Demand inducement, technology choice, and insurance

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Abstract

This study analyses the incentives and welfare implications associated with physicians' technology choice. A monopoly provider invests into a range of technologies according to their profitability and acceptance by patients. Patients can observe the investment decision and the provider's treatment recommendation but not their health status. It turns out that the least healthy patients are overtreated whereas at the same time undertreatment occurs for the healthiest range of patients. If an innovation is adopted, it makes some patients better off due to better treatment and makes some worse off due to more costly or less effective overtreatment. Welfare losses can be counteracted by introducing technology specific copayments, with higher copayments for less costly and more effective new technologies.

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1 Introduction

The importance of technological change in the health sector has been a widely discussed topic in the economic literature[1]. Especially the discussion of the reasons for expenditure increases and cost explosion has recognized the key role of technical advances[2]. Increasingly, economic evaluation is becoming an important tool in political decision making. Health technology assessment and other types of economic evaluation are meant to ensure that health care expenditure is used in an efficient way. Nevertheless, a better theoretical understanding and empirical investigation of the factors which influence the diffusion of new technologies is of crucial importance for explaining which innovations will actually be used in the health care market, and how the usage of cost effective technologies can be implemented. An economic evaluation is necessary before a technology is allowed to be used by providers of health care, but it is not sufficient for ensuring that the technology is actually adopted and offered to patients, nor that it is offered to those patients who should receive this treatment.

This study focuses on the crucial role of providers in this process. It intends to contribute to the discussion by analysing a monopoly provider's technology choice and incentives for adopting a new technology in a setting where patients can only observe the investment decision and the provider's treatment recommendation but not their health status. It turns out that the monopoly provider invests into a range of technologies according to their profitability and acceptance by patients. The least

[1] See for example Fuchs (1996) and Weisbrod (1991).

[2] Some empirical studies (e. g. Newhouse (1992)) show at an accounting level that static supply and demand factors can only explain less than half of the growth of medical spending. They attribute the residual to technological change. Cutler and McClellan (1996) investigate the factors driving the diffusion of technologies more closely. They examine the sources of expenditure growth in heart attack treatment. They first show that essentially all of the cost growth is a result of the diffusion of particular intensive technologies. Then they conclude that insurance variables, technology regulation, and provider interactions have the largest quantitative effect on technology diffusion. These factors affect both technology acquisition and the frequency of technology use.

healthy patients are overtreated, whereas at the same time undertreatment occurs for the healthiest range of patients if they do not visit the physician due to fear of overtreatment or costly diagnosis. The adoption of a new technology makes some patients better off due to better treatment and makes some worse off due to more costly or less effective overtreatment. The state can reduce inefficiencies associated with the introduction of a new technology by adequately choosing reimbursement schemes and by increasing patient copayment for new and cost effective technologies.

The physician is modelled as an expert who gains an informational advantage by diagnosing the patient. He knows the patient's health status more exactly than the patient and therefore can to a certain extent induce demand for treatment which the patient accepts but would not want if he was fully informed. This informational asymmetry cannot be resolved even after treatment because from the ex post health status the correct treatment recommendation cannot be concluded with certainty. The patient is restricted to a "consent" or "no consent" decision to a treatment recommendation. Taking the physician's behaviour into account the patient will only consent to treatment if his symptoms are severe enough. He may be willing to consent to certain treatment technologies but not to others which are more costly or less effective. Therefore, the provider will offer different technologies to different ranges of patients. His offer will be led by profitability considerations and patients' willingness to consent. Consequently, the patients with most severe symptoms will be offered the most profitable technology in a pooling equilibrium, which means that they receive treatment irrespective of their true health status. The patients whose symptoms are a bit less severe and who would not accept the most profitable technology are offered a less profitable one which they are willing to accept, and so on. If there exist technologies which do not allow profits for the physician, an intermediate range of patients receives the correct amount of treatment in a separating equilibrium, that is they are only offered treatment if they really need it. The range of patients with the least severe symptoms may decide not to visit the physician if diagnosis is costly for them or if they fear overtreatment. Thus the first main result of the paper states that informational asymmetries may at the same time provoke overtreatment for certain ranges of patients and too little treatment for others.

When a new technology comes on the market which is reimbursed according to the same scheme as a currently used one the physician adopts it if it is more profitable and / or if it is accepted by a larger range of patients. This implies the second main result: Given equal profitability, the physician adopts technologies which reduce his non-monetary costs of applying them, reduce the patients' non-monetary costs from treatment, and increase the effectiveness of treatment, that is the probability of health being completely restored. Under cost sharing and cost reimbursement, the physician adopts technologies which reduce costs[3].

Interestingly, these incentives do not translate into clear welfare improvements. Whereas there is always a range of patients who gain from better treatment another fraction of patients lose because they are now willing to accept being treated with this new technology which is more costly or less effective than the one they would have got previously. Consequently, the third result establishes that the adoption of an innovation implies ambiguous effects on social welfare.

Finally, the state can counteract these welfare losses by introducing technology specific copayments, with higher copayments for less costly and more effective new technologies. This limits the increase in patients' willingness to consent and therefore prevents the physician from offering these treatments inadequately. But only changes in effectiveness can be accompanied by copayment adjustments which allow an overall Pareto improvement. Changes in monetary or non-monetary costs of treatment will always make some patients worse off.

These results have been derived by taking the premium which the insured patients pay as given. Obviously, cost saving or cost increasing new technologies will

[3]Under a system of cost subsidies, the overall effect is not clear. Since the dicscussion of cost subsidies does not add much insight and is hardly observed in reality, it will be neglected in the following.

induce a premium adjustment. It will be shown that the above results still hold for CARA and for DARA utility functions when taking premium adjustments into account. So far, changes in only one technology parameter have been studied. It remains to extend the analysis to simultaneous parameter changes of innovations and to verify whether the results change.

The existing theoretical literature in the field does not explain the diffusion of new technologies nor look at the impact of regulation and the role of providers of health care. It has not attempted to explain the actual adoption of technological innovations and their use by providers. There are only a few studies which try to model technical advances in the health sector. They focus on the role of insurance coverage for welfare effects of technological change. Goddeeris (1984a, 1984b) derives conditions under which a costly technological change that increases capabilities increases or decreases welfare. Each technology is defined by a "healing function" which depends on health care expenditures. A technical advance changes this functional form such that a higher level of healing is possible using the same financial resources. This special structure does not allow differentiation between various types of technological advances. One could for instance imagine a new technology which uses the same financial resources for producing the same healing level as the old standard technology but which causes less suffering to the patient during the treatment. Certainly, we would want to capture this as a real "advance" from a welfare point of view. Baumgardner (1991) addresses this issue by describing a technology by three parameters: monetary costs of treatment, non-monetary costs, and the technical boundary up to which healing is possible using this technology. He analyses welfare effects of technological change under different insurance systems, but the type of technical advance can now be specified more clearly. Each parameter change can be analysed separately, which allows a better qualitative and quantitative measuring of technological change.

In a complementary paper, Kühn (2002) builds on the existing literature and analyses the incentives of health care providers to adopt new technologies in a world where patients exert ex-post moral hazard. The first main result of this paper is that even in a world which is second best efficient with respect to insurance coverage, there generally does not exist a simple remuneration scheme which implements the adoption of second best efficient technologies. Only in very special cases, using a cost subsidy, can correct incentives be given to providers for adopting technologies which are welfare improving with respect to all parameter changes. The second result deals with the welfare implications of technology parameter changes assuming a budget breaking standard coinsurance contract which is in general not second best efficient. It is shown that increases in monetary and non-monetary costs of treatment to the patient may be a welfare improvement if the patient's response to such increases is highly elastic. A shift from cost reimbursement to capitation which has been introduced in many countries to slow down health care cost increases may indeed drive monetary costs down but may also have undesirable effects on the incentives for adopting new technologies which could reduce non-monetary costs to the patient. Also, physicians then tend to adopt technologies which reduce the feasible level of healing. This may not be socially desirable. Especially for the case of extremely severe illnesses, welfare decreasing effects with respect to changes in non-monetary costs and technological boundary are likely to offset the positive effects of cost savings. The approach seems reasonable for modelling preventive treatment, e. g., where the patient has a clear say concerning the frequency of use. Yet in many cases the patient's role is reduced to the decision of undergoing a treatment or not. The current approach deals with these situations.

The analysis follows the models of demand inducement in a profit maximization context as opposed to those which limit inducement by a disutility of acting against the best interest of the patient[4]. The setup is related to Dranove's (1988) approach where the physician recommends treatment and is in his inducement limited by the patient's willingness to consent. Yet the focus of this study is on welfare implications of the regulation of reimbursement schemes, insurance contracts, and technological

[4]See McGuire (2000) for the distinction between these approaches.

change. Therefore the setup studies a variety of reimbursement schemes and an insurance contract which are set by the state whereas Dranove considers a situation in which the physician sets a price. Also, the inclusion of patient's copayment adds the problem of ex-post moral hazard to the setup. Policy recommendations with respect to reimbursement and insurance contracts can thus be given. The similarities and differences to Dranove's results will be mentioned in due course.

The rest of the paper is structured as follows: In section 2, the model is set up and technology choice and treatment pattern in equilibrium are analysed. Section 3 deals with the physician's incentives to adopt an innovation, and in section 4 the corresponding welfare effects are studied. In section 5, the scope for welfare improvements through the adequate design of reimbursement schemes and insurance contract is examined. Section 6 concludes.

2 Model Setup

This section sets up the model and looks at technology choice and treatment pattern in equilibrium. In the first place, the state insurer offers an insurance contract to the patients and a remuneration contract for diagnosis and all available types of treatment to the physician. It is assumed that the physician is a monopolist. His contract specifies for each treatment a fixed payment R and a net share s in total costs of diagnosis/treatment that he has to bear. If $1 \geq s > 0$ the physician has to undergo cost sharing. If $s = 0$ his contract is characterised by cost reimbursement. The fixed payment R is used to model capitation (as a cost-plus regulation) and to allow a variety in overall profitability of technologies even under cost reimbursement. There is only one type of diagnosis which comes at a cost D and is reimbursed according to a scheme $(R_D,\ s_D)$. Diagnosis is assumed to be independent of the treatment technology. For each technology i a payment scheme $(R_{Ti},\ s_{Ti})$ is specified.

The insurance contract for the patients contains a premium P and a copayment rate[5] a with $0 \leq a < 1$. The patients accept or reject the insurance contract in the next stage, whereas the physician decides on participation. Then, the physician chooses the range of technologies which he wants to invest into and consequently can offer to the patients in case of illness. Each technology requires a fixed investment cost F_i which can be thought of as the purchase of new machinery or the acquisition of knowledge on the correct application[6]. If the technology is applied it is characterised by four parameters: monetary costs of treatment C_i, non-monetary costs of treatment to the patient N_i, non-monetary costs of applying the technology to the physician K_i, and a probability parameter $0 \leq p_i \leq 1$ which indicates the probabiliy that health is completely restored in the case of applying the technology to an ill patient. With probability $1 - p_i$ the illness level is unchanged after treatment.

It is assumed that each patient can observe the range of technologies which the physician has invested into and consequently could offer him in case of illness. Furthermore, patients are perfectly informed on reimbursement schemes, on the costs and on the effectiveness of all available technologies. When falling ill, patients are uniformly distributed between 0 and 1. Their type r is drawn by nature from this distribution and indicates the (perceived) severety of their illness. r is the probability of being ill and can be interpreted as the symptoms that the patient himself observes before deciding whether to consult a doctor or not. At the same time, r is assumed to be a common prior because the patient tells the physician all the symptoms that he experiences when he visits him for the first time[7]. When a

[5]The restrictions imposed ($a \geq 0$, $s \leq 1$) are necessary due to truthtelling requirements which have been discussed elsewhere (see Ma and McGuire (1997)).

[6]These fixed costs do not enter the calculations in this study because they would add complexity without being at the centre of the analysis. They merely represent a signal to the patient for the availability of the technology. In Germany, e. g., investment costs in hospitals are born by the regional government as opposed to costs of usage which the hospital bears. The fixed costs could also be seen as incorporated in the overall reimbursement (neglecting scale effects).

[7]Of course, one could also interpret the symptoms of a patient as his private signal on the illness state (see Dranove (1988)). But it is reasonable to assume that the doctor's signal after diagnosis is better than the patient's signal on the illness state. Therefore a limit case is analysed

patient visits a doctor, the physician not only learns the type r but also diagnoses the patient and finds out whether he is truly ill or not. The patient cannot observe the result of the diagnosis but only receives a signal when the physician recommends "treatment with technology T_i" or "no treatment". Based on this recommendation the patient decides whether to consent to treatment or whether to refuse treatment. If "no treatment" is recommended the patient can only accept this decision as here the monopoly case is assumed.

Let us briefly recapitulate the stages of the game: In the first stage, contracts are offered to patients and physician. In the second stage, these contracts are accepted or not. Thereafter, the physician invests into a range of technologies. In the fourth stage of the game, nature decides whether patients fall ill or not, and patients learn their type r by experiencing certain symptoms. Subsequently, the patients decide whether they visit the physician or not. If they visit the physician a signalling subgame is played in the sixth stage in which the physician diagnoses the patients and then recommends treatment with a certain technology or no treatment. Each patient consents to treatment or not. The game is now solved by backward induction.

The signalling subgame

As a first step, the signalling subgame once the patient has fallen ill and decided to visit the physician is analysed. I will concentrate on the equilibria in pure strategies, i. e. on two pooling equilibria where the physician independently of the true health status of the patient recommends "treatment" $(T_i(r), T_i(r))$ or "no treatment" (NT, NT) respectively, and on two separating equilibria $(NT, T_i(r))$ and $(T_i(r), NT)$. The first recommendation in brackets refers to the illness case, the second one to the no-illness case. Under reasonable assumptions, the two equilibria (NT, NT) and $(NT, T_i(r))$ are not stable. In line with the literature (see e. g. Pitchik and Schotter (1987)) it is assumed that a liability rule is in place which

which captures the underlying effects very clearly and allows us to neglect an otherwise necessary screening of the patient's type.

prevents that the physician recommends "no treatment" in case the patient is diagnosed as ill. The liability rule works through a punishment which makes the physician deviate in either case. One could also interpret this punishment as the outcome of medical ethics. The physician suffers from not treating an ill person whereas he does not suffer from treating a healthy person. Similarly to Ma and McGuire (1997) medical ethics is represented by a lower bound on the health benefits that a physician is willing to provide to a patient. In order to destabilize these equilibria the punishment does not have to be very harsh - it just needs to be less profitable / more costly than treating the patient.

Let us consider the pooling equilibrium $(T_i(r), T_i(r))$. By getting a treatment recommendation the patient does not learn anything about his type, he still assumes that with probability r he is ill. He therefore consents with the treatment recommendation if

$$\begin{aligned} & r \cdot [p_i \cdot U(Y - P - a \cdot (C_i + D) - N_i) + (1 - p_i) \cdot U(Y - P - a \cdot (C_i + D) - N_i - \epsilon)] + \\ & (1 - r) \cdot U(Y - P - a(C_i + D) - N_i) \geq \\ & r \cdot U(Y - P - a \cdot D - \epsilon)] + (1 - r) \cdot U(Y - P - a \cdot D) \end{aligned} \tag{1}$$

The left-hand side of this equation is the expected utility from receiving treatment. With probability r, the patient is ill and correctly receives treatment. The treatment is successful with probability p_i, and he then has a utility U which depends on his initial income Y minus the premium P, the share in costs of treatment and diagnosis he has to bear $a \cdot (C_i + D)$, and the non-monetary costs of treatment N_i. With probability $1 - p_i$ the treatment is not successful and he still suffers from the illness shock ϵ. In case he receives treatment although he is actually healthy (probability $1 - r$) he still has to incur the costs from treatment. The right-hand side of the equation is the expected utiliy from rejecting treatment. Again, with probability r the patient is ill and suffers from the illness shock, with probability $1 - r$ he is healthy and only incurs the costs from having been diagnosed.

If this condition holds then the physician does not have an incentive not to recommend treatment as long as treating the patient does not come at a cost[8], i. e. $\Pi_i = R_{Ti} - s \cdot C_i - K_i \geq 0$. If the parameter constellations are such that the patient does not consent (i. e. condition (1) does not hold) then $(T_i(r), T_i(r))$ is not an equilibrium. It is assumed that the physician slightly prefers to recommend "no treatment" (in the case of a healthy patient, where there is no punishment for recommending "no treatment") to recommending treatment and then being rejected. One could think of the explanation of treatment coming itself at a little cost.

In the separating equilibrium $(T_i(r), NT)$, the patient when being recommended treatment knows that he is ill. He therefore consents to treatment if

$$p_i \cdot U(Y - P - a \cdot (C_i + D) - N_i) + (1 - p_i) \cdot U(Y - P - a \cdot (C_i + D) - N_i - \epsilon] \geq U(Y - P - a \cdot D - \epsilon) \tag{2}$$

The left-hand side here is the expected utility from being treated in case of illness, whereas the right-hand side is the utiliy from not being treated when ill. But this can only be an equilibrium if treating the patient does not make profits, i. e. $\Pi_i = R_{Ti} - s \cdot C_i - K_i \leq 0$. Because otherwise the physician has an incentive to deviate and to always announce "treatment". If the parameters are such that the patient chooses not to consent then the equilibrium is stable if not recommending treatment in case of illness is punished harshly as described above. Of course it has to be born in mind that this will affect the patient's decision to visit the physician in the first place as will be discussed next. But before that the results which have been obtained so far should be summarized.

Lemma 1 *Under reasonable assumptions, there exist only two equilibria of the signalling subgame in pure strategies:*
Under condition (1) and $\Pi_i \geq 0$, a pooling equilibrium exists in which the physician recommends treatment independently of the true health status of the patient. The patient consents to treatment.

[8] Throughout the analysis it is assumed that reimbursement schemes are not changed after the physician has invested into the technologies. Discuss lock-in effect later?

If $\Pi_i \leq 0$, a separating equilibrium exists in which the physician recommends treatment if the patient has been diagnosed as ill and does not recommend treatment if the patient has been diagnosed as healthy. Under condition (2), the patient consents to treatment. If the condition does not hold, the patient does not consent to treatment.

The decision to visit the physician

Let us now go one step further in the analysis of the game by backward induction. Before the signalling subgame is played the patient decides whether to visit the physician or not. He compares the payoffs of the signalling subgame with the option of not visiting the physician at all. Therefore, the above conditions must be modified. The patient prefers to be treated in a pooling equilibrium to not visiting the physician if

$$\begin{aligned} & r \cdot [p_i \cdot U(Y - P - a \cdot (C_i + D) - N_i) + (1 - p_i) \cdot U(Y - P - a \cdot (C_i + D) - N_i - \epsilon)] + \\ & (1 - r) \cdot U(Y - P - a(C_i + D) - N_i) \geq \\ & r \cdot U(Y - P - \epsilon) + (1 - r) \cdot U(Y - P) \end{aligned} \tag{3}$$

He prefers to be treated in a separating equilibrium to not visiting the physician if

$$\begin{aligned} & r \cdot [p_i \cdot U(Y - P - a \cdot (C_i + D) - N_i) + (1 - p_i) \cdot U(Y - P - a \cdot (C_i + D) - N_i - \epsilon)] + \\ & (1 - r) \cdot U(Y - P - a \cdot D) \geq \\ & r \cdot U(Y - P - \epsilon) + (1 - r) \cdot U(Y - P) \end{aligned} \tag{4}$$

The right-hand side of both equations is the expected utiliy without visiting the physician. Clearly, the costs from diagnosis do not have to be born in this case. The left-hand side is the ex ante expected utility from being treated in a pooling and separating equilibrium, respectively. Obviously, condition (3) is more restrictive than condition (1) in the pooling equilibrium of the signalling subgame, as long as $a > 0$ and $D > 0$. If $a = 0$ and/or $D = 0$ both conditions coincide.

Rearranging condition (4) yields

$p_i \cdot U(Y - P - a \cdot (C_i + D) - N_i) + (1 - p_i) \cdot U(Y - P - a \cdot (C_i + D) - N_i - \epsilon] \geq$

$U(Y - P - \epsilon) + \frac{1-r}{r}[U(Y - P) - U(Y - P - a \cdot D)]$ (4')

From this it can be easily seen that condition (4) is more restrictive than condition (2) in the separating equilibrium of the signalling subgame, as long as $a > 0$ and $D > 0$. If $a = 0$ and/or $D = 0$ both conditions coincide. Conditions (3) and (4) thus hold for a smaller or equal share of patients than conditions (1) and (2), respectively. The intuition behind these results is that bearing costs from being diagnosed will prevent the healthier patients from visiting the physician in the first place. The analysis of this stage of the game can be summarized as follows:

Lemma 2 *Under reasonable assumptions, there exist three equilibria in pure strategies of the subgame at the stage of the patient's decision whether to visit the physician:*

Under condition (3) and $\Pi_i \geq 0$, a pooling equilibrium exists in which the physician recommends treatment independently of the true health status of the patient. The patient visits the physician and consents to treatment.

Under condition (4) and $\Pi_i \leq 0$, a separating equilibrium exists in which the physician recommends treatment if the patient has been diagnosed as ill and does not recommend treatment if the patient has been diagnosed as healthy. The patient visits the physician and consents to treatment.

In any other case the patient does not visit the physician and the game ends.

Choice of profitable technologies

Building on these results it can now be analysed how the physician decides on his technology range before the patient's decision to visit him. If reimbursement is such that all available technologies make a profit when they are applied then Lemma 2 states that a separating equilibrium does not exist. That means that patients whenever they visit the physician and are recommended treatment they are "pooled" and do not acquire further information on their health status. Accordingly, they visit the physician and consent to the treatment recommendation with technology i if condition (3) holds. For each technology, a cutoff r^p_{ci} can be determined when (3) holds with equality:

$$r^p_{ci} \cdot [p_i \cdot U(Y - P - a \cdot (C_i + D) - N_i) + (1 - p_i) \cdot U(Y - P - a \cdot (C_i + D) - N_i - \epsilon)]+$$
$$(1 - r^p_{ci}) \cdot U(Y - P - a(C_i + D) - N_i) =$$
$$r^p_{ci} \cdot U(Y - P - \epsilon)] + (1 - r^p_{ci}) \cdot U(Y - P) \tag{5}$$

All patients with symptoms indicating an illness probability of r^p_{ci} or higher will visit the physician and consent to being treated with technology i. All patients with less severe symptoms will not visit the physician[9]. Now the physician can rank all available technologies according to their reimbursement $\Pi_i = R_{Ti} - s \cdot C_i - K_i$, starting with the most profitable one. This technology implies a cutoff r^p_{c1} and will be offered to all patients of type $r^p_{c1} \leq r \leq 1$. Then the physician works through his ranking, looking at the second most profitable one. If it induces a cutoff r^p_{c2} which is below r^p_{c1}, then the physician offers it to all patients of type $r^p_{c2} \leq r < r^p_{c1}$. If the cutoff is above r^p_{c1} the technology is not applied - and consequently not invested into, either - and the physician analyses the next technology on his list in the same manner. This procedure continues until only the healthiest fraction of patients does not receive treatment because they reject overtreatment for any available profit making technology[10]. These patients prefer no treatment to being treated in a pooling equilibrium. As long as diagnosing a patient does not make a loss (or more exactly, as long as diagnosing and treating the range of patients below the cutoff does not make a loss in expectation) the physician would want to treat also the healthier range of patients but as he cannot credibly commit not to "pool" them these patients prefer not to visit him. Consequently, the range of patients below the cutoff receives too little treatment whereas the less healthy patients - who are willing to be treated ir-

[9]These results are in line with Dranove's (1988) findings that patients are less willing to consent to treatment if their diagnostic skills improve or if the perceived symptoms of their illness are reduced (r can be interpreted in either way).

[10]From condition (3) it is clear that a cutoff $r^p_{ci} = 0$ cannot be achieved as long as there does not exist a technology which comes at neither monetary nor non-monetary costs of treatment and diagnosis. Only in this case the full range of patients could be treated in a pooling equilibrium.

respective of their true health status - receive too much treatment when all available treatments are profitable for the physician.

Choice of zero-profit technologies

Let us now consider a situation where not only profitable technologies exist but also some which break even, i. e. where $\Pi_i = R_{Ti} - s \cdot C_i - K_i = 0$. Lemma 2 shows that for technologies which break even a pooling as well as a separating equilibrium may exist in which patients receive treatment only if they really need it. Looking at conditions (3) and (4) it becomes clear that in this situation, whenever a pooling equilibrium exists then also a separating equilibrium exists but not the other way around. When condition (4) holds with equality a second cutoff r^s_{ci} is induced which indicates the range of patients willing to visit the physician in a separating equilibrium:

$$\begin{aligned} &r^s_{ci} \cdot [p_i \cdot U(Y - P - a \cdot (C_i + D) - N_i) + (1 - p_i) \cdot U(Y - P - a \cdot (C_i + D) - N_i - \epsilon)] + \\ &(1 - r^s_{ci}) \cdot U(Y - P - a \cdot D) = \\ &r^s_{ci} \cdot U(Y - P - \epsilon)] + (1 - r^s_{ci}) \cdot U(Y - P) \end{aligned} \tag{6}$$

According to conditions (3) and (4) it must be that $0 \leq r^s_{ci} \leq r^p_{ci}$. For the same technology, the least healthy patients accept overtreatment ($r^p_{ci} \leq r \leq 1$), the intermediate and least healthy patients accept the correct amount of treatment ($r^s_{ci} \leq r \leq 1$), and the healthiest patients do not accept either equilibrium and therefore do not visit the physician at all ($0 \leq r < r^s_{ci}$). Only if diagnosing does not imly a cost to the patient then the whole range of patients accepts a separating equilibrium and $r^s_{ci} = 0$ can be achieved. As long as $a > 0$ and $D > 0$ the healthiest range of patients abstains from visiting the physician, $r^s_{ci} > 0$.

Distribution of patients across technologies

As long as the technology is profitable the physician plays a pooling equilibrium. When treatment comes at zero profits the physician is assumed to be indifferent between treatment/consent and no treatment. This of course is no longer valid as soon as the physician is capacity constrained and would e. g. rather diagnose more patients instead of treating some at zero profits. Consequently, as long as diagnosing the intermediate range of patients does not make a loss, now the physician will invest into one technology which breaks even. He can credibly play a separating equilibrium with the intermediate range of patients where only those who are really ill are recommended treatment. He will choose the budget breaking technology which induces the lowest cutoff r^s_{ci} as there is no need to rank these technologies according to their profitability. That means that in this case the healthiest range of patients ($r < r^s_{ci}$) receives too little treatment, the intermediate range of patients receives the correct amount of treatment whereas the least healthy ones still receive too much treatment. If diagnosing a patient comes at a cost then the physician prefers not to invest into a budget breaking technology. Then, we are back in the situation of purely profitable technologies where the healthiest and intermediate range of patients does not visit the physician and is undertreated[11].

The distribution of patients on technologies according to cutoff levels is illustrated in Figure 1. Profitable technologies with decreasing cutoff levels are offered to the least healthy patients. They are overtreated in a pooling equilibrium. In the example of Figure 1, three profitable technologies are adopted. Technology 3 is more profitable than technoloy 4 but is not adopted because it induces a higher cutoff than technology 2. The intermediate range of patients receives correct treat-

[11]For loss-making technologies, a separating equilibrium may exist. But, as long as profitable and budget breaking technologies are on the market as well, a loss-making technology will in general not be chosen by the physician. Only if loss-making technologies could induce lower cutoffs than budget breaking technologies and if at the same time diagnosing patients is so profitable that in expectation the physician makes a profit will he continue to select technologies from his ranking, starting with the least loss-making technology. If all technologies are loss-making then the physician chooses increasingly unprofitable ones according to the same concept as in the case of profitable technologies. It is assumed that losses are in this case cross-subsidized via the revenues from diagnosis because otherwise the physician would not participate.

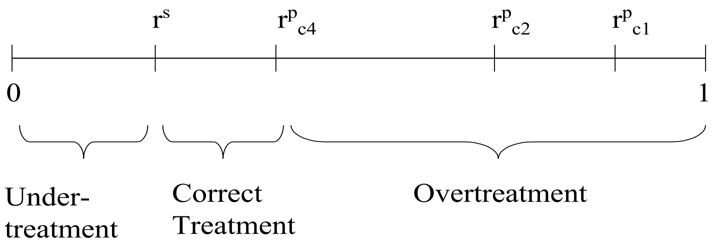

Figure 1: Distribution of patients on technologies

ment in a separating equilibrium with a technology which renders zero profits. The healthiest patients do not visit the physician and therefore receive too little treatment.

These results are summarized in the following

Proposition 1 *Range of provided technologies and treatment patterns*
The physician chooses technologies according to their profitability and to the cutoffs they induce, starting with the most profitable one and then adding decreasingly profitable ones which induce lower cutoffs.
The least healthy range of patients receives too much treatment as long as at least one available technology is profitable. If no technology is profitable they receive the correct amount of treatment in a separating equilibrium.
The intermediate range of patients does not visit the physician and therefore receives too little treatment if all available technologies make a profit for the physician. If there exist technologies which allow treatment without making profits or with losses being cross-subsidised through diagnosis reimbursement then these patients receive the correct amount of treatment.

The healthiest range of patients never visits the physician and consequently receives too little treatment as long as diagnosis comes at a cost to them. If diagnosis is costless their behaviour is equivalent to the intermediate range.

This proposition states that in general there will be overtreatment, correct treatment and undertreatment for different groups of patients at the same time. Possible welfare improvements will be discussed in chapter 4, but it can already be established that the state has to tackle both over- and undertreatment in order to increase welfare.

A comment should be made on the equilibrium analysis in this section. Comparing conditions (1) and (3) and conditions (2) and (4), respectively, makes clear that there exists a fraction of patients for each technology who would not accept treatment with this technology ex ante, but would do so once they have been diagnosed. This implies that the physician would want to deviate and offer them the more profitable technology once they have shown up. Anticipating this deviating behaviour, the patients would prefer not to visit the physician. Consequently, certain fractions of patients do not receive treatment. The analysis of this case will be neglected here because it would add complexity to the results without providing further insights into the physician's technology choice .

3 Adoption of Innovations without Insurance Premium Adjustment

3.1 Adoption Decision

Having studied the equilibrium strategies and technology choice of the game, this section focuses on the physician's decision whether to adopt a new technology or not when it is made available on the market. The starting point for the analysis is to assume that an innovation is introduced which differs from an existing technology in only one technology parameter. Since only more cost effective technologies are introduced they may reduce (monetary or non-monetary) costs or increase effectiveness of treatment. A reimbursement scheme is announced before the technology is made available on the market. It is assumed throughout this section that premia are not adjusted due to the physician's decision.

The discussion has made it clear that the new technology in order to be adopted by the physician has to fulfill at least one out of the following two criteria: It has to be more profitable than a currently used technology which induces the same cutoff and / or it has to induce a lower cutoff than a currently used technology which is equally profitable.

The direct effect on profits is straightforward. It certainly depends on the announced reimbursement scheme (R_{Ti}, s_{Ti}). But profits $\Pi_i = R_{Ti} - s \cdot C_i - K_i$ are also directly influenced by the monetary costs of the new technology C_i and the non-monetary costs to the physician K_i. Let us assume in the following that the reimbursement scheme (R_{Ti}, s_{Ti}) remains unchanged as compared to a comparable currently used technology[12]. Therefore we can focus on the direct and indirect effects of changes of technology parameters on profits.

Non-monetary costs to the physician

The parameter easiest to analyse is the non-monetary cost to the physician K_i. K_i does not influence the patient's consent decision, therefore the cutoff remains unchanged when K_i varies. It is straightforward that the physician is going to adopt any technology which reduces his non-monetary costs because of the direct profit-increasing effect.

Monetary costs

Also monetary costs of treatment C_i have a direct effect on the physician's profits. A reduction in monetary costs reduces profits under a subsidy ($s < 0$). In a system of

[12]This is a reasonable starting point for the analysis as in most systems the reimbursement scheme is the same for all available treatments.

cost reimbursement ($s = 0$) there is no direct effect of changes of monetary costs on profits. But a change in monetary costs also influences the patients' consent decision and therefore the cutoff for a pooling equilibrium. Since we assume that $a \geq 0$ the effect of a change in monetary costs on the cutoff is[13] $\frac{\partial r_i}{\partial C_i} \geq 0$. That means that lower monetary costs reduce the cutoff for patients' consent to pooling. Intuitively, a reduction in monetary costs increases the expected utility from treatment for the patient which induces him to consent to pooling even with a lower illness probability than before the change[14]. Remember that if the physician uses a technology he offers it to every patient in the range of the cutoff of the next more profitable technology with a higher cutoff and the cutoff of this technology. The physician therefore wants the cutoff to be as low as possible as this increases the range of patients for whom this technology can be applied. This will increase his profits as a larger fraction of patients is treated with a more profitable technology and a lower fraction with a less profitable one or left without treatment, respectively.

In the case of cost sharing the direct effect on profits and the indirect effect through a change in the cutoff go in the same direction. Under cost sharing the physician will therefore adopt a technology with lower monetary costs of treatment. Under cost reimbursement, the only effect taken into account by the physician is the indirect effect of a changing cutoff level. Again, cost cutting new technologies will be adopted.

Non-monetary costs to the patient and probability of healing

Non-monetary costs of treatment N_i and the probability p_i that health is completely restored do not directly influence the physician's profits. But they influence the pooling respectively separating cutoff, that is the share of patients who are

[13]Proof in the appendix. Superscripts p and s are suppressed in this section because the analysis applies to both the pooling and the separating cutoff.

[14]Again, this is in line with Dranove's (1988) results: If the price of treatment decreases, patients are more willing to consent.

offered this technology. Again, the physician wants this cutoff to be as low as possible. Whereas a decrease in N_i reduces the cutoff (increases the share), an increase in p_i has the same effect[15]. Intuitively, expected utility from treatment increases when non-monetary costs go down or when the likelihood of success increases. The physician will therefore adopt technologies which reduce N_i and increase p_i. Let us summarize the results in the following

Proposition 2 *Adoption of a new technology*
Whether a new technology is adopted by the physician depends on its direct and indirect effects on profits. Taking the reimbursement scheme as given, the physician adopts a technology with lower non-monetary costs of applying it K_i because this directly increases his profits.
He adopts technologies with lower non-monetary costs to the patient N_i and a higher success probability p_i due to the favourable effects on the patients' willingness to consent to treatment.
Under cost sharing and cost reimbursement, he adopts technologies which reduce monetary costs of treatment C_i because of favourable effects on the patients' willingness to consent to treatment and, in the case of cost sharing, because of an additional direct profit increasing effect.

So far it can be established that the physician adopts cost effective innovations. The next section focuses on the welfare implications of this behaviour.

3.2 Welfare Implications

It seems natural to focus on the welfare effects of new technologies on the patient's expected utility before visiting the physician. The (state) insurer is assumed to aim at zero profits while maximizing the patient's expected utility whereas the physician maximizes his profits. He would obviously not adopt a technology if it reduced his

[15]Proof in the appendix.

profits. In a more complete analysis of social welfare the patients' utility changes would have to be weighted against the physician's profit increase.

Taking all technologies as given, from the point of view of the patient the separating equilibrium $(T_i(r), NT)$ is strictly preferred to the pooling equilibrium $(T_i(r), T_i(r))$ because in the latter the patient has to undergo and partly pay for unnecessary treatment. The physician prefers to pool patients as long as treatment is profitable.

Now consider the case where a physician adopts a new technology. Again, the starting point of the analysis is a new technology where only one technology parameter is changed. Clearly, changes in the physician's non-monetary costs K_i do not influence the patient's expected utility, therefore this welfare measure remains unchanged.

The marginal patient at the old cutoff

As has been pointed out above, changes of monetary costs C_i, non-monetary costs to the patient N_i, and the probability of successful treatment p_i influence the cutoff[16] down to which this technology is used. Let us label the old cutoff r_{ci}^{old} and the new one r_{ci}^{new}, with $r_{ci}^{new} < r_{ci}^{old}$. Considering the marginal patient at the cutoff levels allows us to qualify the welfare implications of such a change. The patient at the old cutoff level with illness probability r_{ci}^{old} is before the technology change pushed down to his reservation utility from not being treated (the right hand side of equation (3)and (4), respectively). Thus his expected utility from treatment with technology T_i^{old} is

$$EU(r_{ci}^{old}, T_i^{old}) = r_{ci}^{old} \cdot U(Y - P - \epsilon) + (1 - r_{ci}^{old}) \cdot U(Y - P) \tag{7}$$

We know that after the technology change from T_i^{old} to the more cost effective T_i^{new} the cutoff goes down. So by definition for this same patient condition (3) is not binding any more but holds with strict inequality. Therefore his expected utility

[16] Again, superscripts are neglected as the analysis holds for both types of cutoff.

from the new treatment is higher than under the old treatment:

$$EU(r_{ci}^{old}, T_i^{new}) > r_{ci}^{old} \cdot U(Y - P - \epsilon) + (1 - r_{ci}^{old}) \cdot U(Y - P) \tag{8}$$

The marginal patient at the new cutoff

The equivalent argument can be made for the patient at the new cutoff level who has an illness probability of r_{ci}^{new}. Before the technology change he is treated with the next less profitable technology T_l, but as long as for that technology he is not the marginal patient (that is as long as $r_{ci}^{new} > r_{cl}$), his expected utility is given as follows:

$$EU(r_{ci}^{new}, T_l) > r_{ci}^{new} \cdot U(Y - P - \epsilon) + (1 - r_{ci}^{new}) \cdot U(Y - P) \tag{9}$$

After the technology change he receives treatment with technology T_i^{new} instead, and his participation constraint now is binding:

$$EU(r_{ci}^{new}, T_i^{new}) = r_{ci}^{new} \cdot U(Y - P - \epsilon) + (1 - r_{ci}^{new}) \cdot U(Y - P) \tag{10}$$

Obviously, his expected utility has been reduced. Thus one can conclude from this that whenever a new technology is adopted which changes the cutoff level there will be some patients who lose and others who gain from this change. The situations cannot be ranked according to the Pareto criterion. The intuition behind these results is that the less healthy patients gain through better treatment and the healthier ones lose through more costly or less effective overtreatment.

A clear Pareto improvement can only be achieved if the cutoff level of the least profitable technology which is used is shifted downwards such that for the patient at the old cutoff level, the same argument as above applies (for him, the change is a welfare improvement), whereas the patient at the new cutoff level has not received treatment before the change. His utility is unchanged through treatment, as his expected utility without treatment is

$$EU(r_{ci}^{new}, NT) = r_{ci}^{new} \cdot U(Y - P - \epsilon) + (1 - r_{ci}^{new}) \cdot U(Y - P) \tag{11}$$

Comparison with equation (10) shows that his expected utility remains unchanged, so all patients are made at least as well off as before the change, a Pareto improvement. Yet if the healthiest range of patients is treated in a separating equilibrium because diagnosis is costless for them then the welfare effect for the healthiest patient ($r = 0$) is ambiguous because it is not clear whether his participation constraint is binding before and / or after the technology change.

Figure 2 shows patients' expected utility without and with treatment with various technologies. It is shown in the appendix that the slope of the expected utility without visiting the physician (outside option) is always steeper than the slope of the patients' expected utility under treatment. Otherwise conditions (3) and (4) are not satisfied. In Figure 2, technology 2 is replaced by technoloy 2' which is equally profitable but induces a lower cutoff. Any change in only one technology parameter which reduces the cutoff also makes the slope of the expected utility from treatment less steep[17] which implies that all patients to the right of the old cutoff will gain from the new treatment. Expected utility for patients to the right of the old cutoff is increased but reduced at least for some patients between the old and the new cutoff. Note that some patients to the left of the old cutoff might also gain through the change if the slope of the new technology is very flat as compared to the previously used one.

Proposition 3 *Welfare implications of new technologies*
If the physician adopts a new technology which changes the cutoff down to which this technology is used, then in general some patients win and some lose from this change.
If the cutoff decreases then patients to the right of the old cutoff gain from better treatment and patients to the right of the new cutoff lose through more costly or less effective overtreatment.
Only if the healthiest range of patients does not receive treatment, a reduction in the

[17] Proof in the appendix.

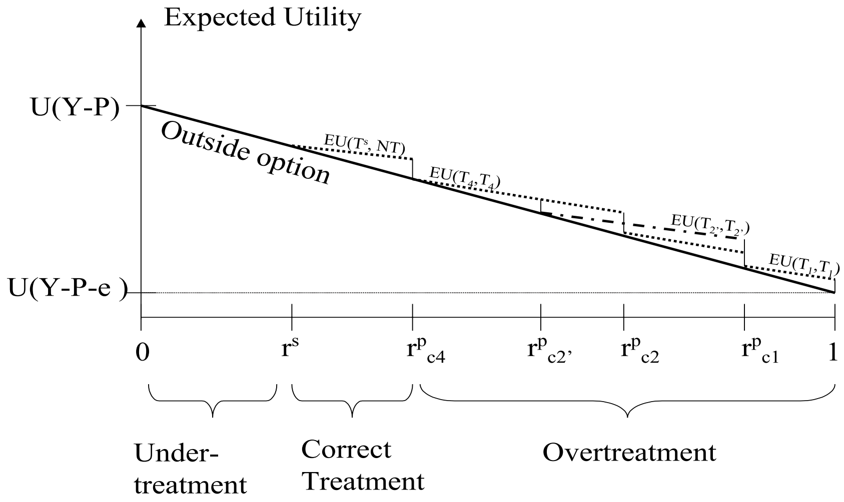

Figure 2: Welfare implications of a changed cutoff

lowest cutoff is a clear welfare improvement as more patients receive treatment .

3.3 The Scope for Welfare Improvements: Reimbursement and Insurance

This section studies the possibilities of the state to induce welfare improvements through the adequate design of insurance and remuneration contracts. Following the two preceding sections it will first be analysed how remuneration should be structured in general to reduce overtreatment as well as undertreatment. Then I will ask how a new technology which comes on the market should be remunerated in order to be adopted and to imply a welfare improvement.

General structure of reimbursement

From Proposition 1 it has become clear that overtreatment can only be reduced by a reduction of the overall profitability of technologies. As we have seen overtreatment here means treatment of patients in a pooling equilibrium such that also patients who have been diagnosed as healthy receive (unnecessary) treatment. Pooling occurs as long as treatment is profitable, whereas a separating equilibrium exists as long as treatment is not profitable. Overtreatment can thus be reduced by reimbursement schemes which do not allow profits. At the same time, this measure helps reducing undertreatment at the other end of the spectrum of patients. A separating equilibrium which allows treatment for the intermediate range of patients only exists if at least some technologies are not profitable. On the other hand, unprofitable reimbursement may induce undertreatment because the physician prefers not to treat patients, and therefore this can only be recommended if punishment for not treating ill patients is harsh enough.

If all (new) technologies are unprofitable the physician initially only chooses one technology which induces the lowest cutoff and furthermore does not have an incentive to adopt new technologies which come on the market. It seems reasonable to think of the adoption coming at little costs of knowledge acquisition etc. which prevent the physician from choosing a new treatment. This is most likely not a socially desirable outcome since people with more severe symptoms might achieve higher expected utility from technologies which the healthier patients would not accept. In addition, innovation incentives are hindered. At the same time, the state cannot force the physician to adopt certain technologies as the physician has superior information on the patients' needs. Conditioning reimbursement on measures of cost effectiveness is the first step to make treatment profitable, though. As the physician furthermore ususally has superior information on the true (especially non-monetary) costs of applying a technology, reimbursement is very likely to be profitable at least for some time span before adjustments can be made.

Finally, Proposition 1 states that undertreatment will occur for the healthiest range of patients as long as being diagnosed comes at a cost to them. It is therefore desirable from the point of view of the patient to make diagnosis costless to patients and to include the costs into the insurance premium instead[18]. Overall, the socially

[18]It is assumed throughout the paper that all available diagnosis as well as treatment technologies

most desirable situation is one in which treatment is slightly profitable. At the same time, diagnosis should be costless for the patients.

Reimbursement of innovations

Bearing in mind Propositions 2 and 3, the reimbursement of new technologies will now be studied. Changes of the technology parameters influence the cutoff and therefore the profitability of a technology for the physician. It has become clear that the physician has an incentive to adopt technologies which reduce his non-monetary costs K_i, the patients' non-monetary costs N_i, the monetary costs C_i, and which increase the success probability p_i. But only a reduction in K_i is a clear social welfare improvement (as it increases profits for the physician), whereas the changes in the other parameters induce a reduction in the relevant cutoff and a change in the slope of the expected utility from treatment. This makes the less healthy patients who are treated under this regime better off due to more effective or less costly treatment and makes the healthier ones worse off due to less effective or more costly overtreatment. The welfare losses can be counteracted by an increase in the patient's copayment rate a or an associated deductible which limit the decrease in the cutoff. This implies a technology specific copayment scheme. At the same time, the change of the slope of the expected utility function is counteracted, too. It can be shown[19] that for monetary costs, non-monetary costs, copayment or an eventual deductible these changes exactly offset each other. That means that if for example after the adoption of a cost reducing technology the increase in copayment is so high that the technology cutoff remains unchanged then also the slope of the expected utiliy function remains unchanged and there are no losers nor winners from technological change. The same arguments hold for monetary costs C_i under cost sharing or cost reimbursement.

are cost effective and that their use is socially desirable even for the healthiest patients. Otherwise, costly diagnosis might be used to deter healthy patients from visiting the physician.

[19]See appendix.

The situation is different for changes in the effectiveness of treatment p_i. If an increase in p_i leads to a reduction in the cutoff and this reduction is exactly offset by an increase in copayment, then the effect of the change in p_i on the slope of the expected utility function (making it less steep) outweighs the effect of a on the slope. Thus it is possible to achieve a clear welfare improvement by accompanying a more effective treatment with the right regulatory adjustments.

These results are surprising because a tendency to lower monetary and non-monetary costs as well as the incentive to increase the rate of success of a technology has to be accompanied by a higher copayment or deductible by the patient in order to increase welfare. Reducing ex post moral hazard through higher copayment may help reducing inefficiencies caused by demand inducement. It should be emphasised, though, that the socially optimal copayment may not restore the old cutoff level.

Proposition 4 *The scope for welfare improvements*
Welfare losses induced through a decrease in cutoffs due to the adoption of technologies which reduce costs or increase success probabilities should be counteracted by an increase in the patient's copayment or deductible for this technology.
Welfare remains unchanged if cutoff reductions induced by changes in costs are offset completely. Welfare increases if a cutoff reduction induced by increased effectiveness of treatment is offset completely.

4 Taking Premium Adjustment into Account

In general, the adoption of a new technology will have an effect on overall health care costs and therefore on the premium P which the insured individual has to pay to the insurer. Not only does the adoption of cost reducing technologies reduce premiums but also a more extended application of more or less costly technologies due to changes in other technology parameters may increase or reduce premiums. It is important to incorporate this effect in the above analysis.

First of all, the effect of premium changes on technology cutoffs is studied. A change in the premium P is equivalent to a change in income as it reduces or increases an individual's ressources in all states of the world. Consequently, the impact on the cutoff which resembles the willingness to accept treatment with a certain technology depends on the patient's attitude to risk, measured by his coefficient of absolute risk aversion. It turns out that the cutoff down to which a technology can be used is unchanged by premium adjustments if the patient exhibits constant absolute risk aversion, but decreases with higher premium payments if the patient has decreasing absolute risk aversion. The proof can be made graphically:

Consider the individual with illness probability r_{ci} which is exactly indifferent between undergoing treatment and not visiting the physician. Both lotteries, the left hand and the right hand side of equation (5) generate the same expected utility and therefore leave the individual on the same indifference curve depicted in figure 3. On the horizontal axis, the healthy state and incomes without treatment/visiting the physician and with treatment are indicated. On the vertical axis, the lower income in the illness state without treatment and the certainty equivalent income of the expected utility from treatment when ill are indicated. Now, if premium decreases income and certainty equivalent income in all states of the world go up. With a CARA utility function, the situation in figure 3 results: All incomes as well as the certainty equivalent income increase by the same amount, and in the new situation the individual is again on one and the same indifference curve for both the left and the right hand side of equation (5). If, however, the individual exhibits DARA then firstly, the certainty equivalent income of treatment in the illness state increases by less than the full premium reduction, and secondly, the indifference curves in each new endowment point are steeper than before. Consequently, expected utility without treatment is after the premium reduction now higher for this individual than expected utility from treatment. The patient who before the adjustment was just indifferent between accepting this treatment or not, is now decidedly against it: the cutoff has increased. From this it can be concluded that for CARA utility

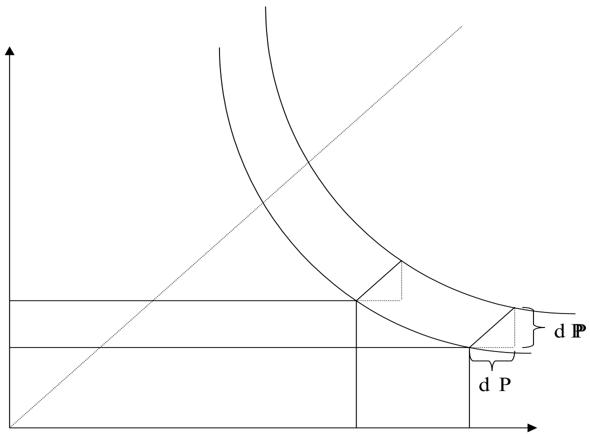

Figure 3: Effect of premium adjustment on cutoff

functions, the physician's adoption incentives are unchanged. In the case of DARA utility functions, a new counteracting incentive makes the physician less prone to adopt less costly technologies since a decrease in insurance premiums will in addition increase all other cutoffs, therefore all technologies can only be given to a smaller range of patients.

For the welfare analysis, it has to be considered that both outside option and expected utility from treatment are changed when premium changes. In figure 2, the outside option line and all the expected utility lines are shifted upwards when premium decreases and vice versa. It still holds, though, that some patients to the right of the new cutoff may be worse off and an increase in copayment for the new technology reduces this externality. For the case of DARA utility functions it can be established that the increase in copayment can be less than for CARA utility functions as the accompanying decrease in premium works in the same direction of reestablishing the old cutoff.

5 Discussion

So far, only cost effective new technologies with one changed technology parameter have been analysed. Studying more than one parameter change simultaneously is likely to complicate the analysis further. Firstly, it is not clear any more that a cost effective new technology decreases the cutoff down to which it can be used. This is due to the fact that changes in costs, as is shown in the appendix, have symmetric effects on cutoff and slope of expected utility whereas effectiveness of treatment has a stronger effect on the slope of the expected utility function than on the cutoff. This results from the fact that healthier persons (exactly, persons with less severe symptoms) value a change in effectiveness less than ill persons. This asymmetric effect has an impact on the adoption decision and translates into the welfare analysis. Probably it will turn out that new technologies have to be categorized according to the new properties they exhibit and then policy recommendations have to be given for each category.

A further interesting approach is the consideration of more than one provider. Competition between providers may result in specialization which might reduce overtreatment. The results will depend on the profitability of different technologies and people's preferences for certain technologies.

Appendix

Effects of technology parameter changes on the cutoff

The cutoff r^p_{ci} for each technology is implicitly defined by condition (5)

$r^p_{ci} \cdot [p_i \cdot U(Y - P - a \cdot (C_i + D) - N_i) + (1 - p_i) \cdot U(Y - P - a \cdot (C_i + D) - N_i - \epsilon] +$

$(1 - r^p_{ci}) \cdot U(Y - P - a(C_i + D) - N_i) =$

$r^p_{ci} \cdot U(Y - P - \epsilon)] + (1 - r^p_{ci}) \cdot U(Y - P)$

Rearranging this and applying the Implicit Functions Theorem yields

$$\frac{\partial r^p_{ci}}{\partial C_i} = \frac{r^p_{ci} \cdot a \cdot [p_i \cdot U'(Y-P-a\cdot(C_i+D)-N_i)+(1-p_i)\cdot U'(Y-P-a\cdot(C_i+D)-N_i-\epsilon)]+(1-r^p_{ci})\cdot a \cdot U'(Y-P-a(C_i+D)-N_i)}{[p_i \cdot U(Y-P-a\cdot(C_i+D)-N_i)+(1-p_i)\cdot U(Y-P-a\cdot(C_i+D)-N_i-\epsilon)-U(Y-P-\epsilon)]-[U(Y-P-a(C_i+D)-N_i)-U(Y-P)]}$$

The denominator can be simplified using condition (5) which yields the following expression:

$$\frac{\partial r^p_{ci}}{\partial C_i} = \frac{r^p_{ci} \cdot a \cdot [p_i \cdot U'(Y-P-a\cdot(C_i+D)-N_i)+(1-p_i)\cdot U'(Y-P-a\cdot(C_i+D)-N_i-\epsilon)]+(1-r^p_{ci})\cdot a \cdot U'(Y-P-a(C_i+D)-N_i)}{-\frac{1}{r^p_{ci}}[U(Y-P-a(C_i+D)-N_i)-U(Y-P)]}$$

From this it can be seen that $\frac{\partial r^p_{ci}}{\partial C_i} \geq 0$ as long as $a \geq 0$.

Similarly, it can be derived that

$$\frac{\partial r^p_{ci}}{\partial N_i} = \frac{r^p_{ci} \cdot [p_i \cdot U'(Y-P-a\cdot(C_i+D)-N_i)+(1-p_i)\cdot U'(Y-P-a\cdot(C_i+D)-N_i-\epsilon)]+(1-r^p_{ci})\cdot U'(Y-P-a(C_i+D)-N_i)}{-\frac{1}{r^p_{ci}}[U(Y-P-a(C_i+D)-N_i)-U(Y-P)]} \geq 0$$

$$\frac{\partial r^p_{ci}}{\partial p_i} = -\frac{r^p_{ci} \cdot [U(Y-P-a\cdot(C_i+D)-N_i)-U(Y-P-a\cdot(C_i+D)-N_i-\epsilon)]}{-\frac{1}{r^p_{ci}}[U(Y-P-a(C_i+D)-N_i)-U(Y-P)]} \leq 0$$

The equivalent proof holds for r^s_{ci}.

Comparison of the slopes of expected utility without treatment and with treatment (pooling equilibrium)

It is shown that the difference in expected utiliy between treatment in a pooling equilibrium and no treatment is strictly increasing in r as long as condition (3) holds. Rewriting (3) gives the differential Δ^p as

$\Delta^p = r \cdot [p_i \cdot U(Y - P - a \cdot (C_i + D) - N_i) + (1 - p_i) \cdot U(Y - P - a \cdot (C_i + D) - N_i -$

$\epsilon)] + (1 - r) \cdot U(Y - P - a(C_i + D) - N_i) - r \cdot U(Y - P - \epsilon) - (1 - r) \cdot U(Y - P) \geq 0$

Taking the derivative with respect to r yields

$\frac{\partial \Delta^p}{\partial r} = p_i \cdot U(Y - P - a \cdot (C_i + D) - N_i) + (1 - p_i) \cdot U(Y - P - a \cdot (C_i + D) - N_i - \epsilon) - U(Y - P - a(C_i + D) - N_i) - U(Y - P - \epsilon) + U(Y - P) > 0$

because (3) can be transformed to

$p_i \cdot U(Y - P - a \cdot (C_i + D) - N_i) + (1 - p_i) \cdot U(Y - P - a \cdot (C_i + D) - N_i - \epsilon) - U(Y - P - a(C_i + D) - N_i) - U(Y - P - \epsilon) + U(Y - P) \geq \frac{U(Y-P) - U(Y-P-a\cdot(C_i+D)-N_i)}{r} > 0$

The same holds for Δ^s although only with weak inequality if diagnosis is costless for the patient.

Effect of changes in one technology parameter on the slope of the expected utility function under treatment (pooling equilibrium)

Taking the derivative of the left-hand side of equation (3) with respect to r gives the slope of the expected utility function under treatment:

$\frac{\partial EU((T_i,T_i))}{\partial r} = (1 - p_i) \cdot [U(Y - P - a \cdot (C_i + D) - N_i - \epsilon) - U(Y - P - a \cdot (C_i + D) - N_i)]$

Taking the derivative with respect to various technology and insurance parameters gives

$\frac{\frac{\partial EU((T_i,T_i))}{\partial r}}{\partial C_i} = -a(1-p_i)[U'(Y-P-a\cdot(C_i+D)-N_i-\epsilon)-U'(Y-P-a\cdot(C_i+D)-N_i)] < 0$

$\frac{\frac{\partial EU((T_i,T_i))}{\partial r}}{\partial N_i} = -(1-p_i)\cdot[U'(Y-P-a\cdot(C_i+D)-N_i-\epsilon)-U'(Y-P-a\cdot(C_i+D)-N_i)] < 0$

$\frac{\frac{\partial EU((T_i,T_i))}{\partial r}}{\partial p_i} = -[U(Y - P - a \cdot (C_i + D) - N_i - \epsilon) - U(Y - P - a \cdot (C_i + D) - N_i)] > 0$

$\frac{\frac{\partial EU((T_i,T_i))}{\partial r}}{\partial a} = -(C_i + D) \cdot (1 - p_i) \cdot [U'(Y - P - a \cdot (C_i + D) - N_i - \epsilon) - U'(Y - P - a \cdot (C_i + D) - N_i)] < 0$

The equivalent proof holds for the separating equilibrium.

Comparison of effect of simultaneous changes of two technology parameters on cutoff and slope of expected utiliy function

Assume that a new technology is adopted which at the same time reduces non-monetary costs and increases monetary costs. The ratio of changed slope through changed monetary costs over changed slope through changed non-monetary costs is given by $\frac{\frac{\frac{\partial EU((T_i,T_i))}{\partial r}}{\partial C_i}}{\frac{\frac{\partial EU((T_i,T_i))}{\partial r}}{\partial N_i}} = a$

The equivalent ratio for the change in cutoff is $\frac{\frac{\partial r^p_{ci}}{\partial C_i}}{\frac{\partial r^p_{ci}}{\partial N_i}} = a$

Therefore, if $\frac{\partial r^p_{ci}}{\partial C_i} = -\frac{\partial r^p_{ci}}{\partial N_i}$ then $\frac{\frac{\partial EU((T_i,T_i))}{\partial r}}{\partial C_i} = -\frac{\frac{\partial EU((T_i,T_i))}{\partial r}}{\partial N_i}$ and vice versa. That means if simultaneous changes in C_i and N_i are such that the cutoff remains unchanged then also the slope of the expected utility function and consequently welfare remains unchanged. This symmetry result holds for changes in monetary costs C_i, non-monetary costs N_i, copayment a and an eventual deductible the effect of which would equal N_i.

The symmetry does not hold for p_i. Consider simultaneous changes in p_i and N_i, for example. The ratio of slopes is $\frac{\frac{\frac{\partial EU((T_i,T_i))}{\partial r}}{\partial N_i}}{\frac{\frac{\partial EU((T_i,T_i))}{\partial r}}{\partial p_i}} = -\frac{(1-p_i)[U'(Y-P-a\cdot(C_i+D)-N_i-\epsilon)-U'(Y-P-a\cdot(C_i+D)-N_i)]}{U(Y-P-a\cdot(C_i+D)-N_i)-U(Y-P-a\cdot(C_i+D)-N_i-\epsilon)}$

The ratio of cutoff changes is

$$\frac{\frac{\partial r^p_{ci}}{\partial N_i}}{\frac{\partial r^p_{ci}}{\partial p_i}} = -\frac{r^p_{ci}\cdot[p_i\cdot U'(Y-P-a\cdot(C_i+D)-N_i)+(1-p_i)\cdot U'(Y-P-a\cdot(C_i+D)-N_i-\epsilon)]+(1-r^p_{ci})\cdot U'(Y-P-a(C_i+D)-N_i)}{r^p_{ci}[U(Y-P-a\cdot(C_i+D)-N_i)-U(Y-P-a\cdot(C_i+D)-N_i-\epsilon)]} =$$

$$= \frac{\frac{\frac{\partial EU((T_i,T_i))}{\partial r}}{\partial N_i}}{\frac{\frac{\partial EU((T_i,T_i))}{\partial r}}{\partial p_i}} - \frac{U'(Y-P-a\cdot(C_i+D)-N_i)}{r^p_{ci}[U(Y-P-a\cdot(C_i+D)-N_i)-U(Y-P-a\cdot(C_i+D)-N_i-\epsilon)]}$$

Therefore, if changes are such that the cutoff remains unchanged, the effect on the slope induced by the change in p_i will always outweigh the induced change by N_i. This holds for any other cost parameter as well.

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