Adverse selection and risk adjustment under imperfect competition

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March 22, 2014

Abstract

This paper analyzes the distortions of health insurers' benefit packages due to adverse selection when there is imperfect competition. Using the (conditional and mixed) logit model for a theoretical analysis of market equilibria under adverse selection, for the case of two risk types the following main results are derived: For intermediate levels of competition, the benefit packages of both risk types are distorted in the separating equilibrium. If the level of competition decreases, the distortion decreases for the low risk type, but increases for the high risk type; in addition, the number of insurers offering the benefit package for the high risk type decreases. If the level of competition is low enough, a pooling equilibrium emerges, which generally differs from the Wilson-equilibrium. It is shown that these results have important implications for risk adjustment: For intermediate levels of competition, risk adjustment can be ineffective or even decrease welfare if it is not reasonably precise.

JEL-**classification:** I 18.

Keywords: Adverse selection, discrete choice, imperfect competition.

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1 Introduction

Adverse selection has long been recognized as a potentially serious problem for insurance markets in general, and health insurance markets in particular.[1] If individuals differ in their expected medical cost, but health insurers are not allowed to charge an individual-specific premium, this creates incentives to distort the benefit package, so that the medical services offered are attractive for some individuals, but not for others. Insurers who respond to these incentives are said to perform indirect risk selection: they exploit adverse selection to influence the risk structure of their insured. Several empirical studies have shown that these distortions exist and can be severe.[2] Because many health insurance markets, especially in Europe, but also in the U.S., are characterized by community rating, the number of individuals affected by these distortions is likely to be substantial.

Theoretical studies analyzing these distortions have usually considered the case of perfect competition, see, e.g., the highly influential study of Glazer and McGuire (2000). Health insurance markets may, however, not always be perfectly competitive. For the U.S., Dafny (2010) has demonstrated that in some markets, health insurers have a considerable degree of market power.[3] For the European context, Schut et al. (2003) and Tamm et al. (2007) have shown that price elasticities of demand are low and that the number of individuals switching insurers is smaller than what would have to be expected in a perfectly competitive market. Some health insurance markets are rather imperfectly competitive.

This paper analyzes the interaction of these two phenomena – adverse selection and imperfect competition – with a special focus on the distortions of the benefit packages offered. For health insurances markets, this interaction so far has only been examined for the following two settings: In the first one, an arbitrary number of risk types is considered, but a pooling equilibrium is assumed, so that all insurers offer the same contract, see Frank et al. (2000). We relax this assumption and show that whether a separating or a pooling equilibrium emerges depends on the level of competition.

In the second setting, a separating equilibrium for the case of two risk types is analyzed. Imperfect competition is captured with a Hotelling-model, where each insurer offers two contracts (so that the incentive compatibility condition is satisfied); see, e.g., Olivella and Vera-Hernandez (2007).[4] This second class of models allows for sorting into different contracts, but also implies a strong asymmetry of demand responses which in some health insurance markets may not apply: Consider a group of individuals holding a contract from a particular insurer. A new contract, yielding slightly higher utility than the contract they currently hold, would attract all these individuals, if offered by the same insurer, but only a small share of them, if offered by a different insurer. For some health insurance settings, this is a reasonable assumption and captures the behavior of the insured well. One example is a fee-for-service setting, where contracts differ mainly in the deductibles and coinsurance

[1] See Cutler and Zeckhauser (2000) and Breyer et al. (2011).

[2] See Frank et al. (2000), Cao and McGuire (2003) and Ellis and McGuire (2007). For the distinction between direct and indirect risk selection, see Breyer et al. (2011), p. 729; for an overview of risk selection, see van de Ven and Ellis (2000).

[3] See also Cebul et al. (2011); for the Medigap market, see Maestas et al. (2009) and Starc (2013).

[4] See also Biglaiser and Ma (2003), Jack (2006) and Bijlsma et al. (2011).

rates. Insured will easily switch to a different contract of the same insurer if it yields higher utility, but – being not perfectly informed about whether other insurers reimburse bills as timely and at the same level of generosity – may hesitate to switch to another insurer if the benefit package itself is only slightly superior.

In some health insurance settings, however, insurers do not specify reimbursement rates, but offer benefit packages of medical services, which may differ in the drug formularies, the physician networks, the hospitals that can be attended or the disease management programs that are implemented. In this case, from the perspective of an individual it will not make much of a difference, wether a new contract with, say a different physician network, is offered by the same insurer or by a different insurer. For these health insurance settings, it is important to relax the assumption of a strong demand asymmetry, and we do so by analysing a model where each insurer offers only one contract, so that this asymmetry cannot occur.[5]

To keep the analysis simple, we consider the case of two risk types. If each insurer offers only one contract, but there are two risk types, a meaningful model that is supposed to also capture a separating equilibrium must comprise more than two insurers. Therefore, a Hotelling-model is not appropriate. This is why we consider a discrete choice model, namely, the (conditional and mixed) logit model.[6] The logit model has been extensively used in empirical analyzes of health insurance choice.[7] In this paper we suggest that it is also a very useful model for a theoretical analysis of market equilibria under adverse selection when there is imperfect competition: It can capture any number of insurers, allows to endogenize whether a separating or a pooling equilibrium emerges, and – by introducing the concept of 'indifference curve areas' – has a graphical representation that provides an intuitive understanding of the economic forces driving the additional distortions under imperfect competition. It shows that of the two parameters that influence the level of competition – the number of insurers and individuals' responsiveness to differences in the benefit package – the latter is more important than the former. Finally, it captures the fact that some individuals 'make mistakes' when choosing their health insurance contract, e.g., because of inertia or information problems.[8]

For a very high level of competition, the discrete choice model replicates the results of a model under perfect competition, where an efficient benefit package is offered for the high risk type H, and an inefficient one for the low risk type L (Rothschild and Stiglitz 1976); see Figure 1, where we present – schematically – the distortions under perfect and imperfect

[5] One could also relax the assumption in a setting where each insurer offers more than one contracts. This would complicate the model because each insurer would then have to take into account the consequences of changing one contract on the demand of its other contracts. If the number of insurers is large, this effect will be small, but if the number of insurers is small, it may not be negligible. However, all the distortions we derive would also occur in this setting.

[6] Olivella and Vera-Hernandez (2010) have analyzed a different extension of the Hotelling-model, the spokes model of Chen and Riordan (2007). They show that when each insurer can offer two contracts, a pooling equilibrium does not exist; also, an equilibrium where each insurer offers only one contract (but contracts differ by insurer) does not exist either: At least one insurer offers both contracts so that the incentive compatibility constraint is satisfied. This implies the strong demand asymmetry which does not apply to the setting we analyze.

[7] See, e.g., Feldman et al. (1989), Royalty and Solomon (1999), Harris et al. (2002), Keane (2004) and Ericson and Starc (2012).

[8] See Handel and Kolstad (2013) and Sinaiko and Hirth (2011)) for empirical evidence.

competition. m^* represents the efficient benefit package. Under perfect competition, which is depicted at the beginning of the abscissa, we have $m^H = m^*$ and $m^L < m^*$.

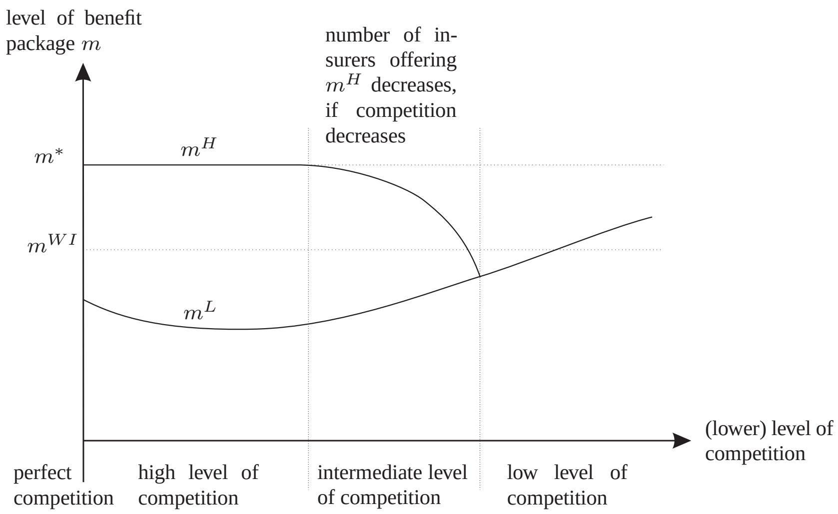


Figure 1: Distortions of the benefit packages under perfect and imperfect competition. m^* denotes the efficient level, m^{WI} the Wilson-equilibrium.

With imperfect competition, we can distinguish three levels of competition: For high levels of competition, m^H is always at the efficient level, while, initially, m^L decreases if the level of competition goes down.

For intermediate levels of competition, both m^H and m^L are distorted. If the level of competition goes down, m^H decreases and m^L increases. In addition, the number of insurers offering the benefit package for the high risk type decreases, until, for a low level of competition, the pooling equilibrium emerges. For the pooling equilibrium, if the level of competition goes down, m increases, so it coincides with the Wilson-equilibrium m^{WI} only for one particular level of competition.[9]

These results show that imperfect competition has a direct effect on the distortions of the benefit packages offered. The famous result of no distortion at the top clearly does not hold in general under imperfect competition: For intermediate levels of competition, both benefit packages are distorted in a separating equilibrium. This implies that the most generous generous benefit package offered in a health insurance market may be a (severely) biased indicator of the efficient level of medical services; this may contribute to explain why a number of recent empirical studies have found the welfare losses caused by adverse selection to be surprisingly small.[10] However, these studies have estimated the welfare losses due to inefficient pricing of a *given* set of benefit packages, but as explicitly stated by Einav, Finkelstein, and Levin (2010), the welfare losses due to an inefficient set of benefit packages may be much larger, and we show, how these inefficiencies depend on the level of competition.

In the second part of this paper we show that the economic forces driving these results

[9] If m^{WI} is very low, it may occur that all pooling equilibria of the discrete choice model are above m^{WI}.

[10] See Einav, Finkelstein, and Cullen (2010), Bundorf et al. (2012) and Handel (2013).

have important implications for risk adjustment: For intermediate levels of competition, a risk adjustment scheme that is imprecise and only partially compensates insurers for the cost differences of different risk types may be ineffective or even increase distortions; at such levels of competition, risk adjustment only increases welfare if the cost differences are reduced by a considerable amount. This contrasts with the case of either high or low levels of competition, where risk adjustment always increases welfare, even if transfers only compensate cost differences to a small degree. With these results we add to the small literature that analyzes the negative side effects of risk adjustment.[11]

The remainder of this paper is organized in a way so that an intuitive understanding of the economic forces driving the results can be provided. We begin with the case that risk types are observable in Section 2: We introduce the discrete choice model in Section 2.1 and determine the equilibrium if there is one risk type in Section 2.2; we present an intuitive graphical representation of this logit model in Section 2.3 by introducing the concept of 'indifference curve areas' and briefly discuss the case of two observable risk types in Section 2.4.

We then analyze the case that risk types are unobservable – or that risk types are observable but community rating is imposed by regulation – in Section 3:[12] We derive the separating equilibrium in Section 3.1 and show, how it depends on the level of competition in Section 3.2. The pooling equilibrium is discussed in Section 3.3. We comment on the welfare effects of different levels of competition for both the separating and the pooling equilibrium in Section 3.4 and provide an example in Section 3.5.

We consider the implications of our results for risk adjustment in Section 4. Using the example introduced in Section 3.5, we first show that welfare may decrease if a risk adjustment scheme becomes more precise (Section 4.1). We then explain why such a decrease can only occur in a separating equilibrium (Section 4.2), but not in a pooling equilibrium (Section 4.3).

Finally, some of the assumptions of the model are discussed in Section 5, and Section 6 concludes.

2 The discrete choice model

2.1 Basic model

We consider a setting as in Frank et al. (2000), where each individual may suffer from S different illnesses. In case an illness s is developed, utility changes by $v_s(m_s)$, where m_s is the medical services (measured in monetary terms) provided by the insurer; $v_s(m_s)$ is increasing at a decreasing rate, i.e. $v_s'(m_s) > 0$ and $v_s''(m_s) < 0$. The individual has

[11] See Brown et al. (2012) who show that for the U.S., the improvement of the risk adjustment scheme used for Medicaid has increased the incentive to enroll certain subgroups of individuals which are now even more 'overpriced' than before the reform; this increases health insurers' wasteful expenditures to attract these individuals.

[12] Throughout the paper we will refer to this case by 'unobservable risk type'; regarding the distortions we analyze it is of course identical to the setting 'observable risk type under community rating'.

income y and has to pay a premium $\widetilde{R}$. Utility is given by

$$u = y - \widetilde{R} + \sum_{s=1}^{S} p_s v_s(m_s),$$

where p_s is the probability for illness s. The efficient level of medical services for each illness is implicitly defined by $v_s'(m_s^*) = 1$.

Insurers maximize profits by deciding which levels of medical services to offer and which premium to charge.[13] It is straightforward to show that for all illnesses s for which the probability p_s is identical across individuals, insurers will offer the efficient level of medical services. Distortions only arise for those illnesses for which there is heterogeneity in risk.

To keep the model simple, we analyze the case where probabilities differ for only one of the illnesses, for which we assume two risk types $r = H, L$, with $p^H > p^L$. Since insurers will offer all the other medical services at the efficient level, we can skip these other illnesses (and income y) to simplify the notation, and write utility as

$$u = p^r v(m) - R. \tag{1}$$

We consider, however, the full model to be that in addition to m, insurers also offer these other medical services (at the efficient level) and charge a premium $\widetilde{R}$ that differs from R by the expected cost of these other illnesses. The distortions of m that we describe should thus be considered to apply to a specific illness like, e.g., diabetes (or an illness category, like mental illnesses) rather than the overall level of medical services.[14]

There are n insurers j, each offering a contract $\{m^j, R^j\}$. Within a discrete choice model, individuals' utility as given by (1) is augmented by an insurer specific utility component ε_{ij}, that comprises all the influences on the choice of an insurer that are independent of m and R.[15] The utility of an individual i (being of risk type r) when choosing an insurer j therefore is

$$u_i(m^j, R^j) = p^r v(m^j) - R^j + \varepsilon_{ij}. \tag{2}$$

We assume ε_{ij} to be i.i.d. extreme value, so that the logit model arises, but later show that the main results also hold for other distributional assumptions.

The level of competition is determined by the variance of ε_{ij}, $Var(\varepsilon_{ij}) = \sigma^2 \frac{\pi^2}{6}$:[16] If σ is large, ε_{ij} assumes large positive and negative values, so the additional utility component is important; then competition with respect to different benefit packages is low: If an insurer raises its premium or lowers the level of medical services, only a few of its insured will switch to another insurer. Because insurers are not close substitutes, each insurer has a

[13] We discuss the case that the premium is set by a regulator in Section 5.3.

[14] Regarding the overall level of medical services it would certainly be more appropriate to assume a continuous distribution, but for an illness like diabetes or depression, the most important distinction is whether an individual is chronically ill ($p^H = 1$) or not (p^L rather small).

[15] ε_{ij} thus may capture, e.g., perceived friendliness of personnel, location, or, which insurer was recommended by family and friends, but it may also be unfounded and therefore represent decision mistakes.

[16] Note that it is common to state the variance of ε_{ij} as a multiple of $\frac{\pi^2}{6}$ for the extreme value distribution, see Train (2009, p. 24).

considerable degree of market power. If, on the other hand, σ is small, ε_{ij} only has a small influence on the decision of which insurer to choose, so competition is high. With $\sigma = 0$, the model encompasses the case of perfect competition.[17] For $\sigma > 0$, the level of competition of course also increases in the total number of insurers, n.[18]

2.2 The Equilibrium with one risk type

Denote the utility component that does not depend on ε_{ij} by[19]

$$V^j = pv(m^j) - R^j. \tag{3}$$

Each individual chooses the insurer that offers the highest overall level of utility, including ε_{ij}. Individual i will therefore choose insurer k if

$$V^k + \varepsilon_{ik} > V^l + \varepsilon_{il} \quad \forall\, l \neq k.$$

For ε_{ij} distributed i.i.d. extreme value with variance $Var(\varepsilon_{ij}) = \sigma^2 \frac{\pi^2}{6}$, the probability of individual i choosing insurer k is given by[20]

$$Prob(i \text{ chooses } k) = \frac{e^{\frac{V^k}{\sigma}}}{\sum_j e^{\frac{V^j}{\sigma}}}. \tag{4}$$

The mass of individuals is normalized to one, so that expression (4) also represents insurer k's market share, which we denote by P^k. Assuming profit maximization, the objective of insurer k is to maximize $\pi^k = P^k \pi_i^k$, where $\pi_i^k = R^k - pm^k$ denotes insurer k's profit per individual.

It will turn out much easier to derive the main results for the case of unobservable risk types if we reformulate the insurer's objective in terms of $\{m^j, V^j\}$ instead of $\{m^j, R^j\}$. Graphically, in an m-R-diagram, each insurer j chooses an indifference curve I^{V^j} associated with the utility level V^j, and a level of medical services m^j along this indifference curve.

Using (3) to substitute for R^k, we therefore state insurer k's objective as

$$\max_{m^k, V^k} \pi^k = P^k \pi_i^k = \frac{e^{\frac{V^k}{\sigma}}}{\sum_j e^{\frac{V^j}{\sigma}}} \left(pv(m^k) - V^k - pm^k \right). \tag{5}$$

A convenient property of the market share P^k, which simplifies the derivation of the results, is that its derivative can be expressed in terms of P^k itself in a simple way:

$$\frac{\partial P^k}{\partial V^k} = \frac{P^k(1 - P^k)}{\sigma}. \tag{6}$$

[17]Note that the parameter σ has a similar impact on the degree of market power insurers have as the parameter t, the transportation cost, in a Hotelling-model.

[18]We analyze the effect of different numbers of insurers, but do not endogenize n. However, this could easily be done by assuming fixed costs of setting up a new health insurance.

[19]Because in this section we consider the case of only one risk type, we replace p^r by p.

[20]See Train (2009, p. 40).

Using (6), the FOCs for the insurer's objective (5) are given by

$$\frac{\partial \pi^k}{\partial m^k} = P^k \left[pv'(m^k) - p \right] = 0 \tag{7}$$

$$\frac{\partial \pi^k}{\partial V^k} = \frac{P^k(1-P^k)}{\sigma} \pi_i^k - P^k = 0. \tag{8}$$

Condition (7) requires $v'(m^k) = 1$, so m^k is chosen efficiently. Condition (8) shows the two countervailing effects of increasing V^k: The share of individuals choosing k increases by $P^k(1-P^k)\frac{1}{\sigma}$; weighting by π_i^k captures the additional profit. On the other hand, increasing V^k implies reducing R^k (and thereby π_i^k) by the same amount; this applies to the share of individuals choosing k, P^k, capturing the loss in profit. For these two effects to cancel out, we have to have $\pi_i^k = \frac{\sigma}{1-P^k}$.

It can be shown that the only equilibrium is a symmetric one, where all insurers choose the same level of utility $V^j = \widetilde{V}\ \forall j$. Since, in this case, $P^k = \frac{1}{n}$, in equilibrium profit per individual is

$$\pi_i^k = \frac{n}{n-1}\sigma, \tag{9}$$

and total profit per insurer is

$$\pi^k = \frac{\sigma}{n-1}. \tag{10}$$

As is to be expected, more competition leads to lower profits: both, profit per individual, π_i^k, and total profit per insurer, π^k, increase in σ and decrease in n.

If σ is small, offering a higher utility level yields a large increase in the share of individuals, because individuals are responsive even to small differences in contracts. This raises the incentive to offer a higher utility level, thereby reducing profits in equilibrium.

If n is large, each insurer's market share is small. Offering a higher utility level then attracts individuals from a large 'external' market share $1 - P^k$. This again raises the incentive to offer higher utility levels, lowering profits. We refer to this as the 'more competition due to a larger external market share'-effect. This effect plays an important role when risk types are unobservable.

Note that this external market share $1 - P^k$ is confined to the interval $[0.5, 1[$. The effect of the total number of insurers on profits is therefore rather limited: Increasing this number from $n = 2$ to $n \to \infty$ only cuts profit per individual π_i^k in half, see condition (9). In contrast, the effect of σ on profit per individual is not bounded. In that sense, σ is the more important variable to capture large differences in the level of competition.

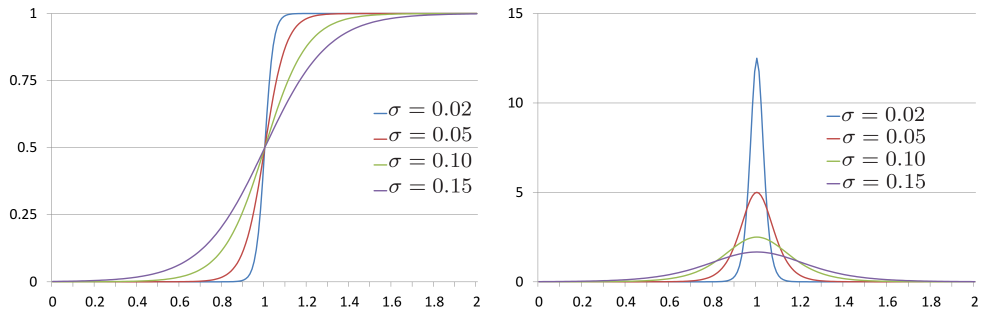
2.3 Graphical representation of the equilibrium with one risk type

We will now present the solution graphically in somewhat greater detail than necessary for this basic model, because it greatly facilitates the derivation of the results for the case of unobservable risk types.

As P^k denotes the share of all individuals choosing insurer k, it can be considered a distribution function $P^k(V^k)$. In equilibrium, when all the other insurers offer the same level of utility $\widetilde{V}$, we have

$$P^k = P^k(V^k|\sigma, \widetilde{V}) = \frac{e^{\frac{V^k}{\sigma}}}{e^{\frac{V^k}{\sigma}} + (n-1)e^{\frac{\widetilde{V}}{\sigma}}}. \tag{11}$$

The shape of this distribution function and of the corresponding density $P^k(1-P^k)\frac{1}{\sigma}$ is shown in Figure 2.



(a) Distribution function (b) Density function

Figure 2: Distribution function $P^k(V^k|\sigma, \widetilde{V})$ and density function $P^k(1-P^k)\frac{1}{\sigma}$ with $n = 2$ and $\widetilde{V} = 1$ for different values of σ

We can depict this distribution function P^k in the m-R-diagram that shows the equilibrium where all insurers offer $\{m^*, \widetilde{V}\}$ by drawing a shaded area around the $I^{\widetilde{V}}$-indifference curve representing the corresponding density $P^k(1-P^k)\frac{1}{\sigma}$, see Figure 3; the different levels of darkness of this shaded area are a measure of the level of this density.[21]

If one insurer k charges a higher premium and thereby offers a utility level $V^k < \widetilde{V}$, the corresponding indifference curve I^{V^k} lies above $I^{\widetilde{V}}$, see Figure 3 again. As contract A is above the shaded area, both P^k and the corresponding density are zero.[22] Increasing utility V^k then moves contract A (along the line $m = m^*$) into the shaded area, which increases P^k and decreases π_i^k. These two effects cancel out when contract A lies on the $I^{\widetilde{V}}$-indifference curve. Increasing V^k even further then increases P^k beyond $\frac{1}{n}$, and as soon as contract A is below the shaded area, $P^k = 1$.

For the following reason, this shaded area could be referred to as an 'indifference curve area': Consider the case that $n = 2$, so that there is only one other insurer j that offers $\widetilde{V}$. Insurer k, to be chosen by individual i, has to offer a utility level

$$V^k > V^j + (\varepsilon_{ij} - \varepsilon_{ik}).$$

[21]As a technical detail, note that for $n = 2$, the maximum of this density is at $V^k = \widetilde{V}$, but for $n > 2$, it is at $V^k > \widetilde{V}$. Therefore the 'center' of the shaded area is at the $I^{\widetilde{V}}$-indifference curve for $n = 2$, and somewhat below it for $n > 2$. To simplify the exposition in the graphs, we will always draw the center of the shaded area at $\widetilde{V}$.

[22]In Figure 2, contract A could be, e.g., at $V^k = 0.1$. Of course, strictly speaking, $P^k > 0 \; \forall \; V^k$, see (11), but above the shaded area, both P^k and the density $P^k(1-P^k)\frac{1}{\sigma}$ are extremely small and almost equal to zero.

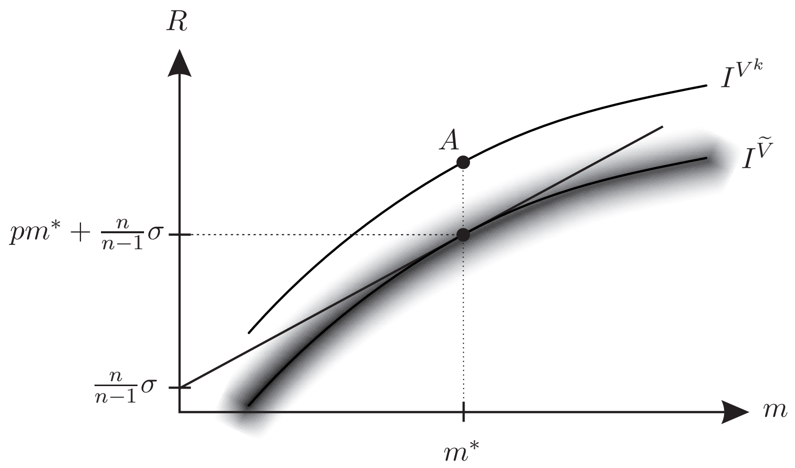


Figure 3: Equilibrium contract $\{m^*, pm^* + \frac{n}{n-1}\sigma\}$ in the discrete choice model with one risk type. The shaded area around the indifference curve $I^{\widetilde{V}}$ represents the density $P^k(1-P^k)\frac{1}{\sigma}$ of the distribution function P^k.

For some individuals, $\varepsilon_{ij} - \varepsilon_{ik} > 0$, so the indifference curves insurer k must offer to make these individuals indifferent between the two insurers are below the $I^{\widetilde{V}}$-indifference curve; if $\varepsilon_{ij} - \varepsilon_{ik} < 0$, it suffices to offer an indifference curve above $I^{\widetilde{V}}$. From the perspective of insurer k the shaded area therefore also represents the whole set of all indifference curves, i.e., an 'indifference curve area'.[23]

There are two effects if σ increases: First, the iso-profit line associated with the equilibrium contract is shifted upwards. Secondly, it is straightforward to show that the distribution function P^k as stated in (11) increases for $V^k < \widetilde{V}$ and decreases for $V^k > \widetilde{V}$; it becomes less steep at $V^k = \widetilde{V}$, so the density decreases around $\widetilde{V}$ (see Figure 2). If σ increases, the distribution function is spread out (over a wider range), which can be depicted in Figure 3 by drawing a wider (and lighter) shaded area around the indifference curve $I^{\widetilde{V}}$.

Finally note that if insurer k moves its contract along the I^{V^k}-indifference curve, P^k does not change, regardless of whether I^{V^k} is above, within or below the shaded area. This is because the distance between I^{V^k} and $I^{\widetilde{V}}$ in the R-direction is the same for all levels of m. The I^{V^k}-indifference curve is therefore also an iso-P^k-curve.

2.4 The equilibrium with two observable risk types

We now turn to the case that there are two risk types, $r = H, L$, with $p^H > p^L$; the share of L-types is λ. We denote the insurers offering a contract for the L-types as insurers of type A, and insurers offering a contract for the H-types as insurers of type B.[24] The number of

[23]If there is more than one other insurer, the argument is the same if ε_{ij} is replaced by $max_{j \neq k}\varepsilon_{ij}$.

[24]The following Section 3.1 will make clear why do not index insurers by L and H.

insurers is n^A and n^B respectively, with $n^A + n^B = n$.

It follows immediately from what we derived for the case of one observable risk type that, in equilibrium, all insurers will offer the efficient level of medical services $m^A = m^B = m^*$, but premiums will differ according to risk type. Because insurers can decide whether to be of type A or type B, total profits per insurer have to be the same for both types of insurers, i.e. $\pi^A = \pi^B$. These profits are given by

$$\pi^A = \lambda \frac{\sigma}{n^A - 1} \quad \text{and} \quad \pi^B = (1-\lambda)\frac{\sigma}{n^B - 1}, \tag{12}$$

and are equal for

$$n^A = \lambda n + (1 - 2\lambda) \quad \text{and} \quad n^B = (1-\lambda)n - (1-2\lambda). \tag{13}$$

Of course, n^A and n^B have to be integer numbers, so that the expressions given in (13) are only an approximation to the true value.[25] As it is not important for the derivation of our main results, we do not elaborate on whether n^A as given by (13) has to be rounded up or off.

However, the requirement of n^A and n^B to be integer can, for some parameter settings, cause an equilibrium not to exist: For some values of n^A and n^B, it may be profitable for an insurer of type B to enter the market for the L-types and become an insurer of type A; but after the new 'equilibrium' has been attained, where π_i^A is decreased and π_i^B increased, the same insurer may then find it profitable to become of type B again. Following Newhouse (1996), assuming a small fixed cost of setting up a new contract (in this case for switching from one insurer type to the other) then stabilizes the equilibrium.[26]

As is apparent from condition (13), n^A and n^B do not depend on σ, the level of competition. This, however, is different for the case of unobservable risk types.

3 Two unobservable risk types

Under perfect competition, for the separating equilibrium to exist, the share of L-types must be below a critical level (Rothschild and Stiglitz 1976). The same applies for this discrete choice model if the level of competition is high (or intermediate). In this case, the argument for the non-existence of an equilibrium is the same as under perfect competition: If the share of L-types is too large, the 'separating equilibrium' can be destroyed by offering a contract that would be chosen by both risk types and yield a higher profit than either of the two contracts in the 'separating equilibrium'. Such a 'pooling equilibrium' can then be destroyed by offering a contract chosen only by the L-types.

[25] Note that according to (13), the share of insurers of type A equals the share of L-types only if $\lambda = \frac{1}{2}$. For $\lambda < \frac{1}{2}$, we have $n^A > \lambda n$. This is because with $\lambda < \frac{1}{2}$, there will be fewer insurers of type A than of type B, ($n^A < n^B$), so the market served by insurers of type A will be less competitive. This, c.p., causes profits per individual to be higher in the smaller market, which induces a somewhat higher number of insurers to become of type A than given by λn.

[26] In the large number of simulations where we determined the equilibrium values explicitly, the problem of non-existence of an equilibrium only occurred for a small fraction of parameter combinations.

This is different if the level of competition is low; in this case, the pooling equilibrium is stable and emerges irrespective of the level of λ.[27] Table 1 summarizes which equilibria occur.

Table 1: Type of equilibrium for different levels of competition and different shares of low risk types.

	perfect competition ($\sigma = 0$)	high/intermediate level of comp. (σ small/intermediate)	low level of competition (σ large)
λ low enough	separating equilibrium	separating equilibrium	pooling equilibrium
λ too high	no equilibrium	no equilibrium	pooling equilibrium

In the following Section 3.1, where we want to analyze the separating equilibrium, we therefore assume both λ and σ to be low enough so that this equilibrium exists. We begin with the case of a very low level of σ, so that overall profits are small and the contract designated for the L-types yields a negative profit when chosen by an H-type. The effects of an increase in σ are then derived in Section 3.2 and the pooling equilibrium is discussed in Section 3.3.

3.1 The separating equilibrium for a low level of σ

If the risk type is unobservable, a contract offered by insurer A (or B) may be chosen by both risk types.[28] Therefore, for both types of insurers, risk type specific utility levels, probabilities and profits have to be defined.

For insurer A, the utility level associated with a contract $\{m^A, R^A\}$ depends on the risk type $r = L, H$ according to

$$V_r^A = p^r v(m^A) - R^A.$$

The probability that an individual of risk type r chooses insurer A is given by

$$P_r^A = \frac{e^{\frac{V_r^A}{\sigma}}}{e^{\frac{V_r^A}{\sigma}} + \sum_{j \neq A} e^{\frac{V_r^j}{\sigma}}}. \tag{14}$$

Finally, type specific profits in terms of V_L^A and m^A are

$$\pi_r^A = p^L v(m^A) - V_L^A - p^r m^A. \tag{15}$$

V_r^B, P_r^B and π_r^B are defined equivalently.

We formulate the objective of insurer A in terms of V_L^A and m^A, and express V_H^A as

$$V_H^A = V_L^A + (p^H - p^L)v(m^A). \tag{16}$$

[27] We explain why this is the case in Section 3.3.3.

[28] In the following we will often use the term ‘insurer A’ instead of ‘one of the insurers of type A.’

Using these definitions, insurer A's objective can be stated as

$$\max_{V_L^A, m^A} \pi^A = \lambda P_L^A \pi_L^A + (1-\lambda) P_H^A \pi_H^A, \tag{17}$$

with FOCs

$$\frac{\partial \pi^A}{\partial V_L^A} = \lambda \left[\frac{P_L^A(1-P_L^A)}{\sigma} \pi_L^A - P_L^A \right] + (1-\lambda) \left[\frac{P_H^A(1-P_H^A)}{\sigma} \pi_H^A - P_H^A \right] = 0 \tag{18}$$

$$\begin{aligned} \frac{\partial \pi^A}{\partial m^A} &= \lambda P_L^A \left[p^L v'(m^A) - p^L \right] + (1-\lambda) P_H^A \left[p^L v'(m^A) - p^H \right] \\ &\quad + (1-\lambda) \frac{P_H^A(1-P_H^A)}{\sigma} (p^H - p^L) v'(m^A) \pi_H^A = 0, \end{aligned} \tag{19}$$

and likewise for insurer B.[29] In addition, we have to have $\pi^A = \pi^B$, i.e.

$$\lambda P_L^A \pi_L^A + (1-\lambda) P_H^A \pi_H^A = \lambda P_L^B \pi_L^B + (1-\lambda) P_H^B \pi_H^B. \tag{20}$$

In equilibrium, when all insurers of type A offer the same contract for the L-types, and all insurers of type B offer the same contract for the H-types, we have

$$P_L^A = \frac{e^{\frac{V_L^A}{\sigma}}}{n^A e^{\frac{V_L^A}{\sigma}} + n^B e^{\frac{V_L^B}{\sigma}}}. \tag{21}$$

The other market shares, P_H^A, P_L^B and P_H^B, are defined accordingly.

We will first present the separating equilibrium graphically and then show how the solution can be derived from the four FOCs and the profit equality constraint.

With unobservable risk types and perfect competition, in Figure 4, the equilibrium consists of contract B, chosen by the H-types, and contract A_1, chosen by the L-types.[30] However, as the shaded area around the $I^{V_H^B}$-indifference curve shows, under imperfect competition, insurer A would find a considerable share of H-types choosing contract A_1.[31] Therefore, contract A_1 has to be shifted outside the shaded area.

Assume, that it is shifted (along the iso-π_L^A-line) to A_2, where (almost) none of the H-types choose this contract. But then insurer A could move its contract along the $I^{V_L^A}$-indifference curve to the right: This would leave the number of L-types choosing this insurer unaffected (see the definition of P_L^A in (14)), but increase profits per L-type, π_L^A, because the slope of the $I^{V_L^A}$-indifference curve is larger than the slope of the iso-π_L^A-lines for all contracts with $m^A < m^*$. It would also increase the number of the H-types choosing insurer A; however, since the density $P_H^A(1-P_H^A)\frac{1}{\sigma}$ is (almost) zero at contract A_2, at the boundary of the shaded area this effect is of second order. There is a third effect when moving along $I^{V_L^A}$: Depending on whether the slope of the $I^{V_L^A}$-indifference curve is smaller or larger than the

[29] As insurer B offers a contract for the H-types, we formulate its objective in terms of V_H^B, (not V_L^B).

[30] In this case, the iso-profit lines would of course start at the origin, as $\sigma = 0$.

[31] Here, the shaded area represents the density of the distribution function $P_H^A(V_H^A) = P_H^A(V_L^A, m^A)$, or the 'indifference curve area' of the H-types from the perspective of an insurer of type A.

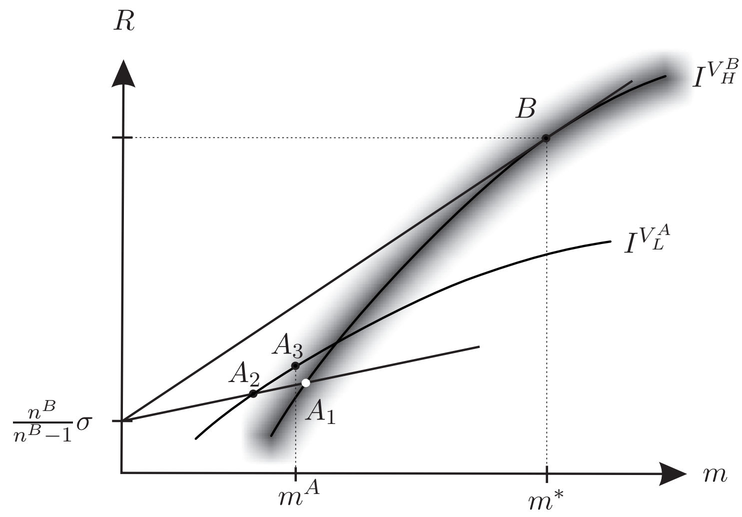


Figure 4: Separating equilibrium with two unobservable risk types. Contracts B and A_3 are offered. The case $n^A = n^B$, i.e. $\lambda = 0.5$, is depicted; for $n^A \neq n^B$, the iso-profit lines start at different points on the ordinate.

slope of the iso-profit lines for the H-types, p^H, this will increase or decrease profit per H-type, π_H^A.

Insurer A will therefore move its contract along the $I^{V_L^A}$-indifference curve until these three effects – the increase of π_L^A, the increase of P_H^A, and the change of π_H^A – cancel out, which will be at a contract as indicated by A_3.

In equilibrium, a small share of H-types chooses contract A. This contrasts with the contract offered by insurer B: As contract B is far away from the shaded area that can be drawn around the $I^{V_L^A}$-indifference curve, none of the L-types choose contract B.[32] As there is no interference of the L-types, contract B is at the efficient level, as in the case of perfect competition.

Result 1. *In the separating equilibrium, if σ is small, then only the benefit package for the L-types is distorted: $m^A < m^*$ and $m^B = m^*$. A small share of the H-types chooses the contract designated for the L-types, but none of the L-types choose the contract designated for the H-types: $P_H^A > 0$ and $P_L^B = 0$.*

In the remainder of this section we show how these results are reflected in the FOCs. We begin with insurer B: With $P_L^B = 0$, the FOC with respect to m^B simplifies to $v'(m^B) = 1$, so $m^B = m^*$. For the FOC with respect to V_H^B, we have $\pi_H^B = \frac{P_H^B}{1-P_H^B}\sigma$. For insurer B, both FOCs are identical to the case that risk types are observable.

This is different for insurer A: If P_H^A was equal to zero, condition (19) would simplify to $v'(m^A) = 1$, so we would have $m^A = m^*$. This, together with the lower premium, would induce at least some of the H-types to choose insurer A, a contradiction to $P_H^A =$

[32]The shaded area around the $I^{V_L^A}$-indifference curve represents the density of $P_L^B(V_L^B) = P_L^B(V_H^B, m^B)$.

0, so $P_H^A > 0$. With $P_H^A > 0$, condition (19) is violated for $v'(m^A) = 1$, because both $[p^L v'(m^A) - p^L]$ and π_H^A (in the second and third summand) are negative; therefore, $v'(m^A) > 1$, so $m^A < m^*$.

The FOC with respect to V_L^A, condition (18), would simplify to $\pi_L^A = \frac{P_L^A}{1-P_L^A}\sigma$ for $P_H^A = 0$. However, with $P_H^A > 0$, the second bracket is negative because $\pi_H^A < 0$; therefore, π_L^A has to be larger than for the case of $P_H^A = 0$, so the equilibrium contract A_3 is above the iso-profit line as shown in Figure 4.

As in this section we consider the case that σ is very small, P_H^A will be close to zero, because the density $P_H^A(1 - P_H^A)\frac{1}{\sigma}$ will already be large for a small value of P_H^A.[33] Therefore, A_3 will only be slightly above the iso-profit line as shown in Figure 4. As π_L^A is almost not affected by the very low share of high risks, the number of insurers of type A and type B, n^A and n^B, will then not be different from the case when risk types are observable. This, however, changes as σ increases.

3.2 The dependence of the separating equilibrium on the level of competition

So far, the equilibrium under imperfect competition looks rather similar to the case of perfect competition. We will now show that this only holds for high levels of competition. In the following Section 3.2.1, we analyze the effects of a decrease in competition due to an increase in σ; we discuss a decrease of competition due to a decrease of n in Section 3.2.2.

3.2.1 The dependence of the separating equilibrium on σ

In Section 2.2 it was shown that an increase in σ increases profits, as insurers reduce the utility levels they offer by increasing the premium, which shifts the iso-profit line associated with the equilibrium upwards. The same applies in this separating equilibrium. However, because of the following additional effects, the increase in premiums alone does not yet constitute the new equilibrium:

Effect on m^A

If σ increases, the shaded area around the $I^{V_H^B}$-indifference curve becomes wider; contract A_3, if not moved, would be closer to the center of this area (relative to its boundaries), so P_H^A would increase.[34] To avoid being chosen by these additional H-types, which incur a negative profit, insurer A has to reduce m^A. On the other hand, there is the countervailing effect that as premiums increase, insuring an additional H-type now causes a smaller loss, which creates an incentive to increase m^A.

For a general utility function $v(\cdot)$, the aggregate of these two effects on m^A for a particular level of σ is indeterminate. However, if σ is very small, P_H^A is close to zero, while π_H^A is

[33] This also follows immediately from condition (19), which, if σ is close to zero, can only be satisfied for P_H^A close to zero.

[34] This also follows directly form the definition of P_H^A, which increases in σ for all values $V_H^A < V_H^B$.

far below zero. The relative increase of P_H^A then outweighs the relative increase of π_H^A, and m^A decreases.[35] Graphically, in Figure 4, if $\sigma = 0$, the shaded area corresponds to the $I^{V_H^B}$-indifference curve; if σ becomes larger than zero, the shaded area becomes wider than the indifference curve, and contract A has to be shifted to the left, irrespective of any effect on π_H^A.[36]

If σ increases, π_H^A increases and gets closer to zero. As the loss incurred by the H-types approaches zero (and eventually even becomes a profit), the incentive to avoid being chosen by the H-types is greatly reduced (and eventually vanishes), so that at some point, insurer A increases m^A.

Effect on P_H^A

The share of H-types choosing insurer A increases in σ. The proof is given in Appendix A.1; here, we only provide a brief intuitive explanation: If, (because of the wider shaded area), m^A was reduced to a level so that P_H^A was the same as before the increase in σ, there would then be an incentive to increase m^A, and thereby P_H^A, for three reasons: First, because of the lower value of m^A, $v'(m^A)$ is increased; with P_H^A at the same level as before, condition (18) is not satisfied anymore and m^A has to be increased. Secondly, if P_H^A is at the same level as before, the density $P_H^A(1-P_H^A)\frac{1}{\sigma}$ is now lower (due to the larger value of σ), so that moving along the $I^{V_L^A}$-indifference curve does not attract as many H-types as before. Thirdly, π_H^A is increased, so attracting an additional H-type now causes a smaller loss.

Effect on n^A

If σ increases, profits increase faster for type-A insurers than for type-B insurers, so that at some point it will be profitable for one of the type-B insurers to switch and to become a type-A insurer. The proof can be found in Appendix A.2; here again, we only provide an intuitive explanation: We just showed that P_H^A increases in σ, so the number of individuals choosing any of the type-B insurers decreases. This is the first effect reducing total profits of type-B insurers relative to type-A insurers.

In addition, as the number of individuals choosing the type-A insurers increases, for the type-B insurers there is the ‘more competition due to a larger external market share’-effect, which, as we saw in Section 2.2, decreases profits per individual. Due to these two effects, π^B increases at a lower rate than π^A, so that at some level of σ, the first of the type-B-insurers finds it profitable to become an insurer of type A, and n^A increases. If σ increases further, the second type-B insurer switches, and so on, until at some level of σ the last of the type-B insurers becomes a type-A insurer, and the pooling equilibrium emerges.[37]

[35]It is straightforward to show that with m^A held fixed, both P_H^A and the density $P_H^A(1-P_H^A)\frac{1}{\sigma}$ increase in σ for σ close to zero; $v'(\cdot)$ then has to be increased, so that condition (19) is still satisfied.

[36]Note that the decrease of m^A is not necessarily confined to a small interval of σ close to zero, but can occur for a wide range of σ, see Section 3.5.

[37]Note that a single insurer of type B can not charge an excessively high premium, because this insurer would lose its insured to the insurers of type A.

Effect on m^B

We finally discuss why for intermediate levels of competition, contract B is distorted. If σ increases, the shaded areas around both indifference curves get wider. At some level of σ, the shaded area around the indifference curve of the L-types, $I^{V_L^A}$, becomes so wide that it 'reaches' contract B, so that a small share of the L-types chooses contract B (see Figure 5, where only the shaded area around the $I^{V_L^A}$-indifference curve is drawn). It will then be profitable for insurer B to move its contract along the $I^{V_H^B}$-indifference curve and reduce m^B. This leaves the share of the H-types choosing this insurer unaffected, but increases the share of the L-types, (as the iso-P_L^B-curves have a lower slope than the $I^{V_H^B}$-indifference curve), thereby increasing profits. Of course, this also reduces profits per H-type, π_H^B, but at (or close to) the efficient level of m, this effect is of second order.[38] The larger the density $P_L^B(1 - P_L^B)\frac{1}{\sigma}$ around contract B, the larger the distortion of this contract. Therefore, as long as the widening of the shaded area around the $I^{V_L^A}$-indifference curve leads to an increase of the density at contract B, the distortion will increase in σ.

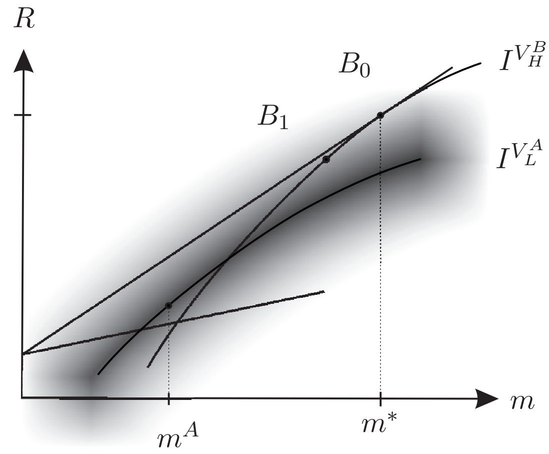


Figure 5: Separating equilibrium with two unobservable risk types and σ large: Contract B distorted from B_0 to B_1.

Comparing the effects of a decrease in competition on m^A and m^B, there is an asymmetry in that an increase in σ changes m^A even for low values of σ, while the effect on m^B only arises above some threshold level of σ, at which the shaded area around $I^{V_L^A}$ 'reaches' contract B.

Result 2. *In the separating equilibrium,* m^A *first decreases and then increases in* σ*. For intermediate levels of* σ*, both benefit packages are distorted:* $m^A < m^B < m^*$*; in addition, a share of both risk types chooses the contract designated for the other risk type:* $P_H^A > 0$ *and* $P_L^B > 0$*. The number of insurers offering the contract designated for the* L*-types increases in* σ*.*

[38] Of course, strictly speaking, m^B is always distorted, as P_L^B is always larger than zero. However, for low levels of σ, P_L^B is so close to zero, that the distortion of m^B is negligible. In the example we present in Section 3.5, P_L^B is on the order of 10^{-30} for low levels of σ.

3.2.2 The dependence of the separating equilibrium on the total number of insurers

If the total number of insurers n increases, n^A and n^B increase proportionally for $\lambda = \frac{1}{2}$, and almost proportionally for $\lambda \neq \frac{1}{2}$. Accordingly, all market shares decrease (about) proportionally, which leaves condition (19) unchanged. Also, there is no widening of the shaded areas around the indifference curves;[39] there is only an effect on on profits: If n increases, profits per individual go down. This increases the loss caused by an H-type, so the incentive to avoid the H-types increases. This is reflected in condition (18) where m^A has to be decreased when π_H^A decreases. Therefore, m^A decreases in n.

Result 3. *In the separating equilibrium, the distortion of the benefit package of the low risk type increases in the total number of insurers:* $\frac{\partial m^A}{\partial n} < 0$.

3.3 The pooling equilibrium

3.3.1 The dependence of the pooling equilibrium on the level of competition

As has been shown in Section 3.2.1, if σ increases, the number of insurers of type A goes up. At some point, the last insurer of type B becomes an insurer of type A, and a pooling equilibrium occurs.[40] Using the fact that in this case $n^B = 0$ and $P_L^A = P_H^A = \frac{1}{n^A}$, where $n^A = n$, condition (18), the FOC with respect to V_L^A, simplifies to

$$\lambda \pi_L^A + (1-\lambda)\pi_H^A = \frac{n\sigma}{n-1}. \tag{22}$$

Solving for π_H^A and substituting in (19), the FOC with respect to m^A, we have

$$\left[1 - \frac{\lambda(1-\lambda)(p^H - p^L)^2}{\frac{n\sigma}{n-1}\overline{p}} m^A\right] v'(m^A) = 1. \tag{23}$$

Because the fraction in (23) is positive, it is immediately apparent that $v'(m^A) > 1$, so that m^A is distorted downward. As is to be expected, the distortion increases in the difference $p^H - p^L$. Also, it decreases in σ and increases in n: The distortion in the pooling equilibrium is less severe if the market is less competitive.

Result 4. *In the pooling equilibrium, the distortion increases in the level of competition:* $\frac{\partial m^A}{\partial n} < 0$ *and* $\frac{\partial m^A}{\partial \sigma} > 0$.

3.3.2 Comparison of the pooling equilibrium with the Wilson-equilibrium

In general, this pooling equilibrium does not coincide with the Wilson-equilibrium (Wilson 1977), which consists of the contract on the pooling zero-profit line that maximizes the util-

[39] The distribution function P^k depends on the utility levels offered by the other insurers only via the aggregate $\sum_{j \neq k} e^{\frac{V^k}{\sigma}}$. If this aggregate increases (e.g., due to an increase in n), this shifts the distribution function to the right (in Figure 2), but does not change its shape.

[40] To keep the notation simple, we do not introduce an additional index for the pooling equilibrium but denote all insurers to be of type A.

ity of the L-types.[41] We will denote this contract, as it would not be the Wilson-*equilibrium* if the share of L-types was low enough for the separating Rothschild-Stiglitz-equilibrium to exist, simply as the Wilson-*contract*.

Formally, for the Wilson-contract, m satisfies $p^L v'(m^{WI}) = \overline{p}$. Using conditions (22) and (23), it is straightforward to show that for the discrete choice model, this requires $\pi_H^A = 0$, see Appendix A.3. Of course, if profits for the H-types are zero, H-types do not play a role when choosing the optimal contract on the iso-profit line, so insurers will maximize the utility of the L-types (to have as many L-types as possible).

However, if $\pi_H^A < 0$, it will be profitable to reduce m^A below m^{WI}: this will only have a second order effect on the utility of the L-types, but a first order effect of reducing the number of H-types. In this case, $m^A < m^{WI}$. If, on the other hand, $\pi_H^A > 0$, then having more H-types increases profits, so insurers will raise m above m^{WI}.

Result 5. *The pooling equilibrium only coincides with the Wilson-contract if profit per H-type is zero: $m^A \gtreqless m^{WI}$ for $\pi_H^A \gtreqless 0$.*

3.3.3 Stability of the pooling equilibrium

From a technical perspective, this result shows that in a Rothschild-Stiglitz model, a pooling equilibrium as a Nash-equilibrium in pure strategies can exist if there is imperfect competition. The pooling equilibrium can therefore be rationalized without imposing Wilson-foresight, a concept that has been criticized by Rothschild and Stiglitz (1997).

Newhouse (1996) had already identified a reason for a pooling equilibrium to exist, fixed costs of setting up a new contract: If trying to attract the L-types with a new contract causes high costs, the pooling equilibrium is stable.

Here, the pooling equilibrium is stable for a different reason: Offering a contract between the indifference curves of the two risk types would, under perfect competition, only attract all the L-types and thereby destroy the pooling equilibrium. Here, if σ is large, a contract close to the pooling equilibrium attracts both L- and H-types, where, due to the large influence of the utility component ε_{ij} that is independent of the benefit-premium-bundle, the relative share of the L-types in this new contract is not much larger than in the pooling equilibrium. To only attract the L-types, the new contract would have to be far away from the pooling equilibrium, so that it is on the same indifference curve of the L-types, but outside (i.e. above) the shaded area of the H-types. Such a contract would be associated with a much lower premium, and thereby not provide a higher profit than the contract of the pooling equilibrium.

[41] It is common to refer to the Wilson-equilibrium whenever – because the share of the L-types is too large – the separating Rothschild-Stiglitz-equilibrium does not exist; see Zweifel et al. (2009, p. 178). Of course, we only compare the level of m, and not premiums.

3.4 Welfare effects of different levels of competition

In this model, welfare W is given as the sum of expected surplus generated by the consumption of m,

$$W = \sum_i S^i = \sum_i \left(p^i v(m^i) - p^i m^i\right), \tag{24}$$

with m^i being the level of medical services consumed by individual i. Of course, the premium R does not appear in (24), as it is only a transfer from the insured to the insurer.

From what has been derived in the previous sections it follows that the welfare effects of a decrease in competition for the separating equilibrium are ambiguous, while for the pooling equilibrium, welfare increases.

For the separating equilibrium, welfare decreases in σ if σ is close to zero, because m^A decreases and P_H^A increases, so that a larger number of individuals chooses the benefit package that is more distorted. For intermediate levels of σ, the welfare effects of an increase in σ are indeterminate: On the one hand, m^A increases, but on the other hand m^B decreases and P_H^A and n^A increase. The welfare effects of a decrease in competition due to a decrease in the total number of insurers are indeterminate as well. It was shown that as n decreases, m^A increases, because the loss associated with the H-types decreases as competition goes down. But for the same reason P_H^A increases, creating a countervailing effect on welfare.

For the pooling equilibrium, on the other hand, as competition goes down, welfare unambiguously increases, see condition (23); this holds for both the increase in σ and the decrease in n.

Result 6. *For very high levels of competition, welfare decreases in σ: $\frac{\partial W}{\partial \sigma} < 0$ for σ close to zero. For low levels of competition, (so that a pooling equilibrium emerges), welfare decreases in the level of competition: $\frac{\partial W}{\partial \sigma} > 0$ and $\frac{\partial W}{\partial n} < 0$ for $n^B = 0$.*

3.5 Example

We finally illustrate the results with an example, for which we assume $n = 10$, $p^L = 0.2$, $p^H = 1$, $\lambda = 0.5$ and $v(m) = \ln(m)$, so that the efficient level of medical services is $m^* = 1$ and one of the risk types is chronically ill. The equilibrium values for different levels of σ are shown in Table 2; the Rothschild-Stiglitz-equilibrium can be found in the first, the Wilson-contract in the last row.

Under imperfect competition, m^A first decreases and then increases in σ; in addition, n^A increases, until the pooling equilibrium is reached at $\sigma = 0.19$.[42]

Even for the lowest level of σ, some of the H-types choose contract A; the share of H-types among all insured choosing an insurer of type A then steadily increases in σ. On the other hand, none of the L-types choose an insurer of type B until the shaded area around the $I^{V_L^A}$-indifference curve reaches contract B; this occurs at $\sigma = 0.08$, where also the distortion of

[42]In this example, in all pooling equilibria, m^A is above the level of the Wilson-contract. For higher levels of p^L, e.g., $p^L = 0.4$, in some of the pooling equilibria $m^A < m^{WI}$.

Table 2: Example I with $v(m) = \ln(m)$, $p^L = 0.2$, $p^H = 1$, $\lambda = 0.5$, $n = 10$, for different values of σ. The first row (RS) contains the Rotschild-Stiglitz-equilibrium, the last row (WI) the 'Wilson'-contract.

σ	n^A	n^B	m^A	m^B	A's share of H-types	B's share of L-types	W
RS	-	-	.398	1.00	0.0%	0.0%	-.632
.01	5	5	.377	1.00	0.5%	0.0%	-.636
.02	5	5	.364	1.00	1.2%	0.0%	-.640
.04	5	5	.346	1.00	2.8%	0.0%	-.647
.06	5	5	.337	1.00	5.1%	0.0%	-.654
.08	5	5	.334	.998	7.9%	0.1%	-.662
.10	6	4	.324	.994	12.5%	0.1%	-.677
.15	7	3	.362	.940	29.7%	1.4%	-.717
.17	8	2	.395	.884	39.2%	3.4%	-.736
.18	9	1	.418	.847	45.4%	5.0%	-.749
.19	pooling		.442	-	50.0%	-	-.755
.25	pooling		.510	-	50.0%	-	-.710
WI	pooling		.333	-	50.0%	-	-.859

m^B sets in. If σ increases further, m^B decreases and is way below the efficient level for $\sigma = 0.18$.

Regarding welfare, we find that it decreases in σ in the separating equilibrium for all levels of σ (and not just if σ is close to zero)), and, of course, increases in σ for the pooling equilibrium.

4 Implications for risk adjustment

We now discuss the implications of the results derived so far for risk adjustment. In particular, we show that the welfare effects of introducing or improving a risk adjustment scheme (RAS) critically depend on the level of competition: For low and high levels of competition, a RAS that becomes more precise unambiguously increases welfare; however, for intermediate levels of competition, welfare may initially remain constant or even decrease.

We will not model explicitly which risk adjusters are used in the RAS, or which econometric method is applied to estimate the payments. What is important for our model is that whenever a RAS becomes more precise, it reduces the cost difference between the two risk types to a larger extent. A RAS can be improved by, e.g., using more and more risk adjusters, like hospital stays, or diagnostic information, which are more informative signals for the risk type than just demographic information. A regulator may also apply the formula for optimal risk adjustment developed by Glazer and McGuire (2000). In all cases, the cost difference between risk types will be reduced, and with a perfect RAS, this difference is eliminated completely.

We will model the RAS in the easiest way possible: Each insurer receives a payment of RA^H for an H-type, and has to pay RA^L for an L-type. For the RAS to break even, we have to have

$$\lambda RA^L = (1-\lambda)RA^H.$$

Setting RA^H to some level RA, this requires $RA^L = \frac{1-\lambda}{\lambda}RA$. In this way, the RAS can be expressed with only one parameter, RA. As RA increases, the RAS becomes more precise.

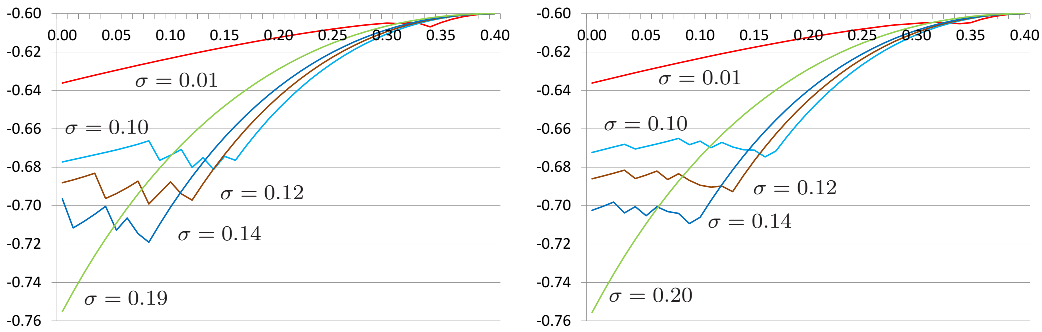
We will first present an example to show how the welfare effects of increasing RA depend on the level of competition. We then explain why for intermediate levels of competition welfare may decrease in RA in the separating equilibrium (Section 4.2), but not in the pooling equilibrium (Section 4.3).

4.1 Example

We present the same example as in Section 3.5, with $v(m) = \ln(m)$, $p^L = 0.2$, $p^H = 1$ and $\lambda = 0.5$, and show the impact on welfare by increasing $RA = RA^H = RA^L$ from 0 to 0.4, at which level the cost difference between the L-type and the H-type is eliminated completely. Results are shown for 10 and 20 insurers (see Figure 6(a) and (b) respectively), for different levels of competition: $\sigma = 0.01$ (very competitive), $\sigma = 0.10$, $\sigma = 0.12$ and $\sigma = 0.14$ (intermediate levels of competition), and for the lowest level of σ for which the pooling equilibrium emerges: $\sigma = 0.19$ for 10 insurers, and $\sigma = 0.20$ for 20 insurers.

The equilibrium values for the level of medical services m^A and m^B and the number of insurers n^A and n^B for one of the cases ($n = 20$ and $\sigma = 0.12$) can be found in Table 4 in Appendix A.4. Here, we only plot the equilibrium levels of welfare as a function of RA for these five different values of σ. The highest level of welfare for this example is 0.6, which occurs when all individuals receive $m^* = 1$.

Figure 6: Example III with $p^L = 0.2$, $p^H = 1$, $\lambda = 0.5$ and different levels of σ. Welfare W is depicted as a function of RA, with RA increasing from 0 to 0.40.



(a) 10 insurers

(b) 20 insurers

As can be seen, for $\sigma = 0.01$ and $\sigma = 0.19$, (or $\sigma = 0.20$ in case of $n = 20$ insurers), welfare increases monotonously in RA.[43] However, for intermediate levels of competition, welfare stays about constant or even decreases as long as RA is below the threshold level, at which the pooling equilibrium is reached; only above this level, does welfare increases in RA.[44] For the case of 20 insurers and $\sigma = 0.10$, this threshold level is as high as $RA = 0.17$: Although the RAS reduces the cost difference between the two risk types by more than 40%, there is no increase in welfare.

For intermediate levels of competition welfare initially does not increase in RA because the RAS not only reduces a distortion (by increasing m^A), but also introduces or exacerbates two other distortions: As we show in the following section, the share of H-types choosing the benefit package designated for the L-types increases in RA; in addition, the distortion of the benefit package for the H-types becomes more severe (m^B decreases).

This contrasts with the case of either a low or a high level of competition, where these additional distortions do not occur (or are so small that they are negligible); for these levels of competition, welfare increases in RA.

4.2 Risk adjustment in the separating equilibrium

Taking into account the payments of the RAS, type specific profits for insurer A are

$$\pi_L^A = p^L v(m^A) - V_L^A - \frac{1-\lambda}{\lambda} RA - p^L m^A \tag{25}$$

$$\pi_H^A = p^L v(m^A) - V_L^A + RA - p^H m^A. \tag{26}$$

The FOCs for insurer A's objective are therefore identical to (18) and (19), but with π_L^A and π_H^A now defined by (25) and (26). The same applies to insurer B.

For insurer B, from the FOC with respect to m^B it follows that for low values of σ (so that $P_L^B = 0$), we have $v'(m^B) = 1$, as before. From the FOC with respect to V_H^B, we have $\pi_H^B = \frac{n^B}{n^B-1}\sigma$, again as before. If RA is increased, so that insurer B receives a larger subsidy for each H-type, premiums are reduced (and utility V_H^B increased) by the same amount, so that π_H^B stays constant. For insurer B, we can therefore depict an increase in RA by a decrease in R^B of equal size: In Figure 7, the contract offered is shifted from B_0 to B_1; accordingly, there is a downward shift of the corresponding iso-profit line and the indifference curve.[45]

There is an opposite effect on the premium of insurers of type A: as RA increases, this, c.p., increases the premium R^A (and reduces V_L^A) by $RA^L = \frac{1-\lambda}{\lambda} RA$, shifting the iso-profit line

[43] For $\sigma = 0.01$, there is a small decrease in welfare for some high level of RA; this is because at this level of RA there is a switch from the separating to the pooling equilibrium.

[44] Note that for these intermediate levels of competition, there is usually one level of RA for which an equilibrium does not exist: As we already mentioned in Section 2.4, for one of the candidate equilibria (m^A, V_L^A, m^B, V_H^B), one of the insurers of type B has an incentive to become an insurer of type A; in the candidate equilibrium for these new levels of n^A and n^B, an insurer of type A then has an incentive to become an insurer of type B. In Figure 6 we plot the higher of the two levels of welfare of the two candidate equilibria to present the case where the RAS is more successful in improving welfare.

[45] In Figure 7, the case of a very low level of σ is depicted, so that the two shaded areas do not overlap and can be distinguished.

upwards. Similar to the case of an increase of σ in Section 3.2.1, this does not yet constitute the new equilibrium; there will also be an effect on m^A.

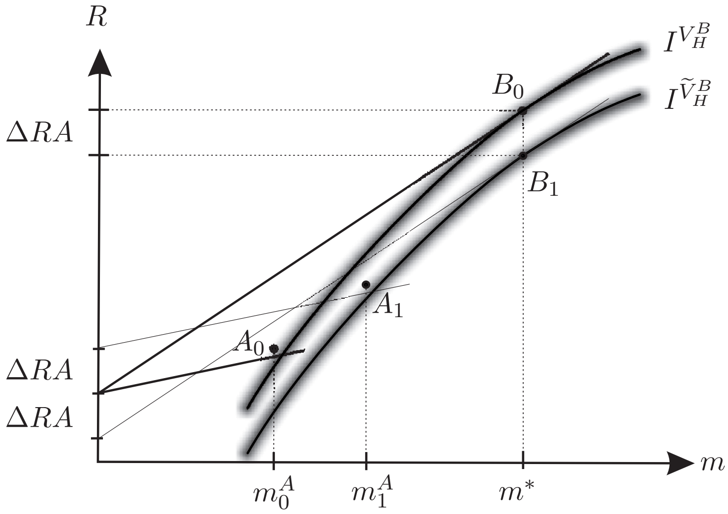


Figure 7: Equilibrium without and with (imprecise) risk adjustment; the case $RA^L = RA^H$, i.e. $\lambda = 0.5$, is depicted.

As can be seen from Figure 7, due to the downward shift of the $I^{V_H^B}$-indifference curve (to $I^{\widetilde{V}_H^B}$), and the upward shift of the iso-profit line of insurer A, offering a contract with the same level of m^A reduces the share of H-types choosing contract A. This also follows immediately from the definition of P_H^A, which decreases as V_H^A decreases and V_H^B increases.

This decrease in P_H^A creates an incentive to increase m^A, which can also be seen from the FOC with respect to m^A: rearranging terms, condition (19) reads as

$$v'(m^A) - 1 + \frac{1-\lambda}{\lambda}\frac{P_H^A}{P_L^A}\left[v'(m^A) - \frac{p^H}{p^L}\right] + \frac{1-\lambda}{\lambda}\frac{P_H^A}{P_L^A}\frac{1-P_H^A}{\sigma}\frac{p^H-p^L}{p^L}\pi_H^A v'(m^A) = 0. \tag{27}$$

As P_H^A is reduced, m^A has to be increased, so that this condition is satisfied again. In addition, due to the payments of the RAS for the H-types, π_H^A is increased, which – in an equivalent manner as for the case of an increase in σ in Section 3.2.1 – creates a second incentive to increase m^A. As m^A unambiguously increases, this, c.p., leads to an increase in welfare.

The effect on P_H^A, however, is ambiguous: Assume that m^A is increased to a level so that P_H^A is the same as before. At that point, it is not clear whether there is an incentive to increase m^A, and thereby P_H^A, even further or not. On the one hand, π_H^A is increased, but on the other hand, $v'(m^A)$ has already been decreased, so for a general utility function, it is indeterminate whether (27) is positive or negative. However, as the effect of RA on π_H^A is linear, while the effect on v' is decreasing, it is likely that P_H^A increases in RA, if RA is large.[46]

[46]In the large number of examples for which we derived the equilibrium for a particular utility function explicitly, P_H^A always increased in RA even from the beginning ($RA = 0$).

The increase in P_H^A, if it occurs, captures the first effect that reduces welfare: Each H-type choosing contract A instead of contract B induces a loss of welfare, because $m^A < m^B$. In addition, if P_H^A increases, we have the same effects on profits as already described in Section 3.2.1: Due to the loss of individuals, competition among insurers of type B increases, which reduces profits per individual; together with the smaller market share, total profit per insurer of type B decreases. At some point, one of the type-B insurers will switch and become a type-A insurer. This is the second negative effect on welfare: Each insurer that switches to become an insurer of type A incurs a welfare loss, as all its insured receive m^A instead of m^B.[47]

There is a third negative effect on welfare that occurs regardless of whether P_H^A increases or not: We saw that as RA increases, this shifts the $I^{V_H^B}$-indifference curve downwards, and the $I^{V_L^A}$-indifference curve upwards, so the distance between these two indifference curves decreases at m^*. This will, in similar manner as described in Section 3.2.1, lead to a distortion of m^B below the efficient level, as soon as the shaded area around the $I^{V_L^A}$-indifference curve 'reaches' contract B.

Result 7. *A RAS that becomes more precise reduces the distortion of the level of medical services for the L-types in a separating equilibrium: $\frac{\partial m^A}{\partial RA} > 0$.*

However, a RAS that becomes more precise may also decrease welfare because (i) P_H^B may decrease, (ii) n^B may decrease, and (iii), at some level of RA, m^B decreases below the efficient level.

Whether these three countervailing effects are significant, or only reduce the effectiveness of the improvement of the RAS, of course depends on the specific utility function.

It also depends on the level of σ: If σ is small, the shaded area around the $I^{V_H^B}$-indifference curve will be small. In this case, the density $P_H^A(1 - P_H^A)\frac{1}{\sigma}$ will already be large when P_H^A is still small, so for small values of σ the first countervailing effect is greatly reduced. As P_H^A is small, the difference in profits $\pi^A - \pi^B$ is small (see Appendix A.2), so that none of the insurers of type B switch to become of type A; then the second countervailing effect does not exist. Thirdly, if σ is small, the shaded area around the $I^{V_L^A}$-indifference curve will be narrow, so it will not 'reach' contract B until RA is close to the level, at which the cost difference between the two risk types is eliminated completely; for small and intermediate levels of RA, the third countervailing effect does not exist either. Therefore, if σ is small (and RA not too large), welfare increases as a RAS becomes more precise.

4.3 Risk adjustment in the pooling equilibrium

For the pooling equilibrium, the FOC with respect to m^A simplifies to

$$\left[1 - \frac{(1-\lambda)(p^H - p^L)[\lambda(p^H - p^L)m^A - RA]}{\frac{n\sigma}{n-1}\overline{p}}\right] v'(m^A) = 1. \qquad (28)$$

[47] Of course, when this insurer switches and becomes a type-A insurer, a large share of the H-types of this insurer will choose another insurer of type B; but those with a high preference for this particular insurer (high ε_{ij}) will stay with this insurer, causing the welfare loss.

With $RA = 0$, i.e. without risk adjustment, we have condition (23) from Section 3.3. As RA increases, the fraction in (28) decreases, so m^A increases; with $RA = \lambda(p^H - p^L)m^*$, the distortion is eliminated. For $\lambda = \frac{1}{2}$, as soon as RA equals half the difference in expected costs between the two risk types, the cost difference vanishes, because RA both has to be paid by the insurer for an L-type, and is paid to the insurer for an H-type.

Result 8. *For the pooling equilibrium, an increase in RA unambiguously decreases the distortion of the benefit package and increases welfare: $\frac{\partial m^A}{\partial RA} > 0$ and $\frac{\partial W}{\partial RA} > 0$*

5 Discussion

In this section, we briefly discuss some of the assumptions of our model and how they may affect the results that have been derived.

5.1 Distributional assumption for ε_{ij}

The model has been explicitly solved only under the assumption that ε_{ij} is i.i.d. extreme value, but we think that the results also hold for different distributional assumptions. Because the main effects could also be explained graphically, the results should be similar as long as the shaded areas around the indifference curves represent a unimodal density.

For a large number of examples, we determined the equilibrium under various other distributional assumptions for ε_{ij} and always found the results to be very similar.[48] Table 3 presents the equilibrium values of the example of Section 3.5 for three distributional assumptions of ε_{ij} other than the extreme value: the normal, the triangular and the uniform distribution.[49] Even with a uniform distribution for ε_{ij}, the density represented by the shaded area is unimodal; (e.g., this density would be triangular for $n = 2$).

For low values of σ (see the upper part of Table 3 with $n^A = n^B = 5$), the differences are very small: For all four distributions, m^A decreases in σ, while m^B remains at the efficient level. Also P_H^A, the share of H-types choosing one of the insurers of type A, is very similar for all four distributions.

As σ increases so that n^A increases, two differences emerge: First, the levels of σ at which n^A increases are not identical for the four distributions, see the lower part of Table 3, where always the smallest value of σ after an increase in n^A is presented. E.g., the lowest level of σ so that $n^A = 6$ is 0.10 for the extreme value distribution; it is somewhat higher at 0.14 and 0.15 for the normal and the triangular distribution, and considerably higher for the uniform distribution at 0.21. However, this difference does not seem to be important.

Secondly, the distortion of m^B is much smaller for the other three distributions. This is because for a given level of σ, the shaded area around the indifference curves is widest for the extreme value distribution; as this distribution has fatter tails, the shaded area around the $I^{V_L^A}$-indifference curve 'reaches' contract B for a lower level of σ than is the case for the

[48]The Gauss code is available from the author upon request.

[49]Note that for all four distributions, the variance is given as $Var(\varepsilon_{ij}) = \sigma^2 \frac{\pi^2}{6}$.

Table 3: Example I with $v(m) = \ln(m)$, $p^L = 0.2$, $p^H = 1$, $\lambda = 0.5$, $n = 10$ for different distributional assumptions

		extreme value			**normal**			**triangular**			**uniform**		
n^A	n^B	σ	m^A	m^B	σ	m^A	m^B	σ	m^A	m^B	σ	m^A	m^B
5	5	.01	.377	1.00	.01	.384	1.00	.01	.386	1.00	.01	.387	1.00
5	5	.02	.364	1.00	.02	.373	1.00	.02	.376	1.00	.02	.377	1.00
5	5	.04	.346	1.00	.04	.358	1.00	.04	.360	1.00	.04	.363	1.00
5	5	.06	.337	1.00	.06	.346	1.00	.06	.349	1.00	.06	.351	1.00
5	5	.08	.334	.998	.08	.340	1.00	.08	.340	1.00	.08	.343	1.00
6	4	.10	.324	.994	.14	.330	1.00	.15	.332	1.00	.21	.351	.996
7	3	.15	.362	.940	.18	.355	.994	.19	.361	.999	.28	.363	.981
8	2	.17	.395	.884	.20	.380	.982	.21	.380	.997	.33	.389	.954
9	1	.18	.418	.847	.22	.403	.973	.23	.406	.993	.38	.406	.940
pooling		.19	.442	.442	.23	.421	.421	.24	.416	.416	.42	.423	.423

other distributions. In technical terms, the (excess) kurtosis is largest for the extreme value distribution: $k^{ev} = 2.4$; it is considerably smaller for the normal ($k^n = 0.0$), the triangular ($k^{tr} = -0.6$) and the uniform distribution ($k^u = -1.2$). The higher the kurtosis, the higher the distortion of m^B (for a given level of σ).

On the other hand, the levels of m^A are very similar for the four distributions, as is the level of m when the pooling equilibrium is reached. Also, for each of the four distributions, welfare decreases in σ for the separating equilibrium, and increases in σ for the pooling equilibrium.

5.2 Conditional Logit vs. Nested Logit

At first glance, it may appear as if for an individual who chooses an insurer of type A, another type-A insurer is a closer substitute than a type-B insurer, so that a nested logit model may seem more appropriate than the simple conditional logit that we considered.

From the perspective of an econometrician, this is certainly true, because, a priori, it cannot be ruled out there there are also some unobserved factors that are more alike among type-A insurers than between type-A and type-B insurers. Therefore, the econometrician will simply test whether a nested logit model applies.

Here, however, we want to explicitly analyse the effects that arise due to the differences in the benefit packages. Assuming, in addition, that there are also some unobserved factors which are equal among the type-A insurers, i.e. assuming some non i.i.d.-error term structure, would only obscure the effects we are interested in.

Regarding the IIA assumption that is implied by the logit model, the famous red bus-blue bus problem[50] does not occur in our setting, because we explicitly model two different risk types.[51] Consider, e.g., the case of $\lambda = 0.5$ and four insurers: With σ small enough, two insurers will be of type A, each covering half of the L-types, and a small share of the H-types, say 1% (i.e. 0.5% of the entire market); the other two insurers will be of type B, each covering about half of the H-types. Each insurer of type A will therefore cover 25.5% of the entire market, and each insurer of type B 24.5%. If we now add two more insurers of type A, these four type-A insurers will not cover two thirds of the entire market, as in the red bus-blue bus example. Instead, all L-types are evenly distributed among the four type-A insurers; in addition, the third and fourth type-A insurer will cover about the same share of H-types as the first and the second type-A insurer (1% of the H-types, or 0.5% of the entire market). Therefore, each insurer of type A will cover about $\frac{1}{4} \cdot 50\% + 0.5\% = 13\%$, and the aggregate market share of all type-A insurers will only increase from 51% to about 52%.

5.3 Premium set by regulator

We formulated the model in m-R-space, and not in m_1-m_2-space with R set by a regulator, as was the setting of Glazer and McGuire (2000). We did this to not obscure the welfare effects of different levels of competition. If σ increases, profits go up, so a regulator would have to increase R. However, as we saw in Section 3.2.1, for the case of unobservable risk types, profits for the two types of insurers increase at different rates. Therefore, it is not clear at which rate the regulator would have to increase R to not affect welfare.

Nevertheless, all results regarding the distortions of the benefit packages are easily transferred into m_1-m_2-space. There, a distortion always consists of a too low level of m_1 (if $s = 1$ is the illness for which there is heterogeneity in risk) and a too high level of m_2, see Glazer and McGuire (2000). The shaded areas would then have to be drawn around the indifference curves in m_1-m_2-space, but the arguments for the different effects would be the same.

6 Conclusion

We have analyzed the interaction of imperfect competition and adverse selection in health insurance markets. Within a discrete choice setting which endogenises whether a separating or a pooling equilibrium emerges, the following main results have been derived: In a separating equilibrium, for intermediate levels of competition, both benefit packages are distorted. As the level of competition decreases, the distortion decreases for the low risk type, but increases for the high risk type; in addition, the number of insurers offering the contract for the high risk type decreases, until a pooling equilibrium is reached. The pooling equilibrium may be below, at, or above the ‘Wilson’-contract.

We also showed that although each individual has the same tendency to ‘make mistakes’ by not choosing the contract that is most favorable in terms of medical services and premium,

[50] See Train (2009, p. 46).

[51] Because there is more than one risk type, the model is actually a (rather degenerate) mixed logit, see Train (2009), Chapter 6.

in equilibrium there is an asymmetry in that it is primarily the high risk which choose the 'wrong' contract.

Finally, we showed that under imperfect competition there is no clear-cut distinction between the separating and the pooling equilibrium: for intermediate levels of competition, each of the two contracts of the separating equilibrium is chosen by both risk types. If the level of competition decreases, these 'two pooling contracts of the separating equilibrium' become more alike, until for a low enough level of competition the pooling equilibrium with only one contract emerges.

We also determined the implications of imperfect competition on the effectiveness of a risk adjustment scheme. For intermediate levels of competition we identified three welfare decreasing effects that can occur if an imprecise RAS is only improved to a small degree. If these effects are of economic importance, it is even more important for a regulator to use a RAS that reduces the cost differences between risk types to a large degree, so that one can be confident that the RAS creates the positive welfare effects it is implemented for.

The theoretical model we presented complements a number of very recent empirical studies which analyze adverse selection in health insurance markets with a focus on inefficient pricing of a *given* set of benefit packages. These studies have found that the welfare losses caused by inefficient pricing are surprisingly low.[52] However, as explicitly stated by Einav, Finkelstein, and Levin (2010), the welfare losses due to an inefficient set of benefit packages may be much larger than the welfare losses due to inefficient pricing. Our model focuses on these inefficiencies caused by the distortions of the benefit packages. We showed that even the most generous benefit package offered may not represent the efficient level of medical services, and that too few insurers offer this benefit package. If these additional distortions exist and are of economic importance, the overall welfare losses caused by adverse selection may therefore indeed be considerably higher than those only caused by inefficient pricing.

[52] See Einav, Finkelstein, and Cullen (2010), Bundorf et al. (2012) and Handel (2013).

A Appendix

A.1 Proof that P_H^A increases in σ

We will first consider a small, noninfinitesimal increase in σ by $\Delta\sigma > 0$, which allows to depict some of the effects graphically; we can then let $\Delta\sigma$ become arbitrarily small ($\Delta\sigma \to 0$). A $\sim$ is used to indicate all variables after the increase of σ, so, e.g., $\widetilde{\sigma} = \sigma + \Delta\sigma$.

Denote by S_L^A and S_H^B the surplus generated by m^A and m^B for the respective risk type, i.e.

$$S_L^A = p^L v(m^A) - p^L m^A \quad \text{and} \quad S_H^B = p^H v(m^B) - p^H m^B. \tag{29}$$

Using the FOC with respect to V_H^B, i.e. $\pi_H^B = \frac{\sigma}{1-P_H^B}$, and $\pi_H^B = S_H^B - V_H^B$, we have

$$V_H^B = S_H^B - \frac{\sigma}{1 - P_H^B}. \tag{30}$$

Since for low levels of σ, $m^B = m^*$, and therefore does not depend on σ, we have

$$\widetilde{S}_H^B = S_H^B, \;\text{ so }\; \Delta S_H^B = 0.$$

If P_H^B did not change, ΔV_H^B would be given by

$$\Delta V_H^B = -\frac{\Delta\sigma}{1 - P_H^B}. \tag{31}$$

In Figure 8, this decrease of V_H^B is depicted by the movement of insurer B's contract from B_0 to B_1.

For insurer A, rewrite the FOCs with respect to V_L^A and m^A as

$$\lambda \left[\frac{P_L^A(1-P_L^A)}{\sigma}\pi_L^A - P_L^A\right] + (1-\lambda)\left[\frac{P_H^A(1-P_H^A)}{\sigma}\pi_H^A - P_H^A\right] = 0 \tag{32}$$

$$\left[\lambda p^L P_L^A + (1-\lambda)p^L P_H^A + (1-\lambda)(p^H - p^L)\frac{P_H^A(1-P_H^A)\pi_H^A}{\sigma}\right] v'(m^A) \tag{33}$$
$$= \lambda p^L P_L^A + (1-\lambda)p^H P_H^A.$$

For insurer A, condition (33) can be considered as implicitly defining a function $m^A(V_L^A)$, which for each level of V_L^A determines the optimal level of m^A. Likewise, condition (32) implicitly defines a function $V_L^A(m^A)$. The loci of these two curves of course pass through A_0, the contract offered by insurer A before the increase of σ.

With contract A_0, insurer A will have a certain share of H-types, P_H^A. The set of all the benefit-premium-bundles with which insurer A attracts this share of H-types constitutes the iso-P_H^A-curve; it has the same shape as the $I^{V_H^B}$-indifference curve, shifted upwards; see Figure 8.

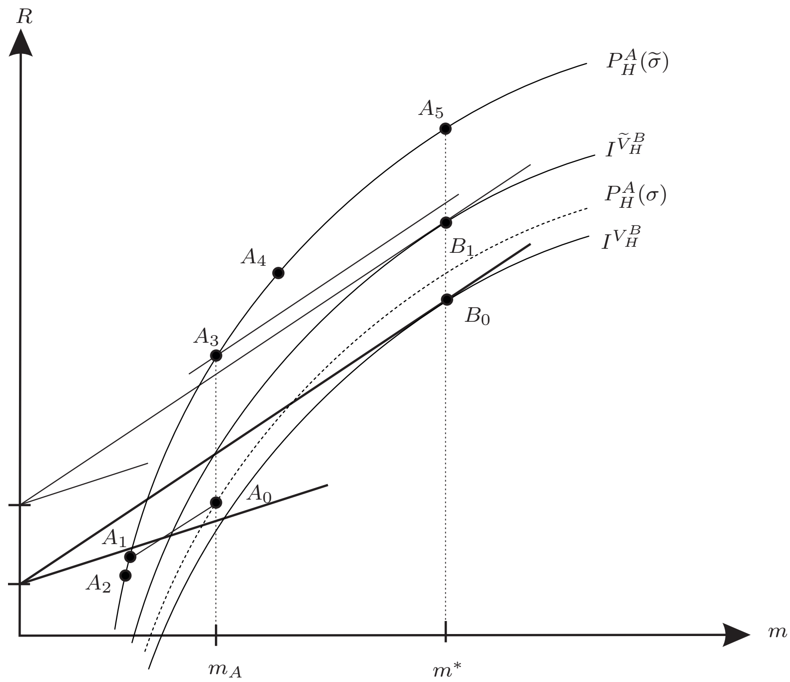


Figure 8: Equilibrium for two different values of σ

If σ increases, V_H^B is reduced; this shifts the $I^{V_H^B}$-curve upwards, and with it the iso-P_H^A-curve. The distance between the two iso-P_H^A-curves is larger than the distance between the two $I^{V_H^B}$-curves, because as σ increases, the shaded area around the indifference curves becomes wider. To leave P_H^A unchanged, insurer A would have to offer a contract on the new iso-P_H^A-curve, which is denoted by $P_H^A(\widetilde{\sigma})$ in Figure 8.

It is now argued that the new contract chosen by insurer A will be to the right of this new iso-P_H^A-curve, so that in equilibrium P_H^A increases. To do so, it will be shown that the locus of the function $\widetilde{m}^A(\widetilde{V}_L^A)$, implicitly defined by (33) with σ increased, is partly to the right of the new iso-P_H^A-curve, and that the new contract is exactly on this part of $\widetilde{m}^A(\widetilde{V}_L^A)$.

Consider first, that insurer A offers contract A_1, which is on the same iso-π_H^A-line as contract A_0. With A_1, in (33) all variables except for m^A and σ are at the same level as before. Because σ has been increased, which increases the bracket, and because m^A has been reduced, which increases $v'(m^A)$, the left hand side of condition (33) is now larger than the right hand side; therefore, m^A has to be increased, which increases P_H^A.

Consider now, instead, contract A_2, which has been chosen so that $\frac{\widetilde{\pi}_H^A}{\widetilde{\sigma}} = \frac{\pi_H^A}{\sigma}$. At A_2, the bracket on the LHS of (33) attains the same value as before the increase of σ. At all points on the new iso-P_H^A-curve above A_2, the bracket is larger than before. In addition, for $\widetilde{m}^A < m^A$, we have $v'(\widetilde{m}^A) > v'(m^A)$. Therefore, for all points on the new iso-P_H^A-curve between A_2 and A_3, the LHS of (33) is larger than the RHS, so m^A has to be increased, which increases P_H^A. Condition (33) could only be satisfied for a point below A_2, or above

A_3. If such a point below A_2 or above A_3 did not exist, the locus of the function $\widetilde{m}^A(\widetilde{V}_L^A)$ would always be to the right of the new iso-P_H^A-curve; in this case, it follows immediately, that P_H^A is increased. We therefore consider the case that these points do exist.

Assume first, condition (33) is satisfied for a point below A_2. At such a point, we would have $\frac{\widetilde{\pi}_H^A}{\widetilde{\sigma}} < \frac{\pi_H^A}{\sigma}$. Condition (32) then requires $\frac{\widetilde{\pi}_L^A}{\widetilde{\sigma}} > \frac{\pi_L^A}{\sigma}$, which implies $\widetilde{\pi}_L^A > \pi_L^A$. However, for all points below A_2, we have $\widetilde{\pi}_L^A < \pi_L^A$. Therefore, at such a point below A_2, V_L^A is too high, and has to be reduced.

Assume now, that condition (33) is satisfied for a contract A_4 above A_3, see Figure 8.[53] At A_4, $\Delta m^A > 0$ and $\Delta V_L^A < 0$. Using $V_L^A = V_H^A - (p^H - p^L)v(m^A)$, we have

$$\Delta V_L^A = \Delta V_H^A - (p^H - p^L)v'(\widehat{m}^A)\Delta m^A, \tag{34}$$

for some $\widehat{m}^A \in [m^A, m^A + \Delta m^A]$. Since P_H^A can be rewritten as

$$P_H^A = \frac{1}{n^A + n^B e^{\frac{V_H^B - V_H^A}{\sigma}}}, \tag{35}$$

for P_H^A to be identical for both levels of σ, we have to have

$$\frac{V_H^B - V_H^A}{\sigma} = \frac{\widetilde{V}_H^B - \widetilde{V}_H^A}{\widetilde{\sigma}} = \frac{V_H^B + \Delta V_H^B - (V_H^A + \Delta V_H^A)}{\sigma + \Delta\sigma}. \tag{36}$$

Solving for ΔV_H^A yields

$$\Delta V_H^A = \Delta V_H^B - (V_H^B - V_H^A)\frac{\Delta\sigma}{\sigma}. \tag{37}$$

Using condition (35), $\frac{V_H^B - V_H^A}{\sigma}$ can be expressed in terms of P_H^A as,

$$\frac{V_H^B - V_H^A}{\sigma} = \ln\left(\frac{1}{n^B P_H^A} - \frac{n^A}{n^B}\right). \tag{38}$$

Substituting in condition (37) yields

$$\Delta V_H^A = -\frac{\Delta\sigma}{1 - P_H^B} - \ln\left(\frac{1}{n^B P_H^A} - \frac{n^A}{n^B}\right)\Delta\sigma, \tag{39}$$

so that for ΔV_L^A we have

$$\Delta V_L^A = -\frac{\Delta\sigma}{1 - P_H^B} - \ln\left(\frac{1}{n^B P_H^A} - \frac{n^A}{n^B}\right)\Delta\sigma - (p^H - p^L)v'(\widehat{m}^A)\Delta m^A. \tag{40}$$

Rewrite condition (32) as

$$\left[\lambda P_L^A(1 - P_L^A) + (1 - \lambda)P_H^A(1 - P_H^A)\right](S_L^A - V_L^A) \tag{41}$$

[53] Note that contract A_4 has to be below A_5, the contract associated with the efficient level of care: If both A_5 and B_1 were offered, almost all L-types would choose B_1.

$$-(1-\lambda)P_H^A(1-P_H^A)(p^H-p^L)m^A - [\lambda P_L^A + (1-\lambda)P_H^A]\sigma = 0.$$

Denote by $F(\sigma)$ the LHS of (41) evaluated at σ, and likewise for $F(\widetilde{\sigma})$. If, at A_4, $F(\widetilde{\sigma}) > 0$, $\widetilde{\pi}_L^A$ is too large and has to be reduced, i.e. $\widetilde{V}_L^A$ has to be increased. Since $F(\sigma) = 0$, $\widetilde{V}_L^A$ has to be increased if $F(\widetilde{\sigma}) - F(\sigma) > 0$. This difference is given by

$$\left[\lambda P_L^A(1-P_L^A) + (1-\lambda)P_H^A(1-P_H^A)\right](\Delta S_L^A - \Delta V_L^A) \tag{42}$$

$$-(1-\lambda)P_H^A(1-P_H^A)(p^H-p^L)\Delta m^A - [\lambda P_L^A + (1-\lambda)P_H^A]\Delta\sigma = 0,$$

with

$$\Delta S_L^A = p^L[v'(\widehat{m}^A) - 1]\Delta m^A, \tag{43}$$

where $\widehat{m}^A$ is defined as above. Substituting (40) and (43) in (42), we have

$$\left[\lambda P_L^A(1-P_L^A) + (1-\lambda)P_H^A(1-P_H^A)\right]\left[p^L(v'(\widehat{m}^A) - 1)\Delta m^A + \frac{\Delta\sigma}{1-P_H^B}\right. \tag{44}$$

$$\left. + \ln\left(\frac{1}{n^B P_H^A} - \frac{n^A}{n^B}\right)\Delta\sigma + (p^H-p^L)v'(\widehat{m}^A)\Delta m^A\right]$$

$$-(1-\lambda)P_H^A(1-P_H^A)(p^H-p^L)\Delta m^A - [\lambda P_L^A + (1-\lambda)P_H^A]\Delta\sigma.$$

Since $v' > 1$, expression (44) is larger than

$$\left[\lambda P_L^A(1-P_L^A) + (1-\lambda)P_H^A(1-P_H^A)\right]\left[\frac{\Delta\sigma}{1-P_H^B} + \ln\left(\frac{1}{n^B P_H^A} - \frac{n^A}{n^B}\right)\Delta\sigma\right] \tag{45}$$

$$-[\lambda P_L^A + (1-\lambda)P_H^A]\Delta\sigma.$$

Solving $n^A P_H^A + n^B P_H^B = 1$ for P_H^B and substituting in (45), expression (45) is positive if

$$\left[\lambda P_L^A(1-P_L^A) + (1-\lambda)P_H^A(1-P_H^A)\right]\left[1 + \left(1 - \frac{1}{n^B} + \frac{n^A}{n^B}P_H^A\right)\ln\left(\frac{1}{n^B P_H^A} - \frac{n^A}{n^B}\right)\right]$$

$$-\left[\lambda P_L^A + (1-\lambda)P_H^A\right]\left(1 - \frac{1}{n^B} + \frac{n^A}{n^B}P_H^A\right) > 0.$$

As can be shown numerically, this condition is always satisfied for any values of P_H^A, P_L^A, λ, n^A and n^B as long as $P_H^A < 0.6P_H^B$ and $\lambda > 0.08$. Unless the share of L-types is very low, this condition is therefore satisfied for all reasonable values of P_H^A.

If there exists a point A_4 above A_3, so that (33) is satisfied, condition (32) is violated in a way, so that V_L^A has to be increased. Therefore, the crossing of the two curves $\widetilde{m}^A(\widetilde{V}_L^A)$ and $\widetilde{V}_L^A(\widetilde{m}^A)$ occurs to the right of the new iso-P_H^A-curve, so $P_H^A(\widetilde{\sigma}) > P_H^A(\sigma)$.

A.2 Proof that n^A increases in σ

In this section it is shown that if σ increases, the difference in profits $\pi^A - \pi^B$ at some point becomes large enough, so that it is profitable for a type-B insurer to become a type-A insurer. To do so, it is shown that $\frac{\pi^B}{\sigma}$ decreases (with a lower bound of zero), while $\frac{\pi^A}{\sigma}$ does not fall below the level when $P_H^A = 0$.

For $\frac{\pi^B}{\sigma}$ we have

$$\frac{\pi^B}{\sigma} = (1-\lambda)P_H^B \frac{\pi_H^B}{\sigma}. \tag{46}$$

Solving the FOC

$$(1-\lambda)P_H^B \left[(1-P_H^B)\frac{\pi_H^B}{\sigma} - 1\right] = 0$$

for $\frac{\pi_H^B}{\sigma}$ and substituting in (46), we have

$$\frac{\pi^B}{\sigma} = (1-\lambda)\frac{P_H^B}{1-P_H^B}, \tag{47}$$

so $\frac{\pi^B}{\sigma}$ decreases as P_H^B decreases, with a lower bound of zero, i.e.

$$\left.\frac{\pi^B}{\sigma}\right|_{P_H^B \to 0} \to 0. \tag{48}$$

For insurer A, using $\pi_H^A = \pi_L^A - (p^H - p^L)m^A$, we have

$$\frac{\pi^A}{\sigma} = \left[\lambda P_L^A + (1-\lambda)P_H^A\right]\frac{\pi_L^A}{\sigma} - (1-\lambda)P_H^A(p^H - p^L)\frac{m^A}{\sigma}. \tag{49}$$

Solving

$$\begin{aligned}\frac{\partial \pi^A}{\partial V_L^A} \quad = \quad & \left[\lambda \frac{P_L^A(1-P_L^A)}{\sigma} + (1-\lambda)\frac{P_H^A(1-P_H^A)}{\sigma}\right]\pi_L^A \\ & -[\lambda P_L^A + (1-\lambda)P_H^A] - (1-\lambda)\frac{P_H^A(1-P_H^A)}{\sigma}(p^H - p^L)m^A\end{aligned} \tag{50}$$

for $\frac{\pi_L^A}{\sigma}$, and substituting in (49) yields

$$\frac{\pi^A}{\sigma} = \frac{(\lambda P_L^A + (1-\lambda)P_H^A)^2}{\lambda P_L^A(1-P_L^A) + (1-\lambda)P_H^A(1-P_H^A)} + \frac{(1-\lambda)\lambda(p^H - p^L)P_L^A P_H^A(P_L^A - P_H^A)}{\lambda P_L^A(1-P_L^A) + (1-\lambda)P_H^A(1-P_H^A)}\frac{m^A}{\sigma}. \tag{51}$$

This expression has to be compared with $\frac{\pi^A}{\sigma}$ for $P_H^A \to 0$, (i.e. for $\sigma \to 0$), where

$$\left.\frac{\pi^A}{\sigma}\right|_{P_H^A \to 0} \to \lambda \frac{P_H^A}{1-P_H^A}. \tag{52}$$

Note that in this case we have $\frac{\pi^A}{\sigma} \to \lambda\frac{n^A}{1-n^A}$, where n^A and n^B is set so that $\pi^A = \pi^B$. It is straightforward to show that for the first fraction of (51),

$$\frac{(\lambda P_L^A + (1-\lambda)P_H^A)^2}{\lambda P_L^A(1-P_L^A) + (1-\lambda)P_H^A(1-P_H^A)} > \lambda\frac{P_L^A}{1-P_L^A}. \tag{53}$$

The second fraction of (51) is positive since $P_L^A > P_H^A$. It can be concluded that $\frac{\pi^A}{\sigma}\Big|_{P_H^A>0}$ is bounded from below by $\lambda\frac{P_H^A}{1-P_H^A} > 0$, see (52), while $\frac{\pi^B}{\sigma}$ decreases in P_H^B, approaching zero as $P_H^B \to 0$, see (48). Therefore, if P_H^B is small enough, $\pi^A - \pi^B$ is large enough, so that it is profitable for one of the type-B insurers to become a type-A insurer.

A.3 Comparison of the pooling equilibrium and the 'Wilson'-contract

Solving condition (22)

$$R^A - \overline{p}m^A = \frac{n\sigma}{n-1} \tag{54}$$

for R^A and substituting in π_H^A yields

$$\pi_H^A = R^A - p^H m^A = \frac{n\sigma}{n-1} - (p^H - \overline{p})m^A. \tag{55}$$

Substituting the condition for the 'Wilson'-contract, $v'(m^{WI}) = \frac{\overline{p}}{p^L}$, in (23), we have

$$\left[1 - \frac{\lambda(1-\lambda)(p^H - p^L)^2}{\frac{n\sigma}{n-1}\overline{p}}m^A\right]\frac{\overline{p}}{p^L} = 1. \tag{56}$$

Solving for m^A,

$$m^A = \frac{(\overline{p} - p^L)\frac{n\sigma}{n-1}}{\lambda(1-\lambda)(p^H - p^L)^2}, \tag{57}$$

and substituting in (55) then yields $\pi_H^A = 0$. Therefore the pooling equilibrium coincides with the 'Wilson'-contract for $\pi_H^A = 0$.

A.4 Example with risk adjustment

Table 4: Example III with $v(m) = \ln(m)$, $p^L = 0.2$, $p^H = 1$, $\lambda = 0.5$, $n = 20$ and risk adjustment. $\sum S_H$ denotes the sum of expected surplus for the H-types, $\sum S_L$ the sum of expected surplus for the L-types, with welfare W the weighted average of these two sums: $W = \lambda \sum S_L + (1 - \lambda) \sum S_H$. For the pooling equilibrium, all insurers are denoted as being of type A.

RA	n^A	n^B	m^A	m^B	P_L^A	P_H^A	P_L^B	P_H^B	$\sum P_L^A$	$\sum P_H^A$	$\sum S_H$	$\sum S_L$	W
.00	12	8	.328	.981	.0831	.0157	.00036	.1014	.997	.189	-1.0838	-.2883	-.6860
.01	12	8	.340	.978	.0831	.0170	.00042	.0995	.997	.204	-1.0856	-.2836	-.6846
.02	12	8	.352	.975	.0830	.0183	.00050	.0975	.996	.220	-1.0874	-.2788	-.6831
.03	12	8	.365	.970	.0829	.0198	.00059	.0952	.995	.238	-1.0890	-.2741	-.6815
.04	13	7	.375	.971	.0766	.0217	.00063	.1025	.996	.283	-1.1009	-.2709	-.6859
.05	13	7	.390	.965	.0765	.0236	.00076	.0990	.995	.307	-1.1022	-.2660	-.6841
.06	13	7	.406	.958	.0764	.0255	.00093	.0954	.993	.332	-1.1028	-.2612	-.6820
.07	14	6	.420	.957	.0710	.0286	.00102	.0998	.994	.401	-1.1158	-.2571	-.6865
.08	14	6	.438	.946	.0709	.0307	.00128	.0950	.992	.430	-1.1144	-.2524	-.6834
.09	15	5	.455	.942	.0662	.0344	.00146	.0968	.993	.516	-1.1257	-.2480	-.6869
.10	16	4	.475	.935	.0621	.0383	.00172	.0969	.993	.613	-1.1352	-.2436	-.6894
.11	17	3	.496	.925	.0585	.0420	.00209	.0954	.994	.714	-1.1416	-.2392	-.6904
.12	18	2	.517	.909	.0553	.0452	.00265	.0928	.995	.814	-1.1445	-.2351	-.6898
.13	pooling		.542	.542	.0500	.0500	-	-	1.00	1.00	-1.1545	-.2309	-.6927
.14	pooling		.559	.559	.0500	.0500	-	-	1.00	1.00	-1.1407	-.2281	-.6844
.15	pooling		.576	.576	.0500	.0500	-	-	1.00	1.00	-1.1277	-.2255	-.6766
.20	pooling		.661	.661	.0500	.0500	-	-	1.00	1.00	-1.0751	-.2150	-.6451
.25	pooling		.746	.746	.0500	.0500	-	-	1.00	1.00	-1.0392	-.2078	-.6235
.30	pooling		.830	.830	.0500	.0500	-	-	1.00	1.00	-1.0163	-.2033	-.6098
.35	pooling		.915	.915	.0500	.0500	-	-	1.00	1.00	-1.0038	-.2008	-.6023
.40	pooling		1.00	1.00	.0500	.0500	-	-	1.00	1.00	-1.0000	-.2000	-.6000

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