contrast, they must solve, in the last period, a standard competitive program that optimizes the low-risks welfare (in each group a and n). Moreover, no-switching constraints must appear in these subprograms in a similar way as in the model without commitment.

If we consider a general model in which all kinds of transfers are allowed (intertemporal and intertype transfers), problem 6 can be rewritten in the context of semi-commitment with renegotiation as follows:

Problem 8

$$\widehat{C_{is}} \in \arg\max V(C_{Ls} \mid p_L) \text{ for } s = a, n$$
$$s.t.$$
$$V(C_{is} \mid p_i) \geq V(C_{js} \mid p_i) \qquad i, j = H, L, \quad i \neq j$$
$$\sum_{i=H,L} q_{is}(x_i)\pi(C_{is} \mid p_i) \geq \overline{\pi}_s$$
$$V(C_{is} \mid p_i) \geq V(C_i^{RS} \mid p_i) \qquad i = H, L.$$

Dionne and Doherty (1994) first show that fully separating strategies, once made robust to renegotiation, degenerate to an outcome that amounts to that of a replication of single-period contracts in terms of welfare, when insureds are bound in relationships. If insureds are allowed to leave their company at the end of period 1, the program includes, in addition, no-switching constraints. As a result of this more constrained problem, the outcome will be worse in terms of welfare relative to a sequence of static contracts without memory. This negative result on separating contracts suggests efficiency will be attained by a partial revelation of information over time (as in the no-commitment model). Dionne and Doherty then show that the solution may involve semi-pooling in the first period followed by separated contracts. They argue that the equilibrium is fully separating when the discount factor is low and tends to a pooling for large discount factors. They also obtain a highballing configuration of intertemporal profits, contrary to the lowballing prediction resulting from models without commitment. Thus, commitment with renegotiation provides the same predictions as those in Proposition 12 except for the fourth result, which becomes: $\sum_{i=H,L} q_i(x_i)\pi(C_i^* \mid p_i) > \sum_{i=H,L}\sum_{s=a,n} q_{is}(x_i)\pi(C_{is}^* \mid p_i)$.

However, if a more general model is considered, in which outside options are endogenous (in which case C_i^{cc} replace C_i^{RS} in Problem 8, i=H,L), the configuration in equilibrium does not necessarily exhibit a decreasing profile of intertemporal profits for the company, meaning that models with commitment and renegotiation do not necessarily rule out the possibility of lock-in.[46] As in models without commitment, insureds are always better off when the information about accident records remains private, i.e. in a statutory situation where no regulatory law requires companies to make record data public.

Finally, the issue of consumer lock-in and the pattern of temporal profits should motivate researchers to undertake empirical investigations of the significance of adverse selection and of the testable predictions that permit discrimination between the competing models. To our knowledge, only two published studies have investigated these questions with multi-period data; their conclusions go in opposite directions. D'Arcy and Doherty (1990) found evidence of lowballing that supports the non-commitment assumption while Dionne and Doherty (1994) report that a significant group of insurers in California used highballing − a result that is more in line with some form of commitment. It is interesting to observe that this group of insurers attracts selective portfolios with disproportionate numbers of low-risks. This result reinforces the idea that some form of commitment introduces more efficiency and the fact that there is adverse selection in this market.

5 Moral hazard and adverse selection

Although in many situations principals face adverse selection and moral hazard problems simultaneously when they design contracts, these two types of asymmetric information have been given separate treatments so far in the economic

[46] However, it is possible to establish that a competitive insurance market always has an equilibrium, due to the compatibility of cross-subsidization with equilibrium, as opposed to the result in static models. The economic intuition is the following: an additional instrument can serve to make rival offers less attractive. It consists in informed insurers' offering unprofitable contracts in the second period. This instrument is possibly used in a case of commitment with renegotiation but cannot be enforced in no-commitment situations.

literature on risk-sharing agreements. Both information problems have been integrated into a single model where all the parties of the contract are risk neutral (Laffont and Tirole, 1986; Picard, 1987; Caillaud *et al*, 1988; Guesnerie *et al*, 1988). Although these models involve uncertainty, they are unable to explain arrangements where at least one party is risk averse. In particular they do not apply to insurance. More recently, some authors have attempted to integrate both information problems into a single model where the agent is risk averse.

As discussed by Dionne and Lasserre (1988) such an integration of both information problems is warranted on empirical grounds. Applied studies are still few in this area, but researchers will find it difficult to avoid considering both kinds of information asymmetry (see, however, Dionne, Michaud, and Dahchour, 2010).

5.1 Monopoly and multi-period contracts

Dionne and Lasserre (1988) show how it is possible to achieve a second-best allocation of risks when moral hazard and adverse selection problems exist simultaneously. While they draw heavily on the contributions of Rubinstein and Yaari (1983), Dionne (1983) and Dionne and Lasserre (1985), the integration of the two types of information problems is not a straightforward exercise. Given that an agent who has made a false announcement may now choose an action that is statistically compatible with his announcement, false announcements may go undetected. They propose a contract under which the agent cannot profit from this additional degree of freedom. Under a combination of moral hazard and adverse selection, several types of customers can adopt different care levels such that they have identical expected losses. When this happens, it is impossible to distinguish those who produce an efficient level of care from the others on the basis of average losses.

However, deviant behaviors can be detected by monitoring deviations from the mean. Thus the insurer's strategy can be written with more than one simple aggregate (as in Dionne and Lasserre, 1985, and Rubinstein and Yaari, 1983). In Dionne and Lasserre (1988) the principal has to monitor two aggregates, the average loss experienced by a given agent and its squared deviation from the mean. It was sufficient to get the desired result because in their model the information problem has only two dimensions. More generally, the insurer would have to monitor one moment of the distribution for each hidden dimension.

Combining moral hazard with adverse selection problems in models that use past experience might involve some synergetic effects. In the model presented in Dionne and Lasserre (1988), the same information required to eliminate either the moral hazard problem alone (Rubinstein and Yaari) or adverse selection alone (Dionne and Lasserre) is used to remove both problems simultaneously. A related subject concerns the efficient use of past information, and the allocation of instruments, toward the solution of each particular information problem. Self-selection mechanisms have long been proposed in response to adverse selection while nonlinear pricing was put forth as a solution to moral hazard. In one-period contracts both procedures used separately involve inefficiency (partial insurance) which can be reduced by the introduction of time in the contracts. Dionne and Lasserre show that self-selection may help solve both moral hazard problems and adverse selection problems. We will now discuss how the use of two instruments may improve resource allocation and welfare when both problems are present simultaneously in single-period competitive contracts.

In a static model which can be considered as a special case of the Dionne and Lasserre's (1988) model, Chassagnon (1994) studies the optimality of a one-period model when both problems are present simultaneously. Three results are of interest in this paper: 1) the Spence-Mirlees propriety is not always verified. Indifference curves may have more than one intersection point; 2) contrarily to the Stiglitz (1977) model where the low-risk individual may not have access to any insurance coverage, in Chassagnon's model, there are configurations (in particular, the configuration *du pas de danse,* 'dance step') where all agents obtain insurance; finally, 3) both types of agents may receive a positive rent according to their relative number in the economy.

The model is specific in the sense that the accident probabilities keep the same order when the effort level is the same. Suppose that there are only two levels of efforts that characterize the accident probabilities of type i: $\underline{p}_i < \overline{p}_i$, $i = H, L$. In Chassagnon's model, $\underline{p}_H > \underline{p}_L$ and $\overline{p}_H > \overline{p}_L$ while $\underline{p}_H$ can be lower than $\overline{p}_L$. In fact the effect of introducing moral hazard in the pure principal-agent model becomes interesting when the high-risk individual is more efficient at care activities than the low-risk individual. Otherwise, when $\underline{p}_H > \overline{p}_L$, the results are the same as in the pure adverse selection selection model where only the H type receives a positive rent.

5.2 Competitive contracts

One of the arguments often used to justify the prohibition of risk categorization is that it is based on fixed or exogenous characteristics such as age, race and sex. However, as pointed out by Bond and Crocker (1990), insurers also use other characteristics that are chosen by individuals. They extend Crocker and Snow (1986) previous analysis of risk categorization in the presence of adverse selection and examine the equilibrium and efficiency implications of risk categorization based on consumption goods that are statistically related to individual's risks, which they termed "correlative products."

Formally, their model introduces endogenous categorization in an environment characterized by both moral hazard and adverse selection. They show that while there is a natural tension between the sorting of risk classes engendered by adverse selection and the correction of externalities induced by moral hazard, the use of risk classification improves efficiency in resource allocation. They also obtain that the sorting of risks based on correlative consumption may give a first-best allocation as Nash equilibria when adverse selection is not too severe, and when the insurer can observe individual consumption of the hazardous good.

This is particularly interesting as an alternative view of how firms, in practice, may overcome the nonexistence of Nash equilibrium problems. They then consider the case where the insurer cannot observe both the individual's consumption and the individual's characteristics. However, the planner can observe aggregate production of the good. They show that taxation of the consumption good now has two roles (reducing moral hazard and relaxing self-selection constraints) that permit Pareto improvements.

Cromb (1990) analyzes the simultaneous presence of moral hazard and adverse selection in competitive insurance markets and concludes that the addition of moral hazard to the standard Rothschild-Stiglitz (1976) model with adverse selection has qualitative effects on the nature and existence of equilibrium. Under certain circumstances the addition of moral hazard may eliminate the adverse selection problem but, more generally, it constitutes a new source of non-existence of a Nash equilibrium.

Chassagnon and Chiappori (1995) also propose an extension to the pure adverse selection model to consider incentives or moral hazard: the individual's probability of accidents is no longer completely exogenous; it depends on the agent's level of effort. In general, different agents choose different effort levels even when facing the same insurance contract. The equilibrium effort level does not depend on the level of accident probability but on its derivative. Consequently, the H type may have more incentive to produce safety to have access to a low insurance premium but he may not have access to efficient technology.

As in Chassagnon (1994), indifference curves may intersect more than once which rules out the Spence-Mirlees condition. As a result, when an equilibrium exists, it may correspond to many Rothschild and Stiglitz equilibria, a situation that is ruled out in the pure adverse selection model. Consequently, the equilibrium must be ranked, and Chassagnon and Chiappori (1995) use Hahn's concept of equilibrium to select the Pareto efficient equilibrium from the Rothschild-Stiglitz candidates. In the pure adverse selection world, both equilibrium concepts are equivalent.

In the same spirit, De Meza and Webb (2001) formalize the argument of "advantageous selection" and examine the relation between risk preference and choice of precaution with a specification that the taste-for-risk parameter is additive in wealth. Under this non-monetary formulation of the cost of prevention, the authors show that the single-crossing condition between risk-neutral and risk-averse individuals may not be satisfied (while Jullien, Salanié and Salanié (2007) show that this property always holds with a monetary formulation of the cost of precaution).

As a starting point, cautious types (more inclined to buy insurance and to put forth more effort) initially coexist with risk-tolerant types (disinclined to insure and to take precautions). The precautionary effort is thus positively correlated with insurance purchase. Depending on parameter values, separating, full pooling and partial pooling equilibria are possible. What allows pooling (partial or full) is the double crossing of indifference curves.

Another important conclusion is about the condition to obtain an equilibrium. It was shown in a previous section that a Rothschild-Stiglitz equilibrium exists if and only if there are enough high-risk agents in the economy. When both problems are present simultaneously, this condition is no longer true. Depending on the parameters of the model, an equilibrium may exist whatever the proportions of agents of different types; or may even fail to exist whatever the respective proportions.

Finally, it is important to emphasize that the individual with higher accident probability, at equilibrium, always has access to the more comprehensive insurance coverage, a conclusion that is shared by the standard model. However, here, this individual is not necessarily of type H. This result is important for empirical research on the presence of asymmetric information problems.[47]

In contrast, several studies suggest that the correlation between risk level and insurance purchases is ambiguous. The above-mentioned "advantageous selection" is called "propitious selection" by De Donder and Hindriks (2009), who also assume that applicants who are highly risk averse are more likely to try to reduce the hazard and to purchase insurance. In a model with two types of individuals differing in risk aversion, two properties (regularity and single-crossing) formalize the propitious argument. Under these two properties, the more risk-averse individuals will both exert more precaution and have a higher willingness to pay for insurance. De Donder and Hindriks (2009) thus prove that there cannot exist a pooling equilibrium. Indeed, a deviating firm can always propose a profitable contract, attractive only for the more risk-averse agents (who are also less risky in accordance with the propitious argument). Finally, the equilibrium contracts are separating with the more risk-averse individuals buying more insurance. Despite the propitious selection, the correlation between risk levels and insurance purchases is ambiguous at equilibrium: even though more risk averse agents behave more cautiously, they also buy more insurance at equilibrium, and with moral hazard, risk increases with coverage.

[47] See Cohen and Siegelman (2010) for a survey and a discussion about empirical work on the coverage–risk correlation that the pure asymmetric information model predicts. See also Chiappori and Salanié (2012) for a more recent review of empirical models on asymmetric information and Dionne, Michaud and Dahchour (2011) for a model that separates moral hazard from adverse selection and learning.

In a two-period model combining moral hazard and adverse selection, Sonnenholzner and Wambach (2009) propose another explanation of why the relationship between level of risk and insurance coverage can be of any sign. They stress the role of (unobservable) individual personal discount in explaining the decision to purchase insurance. Impatient individuals (with a high discount factor) initially coexist with patient individuals (with a low discount factor). A separating equilibrium exists in which patient consumers exert high precaution and are partially covered with a profit-making insurance contract, while the impatient consumers exert low effort and buy a contract with lower coverage or even prefer to remain uninsured. In contrast with the usual prediction, there is a negative correlation between risk and quantity. [48] [49]

These works are very close to the literature on multi-dimensional adverse selection where preferences are not necessarily single-crossing (See 7.2 in this Chapter). However in these multi-dimensional models, the higher risks buy more insurance.

6 Adverse selection when people can choose their risk status

An interesting twist on the adverse selection problem is to allow the information status of individuals to vary as well as the risk status. A traditional adverse selection problem arises when individuals know their risk status but the insurer does not. What will happen in a market where some insureds know their risk status and others do not? The answer to this question depends on whether the information status is observed by the insurer. A further variation arises when the uninformed insureds can take a test to ascertain their risk status. Whether they choose to take the test depends on the menu they will be offered when they become informed and how the utility of this menu compares with the utility of remaining uninformed. Thus, the adverse selection problem becomes entwined with the value of information.

These questions are especially important in the health care debate. Progress in mapping the human genome is leading to more diagnostic tests and treatment

[48] Without loss of generality, Fombaron and Milcent (2007) obtain the same conclusion in a model of health insurance in which they introduce a gap between the reservation utilities. This formulation implies that the low-risks may be more inclined to buy insurance than the high-risks when loss probabilities are symmetric information. This finding suggests that preference heterogeneity may be sufficient in explaining the opposite selection of insurance coverage in various markets.

[49] Cutler, Finkelstein and McGarry (2008) present empirical evidence in life insurance and in long-term care insurance in the US that is consistent with this negative correlation (those who have more insurance are lower risk because they produce more prevention). However, in annuity markets for example, higher risk people seem to have more insurance, as the standard theory would predict. See also Finkelstein and McGarry (2006) and Fang *et al* (2008).

for genetic disorders. It is important to know whether the equilibrium contract menus offered to informed insureds or employees are sufficiently attractive to encourage testing. The policy debate is extended by considering laws that govern access of outsiders (such as employers and insurers) to medical records. For example, many laws require that medical records cannot be released to outsiders without the consent of the patient. [50]

6.1 A full information equilibrium with uninformed agents

The basic analysis will follow Doherty and Thistle, 1996a. This model uses fairly standard adverse selection technology and is illustrated with health insurance. However, further works by Hoy and Polborn (2000) and Polborn, Hoy, and Sadanand (2006) have shown that similar results can be derived in a life insurance market where there is no natural choice of coverage and where individuals can buy from many insurers.[51]

Consider the simplest case in which there are initially three groups, uninformed, informed high-risks and informed low-risks that are labeled "U", "H" and "L" respectively. The contracts offered to each group will be labeled C_U, C_H and C_L. We assume that type U has a probability q_H of being high-risk so we can rank the *a priori* loss probabilities as $p_H > p_U > p_L$. If insurers know the information and risk status of any individual (i.e. they know whether she is U, H or L) the equilibrium competitive contracts are the first best contracts C_U^*, C_H^* and C_L^* depicted in Figure 6. This conclusion seems pretty obvious but there is a potential problem to be cleared before we can be comfortable with this equilibrium contract set. If all the uninformed chose to become informed, then the equilibrium contract set would contain only C_H^* and C_L^*. Thus, we must check when uninformed would choose to become informed and face a lottery

[50] For an overview of regulations and policy statements, see Hoel and Iversen (2002) and Viswanathan *et al* (2007). The latter describe four major regulatory schemes for genetic information in many states, from no regulation to the most strict regulatory structure: in the Laissez-Faire approach, insurers have full freedom to request new tests, disclosure of existing tests and to use tests results in underwriting and rating; under the Disclosure Duty approach, individuals have to disclose to insurers the result of existing tests but cannot be required to undergo additional tests, while under the Consent Law approach, consumers are not required to divulge genetic tests results but if they do, insurers may use this information. Finally, in the Strict Prohibition approach (there is a tendency in most countries to adopt this regulation of information in health insurance policies), insurers cannot request genetic tests and cannot use any genetic information in underwriting and rating.

[51] Because insurance companies don't share information about the amount of insurance purchased by their customers in the context of life insurance, price-quantity contracts are not feasible. As a consequence, insurers can only quote a uniform (average) premium for all life insurance contracts. However, contrary to standard insurance setting, consumers can choose the size of loss and this loss is positively dependent on the probability of death. Hence, increasing symmetric information about risk type leads to changes in the demand for life insurance and in the average price quoted by insurers, contrary to standard setting.

over C_H^* and C_L^* (the former if the test showed them to be high-risk and the latter if low-risk). In fact, the decision to become informed and receive policy C_H^* with probability q_H, and receive policy C_L^* with probability q_L, is a fair lottery (with the same expected value as staying with C_U^*) and would not be chosen by a risk averse person. This confirms that the full information equilibrium is C_U^*, C_H^* and C_L^*.

6.2 Sequential equilibrium with insurer observing information status but not risk type

It is a short step from this to consider what happens when the information status is known to the insurer but not the risk status of those who are informed[52]. For this case and remaining ones in this section, we will look for sequential Nash equilibria. In this case, the insurer can offer a full information zero profit contract C_U^* to the uninformed and the standard Rothschild-Stiglitz contracts, C_H^* and C_L^{**} as shown again in Figure 6. The intuition for this pair is clear when one consider that the uninformed can be identified and, by assumption, the informed high-risks cannot masquerade as uninformed. To confirm this in the equilibrium contract set, we must be sure that the uninformed choose to remain so. The previous paragraph explained that the uninformed would prefer to remain with C_U^* than take the fair lottery of C_H^* and C_L^*. C_L^* would be strictly preferred by an informed low-risk than the Rothschild-Stiglitz policy C_L^{**}(which has to satisfy the high-risk self-selection constraint). Thus, by transitivity, the uninformed would prefer to remain with C_U^* than face the lottery of C_H^* and C_L^{**}.

6.3 Sequential equilibrium when insurer cannot observe information status or risk type

We now come to the more interesting case in which the information status of individuals cannot be observed. This raises the interesting possibility that people can take a test to become informed and, if the news is bad, pretend they are uninformed. Because the insurer cannot observe information status, he has no way of separating these wolves in sheeps' clothing from the uninformed sheep. This presents a problem for the uninformed. To signal that they are really uninformed, and thus avoid subsidizing the high risks, they must accept a contract that would satisfy a high-risk self-selection constraint. This contract, C_U'' is shown in Figure 6. Suppose for the time being they accept this contract. Now what zero profit contract can be offered to the informed low-risks? To

[52]This case may stretch plausibility slightly because it is difficult to imagine an insurer being able to verify that someone claiming to be uninformed is not really an informed high-risk. However, we will present the case for completeness.

prevent the uninformed buying a low-risk contract, the latter must satisfy an uninformed risk self selection constraint and such a contract set is C''_L. Can this triplet, C^*_H, C''_U, C''_L be a equilibrium? The answer depends on the costs of information.

If the uninformed could choose to stay at C''_U or become informed and take a lottery over C^*_H and C''_L, what would they do? It turns out the value of the test is positive. Even though the test introduces more risk, there is a compensating factor that tips the balance in favor of the lottery. Remaining uninformed entails a real cost; policy C''_U must bear risk to satisfy the high-risk self-selection constraint. Thus, the uninformed will remain so only if the cost of the test is sufficiently high. Accordingly the triplet C^*_H, C''_U, C''_L can only be a Nash equilibrium if there are high costs of testing. If the test costs are low, we must consider another possible equilibrium. Suppose insurers expected all the uninformed to take the test, but they could not observe risk status after the test. In that case the only pair satisfying the high risk self selection constraint is the Rothschild Stiglitz pair, C^*_H and C^{**}_L. It is fairly straightforward to show that, if the uninformed remained so, they would choose C^{**}_L over C^*_H. Thus the choice for the uninformed is to keep C^{**}_L valued without knowledge of risk type, or face a lottery between C^*_H (valued with full information of high-risk type) and C^{**}_L (valued with knowledge of low-risk status). It turns out that the value of this lottery is zero. Thus, if the cost of information was zero, and using a tie breaker rule, the uninformed would take the test and the pair, C^*_H, C^{**}_L is a sequential Nash equilibrium. Regardless of the cost of the test, this cannot be an equilibrium.

We can now summarize. If the costs of information are sufficiently high, there is a sequential equilibrium set C^*_H, C''_U, C''_L . If the information costs are positive but below a threshold, then no sequential Nash equilibrium exists. Finally, there is a knife edge case with an equilibrium of C^*_H, C^{**}_L which exists only with zero cost of information.

Insert Figure 6 here.

Hoel *et al* (2006) show that the introduction of heterogeneity about perceived probability of becoming ill in the future allows to circumvent this non-existence of equilibrium. In Hoel *et al* (2006), testing is assumed to be costless, but consumers differ with respect to the disutility or anxiety of being informed about future health risk. Using a model with state-dependent utility, the authors assume that some individuals are attracted to chance, while others are repelled by chance. The first ones are more reluctant to choose testing than the second ones. Like Doherty and Thistle (1996), Hoel *et al* (2006) conclude that a regulatory regime in which the use of genetic information by insurers is allowed is better than one in which it is prohibited, but in contrast to Doherty and Thistle (1996), they obtain that more people undertake the test when test results are verifiable than when they are not. Indeed, in uncertain but symmetric information setting, when being offered full insurance contracts, some individuals sufficiently repeled from chance choose to take a test. When information is asymmetric with test results being verifiable, untested individuals are offered partial insurance, to dissuade high-risk agents from claiming that they were not tested. By relaxing the verifiability of test results, both (tested) low-risk and untested agents are offered partial insurance to dissuade untested agents to claim being low-risk. In contrast to Doherty and Thistle (1996) who find that all agents choose to be tested when insurers cannot distinguish between untested agents and high-risk agents (for $c = 0$), Hoel *et al* (2006) explain why some consumers prefer to stay uninformed even when information on test status is asymmetric.

For other models of insurance purchasing decisions with state dependent utilities, see also Strohmenger and Wambach (2000) who argue that results from standard insurance market models may not be simply transferred to health insurance markets (due to the assumption that treatment costs are sometimes higher than willingness to pay). State-contingent utilities take into account the fact that people in case of illness have the choice between undergoing a treatment or suffering from their diseases. Here again, making the results of genetic tests available to the insurer might be welfare improving.

6.4 The Case of Consent Laws

One of the interesting policy applications of this analysis is *consent laws*. Many states have enacted laws governing the disclosure of information from genetic (and other medical) tests. The typical law allows the patient to choose whether to divulge information revealed by the test to an employer or insurer. This issue was considered by Tabarrock (1994) who suggested that consent laws would encourage people to take the test. This was examined further by Doherty and Thistle (1996b), who derive alternative Nash equilibria under consent laws. The principal feature of their analysis is that informed low-risks can verify their low-risk status by presenting the results of the test. Alternatively, informed high-risks will conceal their identity, i.e., withhold consent. This leads to a potential equilibrium containing policies of set $A \equiv \{C_H^*, C_U'', C_L^*\}$ or set $B \equiv \{C_H^*, C_L^*\}$. For B to be an equilibrium, the uninformed must choose to take a diagnostic test when faced with this contract menu. The value of information, $I(B)$, turns out to be positive; this can only be an equilibrium if the information value exceeds the cost of the diagnostic test, c. The other possible equilibrium, A, can hold only if the uninformed **remains** so. Because the value of information is positive, the equilibrium can only hold if the cost of the test is sufficiently high to discourage testing, $I(A) < c$. Thus, the possible equilibria are A if the cost of the test is sufficiently high and B if the cost of the test is sufficiently low. There are possible situations where no Nash equilibrium exists or where there are multiple equilibria. Summarizing:

$I(A) < c < I(B)$	two equilibrium sets, A and B
$c < I(A), I(B)$	equilibrium set is B
$I(A), I(B) < c$	equilibrium set is A
$I(A) > c > I(B)$	no Nash equilibrium exists.

In the context of life insurance, Hoy and Polborn (2000) and later Polborn, Hoy, Sadanand (2006) obtain positive and normative results that are either consistent with or differ from those described in standard insurance setting. A significant difference is that prohibiting insurance from using information about risk type may increase welfare. In a static setting with initial adverse selection, Hoy and Polborn (2000) argue that genetic testing has a possible dimension for providing positive social value by allowing better informed consumption choices (while in Doherty and Thistle, the social value of the testing opportunity is negative). The authors construct three scenarios in which the existence of the test is either Pareto-worsening, Pareto-improving, or is worse off for some consumers and better off for others. The intuition why additional information may lead to a private benefit is as follows. Even if the average equilibrium premium increases as a result of testing, those who are tested (with good or bad news) gain because they can adjust their life insurance demand to their real risk type. In a three-period model, Polborn, Hoy and Sadanand (2006) assume that people can buy term insurance covering the risk of death either early in life (period 1) before they have received information about their mortality risk and before risk type is known and/or later (period 2) after they have received this information (people face the risk of death only at the beginning of period 3). Here again, if there are sufficiently few individuals who receive bad news about their genetic type, restricting insurers from using information about genetic testing may provide alternative assurance against the risk of classification, in combination with a cap that limits adverse selection.

However, empirical studies deal with the consequences of a ban on the use of genetic testing in life insurance. Hoy and Witt (2007) provide an economic welfare analysis of the adverse selection costs associated with regulations that ban insurers from access to these tests for the specific case of information relating to breast cancer. These adverse selection costs are shown to be very modest in most circumstances and the authors argue in favor of restricting the use of genetic test results for rate-making purposes. Using a discrete Markov chain model, Viswanathan *et al* (2007) find similar results. They track the insurance demand behavior of many cohorts of women who can change their life insurance benefit at the end of each policy year, influenced by the results of tests relating to breast and ovarian cancers (and consequently by their premium changes).

6.5 Moral hazard, public health and AIDS testing

If the costs and benefits to patients of the potential use of information in insurance markets when consent laws are in place are considered, the value of information is positive, and insurance markets can be encouraged to endorse testing. Whether people actually take medical tests also depends on the costs of those tests. These costs are critical in determining which, if any, Nash equilibrium exists. One can generalize the discussion and talk not simply of the costs of the test but also of other benefits. Quite obviously, testing yields a medical diagnosis that can be useful in treating any revealed condition. In general we would expect this option for treatment to have a positive private and social value (see Doherty and Posey, 1998). Accounting for the private value of this option has the same effect as lowering the cost of the test and tends to favor the equilibrium contract set B in which all people take the test. However, this opens up the wider issue of other costs and benefits to acquiring information related to risk status.

An interesting twist on this literature concerns the case of AIDS testing. The result that insurance markets tend to raise the private benefit from testing may be reassuring to those interested in public health who normally consider testing for diseases such as AIDS and inherited disorders to be socially beneficial. Several studies have analyzed behavioral choices in sexual activities and their effect on the transmission of AIDS and the effectiveness of public health measures (Castillo-Chavez and Hadeler, 1994 and Kremer, 1996). The work of Philipson and Posner (1993) is particularly pertinent: they examine the effect of taking AIDS test on opportunities to engage in high-risk sexual activity. Without going into detail, the point can be made by recognizing that people might take the test to verify their uninfected status so they can persuade partners to engage in high-risk sexual activity. Without such certification, they may have been unable to secure partners for high-risk sex. While this is only one part of their analysis, it is sufficient to illustrate their point that AIDS testing can conceivably *increase* the spread of the disease. In spite of the possible social costs of testing, it also shows there are private benefits to diagnostic tests because they expand opportunities for sexual trade.

This works tends to tilt the previous analysis of insurance equilibrium at least for the case of AIDS testing. The insurance equilibrium required a comparison of the costs of testing with the value of (insurance) information revealed by the test. Philipson and Posner (1993) report an exogenous private benefit of testing. Such a private benefit is the same as lowering the cost of testing. Accordingly, it creates a bias in favor of those equilibria in which all individuals are fully informed of their risk status; i.e. contract set B.

Hoel and Iversen (2002) extend Doherty and Thistle's (1996) results by taking into account the availability of preventive measures (as private information).[53] In addition to focusing on the regulation of access to information about

[53] See also Fagart and Fombaron (2006) for a discussion of the value of information under alternative assumptions about what information is available to insurers in a model with preventive measures.

individual test status,[54] Hoel and Iversen (2002) are interested in the possible inefficiencies due to a compulsory/voluntary mix of health insurance.[55] First, they show that genetic testing and prevention may not be undertaken although testing is socially efficient (this inefficiency is likely to occur for systems with high proportion of compulsory insurance). However, tests may be undertaken when testing is socially inefficient (more likely for systems with substantial voluntary supplementary insurance and more important the less prevention is).

Finally, while the above-mentioned models have investigated primary prevention (which reduces the probability of illness), Barigozzi and Henriet (2009) consider a model in which secondary prevention measures (which reduces the health loss when illness occurs) are available. They characterize market outcomes under the four regulatory schemes described by Viswanathan *et al* (2007) and derive an unambiguous ranking of these schemes in terms of social welfare. The Disclosure Duty approach weakly dominates all the other regulatory structures. At the other extreme, the Strict Prohibition approach is dominated by all the other regulatory schemes. The Laissez-Faire and the *Consent Law* approaches appear to be intermediate situations.

7 Concluding remarks: extensions to the basic models

7.1 Risk categorization and residual adverse selection

Adverse selection can explain the use of risk categorization in insurance markets based on variables that procure information at a low cost (Hoy, 1982; Browne and Kamiya, 2012). For example, in automobile insurance, age and sex variables are significant in explaining probabilities of accidents and insurance premia (Dionne and Vanasse, 1992, Puelz and Snow, 1994; Chiappori and Salanié, 2000; Dionne, Gouriéroux and Vanasse, 2001, 2006). Particularly, young male drivers (under age 25) are much riskier to insure than the average driver. Because it is almost costless to observe age and sex, an insurer may find it profitable to offer policies with higher premiums to young males. However, such categorization is now prohibited in some states and countries. For surveys on adverse selection and risk classification, see Crocker and Snow (2012) and Dionne and Rothschild (2011).

Dahlby (1983, 1992) provides empirical evidence that adverse selection is present in the Canadian automobile insurance market. He also suggests that

[54] As in Doherty and Thistle, an individual decides whether or not he wishes to obtain the information from testing.

[55] More precisely, voluntary health insurance is considered as a supplement to compulsory insurance.

his empirical results are in accordance with the Wilson-Miyazaki-Spence model that allows for cross-subsidization between individuals in each segment defined by a categorization variable such as sex or age: low-coverage policies (low-risks) subsidizing high-coverage policies (high-risks) in each segment[56]. This important statistical result raises the following question: Does statistical categorization enhance efficiency in the presence of adverse selection? In other words, can welfare be improved by using the public information on agents' characteristics (such that age and sex) in offering insurance contracts in the presence of adverse selection? Crocker and Snow (1985, 1986) show that, if the observable variables are correlated with hidden knowledge, costless imperfect categorization always enhances efficiency where efficiency is defined as in Harris and Townsend (1981). Another important contribution in Crocker and Snow (1986) concerns the existence of a balanced-budget tax-subsidy system that provides private incentives to use costless categorization. Note that the corresponding tax is imposed on contracts, not on individuals. If a redistribution is made from gains earned on the group in which low-risks are predominant (e.g. old male drivers) to the group in which high-risks are predominant (young male drivers), the classification always permits expansion of the set of feasible contracts. The reason is that the use of categorization relaxes the incentive compatibility constraints. As a result, with appropriate taxes, no agent loses as a result of categorization. The results are shown for the Wilson-Miyazaki-Spence equilibrium concept but can also sustain an efficient allocation in a Nash equilibrium with a tax system (Crocker and Snow, 1986). These conclusions can be applied to the Wilson anticipatory equilibrium or to the Riley reactive equilibrium, for some values of parameters, both with a tax system. It then becomes clear that prohibiting discrimination on equity considerations imposes efficiency costs in insurance markets (such as automobile insurance where categorization based on age and sex variables is costless).

Finally, Crocker and Snow (1986) argue that the welfare effects are ambiguous when categorical pricing is costly. In contrast, Rothschild (2011) shows that Crocker and Snow's (1986) result that categorical pricing bans are inefficient applies even when the categorical pricing technology is costly. In practice, if the government provides breakeven partial social insurance and allows firms to categorize with supplemental contracts, the market will choose to employ the categorical pricing only when doing so is Pareto-improving. In other words, providing partial social insurance socializes the provision of the cross-subsidization.

In recent empirical studies, Chiappori and Salanié (2000) and Dionne, Gouriéroux and Vanasse (2001, 2006) (see also Gouriéroux, 1999) showed that risk classification is efficient to eliminate asymmetric information from an insurer's portfolio, in the sense that there is no residual asymmetric information in the portfolio

[56] However, Riley (1983) argued that the statistical results of Dahlby (1983) are also consistent with both the Wilson anticipatory equilibrium (1977) and the Riley reactive equilibrium (1979). Both models reject cross-subsidization.

studied (see Richaudeau, 1999, for an application with a different data set).[57] They conclude that the insurer was able to control for asymmetric information by using an appropriate risk classification procedure. Consequently, no other self-selection mechanisms inside the risk classes (such as the choice of deductible) are necessary to reduce the impact of asymmetric information, which justify active underwriting activities by insurers (Browne and Kamiya, 2012). See Chiappori and Salanié (2012) and Dionne (2012) for more detailed analyzes of methodologies to isolate information problems in insurance data.

7.2 Multi-dimensional adverse selection

Up to now, it was assumed that risk categories are determined up to the loss probability. However, residual asymmetric information between the insured and the insurers could consist of attitude toward risk. Villeneuve (2003) and Smart (2000) explore the implication of assuming that differences in risk aversion combined with differences in accident probabilities create a multi-dimensional adverse selection problem where the equilibrium allocation differs qualitatively from the classical results of Rothschild and Stiglitz (1976). In Villeneuve (2003), not only may positive profits be sustainable under several equilibrium concepts (Nash, Rothschild and Stiglitz, Wilson, Riley), but equilibria with random contracts are also possible. The former situation is more likely when low-risk agents are more risk averse, whereas the latter is more likely when the low-risk is less risk averse. Villeneuve explores the origin of these phenomena. He gives necessary and sufficient conditions for the comparison of risk aversions that either guarantee or exclude atypical equilibria.

In a companion paper, Smart (2000) obtains similar results. In his model, indifference curves of customers may cross twice; thus the single crossing property does not hold. When differences in risk aversion are sufficiently large, firms cannot use policy deductibles to screen high-risk customers. Types may be pooled in equilibrium or separated by raising premiums above actuarially fair levels. This leads to excessive entry of firms in equilibrium.[58]

Wambach (2000) has extended the model of RS by incorporating heterogeneity with respect to privately known initial wealth.[59] He assumes four unobservable types of individuals; those with high or low-risk with either high or low wealth. When the wealth levels are not too far apart, then types with different wealth but the same risk are pooled, while different risks are separated. The possibility of double-crossing indifference curves occurs for large differences in

[57] In contrast, Cohen (2005) does not reject residual asymmetric information with data from Israel.

[58] See also Landsberger and Meilijson (1994) for an analysis of a monopolistic insurer with unobserved differences in risk aversion.

[59] Similar conclusions would be obtained if individuals differed in the size of losses (in addition to the difference in risk).

wealth. In this case, self-selection contracts that earn positive profit might hold in equilibrium. However, in Villeneuve (2003) and Wambach (2000), insurers are restricted to offering only one contract each (in and off-the-equilibrium).[60]

Snow (2009) argues that profitable contracting advanced in these modified Rothschild-Stiglitz environments cannot be sustained as a Nash equilibrium under competitive conditions, if insurers are allowed to offer menus of contracts. In the three above-mentioned models, the configuration in which the high-risk contract breaks even while the low-risk contract earns a positive profit cannot be a two-stage Nash equilibrium; there always exists a pair of incentive-compatible and jointly profitable contracts attractive to both risk types (an unprofitable contract with full coverage attracting only high-risks and a profitable contract attracting low-risks). Similar reasoning applies to the model investigated by Sonnenholzner and Wambach (2009), combining moral hazard with adverse selection.[61]

Snow (2009) resolves the problem of non-existence of equilibrium in the related instances by appealing to the three-stage game introduced by Hellwig (1987). When insurers can modify their contractual offers in a third stage of the contracting game, the breakeven pooling contract is the strategically stable Nash equilibrium.

Other studies, including Fluet and Pannequin (1997), Crocker and Snow (2011) and Koehl and Villeneuve (2001), focus on situations where two types of individuals with multiple risks coexist. Fluet and Pannequin (1997) analyze two situations: one where insurers offer comprehensive policies against all sources of risk (complete insurance) and one where different risks are covered by separate policies (incomplete contracts). In the second case, they analyze the possibility that the insurer has perfect information about the coverage of other risks by any insurer in the market. They show that when market conditions allow for bundling (getting information to protect insurers against undesirable risks), the low-risk individual in a particular market (or for a particular source of risk) does not necessarily buy partial insurance in that market as in the Rothschild and Stiglitz model.

Their analysis emphasizes the trade-off between bundling and spanning. Multiple-risk contracts allow for perfect spanning (taking correlations between different risks into account) and for perfect bundling (considering all information available to the insurers) while single contracts with imperfect information on contract choice for other risks are inferior because they do not permit risk diversification and information sharing. They show that the former is the more efficient which confirms the practice by insurers in many countries.

[60] In contrast, Smart restricts the entry by a fixed barrier.

[61] In this model, one case in which profitable self-selection contracting arises, with patient types only partially covered exerting high effort (while impatient types exert low effort and receive a lower coverage).

In contrast with Fluet and Pannequin who consider the possibility to bundle several (independent) risks, Crocker and Snow (2011) decompose a given risk of loss into its distinct potential causes. The knowledge of the conditional probability of a particular peril occurring is private as in the model of one-dimensional screening, but applicants signal their type in more than one dimension through the choice of a vector of deductibles. Bundling of coverage for all the perils into a single policy is efficient as in Fluet and Pannequin (relative to the solution where the perils were covered by separate contracts) and does not fundamentally alter the structure of screening; high-risks are unaffected by the introduction of multidimensional screening while low-risks obtain more coverage than the high-risks for perils from which they are more likely to suffer. By reducing the externality cost that low-risk agents must bear to distinguish themselves from high-risk agents, multidimensional screening enhances the efficiency of insurance contracting and circumvents the non-existence problem (by decreasing the critical value above which Nash equilibrium exists).

In the same spirit, Koehl and Villeneuve (2001) consider a multiple-risk environment, but in which exclusivity cannot be enforced and insurers are specialized. The authors compare the profits of the global monopoly and the sum of the profits each monopoly would make in the absence of the other. It is shown that specialization prevents second-best efficiency because it weakens insurers' ability to screen applicants. Even if the market exhibits a form of complementarity that limits the conflict between the insurers (by limiting the conflict between insurers, specialization implicitly sustains collusion between competitors), there are efficiency losses due to specialization, and the profits at the industry level are decreased.

7.3 Symmetric incomplete information

According to recent empirical studies that test the presence of adverse selection in automobile insurance markets (Chiappori and Salanié, 2000, and Dionne, Gouriéroux and Vanasse, 2001), it seems that we can reject the presence of residual asymmetric information in some markets. More precisely, even though there is potential adverse selection on these markets, insurers are able to extract all information on individuals' risk type through very fine risk categorization.

By focusing on these recent empirical results, de Garidel (2005) rejects the presence of initial asymmetries of information and, on the contrary, assumes that information between insurers and insureds is incomplete, but initially symmetric (at the beginning of a two-period contract). He provides a dynamic competitive model in which each agent, together with his initial insurer, learns about his type through accidents. However, other insurers may not, depending on informational structures.

In the absence of ex-ante adverse selection, he shows that "(i) keeping information about accident claims private is welfare-improving, (ii) such a policy does not jeopardize the existence of an equilibrium, and (iii) this equilibrium exhibits both bonus and malus." Thus, in a two-period model, adverse selection arises endogenously through differentiated learning about type and leads to reconsider the widespread idea according to which competition in markets with adverse selection may be undesirable. Indeed, de Garidel (2005) shows that it is welfare-enhancing to produce adverse selection of this kind.[62]

7.4 Reversed adverse selection and double-sided adverse selection

In the literature on decentralized markets under asymmetric information it is commonly assumed that the uninformed party possesses all the bargaining power. This is also the usual assumption of insurance models, whereas it is often argued that companies may be better able to assess the risk of an individual than this individual himself. The paper by Bourgeon (1998) reverses this usual assumption, giving the relevant information to the insurers, in addition to the bargaining power. Under this hypothesis, the insurers' activity is not only to sell a particular good or service but also to produce a diagnosis of the buyers' needs. This is the case in some insurance markets, including health and life, where the sellers appear to be the experts in the relationship.

Assuming risk-averse buyers and risk-neutral sellers, the focus of Bourgeon's model is on symmetric-steady state equilibria of the market game. The only candidates for equilibria are semi-separating ones, i.e., equilibria where the buyers carrying the good state of nature are partially pooled with the low-state ones.Separating equilibria is invalid simply because they violate the sellers' incentive constraints: Assuming a separating equilibrium, the equilibrium contracts involve full coverage of the damages, which are the same in both states accident and no-accident. The only difference between these contracts is thus the premium, which is higher for the high-risk individuals. A seller would thus increase its profit by offering the high-risk contract to a low-risk buyer. A pooling equilibrium cannot occur because of a trickier reason related to the (limited) monopoly power of sellers: knowing that its competitors propose a pooling contract, a seller offers a contract corresponding to the buyer's reservation value. Because the contract is pooling, however, the buyer cannot revise his beliefs and his reservation value is unchanged since his entrance in the market. Consequently, he has no reason to begin a time-consuming search, and therefore the market shuts down. If an equilibrium exists, it thus entails a search, which is long-lasting for all buyers carrying a bad state: sellers always propose high-risk contracts, but because there is a chance that the buyer's risk is low, he visits

[62] See Cohen (2012) for a model of asymmetric learning among insurers on insured risk.

several sellers before accepting this contract. Moreover, he is never convinced of the true price, and sellers consequently charge a lower price than they would charge if the buyer knew the true information. The informational asymmetry is thus advantageous to the high-risk individuals, because they are not charged the entire risk premium corresponding to this state. When choosing a contract for a low-risk, a seller balances between offering the contract for low-risks, which is certain to be accepted by the buyer but gives small profits, and offering a high-risk contract, which is accepted only by some of the buyers but is more profitable.

In a static approach, Fagart (1996b) explores a competitive market of insurance where two companies compete for one consumer. Information is asymmetric in the sense that companies know the value of a parameter ignored by the consumer. The model is a signalling one, so that insureds are able to interpret offered insurance contracts as informative signals and may accept one among these offers or reject them. The features of the equilibrium solution are the following: the information is systematically revealed and profits are zero.

Villeneuve (2000) studies the consequences for a monopolistic insurance firm of evaluating risk better than customers under the adverse selection hypothesis reversed. In a more general model (Villeneuve, 2005), he suggests that information retention and inefficiency have to be expected in many contexts. In a competitive insurance market, he shows that neither revelation of information nor efficiency are warranted, and that the surplus may be captured by some insurers rather than the consumers. Thus, in his model, the classical predictions of Rothschild and Stiglitz are reversed: types may be pooled, high-risk consumers may remain uninsured or obtain partial coverage, and profits are not always zero. The key argument is that the way consumers interpret offers may restrict competitive behavior in the ordinary sense.

Seog (2009) formalizes a double-sided adverse selection by decomposing the risk of a policyholder into two risks: a general risk and a specific risk. He considers that each party to the insurance contract has superior information; policyholders have superior information about specific risk while insurers have superior information about general risk (for example, policyholders have superior information on their own driving habits, but automobile insurers have superior information about accident risks). High-general-risk consumers are self-insured in equilibrium while low-general-risk consumers are covered by an insurance contract (full insurance for high-specific-risk people and partial insurance for low-specific-risk people). As a consequence, when insurers make their information about general risk public, efficiency is unambigously improved.

Chassagnon and Villeneuve (2005) and Jeleva and Villeneuve (2004) propose two extensions of the classical model in which each party knows something that the other does not. Assuming less than perfect risk perception (subjective beliefs), Chassagnon and Villeneuve (2005) characterize the efficient frontier in a competitive setting, while Jeleva and Villeneuve (2004) analyze the equilibrium between a monopolistic insurer confronted with policyholders having beliefs different from the objective probabilities (the authors formalize this disparity using the Rank Dependent Expected Utility model proposed by Quiggin, 1982, and Yaari, 1987). Both papers find that the optimal offer can be a pooling contract and that better risks can be better covered.

7.5 Uberrima Fides

An insurance contract is under uberrima fides when an insured makes a full disclosure of all facts pertaining to his risk that are known to him ex-ante. Under this type of arrangement, the insurer asks questions about the individual risk at the signing of the contract, but keep the right to investigate the truth only when the claim is made, to reduce the audit costs. If the answers are found to be false, the insurer can refuse to pay the claim. This scheme provides a new way to select low-risks at a lower social cost than the Rothschild-Stiglitz method. Some life insurers used individuals declarations about their smoking behavior to set insurance prices. In fact, Dixit (2000) shows that uberrima fides is Pareto-improving when compared to Rothschild-Stiglitz equilibrium.

7.6 Adverse Selection and Participating Contracts

The literature on insurance contract design has focused on non-participating contracts, even if participating contracts are more consistent with Borch's mutualization principle. In the non-participating contracts, the premiums are conditioned only on the individual loss (the risk is only transferred to an external risk bearer (stock insurer)), whereas participating contracts condition payout both on the individual loss and the portfolio experience (the premium is subject to a retroactive adjustment or dividend, which depends on the collective loss experience of the pool).

Extending the earlier work of Borch (1962), Marshall (1974) argues that, in the presence of aggregate or social risk and in the absence of adverse selection, mutual insurance is more efficient, unless there are enough independent risks that the law of large numbers to be applied. In the same spirit, Doherty and Dionne (1993) show how the composite risk transfer implicit in mutual insurance (weakly) dominates the simple risk transfer implicit in stock insurance. They suggest that an efficient insurance contract will decompose risk into diversifiable (or idiosyncratic) and non-diversifiable elements and will let the parties bargain on the sharing of each component.

Smith and Stutzer (1990) introduce adverse selection with undiversifiable aggregate risk. Owing to their participating nature, mutual insurance policies are an efficient risk-sharing mechanism. Smith and Stutzer show that high-risk policyholders fully insure against both individual and aggregate risk, while low-risk individuals partially insure against both risk types.

Because small mutual insurance firms appear to be less risk sharing, Ligon and Thistle (2005) argue that they must offer their policyholders other advantages, namely in solving problems of adverse selection. Even in the absence of aggregate risk, their analysis suggests that organization size may be an important component of the institutional structure and provides an alternative explanation both for the existence of mutual insurance firms and for the coexistence of stock and mutual insurers. Ligon and Thistle assume that even when a risk pool cannot control its composition directly (due to adverse selection), adverse selection can create incentives for the formation of distinct mutual insurers. Adverse selection limits the size of these low-risk mutuals. The combination of stock and mutual insurers is thus shown to solve adverse selection problems, by allowing consumers to choose from a menu of contracts.

As in Smith and Stutzer,[63] high-risk individuals buy conventional fixed-premium policies from stock insurers while low-risk individuals from mutuals. In addition, Ligon and Thistle derive the conditions[64] under which stock insurers (for the monopoly and competitive cases) and mutual insurers can coexist, and show that the mutual can offer higher expected indemnity to low-risk members than the stock insurance policy without attracting high-risk individuals. Low risk individuals are strictly better off forming mutuals than buying stock insurance policies. High-risk individuals are no worse off (under monopoly) or are strictly better off (under competition) buying insurance from the stock insurer than joining the mutual. Finally one empirical implication of their theoretical analysis is that adverse selection may create incentives for some mutuals to be small (while there is no corresponding incentive for stock insurers). Ligon and Thistle find the empirical distribution of insurer size by type corresponds precisely with what their theoretical analysis predicts.

More recently, Picard (2009) finds that allowing insurers to offer either non-participating or participating policies guarantees the existence of an equilibrium in the Rothschild/Stiglitz model. Participating policies act as an implicit threat that dissuades deviant insurers that would like to attract low-risk agents only (when there is cross-subsidization between risk types) and the WMS allocation can be sustained as a subgame perfect equilibrium of a non-cooperative game. In words, an equilibrium holds with high-risk agents having taken out a participating policy subsidized by low-risk individuals because if low-risk agents switch to another insurer, the situation of high-risk agents deteriorates because of the participating nature of their insurance contract. Consequently, it is more difficult

[63] Even if their approach differs from Smith and Stutzer because the problem is one of cooperative game theory.

[64] The conditions under which this separating equilibrium exists are analogous to those under which a separating equilibrium exists in the standard Rothschild/Stiglitz model.

for the deviant insurer to attract only low-risk types without attracting high-risk types as well. When there is no equilibrium in the Rothschild/Stiglitz model with non-participating contracts, an equilibrium with cross-subsidized participating contracts actually exists. Further, this model predicts that the mutual corporate form should be prevalent in insurance lines with cross-subsidization between risk types, while there should be stock insurers in other cases.

In each of these models, coexistence of stock and mutual insurers occurs because of either exogenous aggregate risk (Doherty and Dionne (1993), Smith and Stutzer (1990)) or adverse selection (Smith and Stutzer (1990), Ligon and Thistle (2005), Picard (2009)). A third explanation for the coexistence of mutual and stock insurers focuses on the possibility of a stock insurer's becoming insolvent (i.e. unable to pay all the promised indemnities). Rees, Gravelle and Wambach (1999) take into account this possibility and assume that insolvency can be avoided by choosing appropriate capital funds, and that agents are fully informed about this choice. In a somewhat similar vein, Fagart Fombaron and Jeleva (2002) consider that when unbounded losses are possible, insolvency cannot be excluded. The contracts a stock insurer company offers imply a fixed premium that may be negatively adjusted at the end of the contractual period when the losses of stock insurers are too large to be covered by the company's reserves (capital funds and the collected premia), while the optimal contract offered by a mutual firm involves a systematic ex-post adjustment (negative or positive). These assumptions point to a network effect in insurance (or size effect): the expected utility of an agent insured by a mutual firm is an increasing function of its number of members. For the insurance companies, network externalities also exist but are positive or negative depending on the amount of the capital funds. In an oligopoly game, either one mutual firm or insurance company is active in equilibrium, or a mixed structure emerges in which two or more companies share the market with or without a mutual firm. Bourlès (2009) extends this analysis by endogenizing the choice of capital and gives a rationale for mutualization and demutualization waves.

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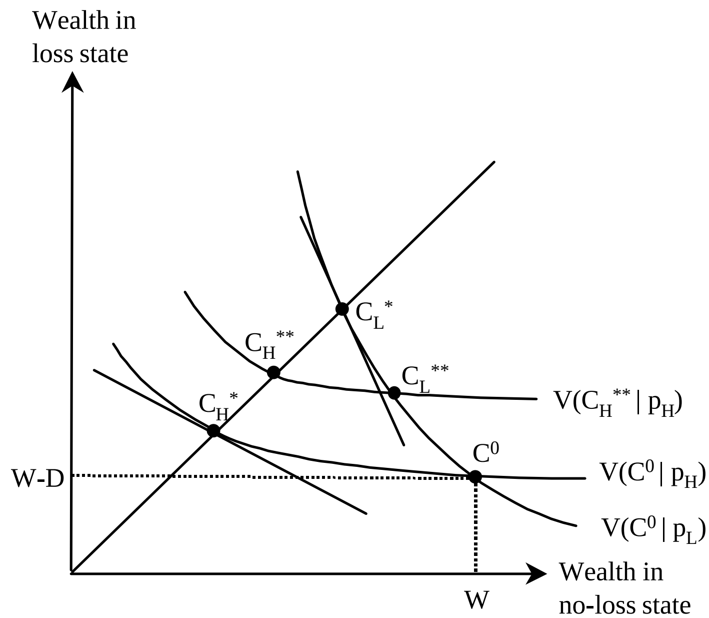

Figure 1 : Monopoly model

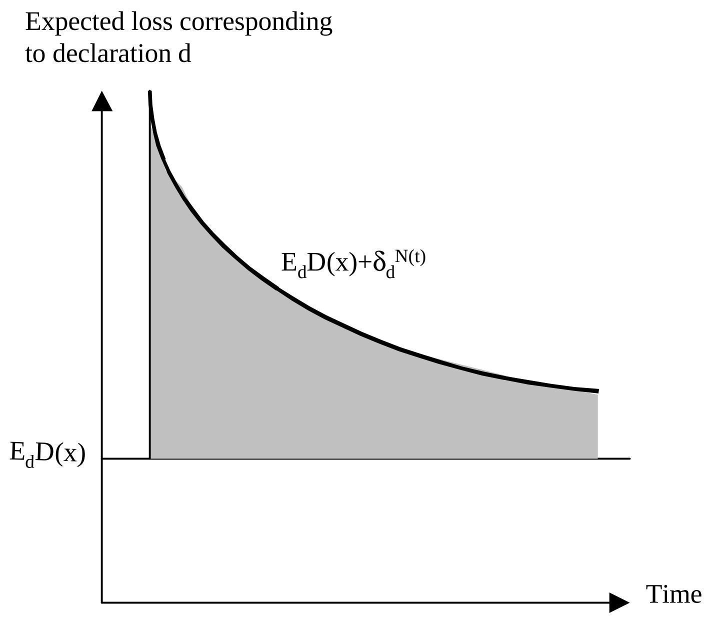

Figure 2 : Graphical representation of $E_d D(x)+\delta_d^{N(t)}$

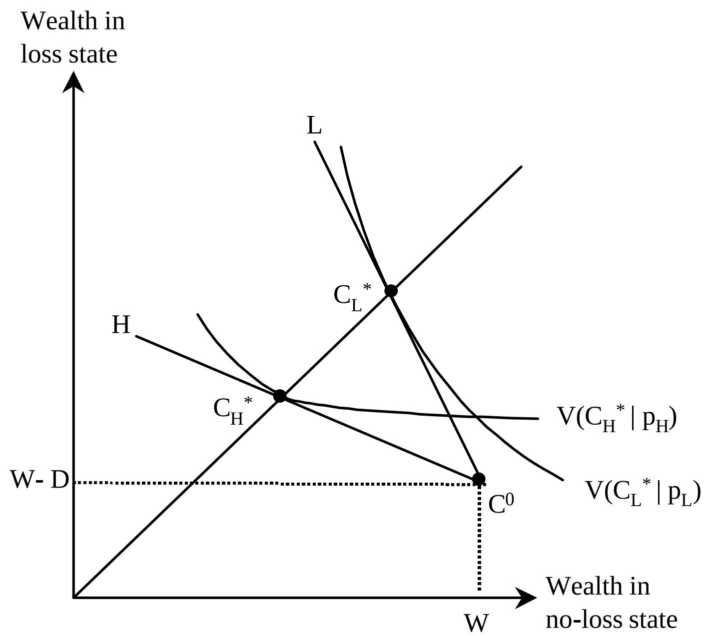

Figure 3 : One-period competitive contracts with full information

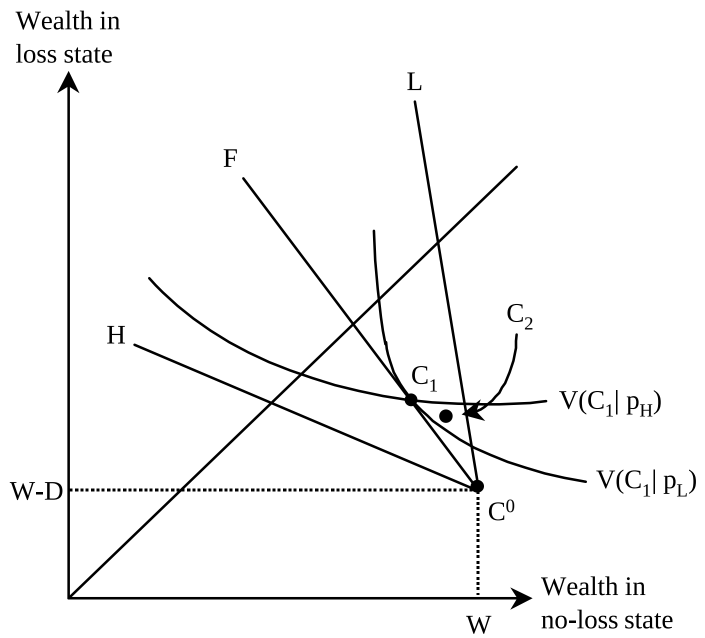

Figure 4a : Inexistence of a Rothschild-Stiglitz pooling equilibrium

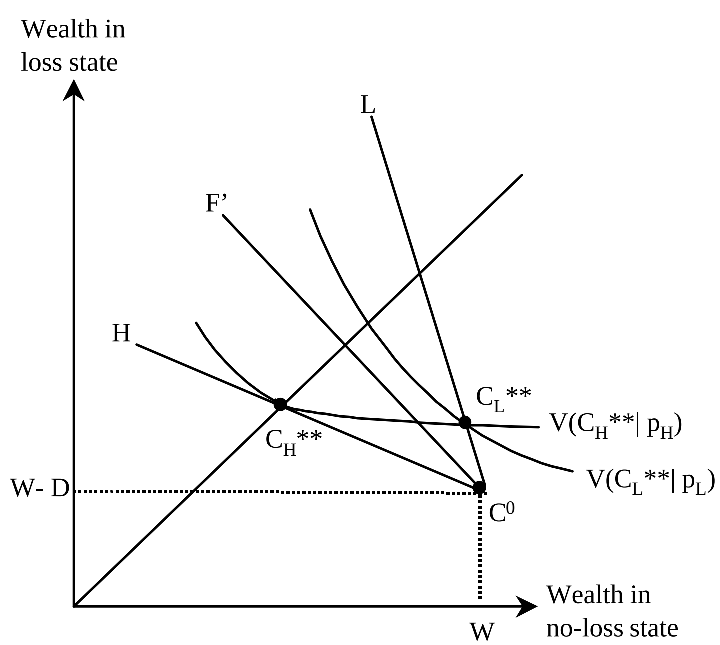

Figure 4b : Existence of a Rothschild and Stiglitz separating equilibrium

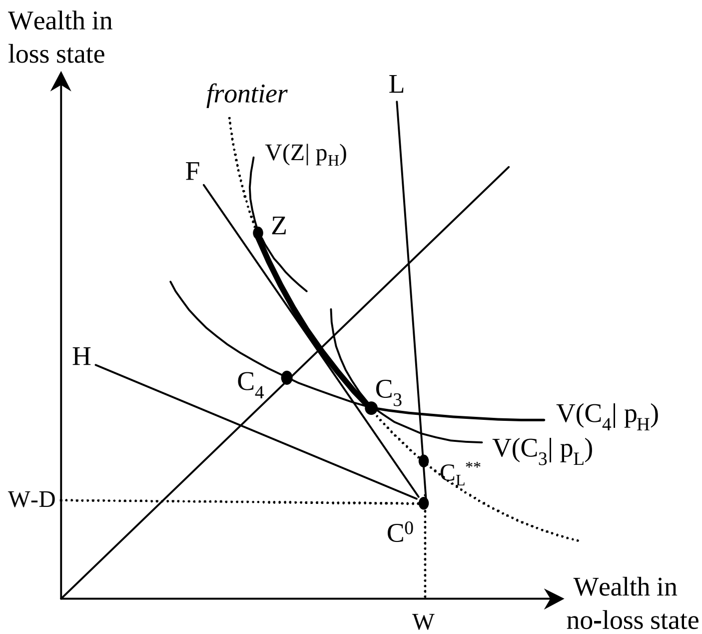

Figure 5 : A Wilson-Miyazaki-Spence equilibrium

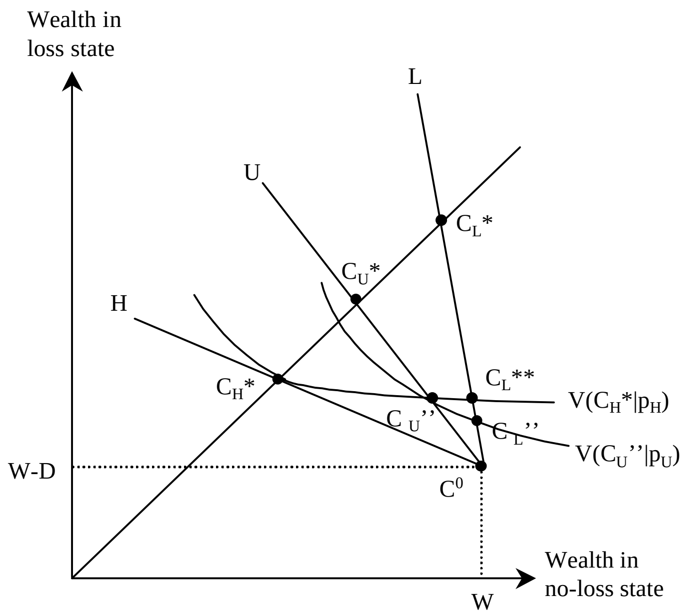

Figure 6 : Endogenous information