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Optimal Risk Adjustment

The Trade-off between Risk Selection and Upcoding

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(Preliminary draft. Do not quote.)

Abstract

In competitive social health insurance systems, risk selection incentives originating in community-rating are typically mitigated by risk adjustment schemes. In recent decades the complexity of these systems was on the rise. Today, many countries relying on this mode of healthcare financing use morbidity information of the insured to calculate the financial needs of health insurers. While this certainly reduces risk selection incentives, it makes risk adjustment schemes more vulnerable to manipulation as diagnostic information is not readily observed by the regulator but reported by health insurers (or healthcare providers). We develop a theoretical duopoly model to analyze the tradeoff between risk selection and diagnoses manipulation incentives and show that the share of diagnostic information used in the optimal risk adjustment system depends on the technologies of risk selection and diagnoses manipulation as well as on the intensity of competition between health insurers. We also demonstrate that an audit allows for more diagnostic information to be used in optimal risk adjustment.

Keywords: Health insurance competition, community rating, risk selection, risk adjustment, diagnoses manipulation, upcoding, auditing

JEL Classification: D43; D82; H51; I11; I13; I18; L51

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1 Introduction

In social health insurance systems, the insurance premiums are not calculated according to individual risk characteristics but based on the risk of the insured collective (community rating). If health insurers are competing against one another, as is the case in Belgium, Germany, Switzerland, or the Netherlands, for example, then there is an incentive to improve the risk structure to exploit unpriced risk heterogeneity and gain a competitive advantage – health insurers have an incentive to engage in risk selection (see, e.g., Newhouse 1996).

If risk characteristics of the insured are observable, the insurance companies can engage in direct risk selection, i.e., reject or deter people with above-average costs and attract those with below-average costs, *ceteris paribus*. If, on the other hand, risk characteristics are not directly observable or are even unknown, indirect risk selection, for example through a suitable design of the benefit package or deductible tariffs, can improve the risk pool (Breyer et al. 2011; Lorenz 2015; van de Ven and Ellis 2000). No matter whether direct or indirect, risk selection distorts the competition among health insurance companies and implies losses in efficiency. Additionally, risk selection activities are costly to insurers and are, thus, pure social waste.

The inefficiencies associated with risk selection call for regulation of the social health insurance market. There are several measures to mitigate risk selection and regulators make extensive use of them. While the regulation of benefit packages or deductible contracts, for instance, aim at mitigating indirect risk selection, an open enrolment requirement aims at mitigating direct risk selection (Breyer et al. 2011). These measures have in common that they restrict health insurance companies' tools to conduct risk selection, but they do not alter the incentives to engage in risk selection. By contrast, the main goal of risk adjustment is to reduce risk selection incentives (van de Ven et al. 2023).

The basic idea of risk adjustment is that insurance companies transfer all collected premiums to a central fund and then receive a transfer from this fund considering the risk structure of the insured collective. Ideally, these transfers resemble risk-rated premiums, then no risk selection incentives would remain. This ideal, however, is very difficult, if not impossible, to achieve. The reason is that individual risk is not directly observed but must be estimated using individual characteristics, so-called risk adjusters. The simplest risk-adjusters are variables like age and gender and the first risk adjustment mechanism implemented in Germany in 1994 was not much more complex than that. Only about 4 per cent of the variation in individual healthcare spending can be explained with such a simple scheme so that considerable risk selection incentives remained. Several reports to the Federal Ministry of Health called for an improvement of the risk adjustment scheme. Indeed, there was evidence for direct risk selection (Bauhoff 2012) and indirect risk selection (Nuscheler and Knaus 2005). As a response, the regulator improved the risk adjustment mechanism by including morbidity information starting in 2009, increasing the fraction of the explained variance in individual healthcare spending to values around 25 per cent. While this certainly reduces incentives to engage in risk selection, it makes risk adjustment more

vulnerable to manipulation (Breyer et al. 2011). Bauhoff et al. (2017) exploited the fact, that morbidity information was restricted to 80 diseases. They found that the number of diagnoses relating to diseases included in the risk adjustment scheme increased faster than those diagnoses related to diseases not included in the scheme. Even though it is difficult to disentangle upcoding from right-coding, there is considerable concern that diagnostic information is manipulated. Starting in 2021, the German risk adjustment model was extended to the full set of diseases (little more than 300), organized in roughly 500 hierarchical morbidity groups. As response to concerns regarding diagnostic manipulation, the new system includes a ‘manipulation brake’. It allows the regulator to exclude hierarchical morbidity groups provided they meet the exclusion criteria, a sufficiently above average increase in diagnoses being one of them.

This regulation highlights a fundamental tradeoff of risk adjustment mechanisms that rely on diagnostic information: When all available diagnostic information is used, risk selection incentives are minimized, while manipulation incentives are at their maximum. The other extreme is a system without diagnostic information, where selection incentives are large and diagnoses manipulation irrelevant. The German system is closer to the former extreme: In 2021, 18 of 495 hierarchical morbidity groups were excluded from the system. The number of excluded hierarchical morbidity groups can be altered using the exclusion criteria. The effects of such changes are currently addressed by the Federal Office for Social Security, the regulatory body administering risk adjustment in Germany, and the advisory board for the improvement of the risk adjustment mechanism.

The current paper addresses this tradeoff from a theoretical perspective and thereby not only complements the empirical analyses mentioned above but also contributes to the emerging debate about the goal of risk equalization in regulated competitive health insurance markets (van de Ven et al. 2023). We argue that the optimal risk adjustment mechanism will typically not be one of the extremes mentioned above but rather a compromise between the two where risk selection incentives are optimally balanced against manipulation incentives. To shed more light on the underlying tradeoff, we use the standard Hotelling (1929) framework and tailor it to the research question at hand. There are two public health insurers with exogenous horizontally differentiated characteristics. The unit demand property of the framework nicely captures the insurance mandate in countries like Germany and beyond. We consider risk heterogeneity and concentrate on two risk types, high and low. Community rating is modeled through price regulation, that is, risk-rated premiums are not allowed. We consider a sequential setting where the regulator chooses the extent of using diagnostic information at the first stage. At the second stage, insurers decide on both, the insurance premium (price) and on the risk selection intensity. Individuals select one of the two health insurers at the third stage. Finally, at the fourth stage, health insurers report their risk structure (they essentially choose their manipulation effort) and receive transfers from the risk adjustment scheme based on their report. We find that the degree to which diagnostic information is used in a socially optimal risk adjustment scheme depends on both, the risk selection technology, and the manipulation technology. The more effective

manipulation (selection), the lower (higher) the optimal degree of diagnostic information in the risk adjustment scheme. Interestingly, the competition intensity interacts with optimal risk adjustment. An increase in competition intensity makes risk selection relatively more important vis-à-vis diagnoses manipulation calling for more diagnostic information in the optimal risk adjustment scheme. In Germany, the regulator can challenge the risk reports of health insurers by conducting an audit. To capture this in an extension of our basis model, we integrate a costly audit at the fourth stage of our game. If successful, the transfer from the central fund to the insurer is based on the actual not on the reported risk structure. This reduces the expected gain of manipulation and with-it manipulation allowing for more diagnostic information in the optimal risk adjustment scheme. Depending on the exogenous success probability and audit costs, the regulator decides at stage 1 whether to implement an audit regime or not.

Our paper contributes to the literature on risk selection and optimal risk adjustment. Many papers seek empirical evidence for risk selection (e.g., Bauhoff 2012; Nuscheler and Knaus 2005). Another large strand of the literature investigates how to improve risk equalization in order to optimize the accuracy of risk adjusted payments and remove incentives for risk selection (e.g., Layton et al. 2018; McGuire et al. 2020; Schokkaert and Van de Voorde 2004; van Kleef et al. 2017). As risk adjustment schemes are getting more sophisticated, however, further improvements come with higher costs. Following this argument, van de Ven et al. (2023) discuss the goal of risk equalization in regulated competitive health insurance markets. There seems to be consensus, that mitigating risk selection incentives should be part of the goal. However, a focus on only this element is considered too strict, because an improvement of risk equalization may have a bearing on efficiency. The authors give a detailed overview over both positive and negative effects on efficiency and highlight the complex relationship between risk equalization and efficiency. To know the overall net effect on welfare, a comprehensive analysis needs to be done of both the negative and positive effects. Eggleston et al. (2012), for instance, contribute to this debate by demonstrating the negative effects of risk adjustment on health insurers' prevention incentives in a theoretical model. They suggest a combination between risk adjustment and pay-for-performance for prevention as a simple cure. We choose a similar approach by performing a welfare analysis, which considers another negative effect of risk adjustment, namely its vulnerability regarding diagnoses manipulation. To the best of our knowledge, we are the first to theoretically illustrate the tradeoff between risk selection and manipulation.

Our paper also relates to the upcoding literature. In addition to Bauhoff et al. (2017) it relates to Geruso and Layton (2020), who find evidence for upcoding behavior among private Medicare plans. Enrollees of these plans generate significantly higher diagnosis-based risk scores than they would under fee-for-service US Medicare, where diagnoses do not affect repayments. The excess in public spending and distortions to firm and consumer behavior are considerable. A related literature on hospitals' responses to diagnosis related group payment systems also finds evidence for upcoding. Jürges and Köberlein (2015), for instance, examine how German hospitals responded to the introduction of DRG payments in 2003 and reveal that hospitals

manipulate newborns' birth weight in a form to receive higher payments. Finally, our paper contributes to the literature on audit policies in public contracts. Regarding the former example on upcoding in neonatology, Hennig-Schmidt et al. (2019) investigate the role of audits and fines using a controlled behavioral experiment. They find, that audits in combination with fines significantly reduce dishonest behavior. Kuhn and Siciliani (2013) choose a more general, theoretical approach to investigate the role of audits and fines in an environment with the possibility to manipulate public sector contracts and show that the audit policy depends on commitment to an audit intensity.

The remainder of our paper is structured as follows. In the next section, we explain the basic model. Section 3 analyzes the behavior of individuals and health insurers and derives manipulation and risk selection in equilibrium. In Section 4, a comprehensive welfare analysis is conducted. We show, how risk selection and manipulation affect consumer welfare and health insurers' profits. We derive the optimal risk adjustment system and perform a comparative statics analysis to characterize the optimal scheme. In Section 5, we integrate an audit into the scheme and analyze how this affects optimal risk adjustment. Chapter 6 concludes.

2 The model

The model is based on Hotelling's framework and therefore allows for price competition with horizontally differentiated products (Hotelling 1929). In our setting, products are insurance contracts with different benefit packages offered by health insurers. The Hotelling line describes all possible variants and characteristics of benefit packages on the unit interval, whereby the exact location of insurance contracts on the interval reflects different tastes of consumers. Since benefit packages are horizontally differentiated, they are all of identical quality. In our context this can be interpreted as a (vertical) regulation of health insurers' benefit packages.

Insurers. The insurance contract $x_i \in [0, 1]$ is offered by health insurer $i \in \{0, 1\}$. We assume the location of insurers on the Hotelling line to be exogenously given by the respective end points of the interval ($x_0 = 0$ and $x_1 = 1$). There is unit demand, meaning that individuals demand exactly one contract. Health insurers maximize profits by choosing prices of insurance contracts, as well as the extent of risk selection and manipulation. The population consists of individuals with different health risks. For simplicity we assume there are only two possible states of health $q \in \{l, h\}$. Depending on the risk type, the extent of marginal treatment costs θ^q , borne by insurers, varies. High risks cause higher treatment costs compared to low risks ($0 < \theta^l < \theta^h$). For simplicity we abstract from administrative costs.¹

¹Douven et al. (2022) address the possibility of administrative costs to depend on the risk type and to be implemented in the risk adjustment scheme. We ignore this possibility, as it would not alter our main results.

Consumers. Both risk types are uniformly distributed on the unit interval, with mass $D_i^q = 1$ each risk type. Total demand is thus of mass $D_i^\diamond = 2$. There is a health insurance mandate with community rating. All individuals are obliged to buy exactly one contract - no matter from which insurer - at the (health state independent) price p_i . The gross willingness-to-pay for health insurance is $v > 0$, what in our context also can be interpreted as a direct benefit from health insurance. The location of an individual $x^q \in [0, 1]$ is the most preferred health insurance contract of the individual. The disutility when purchasing contract x_i is $t|x^q - x_i|$, where $t > 0$ measures the relative importance of mismatch costs vis-à-vis price. In other words, individuals incur linear transport costs, depending on the distance to their preferred insurance contract. The utility of individual $x^q \in [0, 1]$ from buying the insurance contract at insurer i is given by

$$u_i^q = v - p_i - t|x^q - x_i| + r_i^q. \quad (1)$$

Risk selection by insurers r_i^q affects the utility of individuals depending on their risk type. One could imagine different weights of selection in the sense that one risk type is more affected than the other. However, to facilitate the further analysis, we assume that individuals are affected in exactly opposite directions ($r_i^h + r_i^l \stackrel{!}{=} 0$). Selection activities by insurers are therefore clearly defined and captured in one variable $r_i := -r_i^h = r_i^l$.² Risk selection is costly to health insurers. Costs depend on the amount and on the effectivity of conducting risk selection. We measure effectivity with the cost factor a , where low values for a represent a more advanced risk selection technology. The cost function is given by $CR(r_i, a)$, with $CR_r > 0$, $CR_{rr} > 0$, $CR_{ra} > 0$.

Regulator. The regulator administers a self sustaining central health fund. The purpose of this fund is to redistribute money between insurers in form of a (partial) risk adjustment scheme, so that potential financial burdens caused by above average treatment costs of consumers can be reduced and risk selection incentives can be mitigated. To achieve this, the regulator first collects money from health insurers in form of a (negative) transfer or contribution

$$I_i = gD_i^\diamond, \quad (2)$$

which is proportional to the (observable) total number of each health insurer's customers D_i^\diamond . For every individual the insurer has to pay the general contribution rate g . All collected contributions are returned to insurers in form of the (positive) transfer

$$O_i = \alpha [gD_i^\diamond] + (1 - \alpha) [\theta^h \widehat{D}_i^h + \theta^l \widehat{D}_i^l]. \quad (3)$$

²van de Ven and van Vliet (1992) provide an extensive list of measures insurers may use for risk selection. According to Ellis (1998), the influence on individuals' utility can be positive (creaming - over-provision of services to low risks) or negative (skipping - under-provision of services to high risks). We assume the amount and effectiveness of creaming activities to equal the amount and effectiveness of skipping activities.

The transfer consists of two parts. The first term is proportional to the total number of insurers' customers, where for each customer simply the general contribution rate is reimbursed. The second term is risk based, so that each customer's actual treatment costs are tried to be reimbursed. By choosing $\alpha \in [0, 1]$, either part of the transfer is given more weight. Consider both extreme cases. For $\alpha = 1$, the payment is entirely proportional, so that all contributions are paid back to insurers without any risk adjustment. In the other extreme ($\alpha = 0$) the repayment is entirely risk based and therefore depends on *reported* treatment costs of health insurers. Here we assume, that, in contrast to the total number of insured, the amount of risk types for each insurer D_i^q cannot be verified by the regulator.³ For this reason reported numbers of risk types

$$\widehat{D}_i^q = D_i^q + m_i^q \tag{4}$$

vary from actual risk structures of insurers. By choosing manipulation m_i^q , insurers over- or understate the amount of respective risk types. As the regulator can verify total membership numbers, insurers only modify proportions of risk types. The reported total number of customers \widehat{D}_i^q has to equal the true number of customers for each insurer, meaning zero aggregated over- and understatements ($m_i^h + m_i^l \stackrel{!}{=} 0$). Similarly to risk selection, also manipulation activities by insurers are therefore clearly defined and captured in one variable $m_i := m_i^h = -m_i^l$. In the further analysis, we refer to this kind of behavior as to up-code customers or manipulate reports, where both expressions are used synonymous. Manipulation is costly to health insurers. Costs depend on the amount and on the effectivity of manipulation. Effectivity is measured by the cost factor b , where low values for b represent a more advanced manipulation technology. The cost function is given by $CM(m_i, b)$, with $CM_m > 0$, $CM_{mm} > 0$, $CM_{mb} > 0$.

Sequential setting. The model consists of four stages. In *stage one*, the regulator decides on the type of transfers to health insurers by choosing α . Furthermore, he determines the general contribution rate g , that insurers have to pay for each customer into the central health fund. In *stage two*, insurers choose prices p_i and conduct risk selection r_i maximizing their profits. After that, in *stage three*, individuals opt into insurers by selecting their preferred insurance contracts. Subsequently, after receiving the payments from their customers, insurers forward the contributions according to the general contribution rate to the central health fund. Finally, in *stage four*, insurers report their risk structures to the central health fund by choosing manipulation m_i . According to these reports, insurers receive all transfers from the regulator.

Players anticipate the behavior in subsequent stages of all other parties involved. Hence, to ensure subgame perfection, the game must be solved by backwards induction. Section 3 therefore analyses first of all the behavior of health insurers and individuals. Afterwards, section 4

³Note, that the amount of risk types for each insurer is known by the regulator. Our game structure implies a situation under symmetrical and complete information. The regulator thus perfectly anticipates insurer's and individual's behavior, in particular true risk structures of health insurers. However, we assume that although expected by the regulator, true risk structures can only be unambiguously revealed by audits (see section 5).

deals with the decision process of the regulator by conducting a comprehensive welfare analysis. In the following, we assume the regulator not to make use of audits in order to reveal manipulation. Extending the basic model, section 5 relaxes this assumption and compares the benchmark scenario to an audit regime. In this case the regulator would have to decide about its implementation in the first stage and - in the case of an implementation - undertake audits in stage 4 after receiving reports about the risk structures of health insurers.

3 Equilibrium analysis

Manipulation. Insurers report their risk structure at stage four, before receiving transfers from the central health fund. At this point, all decisions of previous stages are taken as given. The general contribution rate and the type of repayment have been set, decisions of insurers on selection and prices are made and individuals already have decided for an insurance contract and paid for it. Now, as insurers anticipate risk adjusted repayments to be based on their reported membership structure, there is an incentive to manipulate these reports in form of over- or understatements of the respective proportions of risk types. To see this, consider the profit function of insurer i :

$$\pi_i = p_i D_i^\circ - \theta^h D_i^h - \theta^l D_i^l - I_i + O_i - CR(r_i, a) - CM(m_i, b) \quad (5)$$

The first term of (5) are all gains from customers' contributions. The second and third term contain all treatment costs caused by consumers. The contributions and transfers are represented in the fourth and fifth term. Finally, the last two terms describe costs of selection and manipulation. At this stage, the only components of profits that still can be influenced by insurers are the risk based part of the transfers and costs of manipulation. Solving the first-order condition for m_i leads to

$$(1 - \alpha) \Delta = CM_m, \quad (6)$$

where we define $\Delta := \theta^h - \theta^l$ as the difference in marginal treatment costs between risk types. As the corresponding second-order condition is negative ($\frac{\partial^2 \pi_i}{\partial m_i^2} = -CM_{mm} < 0$), equation (6) characterizes profit maximizing behavior by health insurers. The left hand side of (6) describes marginal benefits of manipulation. By overstating high risk types, the repayment (and thereby profits) is increased for every unit of manipulation by the difference in treatment costs between risk types Δ weighted with the risk based part of the repayment $(1 - \alpha)$. Of course, in an equilibrium, marginal benefits equal marginal costs of manipulation (CM_m). Note, that the cost function and therefore marginal costs are assumed to be identical for both insurers. Thus the equilibrium is symmetric and insurers manipulate by the same amount ($m_0 = m_1 = m$). The comparative statics analysis shows that insurers manipulate the more

- the higher the share of risk based repayment ($\frac{dm}{d\alpha} = -\frac{\Delta}{CM_{mm}} < 0$)

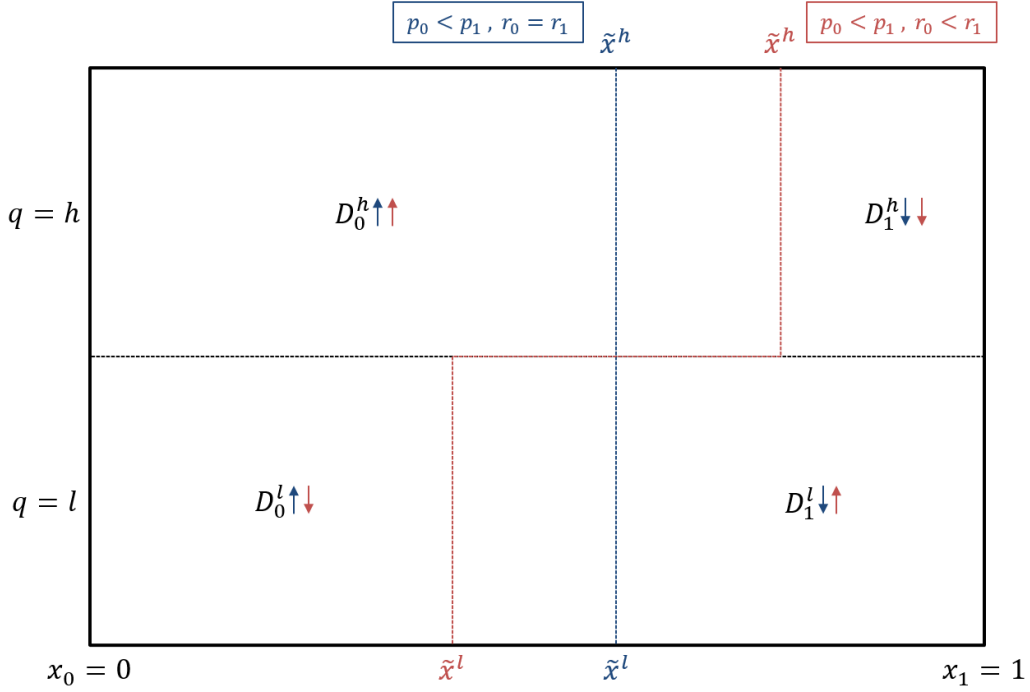


Figure 1: Distribution of customers according to risk selection and prices

- the higher the difference in treatment costs ($\frac{dm}{d\Delta} = \frac{1-\alpha}{CM_{mm}} > 0$)
- the more effective is manipulation ($\frac{dm}{db} = -\frac{CM_{mb}}{CM_{mm}} < 0$)

At this point, it becomes clear how vulnerable to upcoding are pure risk adjustment schemes. In the case of a proportional repayment, there are no manipulation incentives, whereas in the other extreme of entirely risk based transfers, manipulation incentives are at their maximum.

Consumers' behavior. At stage three, individuals have to decide for one of the two health insurers. When choosing an insurer, individuals take all decisions of the regulator and insurers on previous stages as given, of particular importance prices and the amount of risk selection. For each risk type $q \in \{l, h\}$ there exists one customer, who is exactly indifferent between the two insurers $i \in \{0, 1\}$. We determine these customers

$$\tilde{x}^h = \frac{p_1 - p_0}{2t} + \frac{r_1 - r_0}{2t} + \frac{1}{2} \qquad \tilde{x}^l = \frac{p_1 - p_0}{2t} + \frac{r_0 - r_1}{2t} + \frac{1}{2} \qquad (7)$$

by equating the utility functions (1), when choosing health insurer $i = 0$ or $i = 1$. As all individuals to the left of this customer prefer insurer $i = 0$, the corresponding demand for each risk type is given by $D_0^q = \tilde{x}^q$. Accordingly, the demand for each risk type of insurer $i = 1$ is $D_1^q = 1 - \tilde{x}^q$. As illustrated in figure 1, the insurer offering a lower price attracts more individuals of either risk type. In contrast, the insurer investing more resources in risk selection attracts more (less expensive) low risks and less (more expensive) high risks compared to the

other insurer. Note, that the total demand for each health insurer

$$D_0^\diamond = \tilde{x}^h + \tilde{x}^l = \frac{p_1 - p_0}{t} + 1 \quad D_1^\diamond = D_0^\diamond - \tilde{x}^h - \tilde{x}^l = \frac{p_0 - p_1}{t} + 1 \quad (8)$$

only depends on prices and not on risk selection, so that selecting individuals affects the risk pool of health insurers, but not the total number of customers.

Price competition. At stage two, health insurers set prices and decide on the extent of risk selection. In doing so, they anticipate the behavior of individuals when choosing a insurer. All decisions of the regulator with respect to the general contribution rate and the type of repayment in the first stage are taken as given. First, we consider prices p_i . Maximizing profits (5) leads to the first-order condition

$$\frac{\partial \pi_i}{\partial p_i} = D_i^\diamond + \frac{1}{t} \left[-p_i + \bar{\theta} + g - \alpha g - (1 - \alpha) \bar{\theta} \right] \stackrel{!}{=} 0, \quad (9)$$

where we define $\bar{\theta} := \frac{D_0^h \theta^h + D_0^l \theta^l}{D_0^\diamond}$ as average marginal treatment costs. The second-order condition is negative ($\frac{\partial^2 \pi_i}{\partial p_i^2} = -\frac{2}{t} < 0$), thus equation (9) indeed characterizes profit maximizing behavior by insurers. The first term of (9) is a direct effect of marginally increasing prices. Profits of insurers increase, as every customer has to pay a higher price. All terms in brackets are indirect effects, resulting through a decrease of customers by marginally increasing p_i . As customers decrease, of course gains through their contributions decrease (first term). On the other side, less customers have the positive effect of lower treatment costs and less general contributions, that have to be paid in form of the contribution to the central health fund (second and third term). Finally, both types of the transfer decrease with less customers, what in turn negatively influences profits (fourth and fifth term). Rearranging terms leads to the reaction functions

$$p_i(p_j) = \frac{1}{2} \left(t + p_j + \alpha \bar{\theta} + (1 - \alpha) g \right), \quad (10)$$

for $i, j = 0, 1$ with $i \neq j$. Note, that the prize of one insurance contract (p_i) is increasing in the price of the other contract (p_j). Therefore, contracts are strategic complements. The Nash equilibrium can be found in the intersection of both reaction functions. In this point, neither of the insurers has an incentive to deviate from their prizes. Equating the two resulting reaction functions (10) leads to

$$p_i = t + \alpha \bar{\theta} + (1 - \alpha) g. \quad (11)$$

Note, that in the symmetric equilibrium insurers choose identical prices ($p_0 = p_1 = p$) and insure according to (8) the same amount of individuals ($D_0^\diamond = D_1^\diamond = D^\diamond = 1$). Optimal prices of health insurance contracts offered by insurers are increasing in

- transport costs ($\frac{dp}{dt} = 1 > 0$)

- average marginal treatment costs ($\frac{dp}{d\theta} = \alpha \geq 0$)
- the general contribution rate ($\frac{dp}{dg} = 1 - \alpha \geq 0$)
- the risk based share of the transfer ($\frac{dp}{d\alpha} = \bar{\theta} - g \leq 0$)

In line with the standard Hotelling model (Hotelling 1929), product differentiation allows insurers to raise their prices by an amount t (first term) on top of marginal costs. The less substitutable are insurance contracts (increasing t) the higher is this increase in prices.⁴ Prices are increasing in average marginal treatment costs (second term) and in the general contribution rate (third term). In the extreme situation of a purely risk based repayment ($\alpha = 0$) average marginal treatment costs do not affect prices, as the risk adjustment scheme reimburses all treatment costs. Prices thus fully depend on the general contribution rate, that insurers have to pay for every customer to the central health fund. In the other extreme, for a purely proportional repayment ($\alpha = 1$), the general contribution rate does not affect prices, as general contributions are 1:1 reimbursed. Prices therefore are fully based on marginal treatment costs. Finally, prices negatively depend on the transfer rule α . This is, because with more risk adjustment (decreasing α), prices depend to a greater extent on the general contribution rate compared to average marginal treatment costs. As the general contribution rate is, according to the budget restriction (13), higher or equal than average marginal treatment costs ($g \geq \bar{\theta}$), an increasing share of risk based transfer increases prices (second and third term).

Risk selection. The allocation of customers regarding high and low risk types (D_i^q), in contrast to total customers, depends on the extent to which insurers risk select. The optimal degree of selection is determined by maximizing profits (5) with regard to r_i . Solving the corresponding first-order condition leads to

$$\frac{\alpha\Delta}{2t} = CR_{rr}. \quad (12)$$

The second-order condition is negative ($\frac{\partial^2 \pi_i}{\partial r_i^2} = -CR_{rr} < 0$), thus (12) characterizes a profit maximum. In the equilibrium marginal benefits equal marginal costs of risk selection. The left hand side of (12) describes marginal benefits of selection. Selecting low risk types increases profits through a reduction of treatment costs by the difference in costs between risk types Δ . This is only possible with respect to the proportional part of the repayment α . Transport costs are important here, as individuals with lower (higher) transport costs are easier (more difficult) to convince for choosing the more expensive insurer or the insurer with a higher distance to their initial preference. Thus, we can interpret t as switching costs between health insurers and as an additional barrier to conduct risk selection. As in the case of manipulation, marginal costs (right hand side of (12)) do not differ between insurers. As also all other components of the optimal

⁴Transport costs t can thus be considered as a measure for market power of insurers. In an institutional context with highly substitutable (almost identical) benefit packages, for example, market power is very low.

condition are identical, insurers risk select by the same amount ($r_0 = r_1 = r$). According to (7), both insurers thus insure the same share of high and low risks ($D_0^q = D_1^q = D^q = \frac{1}{2}$). The comparative statics analysis confirms, that insurers risk select the more the

- higher the share of proportional repayment ($\frac{dr}{d\alpha} = \frac{\Delta}{2tCR_{rr}} > 0$)
- the higher the difference in treatment costs ($\frac{dr}{d\Delta} = \frac{\alpha}{2tCR_{rr}} > 0$)
- the more effective is risk selection ($\frac{dr}{da} = -\frac{CR_{ra}}{CR_{rr}} < 0$)
- lower are transport costs ($\frac{dr}{dt} = -\frac{\alpha\Delta}{2t^2CR_{rr}} < 0$)

At this point, the basic function of risk adjustment schemes as an instrument to prevent risk selection can be clearly seen. While selection incentives are at their maximum with a proportional repayment, they completely disappear under ideal risk adjustment.

4 Welfare analysis

General contribution rate. At stage one, the regulator determines the general contribution rate and the optimal transfer rule, anticipating all decisions of health insurers and individuals on subsequent stages. For the central health fund's budget to be balanced, the sum of contributions I_\diamond must equal the sum of transfers O_\diamond . Considering this budget constraint, the general contribution rate amounts to⁵

$$g = \bar{\theta} + \frac{m_\diamond \Delta}{2}. \quad (13)$$

Note, that the general contribution rate depends on insurers reports about their risk structure and therefore on equilibrium manipulation. The second term of (13) indicates the amount by which aggregated manipulative behavior m_\diamond increases the general contribution rate compared to a situation without any manipulation in which general contributions would cover all actual costs of treatment. In order to determine the optimal transfer rule α , the following paragraphs will take a closer look at consumer welfare and insurers profits.

Consumer welfare. First, we examine how manipulation and selection influences the utility of individuals. Consumer surplus of risk type q is given by:

$$\begin{aligned} CS^q &= \int_0^{\tilde{x}^q} (v - p - tx + r^q) dx + \int_{\tilde{x}^q}^1 (v - p - t(1-x) + r^q) dx \\ &= v - \left[t + \bar{\theta} + (1-\alpha)m\Delta \right] - \frac{t}{4} + r^q \end{aligned} \quad (14)$$

⁵In the extreme case of a purely proportional repayment ($\alpha = 1$) the budget constraint is redundant, so that the general contribution rate could be set arbitrarily. It has no regulatory effect, as the contributions and transfers of each insurer are determined identically (see (2) and (3)). In fact, this is equivalent to a situation without any regulation in form of a central health fund ($g = 0$).

Welfare effects of manipulation are represented by the fourth term. It is the amount, by which manipulative behavior of insurers increases prices of insurance contracts through an increasing general contribution rate compared to a situation without manipulation (see equations (13) and (11)). This increase has a negative impact on consumer utility, since higher prices have to be paid by individuals. Altogether, manipulation leads to a decrease in aggregated consumer surplus of both risk types CS^\diamond by the amount $2 * (1 - \alpha) m\Delta$.

The last term of (14) represents welfare effects of risk selection. According to our definition of the selection variable ($r_i := -r_i^h = r_i^l$), it is positive for low risks and negative for high risks. Since risk types are evenly distributed, the aggregated effect on total consumer surplus is zero. In our setting, risk selection thus leads to a redistribution of consumer surplus from high to low risks by the amount r , but has no aggregated impact on consumer welfare.

Insurers' profits. Next, the influence of manipulation and risk selection on insurers' profits is to be determined. Due to symmetry, profits are identical for both health insurers ($\pi_0 = \pi_1 = \pi$) and are given by:

$$\begin{aligned} \pi &= p - \bar{\theta} - I + O - CR(r, a) - CM(m, b) \\ &= t + (1 - \alpha) m\Delta - CR(r, a) - CM(m, b) \end{aligned} \tag{15}$$

First, we consider welfare effects of manipulation. Regarding profits, in contrast to consumer welfare, the effect of an increasing general contribution rate through manipulation cancels out, as this increase is fully transmitted to individuals by increasing prices. Nevertheless, there is a positive effect of manipulation on profits. The second term is the amount, by which upcoding increases the risk based part of transfers and therefore profits of insurers. Note, that this positive effect is - in absolute terms - equivalent to the negative effect of manipulation on consumer welfare in form of increasing prices. Insurers' increase in profits through manipulative behavior is thus fully achieved at the expense of individuals. Finally, manipulation is costly. The last term represents the reduction of insurers' profits due to manipulation costs. The remaining welfare effect of upcoding on total profits of both insurers π_\diamond sums up to $2 * [(1 - \alpha) m\Delta - CM(m, b)]$. As insurers choose the amount of manipulation profit maximizing, this effect is clearly positive.

In contrast to manipulation, risk selection leads to individual and thus aggregated losses in profits, even if selection may be individually rational. This is a typical example of a prisoner's dilemma situation. Note, that the negative effect in form of selection costs (third term of (15)) does not face any positive effect. This can be explained by the fact, that risk selection neither affects the total number of insured persons, nor the risk structure in the market. It only affects the distribution of customers between insurers. Selection is individually rational because the own risk structure can be improved at costs of the competing insurer, whose risk structure worsens. In our symmetric equilibrium, however, both insurers select the same amount of individuals and thus face the same risk structure as compared to a situation without any selection activities. Finally, both insurers do not have any advantage from risk selection, but have to bear its costs.

Optimal regulation. So far, the welfare analysis has shown that risk selection by health insurers leads to

- a redistribution from high to low risks [r]
- losses for insurers due to selection costs [$2 * CR(r, a)$]

Manipulation, on the other hand, leads to

- a redistribution from consumers to insurers [$2 * (1 - \alpha) m\Delta$]
- losses for insurers due to manipulation costs [$2 * CM(m, b)$]

Both risk selection and manipulation cause undesirable welfare effects. We have already seen that the regulator is able to control incentives for selection or manipulation with the type of repayment. Depending on the transfer rule α , incentives go in opposite directions. A proportional transfer ($\alpha = 1$) induces maximum incentives for risk selection, whereas insurers do not have any incentives to manipulate. In the case of a completely risk based transfer ($\alpha = 0$), the situation is exactly the opposite. Incentives for manipulation are at their maximum, but there are no selection incentives. Since with the transfer rule α only one instrument is available to prevent two negative welfare effects, it must be weighed up which effect predominates and which type of repayment is to be preferred. As we will see below, a mixed form of both systems ($0 < \alpha < 1$) optimally balances both negative effects and minimizes the welfare loss.

In order to determine the optimal transfer rule α , we now have to define a welfare function. Therefore we assume that the social surplus consists of the aggregated utility of all individuals and profits of both health insurers:

$$W = CS^\diamond + \pi_\diamond = 2 * \left[v - \bar{\theta} - \frac{t}{4} - CR(r, a) - CM(m, b) \right] \quad (16)$$

Note, that the transfer rule α only affects the last two terms - consisting of aggregated manipulation and selection costs. As we have already seen, these costs represent the total welfare loss compared to a first-best solution without any manipulation or risk selection. Maximizing welfare with respect to α and solving the first-order condition leads to

$$\frac{CM_m}{CM_{mm}} = \frac{1}{2t} * \frac{CR_r}{CR_{rr}}, \quad (17)$$

which characterizes the optimal transfer rule. The corresponding second-order condition is negative ($\frac{\partial^2 W}{\partial \alpha^2} < 0$, proof see appendix A.1), thus (17) indeed characterizes a welfare maximum. The left hand side of (17) describes the benefit of marginally increasing α . As the proportional part of the transfer rises, insurers have less incentives to manipulate. Less manipulation by insurers leads to lower associated costs, which benefits total welfare. Marginal costs of an increasing α are represented by the right hand side of (17). With a higher proportional share in the repayment, selection activities by insurers and associated costs rise. In addition to the

risk selection respective manipulation technology, switching costs t play an important role here. As selection incentives are high for low values of t , also marginal costs of an increasing α are high for low values of t . The comparative statics analysis confirms, that the optimal share of proportional transfer should be the higher the

- the more effective is manipulation ($\frac{d\alpha}{db} < 0$, proof see appendix A.2)
- the less effective is risk selection ($\frac{d\alpha}{da} > 0$, proof see appendix A.2)
- higher are transport costs ($\frac{d\alpha}{dt} > 0$, proof see appendix A.2)

In summary, the share of proportional repayment should be high if selection incentives in general are low compared to manipulation incentives. With high switching costs t , for example, insurers can only gain small advantages from risk selection resulting in low incentives to risk select. The regulator can thus focus mainly on preventing manipulation by increasing α , without allowing for too much risk selection. In contrast, when switching costs are low, insurers have high incentives to risk select, since individuals can be easier attracted or deterred by selecting activities. In this case, risk selection would be the more serious of the two problems, and a high share of risk based reimbursement should be the preferred choice (low α). Another factor to be considered when choosing the transfer rule, in addition to transportation costs, is the selection and manipulation technology in the market, represented by the corresponding cost factors a and b . Again, the more attractive risk selection or manipulation is in terms of a higher effectivity the more insurers will take advantage of this. Accordingly, if risk selection is effective, a risk based repayment (low α) should be preferred. On the other hand, if manipulation is relatively more effective, a higher weight should be given on a proportional repayment (high α).

5 Audit regime

The regulator now has the additional option of implementing and announcing an audit regime at stage one. With the help of audits, true risk structures and thus manipulation activities of insurers can be clearly verified and proven. An audit

- causes fixed costs per health insurer of $\gamma > 0$
- reveals true risk structures with a fixed probability $\tau \in (0, 1]$

If the fraud is detected, the risk based part of the transfer depends on actual risk structures of health insurers. If the fraud cannot be detected, everything remains as before and the repayment is based on reported risk structures. From an ex-ante point of view, the transfer to insurers is thus uncertain and, in expected value, amounts to

$$\mathring{O}_i = \alpha [gD_i^s] + (1 - \alpha) \left[(1 - \tau) (\theta^h \widehat{D}_i^h + \theta^l \widehat{D}_i^l) + \tau (\theta^h D_i^h + \theta^l D_i^l) \right]. \quad (18)$$

If the regulator has decided on a regime with audits at stage one, they are executed at stage four after receiving reports about the risk structures of insurers. Health insurers consider the implications of audits in their manipulation decision.⁶ Profit maximization of insurers with respect to m_i leads to the following optimal condition:

$$(1 - \tau)(1 - \alpha)\Delta = CM_m \quad (19)$$

As the corresponding second-order condition is negative ($\frac{\partial^2 \pi_i}{\partial m_i^2} = -CM_{mm} < 0$), equation (19) characterizes profit maximizing behavior by insurers. Compared to the scenario without audits, the optimal level of manipulation from the perspective of insurers now also depends on the effectiveness of audits. More precisely, the marginal benefit of manipulation (left hand side of (19)) decreases with the probability of detecting manipulative behavior. All other influences on optimal manipulation remain unchanged, so insurers manipulate the more the

- the higher the share of risk based repayment ($\frac{d\hat{m}}{d\alpha} = -\frac{(1-\tau)\Delta}{CM_{mm}} < 0$)
- the higher the difference in treatment costs ($\frac{d\hat{m}}{d\Delta} = \frac{(1-\alpha)(1-\tau)}{CM_{mm}} > 0$)
- the more effective is manipulation ($\frac{d\hat{m}}{db} = -\frac{CM_{mb}}{CM_{mm}} < 0$)
- **lower the probability of detection** ($\frac{d\hat{m}}{d\tau} = -\frac{(1-\alpha)\Delta}{CM_{mm}} < 0$)

Compared to the previous section, nothing changes in the decision process of insurers and individuals at stages two and three. The regulator anticipates this at the first stage and has to decide whether the general audit regime should be carried out or not. Consider, that costs of audits can only be financed through an increase in the general contribution rate. With the regulator's new budget constraint ($I_\diamond \stackrel{!}{=} \dot{O}_\diamond + 2\gamma$), the general contribution rate amounts to⁷

$$\dot{g} = \bar{\theta} + (1 - \tau) \frac{\dot{m}_\diamond \Delta}{2} + \frac{\gamma}{(1 - \alpha)}. \quad (20)$$

In order to determine the optimal repayment scheme α , in the following, we will again take a closer look at social welfare and compare it to the benchmark scenario without audits. Consumer

⁶The announcement of an audit regime at the first stage must be credible in the sense that audits will be carried out at stage four under all circumstances. This is a realistic assumption, since the game structure can be interpreted as a repeated game, with the regulator deciding in each period whether to announce and conduct audits. If the regulator does not stick to his announcement, the credibility for following periods is lost.

⁷In the extreme case of a purely proportional transfer ($\alpha = 1$), the budget constraint can never be satisfied under an audit regime. Since in such a scenario all general contributions are fully reimbursed to health insurers (the in- and transfer of each insurer are determined identically (see (2) and (18))), audit costs cannot be financed via the general contribution rate. However, this is an irrelevant case. With a purely proportional transfer there are no manipulation incentives at all, so that an audit regime is not necessary.

surplus of risk type q under an audit regime is given by:

$$\begin{aligned} C\dot{S}^q &= \int_0^{\tilde{x}^q} (v - p - tx + r^q) dx + \int_{\tilde{x}^q}^1 (v - p - t(1-x) + r^q) dx \\ &= v - \left[t + \bar{\theta} + (1 - \alpha)(1 - \tau) \dot{m}\Delta + \gamma \right] - \frac{t}{4} + r^q \end{aligned} \quad (21)$$

Regarding welfare effects of risk selection, nothing changes compared to the benchmark scenario. The aggregated effect on total consumer surplus is zero and risk selection only leads to a redistribution of consumer surplus from high to low risks by the amount r . Welfare effects of manipulation are represented by the fifth term - as before caused by an increasing general contribution rate, which health insurers transmit to consumers through increasing prices. In an audit regime, manipulation thus leads to a decrease in total consumer surplus of both risk types $C\dot{S}^\diamond$ by the amount $2 * (1 - \alpha)(1 - \tau) \dot{m}\Delta$. This welfare effect is - for α remaining unchanged - lower compared to the former effect without audits, as $\tau > 0$ and $\dot{m} < m$. Note, that there is an additional welfare effect in the audit regime beyond the effects of risk selection and manipulation. As we assume audits to be financed by the general contribution rate, also costs of audits are fully transmitted to individuals through increasing prices (sixth term). Total welfare thus decreases by the amount $2 * \gamma$.

Next, we want to determine the influence of an audit regime on health insurers' profits. Profits are identical for both insurers ($\dot{\pi}_0 = \dot{\pi}_1 = \dot{\pi}$) and given by:

$$\begin{aligned} \dot{\pi} &= p - \bar{\theta} - I + \dot{O} - CR(r, a) - CM(\dot{m}, b) \\ &= t + (1 - \alpha)(1 - \tau) \dot{m}\Delta - CR(r, a) - CM(\dot{m}, b) \end{aligned} \quad (22)$$

Again, regarding welfare effects of risk selection, nothing changes compared to the benchmark scenario. Both insurers do not have any advantage from selecting individuals, but have to bear its costs. So risk selection leads to individual and thus aggregated losses in profits in the amount of selection costs (third term). Welfare effects of manipulation, in contrast to risk selection, consist of a positive and a negative effect. On the one hand, insurers profit from manipulation by increasing the risk based part of repayments (positive effect, second term). As in the benchmark scenario without audits, this positive effect is - in absolute terms - equivalent to the negative effect of manipulation on consumer welfare, so that insurers' increase in profits is fully achieved at the expense of individuals. On the other hand, insurers have to bear costs of manipulation (negative effect, fourth term). The remaining welfare effect of upcoding on total profits of both insurers $\dot{\pi}_\diamond$ sums up to $2 * [(1 - \alpha)(1 - \tau) \dot{m}\Delta - CM(\dot{m}, b)]$. This effect is clearly positive, as insurers choose the amount of manipulation profit maximizing.

As in the benchmark scenario without audits, the social surplus consists of the aggregated utility of all individuals and profits of both health insurers:

$$\dot{W} = C\dot{S}^\diamond + \dot{\pi}_\diamond = 2 * \left[v - \bar{\theta} - \frac{t}{4} - CR(r, a) - CM(\dot{m}, b) - \gamma \right] \quad (23)$$

Maximizing welfare with respect to α and solving the first-order condition leads to

$$(1 - \tau) \frac{CM_m}{CM_{mm}} = \frac{1}{2t} * \frac{CR_r}{CR_{rr}}, \quad (24)$$

which characterizes the optimal transfer rule in an audit regime. The corresponding second-order condition is negative ($\frac{\partial^2 W}{\partial \alpha^2} < 0$, proof see appendix A.3), thus (24) indeed characterizes a welfare maximum. An audit regime alters the benefit of marginally increasing α (left hand side of (24)) compared to the scenario without audits. As the proportional part of the transfer rises, insurers have less manipulation incentives leading to lower associated costs. However, this marginal benefit is lowered by the fact, that manipulation can be additionally prevented by audits. A more effective audit technology (high τ) thus decreases the marginal benefit of an increasing α . The right hand side of (24) represents costs of marginally increasing α , that remain the same as in a situation without audits. Since marginal benefits decrease and marginal costs do not change, the proportional part of the repayment under an audit regime is clearly smaller in comparison to a regime without audits ($\hat{\alpha} < \alpha$). The comparative statics analysis reveals, that the optimal share of proportional repayment should be the higher the

- the more effective is manipulation ($\frac{d\hat{\alpha}}{db} < 0$, proof see appendix A.4)
- the less effective is risk selection ($\frac{d\hat{\alpha}}{da} > 0$, proof see appendix A.4)
- higher are transport costs ($\frac{d\hat{\alpha}}{dt} > 0$, proof see appendix A.4)
- **lower the probability of detection** ($\frac{d\hat{\alpha}}{d\tau} < 0$, proof see appendix A.4)

As before, the share of proportional repayment should be high if selection incentives are low compared to manipulation incentives. This is the case for high switching costs t , a high effectivity of risk selection compared to manipulation and now also for a low probability of detecting upcoding. Accordingly, the more effective are audits in detecting manipulative behavior (high τ) the higher should be the share of risk based repayment. To illustrate this, consider the extreme case of perfect audits ($\tau = 1$). According to equation (19), insurers have no manipulation incentives at all, not even if the regulator implements a purely risk based repayment ($\alpha = 0$). By using audits in conjunction with ideal risk adjustment, the regulator can thus prevent both manipulation and risk selection. He now has two regulatory tools at his disposal to prevent two negative welfare effects and a first best solution regarding manipulation and risk selection (without considering audit costs γ) can be achieved.

However, since audits in practice are far from being a perfect regulatory tool ($\tau < 1$ and $\gamma > 0$), the final step is to weigh up whether the positive or negative effects of an audit regime predominate. The disadvantage of audits are its costs (γ) to be paid with certainty. To comply his budget constraint, the regulator will have to increase the general contribution rate, which negatively affects consumer welfare. The advantage of an audit regime, on the other hand, lies in decreasing manipulation incentives. The regulator can therefore increase the share of risk

based repayment ($\hat{\alpha} < \alpha$) and reduce the amount of risk selection as well as the welfare loss attributed to risk selection. Surprisingly, it is not clear whether audits also reduce equilibrium manipulation and its associated costs.⁸ The sum of selection and manipulation costs, however, will clearly decrease compared to a situation without audits.⁹ For a given detection probability τ , we now define $\tilde{\gamma}$ as those audit costs at which positive and negative effects of the audits just cancel out - welfare with or without an audit regime is exactly the same. If actual audit costs γ are below this threshold, the regulator should accordingly choose an audit regime at stage one. Otherwise, audit costs are too high and no audit regime should be implemented at the first stage. Equating the two welfare functions (16) and (23) leads to

$$\tilde{\gamma} = [CR(r, a) - CR(\hat{r}, a)] + [CM(m, b) - CM(\hat{m}, b)] > 0, \quad (25)$$

where \hat{r} and \hat{m} denote, respectively, the optimal extent of risk selection and manipulation under an audit regime. In contrast, r and m , denote equilibrium risk selection and manipulation without an audit regime. As stated above, the first term in brackets is positive. The sign of the second term cannot be unambiguously determined⁸, but overall critical audit costs are necessarily strictly positive.⁹ So for each detection probability $\tau \in (0, 1]$, there exists a critical amount of audit costs ($\tilde{\gamma} > 0$) below which it is worthwhile to implement an audit regime.

We resume that, for $\gamma < \tilde{\gamma}$ ($\gamma > \tilde{\gamma}$), the regulator should (not) implement an audit regime at the first stage, as overall welfare increases (decreases) compared to the benchmark scenario. In addition to this welfare effect, audits affect inequality between risk types. An optimal audit regime unambiguously mitigates the redistributive effect of consumer surplus from high to low risks by reducing the degree of risk selection compared to the benchmark scenario. Thus, in addition to the efficiency rationale, implementing an audit regime could also be interesting thinking about equity regarding health risk. From the results of our model it remains unclear, however, to what extent an audit regime changes equilibrium manipulation and its associated redistributive effects between health insurers and consumers.

Extensions

Alternative budget restriction. *To be added.*

Risk dependent transport costs. *To be added.*

⁸There are two offsetting effects. For constant α , manipulation incentives decrease in an audit regime according to (19). However, the regulator decreases α according to (24), which in turn leads to increasing manipulation incentives. The overall effect is ambiguous.

⁹This is true, because even for α remaining constant there will be an overall decrease in costs (manipulation and hence its associated costs decrease, while selection costs remain unchanged). Since the regulator chooses $\hat{\alpha}$ cost minimizing, overall costs must necessarily further decline.

6 Conclusion

In this paper, we applied Hotelling’s model of horizontal product differentiation in a health insurance setting to derive optimal risk adjustment when there is both risk selection and manipulation of diagnostic information. Our main findings are in contrast to one commonly stated goal of risk adjustment schemes that is to remove all health insurers’ risk selection incentives (van de Ven et al. 2023). Unless we end up in a corner solution, such a policy will never be optimal in our framework. This is, because with full risk adjustment, there is no risk selection but insurers have maximal incentives to manipulate reports about their risk structures. Instead, we find, that the regulator should implement a repayment mix of risk based and proportional payments to optimally balance positive (mitigating risk selection) and negative (increasing manipulation) effects of risk adjustment schemes.

The optimal share of risk based repayment in the scheme depends on the relation from risk selection to upcoding incentives in the market to be investigated. Relatively high risk selection incentives require a more accurate risk adjustment scheme and vice versa. When looking at incentives, besides the upcoding and risk selection technologies, transport respective switching costs play an important role. As they reduce insurers’ risk selection incentives, high transport costs imply less risk adjustment. In addition to these main results based on a pure efficiency criteria, we investigate distributive effects of risk adjustment schemes. In our model, manipulation leads to a redistribution from individuals to health insurers. This is due to manipulative behavior increasing prices of insurance contracts. Risk selection, on the other hand, leads to a redistribution from high to low risk types. This is, because risk selection directly affects utilities of the respective risk types. Depending on the implemented extend of risk adjustment, either of these redistributive effects predominates.

As one extension of the basic model, we implement the possibility of conducting audits in order to detect manipulation. Here, we show, that there exists a critical value of audit costs, below which an audit regime should always be implemented by the health authority in the first stage. Given its implementation, the audit regime tilts the balance towards more risk adjustment, whereby the share of risk based payments is increasing in the probability of detecting manipulation. As a direct consequence of this, the amount of risk selection decreases and total welfare increases compared to the benchmark scenario without audits. It remains unclear from the model, however, whether the audit regime leads to less equilibrium manipulation. Regarding distributive effects, we can draw conclusions according to these results.

We are aware of the restrictive assumptions made in the theoretical model. Especially the fact, that health insurance companies are profit maximizers is up to debate. In some public schemes, including the German system, insurers are not allowed to make profits and have to economize in a way to cover their cost. Nevertheless, we find it plausible to imply profits as the objective function, because also public insurers’ are responsive to financial incentives (Bauhoff 2012). While the general assumptions about the cost functions regarding upcoding

and risk selection leave our theoretical model very flexible, we recognize that it is a challenge to empirically determine these costs. We also recognize, that our model includes only a small portion of various diverse and complex welfare effects originating from risk adjustment schemes. As correctly stated by van de Ven et al. (2023), a comprehensive analysis needs to be done considering all possible impacts of risk equalization on efficiency. Our findings contribute to this challenge and leave further important aspects to be investigated for future research.

The results of our theoretical model can be transferred to real word economies. Looking at an industrial country like Germany, for example, risk selection seems to be the more serious of the two problems. On the one hand, market power in the German public health insurance system is likely to be very low due to almost identical benefit packages. On the other hand, manipulation is probably much more difficult to conduct (less effective) compared to risk selection. Following our model, both arguments tend to favor a high extend of risk adjustment. This is in line with the 2020 public health insurance reform, which expanded the German risk adjustment scheme to a full model including the entire spectrum of diseases (instead of previously only 50 to 80, BMG 2020). The reform also allows the health authority to conduct audits and to refrain from using diagnostic information when manipulation is overwhelming. Such a sharp policy, however, is never optimal in our model. Instead, the regulator should keep using diagnostic information with reduced repayments according to actual risk structures. It is in the hands of policy makers to tackle these challenges, highlighted by our model, in order to enhance the efficiency of risk adjustment schemes.

A Appendix

A.1 Second-order condition - benchmark scenario

Maximizing welfare (16) with respect to α leads to the following first-order condition (FOC):

$$\begin{aligned}\frac{\partial W}{\partial \alpha} &= -2CR_r \frac{dr}{d\alpha} - 2CM_m \frac{dm}{d\alpha} \stackrel{!}{=} 0 \\ \Leftrightarrow -\frac{CR_r}{2tCR_{rr}} + \frac{CM_m}{CM_{mm}} &\stackrel{!}{=} 0\end{aligned}\tag{A1}$$

The corresponding second-order condition (SOC) is given by:

$$\begin{aligned}\frac{\partial^2 W}{\partial \alpha^2} &= \frac{-CR_{rrr} \frac{dr}{d\alpha} 2tCR_{rr} + 2tCR_{rrr} \frac{dr}{d\alpha} CR_r}{(2tCR_{rr})^2} + \frac{CM_{mmm} \frac{dm}{d\alpha} CM_{mm} - CM_{mmm} \frac{dm}{d\alpha} CM_m}{(CM_{mm})^2} \\ &= \frac{\Delta \left(\frac{CR_r CR_{rrr}}{CR_{rr}} - CR_{rr} \right)}{(2tCR_{rr})^2} + \frac{\Delta \left(\frac{CM_m CM_{mmm}}{CM_{mm}} - CM_{mm} \right)}{(CM_{mm})^2} < 0\end{aligned}\tag{A2}$$

Given that Δ , t , as well as the first and second derivatives of the cost functions are greater than zero, (A2) is smaller than zero if the third derivatives of the cost functions are sufficiently small:

$$CR_{rrr} < \frac{(CR_{rr})^2}{CR_r} \qquad CM_{mmm} < \frac{(CM_{mm})^2}{CM_m}\tag{A3}$$

We assume these rather mild conditions on the cost functions to be fulfilled, so that the SOC is negative and (17) characterizes a welfare maximum.

A.2 Comparative statics - benchmark scenario

In order to determine how the optimal α reacts to changes in the parameters b , a , t , and Δ , we totally differentiate the FOC (A1):

$$d \frac{\partial W}{\partial \alpha} = \frac{\partial^2 W}{\partial \alpha^2} d\alpha + \frac{\partial^2 W}{\partial \alpha \partial b} db + \frac{\partial^2 W}{\partial \alpha \partial a} da + \frac{\partial^2 W}{\partial \alpha \partial t} dt + \frac{\partial^2 W}{\partial \alpha \partial \Delta} d\Delta \stackrel{!}{=} 0\tag{A4}$$

The effects of b , a , t , and Δ on the optimal α are given by:

$$\frac{d\alpha}{db} = -\frac{\frac{\partial^2 W}{\partial \alpha \partial b}}{\frac{\partial^2 W}{\partial \alpha^2}} \qquad \frac{d\alpha}{da} = -\frac{\frac{\partial^2 W}{\partial \alpha \partial a}}{\frac{\partial^2 W}{\partial \alpha^2}} \qquad \frac{d\alpha}{dt} = -\frac{\frac{\partial^2 W}{\partial \alpha \partial t}}{\frac{\partial^2 W}{\partial \alpha^2}} \qquad \frac{d\alpha}{d\Delta} = -\frac{\frac{\partial^2 W}{\partial \alpha \partial \Delta}}{\frac{\partial^2 W}{\partial \alpha^2}}\tag{A5}$$

As the SOC is negative, the signs of $\frac{d\alpha}{db}$, $\frac{d\alpha}{da}$, $\frac{d\alpha}{dt}$, and $\frac{d\alpha}{d\Delta}$ are equivalent to the signs of $\frac{\partial^2 W}{\partial \alpha \partial b}$, $\frac{\partial^2 W}{\partial \alpha \partial a}$, $\frac{\partial^2 W}{\partial \alpha \partial t}$, and $\frac{\partial^2 W}{\partial \alpha \partial \Delta}$. Under the implied conditions on the cost functions (A3), the signs of the

respective cross derivatives are as follows (remember that $CR_{ra} > 0$ and $CM_{ma} > 0$):

$$\begin{aligned}\frac{\partial^2 W}{\partial \alpha \partial b} &= \frac{CM_{mm} \frac{dm}{db} CM_{mm} - CM_{mmm} \frac{dm}{db} CM_m}{(CM_{mm})^2} \\ &= \frac{CM_{ma} \left(\frac{CM_m CM_{mmm}}{CM_{mm}} - CM_{mm} \right)}{(CM_{mm})^2} < 0\end{aligned}\tag{A6}$$

$$\begin{aligned}\frac{\partial^2 W}{\partial \alpha \partial a} &= \frac{-CR_{rr} \frac{dr}{da} 2tCR_{rr} + 2tCR_{rrr} \frac{dr}{da} CR_r}{(2tCR_{rr})^2} \\ &= \frac{CR_{ra} 2t \left(CR_{rr} - \frac{CR_r CR_{rrr}}{CR_{rr}} \right)}{(2tCR_{rr})^2} > 0\end{aligned}\tag{A7}$$

$$\begin{aligned}\frac{\partial^2 W}{\partial \alpha \partial t} &= \frac{-CR_{rr} \frac{dr}{dt} 2tCR_{rr} + \left(2tCR_{rrr} \frac{dr}{dt} + 2CR_{rr} \right) CR_r}{(2tCR_{rr})^2} \\ &= \frac{\frac{\alpha \Delta}{t} \left(CR_{rr} - \frac{CR_r CR_{rrr}}{CR_{rr}} \right) + 2CR_r CR_{rr}}{(2tCR_{rr})^2} > 0\end{aligned}\tag{A8}$$

$$\begin{aligned}\frac{\partial^2 W}{\partial \alpha \partial \Delta} &= \frac{-CR_{rr} \frac{dr}{d\Delta} 2tCR_{rr} + 2tCR_{rrr} \frac{dr}{d\Delta} CR_r}{(2tCR_{rr})^2} + \frac{CM_{mm} \frac{dm}{d\Delta} CM_{mm} - CM_{mmm} \frac{dm}{d\Delta} CM_m}{(CM_{mm})^2} \\ &= \frac{\alpha \left(\frac{CR_r CR_{rrr}}{CR_{rr}} - CR_{rr} \right)}{(2tCR_{rr})^2} + \frac{(1 - \alpha) \left(CM_{mm} - \frac{CM_m CM_{mmm}}{CM_{mm}} \right)}{(CM_{mm})^2} \leq 0\end{aligned}\tag{A9}$$

We conclude, that $\frac{d\alpha}{db} < 0$, $\frac{d\alpha}{da} > 0$, and $\frac{d\alpha}{dt} > 0$. The sign of $\frac{d\alpha}{d\Delta}$ is ambiguous and depends on the concrete form of the cost function. There are two counteracting effects, as Δ increases risk selection incentives as well as manipulation incentives. Depending on which of both effects predominates the optimal α decreases or increases.

A.3 Second-order condition - audit regime

Maximizing welfare (23) with respect to α leads to the following first-order condition (FOC):

$$\begin{aligned}\frac{\partial W}{\partial \alpha} &= -2CR_r \frac{dr}{d\alpha} - 2CM_m \frac{dm}{d\alpha} \stackrel{!}{=} 0 \\ &\Leftrightarrow -\frac{CR_r}{2tCR_{rr}} + (1 - \tau) \frac{CM_m}{CM_{mm}} \stackrel{!}{=} 0\end{aligned}\tag{A10}$$

The corresponding second-order condition (SOC) is given by:

$$\begin{aligned}
\frac{\partial^2 W}{\partial \alpha^2} &= \frac{-CR_{rr} \frac{dr}{d\alpha} 2tCR_{rr} + 2tCR_{rrr} \frac{dr}{d\alpha} CR_r}{(2tCR_{rr})^2} \\
&+ \frac{(1-\tau) CM_{mm} \frac{d\dot{m}}{d\alpha} CM_{mm} - CM_{mmm} \frac{d\dot{m}}{d\alpha} CM_m (1-\tau)}{(CM_{mm})^2} \\
&= \frac{\Delta \left(\frac{CR_r CR_{rrr}}{CR_{rr}} - CR_{rr} \right)}{(2tCR_{rr})^2} + \frac{(1-\tau)^2 \Delta \left(\frac{CM_m CM_{mmm}}{CM_{mm}} - CM_{mm} \right)}{(CM_{mm})^2} < 0
\end{aligned} \tag{A11}$$

Under the implied conditions on the cost functions (A3), the SOC (A11) is negative and (24) characterizes a welfare maximum.

A.4 Comparative statics - audit regime

In order to determine how the optimal $\dot{\alpha}$ reacts to changes in the parameters b , a , t , τ and Δ we totally differentiate the FOC (A10):

$$d \frac{\partial W}{\partial \alpha} = \frac{\partial^2 W}{\partial \alpha^2} d\dot{\alpha} + \frac{\partial^2 W}{\partial \alpha \partial b} db + \frac{\partial^2 W}{\partial \alpha \partial a} da + \frac{\partial^2 W}{\partial \alpha \partial t} dt + \frac{\partial^2 W}{\partial \alpha \partial \tau} d\tau + \frac{\partial^2 W}{\partial \alpha \partial \Delta} d\Delta \stackrel{!}{=} 0 \tag{A12}$$

The effects of b , a , t , and Δ on the optimal $\dot{\alpha}$ are given by:

$$\frac{d\dot{\alpha}}{db} = -\frac{\frac{\partial^2 W}{\partial \alpha \partial b}}{\frac{\partial^2 W}{\partial \alpha^2}} \quad \frac{d\dot{\alpha}}{da} = -\frac{\frac{\partial^2 W}{\partial \alpha \partial a}}{\frac{\partial^2 W}{\partial \alpha^2}} \quad \frac{d\dot{\alpha}}{dt} = -\frac{\frac{\partial^2 W}{\partial \alpha \partial t}}{\frac{\partial^2 W}{\partial \alpha^2}} \quad \frac{d\dot{\alpha}}{d\tau} = -\frac{\frac{\partial^2 W}{\partial \alpha \partial \tau}}{\frac{\partial^2 W}{\partial \alpha^2}} \quad \frac{d\dot{\alpha}}{d\Delta} = -\frac{\frac{\partial^2 W}{\partial \alpha \partial \Delta}}{\frac{\partial^2 W}{\partial \alpha^2}} \tag{A13}$$

As the SOC is negative, the signs of $\frac{d\dot{\alpha}}{db}$, $\frac{d\dot{\alpha}}{da}$, $\frac{d\dot{\alpha}}{dt}$, $\frac{d\dot{\alpha}}{d\tau}$ and $\frac{d\dot{\alpha}}{d\Delta}$ are equivalent to the signs of $\frac{\partial^2 W}{\partial \alpha \partial b}$, $\frac{\partial^2 W}{\partial \alpha \partial a}$, $\frac{\partial^2 W}{\partial \alpha \partial t}$, $\frac{\partial^2 W}{\partial \alpha \partial \tau}$ and $\frac{\partial^2 W}{\partial \alpha \partial \Delta}$. Under the implied conditions on the cost functions (A3), the signs of the respective cross derivatives are as follows (remember that $CR_{ra} > 0$ and $CM_{ma} > 0$):

$$\begin{aligned}
\frac{\partial^2 W}{\partial \alpha \partial b} &= \frac{(1-\tau) CM_{mm} \frac{d\dot{m}}{db} CM_{mm} - CM_{mmm} \frac{d\dot{m}}{db} CM_m (1-\tau)}{(CM_{mm})^2} \\
&= \frac{(1-\tau) CM_{ma} \left(\frac{CM_m CM_{mmm}}{CM_{mm}} - CM_{mm} \right)}{(CM_{mm})^2} < 0
\end{aligned} \tag{A14}$$

$$\begin{aligned}
\frac{\partial^2 W}{\partial \alpha \partial a} &= \frac{-CR_{rr} \frac{dr}{da} 2tCR_{rr} + 2tCR_{rrr} \frac{dr}{da} CR_r}{(2tCR_{rr})^2} \\
&= \frac{CR_{ra} 2t \left(CR_{rr} - \frac{CR_r CR_{rrr}}{CR_{rr}} \right)}{(2tCR_{rr})^2} > 0
\end{aligned} \tag{A15}$$

$$\begin{aligned}
\frac{\partial^2 W}{\partial \alpha \partial t} &= \frac{-CR_{rr} \frac{dr}{dt} 2tCR_{rr} + \left(2tCR_{rrr} \frac{dr}{dt} + 2CR_{rr}\right) CR_r}{(2tCR_{rr})^2} \\
&= \frac{\frac{\dot{\alpha} \Delta}{t} \left(CR_{rr} - \frac{CR_r CR_{rrr}}{CR_{rr}}\right) + 2CR_r CR_{rr}}{(2tCR_{rr})^2} > 0
\end{aligned} \tag{A16}$$

$$\begin{aligned}
\frac{\partial^2 W}{\partial \alpha \partial \tau} &= \frac{\left[(1-\tau) CM_{mm} \frac{d\dot{m}}{d\tau} - CM_m\right] CM_{mm} - CM_{mmm} \frac{d\dot{m}}{d\tau} CM_m (1-\tau)}{(CM_{mm})^2} \\
&= \frac{(1-\tau)(1-\dot{\alpha}) \Delta \left(\frac{CM_m CM_{mmm}}{CM_{mm}} - CM_{mm}\right) - CM_m CM_{mm}}{(CM_{mm})^2} < 0
\end{aligned} \tag{A17}$$

$$\begin{aligned}
\frac{\partial^2 W}{\partial \alpha \partial \Delta} &= \frac{-CR_{rr} \frac{dr}{d\Delta} 2tCR_{rr} + 2tCR_{rrr} \frac{dr}{d\Delta} CR_r}{(2tCR_{rr})^2} \\
&+ \frac{(1-\tau) CM_{mm} \frac{d\dot{m}}{d\Delta} CM_{mm} - CM_{mmm} \frac{d\dot{m}}{d\Delta} CM_m (1-\tau)}{(CM_{mm})^2} \\
&= \frac{\dot{\alpha} \left(\frac{CR_r CR_{rrr}}{CR_{rr}} - CR_{rr}\right)}{(2tCR_{rr})^2} + \frac{(1-\tau)^2 (1-\dot{\alpha}) \left(CM_{mm} - \frac{CM_m CM_{mmm}}{CM_{mm}}\right)}{(CM_{mm})^2} \stackrel{\leq}{\geq} 0
\end{aligned} \tag{A18}$$

We conclude, that $\frac{d\alpha}{db} < 0$, $\frac{d\alpha}{da} > 0$, $\frac{d\alpha}{dt} > 0$, and $\frac{d\alpha}{d\tau} < 0$. The sign of $\frac{d\alpha}{d\Delta}$ is - equivalent to the benchmark scenario - ambiguous and depends on the concrete form of the cost function.

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