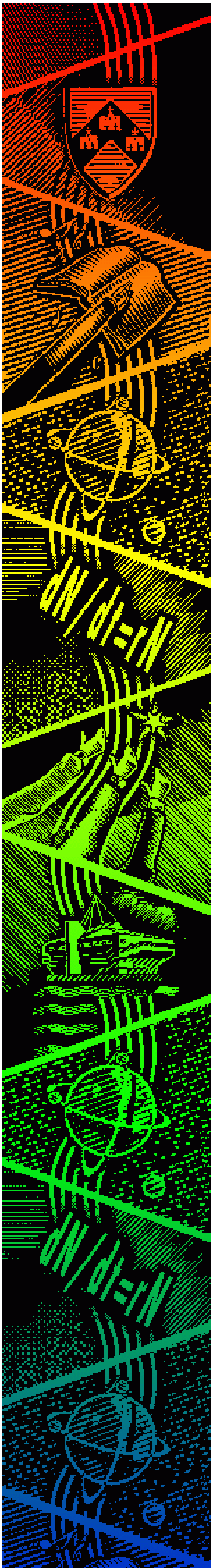

THE UNIVERSITY *of York*

Discussion Papers in Economics

No. 2007/30

An Incentive Mechanism for Using Risk Adjuster to Reimburse Health Care Provider

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An Incentive Mechanism for Using Risk Adjuster to Reimburse Health Care Providers[1]

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Version: September 2009

Abstract: Health care providers are almost always universally reimbursed by third party purchasers. As a result, health care purchasers are faced with risk selection challenges. In response, risk adjustment methods are introduced in the reimbursement for services. However, health care providers under this arrangement have incentives to manipulate the risk elements in an attempt to obtain larger payments from the purchasers i.e. the realisation of risk adjuster then becomes sensitive to the providers' upcoding behaviour. Whilst there is usually an outside auditor (e.g from the office of inspector general of the department of health and human services in the United States) who randomly monitors providers' beahviour and imposes penalty in the event that dishonesty is detected, monitoring such behaviour is highly costly. In this paper, we propose a *reward* scheme to combat such moral hazard problems. We analyse two types of incentive schemes where treatment intensity is contractible in one and not in the other. We show that under

[1] The paper was presented at the 2009 iHEA Congress in Beijing. We thank Karl Claxton, Hugh Gravelle, Neil Rickman, Luigi Siciliani and the conference participants of the iHEA congress for many useful comments. All the remaining errors are ours of course.

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both incentive schemes, the honest provider receives the same reward and obtains higher expected utility in comparison to the full information case. Further, with contractible treatment intensity, the contract resembles the full information one.

Keywords: Upcoding, Asymmetric Information, Health Contracts, Risk Adjuster, Treatment Intensity

JEL Classification: I11, D82

1. INTRODUCTION

Health care providers in the developed nations are almost always universally reimbursed by third party purchasers. In the UK National Health Services (NHS) primary care, the approaches to reimburse providers include the introduction of capitation with monitoring of provider's performance. The primary care trusts and general practices are funded through the arrangement of capitation based on the resource allocation formulas that take into account demographic factors such as sex and age (Carr-Hill and Sheldon, 1992). Under US health care system, fixed budgets and monitoring of performance are widely adopted as well to improve the efficiency of health care provision. Under the US approache of reimbursing providers, diagnosis-based risk adjustment methods are developed to measure the difference in case-mix and morbidity of primary care population. It is well known that the primary purpose of risk adjustment method is to help ensure that morbidity of individual patient is taken into account in the budget allocation. However, with the use of risk adjustment method, the primary care trusts or general practitioners may have less incentives to treat patients with complex health needs (i.e. 'dumped' in the terminology of Ma, 1994) or to choose to treat patients with less complex health problems (i.e. cream-skimming, Barros, 2003).

The data elements used in the risk adjustment systems such as age, sex, and diagnoses, are routinely collected from the administrative records. They therefore suffer from challenges such as incomplete or inaccurate coding of diagnostic data. One major concern with the risk adjustment approach is therefore the possibility for *upcoding*. Upcoding occurs when health care providers engage in strategic behavior by manipulating information about diagnoses or reclassifying diagnoses in an attempt to increase risk-adjusted capitation payment to the providers (Weiner et al, 1996). The fact that informational asymmetry between physicians and patients gives providers an informational advantage has long been recognised by Arrow as he writes: "Because medical knowledge is so complicated, the information possessed by the physician as to the consequences and possibilities of treatment is necessarily very much greater than that of the patient, or at least as it is believed by both parties. Further, both parties are aware of this informational inequality, and their relation is colored by this knowledge" (Arrow, 1963, page 951). McGuire (2000) has also noted that upcoding gives rise to physician's information advantage and generates market power.

The problem of upcoding is aggravated by the fact that it is difficult to pinpoint the provider's discretion to engage in upcoding as there are various ways in which coding errors can occur. O'Malley et al (2005) examined the potential sources of errors occurring in the international classification of disease (ICD) coding process. They discussed that the errors along the 'patient trajectory' relate to the communication among patients and providers: The quality and quantity of information exchanged between patients and admitting clerks or treating clinicians, the clinician's knowledge and experience with illness, and the clinician's attention to detail are all critical determinants of coding accuracy. In addition, coding errors can also occur in the recording procedures along the 'paper trail', e.g. error sources include errors occuring in electronic and written records, coder training and experience, facility quality control efforts, and unintentional and intentional coder errors.

In this paper, we analyse how tendencies towards upcoding by the healthcare providers alter the nature of optimal contracts between providers and purchasers, as upcoding behavior is essentially non-verifiable and hence non-contractible. In the contract between the purchaser and the provider, the purchaser's payoff is usually based on the realization of risk adjuster that is observable to all parties. It is well known, from the derivation of risk adjuster, that diagnostic codes with expensive illness will result in higher values of adjusters and hence, more payment[3]. The realization of the risk adjuster however depends not only upon the nature of illness but also upon the degree of upcoding behavior.

At first it seems that an obvious solution to the upcoding problem will be to invest in resources for auditing coding procedures and use that information in the

[3]ACG Morbidity Index could be used as an example of the risk adjuster. In the next section, we will briefly introduce how the index is created, based on the diagnostic information from ACG system.

contract. If coding behavior can observed by the purchaser, he or she is able to force the provider to record honestly the diagnostic codes and hence the first best will be achieved. For example, Weiner et al (1996) implied that one of the remedies for such upcoding behavior is 'the adoption of auditing and enforcement procedures designed to identify the most obvious examples of coding gaming.' However, full observation of the coding behavior is so costly that it is almost impossible to implement. The purchaser therefore will have to resort to some alternative incentive mechanism to alleviate such moral hazard problems based on available pieces of information.

The main feature of this paper is to use, instead of a direct punishment scheme, a potential *reward* scheme to induce honest recording of diagnistic codes. We assume that there is an 'external' auditor who randomly audits the upcoding behavior. We assume that the auditor is able to observe the provider's behaviour with a certain probability and the provider is punished if any upcoding behaviour is detected. The dishonest provider therefore faces a threat of an exogenously imposed punishment if caught by an external auditor, the value of which is known to all parties. In this paper, we consider the value of this punishment as the potential *reward* that can be awarded to the honest provider. This trade-off between punishment and potential reward is quite crucial in our model as purchasers use this 'carrot and stick' approach to induce honest behaviour. We show that in equilibrium this reward scheme eliminates any incentives for upcoding as the honest provider receives larger expected utility than the dishonest provider does.

Our assumptions about the presence of an external auditor and exogenous punishment are consistent with fact that the US Department of Justice (DOJ) and the Office of Inspector General (OIG) of the Department of Health and Human Services or DOJ) often use the Federal false claims acts as a means to prevent fraudulent claims in the health care inductry (see e.g. Lorence et al 2002 and Salcido 2003).[4] The use of such punishment and reward schemes are quite usual practices in the health care industry. The potential penalties for upcoding behavior could stem

[4] According to Lorence et al. (2001, page 423) improper payments due to misreporting can cost the government as much as $12 billion implying that the government has clear incentives to prevent such behaviour through appropriate punishment. In fact, in some cases penalties can be as harsh as imposing prison sentences.

from the threat of government prosecution or result from the concerns about the damage to providers' reputation. The potential rewards of coding health care information used on reimbursement and the risk of discovery have been widely investigated by authors like Silverman and Skinner 2001, Cleverley 1999, and Kleimuntz et al 1999. In their study investigating Medicare upcoding and market structure in for-profit and non-for-profit hospitals, Silverman and Skinner (2001) discussed the consequences of upcoding behavior, using the concepts developed in the tax evasion literature which is based on the Becker model of crime and punishment (Becker, 1968). They recognized that 'there is a gain in terms of increased revenues from aggressive upcoding, but there is also the risk of detection and subsequent punishment.'

Our assumptions about the presence of an external auditor and exogenous punishment are also similar to that found in the standard costly state verification models, for example, Townsend (1979). Concerns about information manipulation have also drawn widespread attention in financial and accounting literature. Empirical studies provided evidence that performance-based compensation provides managers with incentives to manipulate information in order to increase their payment at a cost to shareholders (see for example Burns and Kedia (2005), Bergstresser and Philippon (2005), Johnson et al. (2005), Sadka (2006), and Goldman et al (2006)).

We consider two payment methods adopted by the purchaser. In the first method, the purchaser reimburses the provider based only on the observed realization of the risk adjuster, where the risk of punishment is the instrument used to alleviate moral hazard. In the second one, the purchaser's payoff depends not only upon the risk adjuster but also upon the treatment intensity[5]. This approach requires that the provider must deliver the treatment package that is relevant to diagnoses which provides, besides the trade off between potential reward and punishment, another channel to reduce the motivation for recording diagnostic codes dishonestly. Indeed, the provider has to spend resources that are contingent upon the diagnoses, regardless of whether they are recorded honestly or dishonestly. That

[5] See Chalkley and Khalil (2005) and Siciliani (2006) for the example using treatment intensity into the payment design.

is, the payoff resulting from upcoding behavior must be spent on the treatment activities rather than contributing to the provider's profit.

The paper is organised as follows: After giving a brief description about risk adjustment system in section 2, we propose our model in section 3. Section 4 provides the full information benchmark. Sections 5 and 6 consider the asymmetric information contracts under two different settings: one with contractible treatment intensity (section 5) and one without (section 6). Section 7 concludes.

2. A BRIEF INTRODUCTION TO THE ACG SYSTEM AND THE ACG MORBIDITY INDEX

The most intensive research on risk adjustment is concentrated on diagnosis-based methods. A leading risk adjustment system, called Adjusted Clinical Group (ACG), has been developed by Jonathan Weiner and colleagues at Johns Hopkins University (Buntin and Newhouse, 1998). The ACG system has been applied to adjust capitation payment rates and for physician profiling in the United States (see, for example, Adams et al 2002 and Knutson 1998) and Canada (see, for example, Reid et al 2002 and Verhulst et al 2001). In Canada, this case-mix system has been validated as a predictor of subsequent health care expenditures by Reid and his colleagues in Manitoba and British Columbia (Reid et al, 1999 and 2002). Hutchison et al (2006) applied this system to assess the usability of neighbourhood level variations in illness burden.

Johns Hopkins ACG case-mix system is applied to characterize population illness burden at the small area level. This system categorizes diagnostic information from administrative health records (e.g. ICD-9/ICD-9-CM) into 32 clinically meaningful groups (ADGs) based on expected clinical outcomes and resource uses. These 32 ADGs are then further collapsed into 12 'collapsed' ADGs (CADGs). According to the combination of CADGs and the individual's age/sex structure, the individual is assigned one of Adjuster Clinical Groups (ACGs) that are mutually exclusive terminal groups.

ACG Morbidity Index was created by Reid and co-worker (Reid et al, 1999 and 2002) to convert the ACG assignment at an individual level to a population-based measure of health need, which therefore can be used as the measure of a risk adjuster for the purpose of reimbursement. This approach first assigns ACGs to the users in each cluster. The expected costs were then obtained by assigning ACG costs (illness weights) that were derived from actual resources used by the users in the ACG category. Hutchison et al (2006) applied and assessed this measure in Ontario scenario. They concluded that the index generated by the ACG case-mix adjustment system can be used to assess the relative need for primary care services and for health services planning at the neighborhood and local community level.

3. THE MODEL

We consider a health care provider who provides health care services to patients within a certain specified area during a particular time horizon, say one year. The area could either be a small geographic area, a health plan or a primary care trust. Given particular medical conditions, the provider records diagnostic codes and chooses the appropriate treatment strategies. The purchaser converts all of the diagnostic codes for all patients within the time period into a summary measure of medical conditions. For the purpose of explanation, we consider ACG Morbidity Index (AMI) as the measure for such medical condition. [6]

Although AMI is a stochastic variable, its realization is measurable as explained above. The purchaser reimburses the provider for his services based on the value of the realization, denoted by x, where the realization of x can take any value within the compact interval $[\underline{x}, \overline{x}]$. As AMI indicates the illness burden of patients, higher values of AMI imply worse health status and vice versa. That is, patients with $\overline{x}$ have the worst health status, while those with $\underline{x}$ have the best. Formally, the payoff $t = t(x)$.

The provider's preference is represented by the utility function $U(t, y)$. The

[6] There are other evidence-based instruments used to measure population medical conditions for the purpose of reimbursement (see, for example, the summary reviews by Buntin and Newhouse, 1998).

variable y measures the treatment intensity. The treatment intensity corresponds to the diagnostic codes, based on which AMI is created. The intensity variable y can be thought of as an index measurement characterizing all treatment episodes delivered by the provider within the particular time period. Therefore, the intensity index y is also the function of x, say $y = y(x)$. We assume that the provider's utility increases in the payoff $t(x)$ and decreases in the intensity index $y(x)$. Specifically, we assume that $U_t(t, y) > 0$, $U_{tt}(t, y) < 0$, $U_y(t, y) < 0$ and $U_{yy}(t, y) < 0$. We also assume that the provider's utility at the boundary value, i.e. at $x = \overline{x}$, is not less than zero. Precisely, $U(\overline{t}, \overline{y}) \geq 0$, where $\overline{t} = t(\overline{x})$ and $\overline{y} = y(\overline{x})$. This assumption ensures that health care services could be provided to the patients with the worst medical conditions.

The purchaser is concerned about the patients' health gain resulting from the consumptions of the health care services. Patients with AMI x receiving treatment intensity y will have a gain in health status, say $h(x, y)$. We assume that the purchasers' benefit from health care service is directly related to the patients' health gain i.e. $b(x, y) \equiv b(h(x, y))$. Further, we assume that the benefit increases and is strictly concave in y and decreases in x: $b_y(x, y) > 0$, $b_{yy}(x, y) < 0$ and $b_x(x, y) < 0$. The assumption $b_x(x, y) < 0$ implies, for a given a treatment intensity, that worse the patient's medical conditions are, the lower is the benefit. The purchaser maximizes the benefit from consuming health care services minus the monetary transfers to the provider, namely, $V = b(x, y) - t(x)$.

To simplify the moral hazard problem, we assume that the provider's upcoding behaviour is represented by the variable a taking binary values 0 and 1: i.e. $a = \{0, 1\}$, where $a = 1$ implies that the provider exerts upcoding, whilst $a = 0$ indicates 'no upcoding' (i.e. exhibits honest behaviour). The variable x is then distributed with conditional distribution function $F(x|a)$, and the density function $f(x|a)$, that depend not only upon the nature of medical conditions but also upon the variable a.

In our model, a public inspector, such as the ones employed by the United States Department of Justice (DoJ) and/or the Office of Inspector General (OIG) of the Department of Health and Human Services, is introduced to catch the upcoding behaviour.[7] Thus, auditing does not cost the purchaser anything directly in this model.[8] We assume that performance of the public inspector is *imperfect*: perfect auditing that entails the first best solution by eliminating any dishonest behaviour requires auditing with a very high probability that is extremely costly to implement. Instead, DoJ or OIG can only inspect provider's claims randomly and hence upcoding behavior will be caught only with a probability. We assume that the audit probablities are known by both the purchaser and the provider.[9] Thus in our model, punishment can be treated as an exogenous variable with a known (expected) value as it is imposed by an external organization (e.g. DOJ) rather than the purchaser. We denote this value of (potential) punishment by ψ[10].

A mechanism inducing zero upcoding behaviour must therefore satisfy the following participation constraints

$$\int_{\underline{x}}^{\overline{x}} U(t,y)\, f(x|0)dx \geq 0$$

$$\int_{\underline{x}}^{\overline{x}} U(t,y)\, f(x|1)dx \geq 0$$

and the following incentive compatibility constraint

$$\int_{\underline{x}}^{\overline{x}} U(t,y)\, f(x|0)dx \geq \int_{\underline{x}}^{\overline{x}} U(t,y)\, f(x|1)dx + \psi$$

Note that the meaning of the incentive compatibility constraint is quite different in our context: In contrast to the standard theory that focuses on the trade-off be-

[7] For instance, the Office of Inspector General of the Department of Health and Human Services has implemented the Federal False Claims Act in order to prevent fraudulent claims in health care industry (see, for example, Lorence et. al (2002) and Salcido (2003)).

[8] The issue of collusion between the auditor and the provider can be safely ignored in this model: since the public inspector is hired by the Government directly (and there is no contractual relationship between the auditor and the purchaser), we can safely assume that only honest auditors are hired by the Federal bodies otherwise the government's reputaion will be at stake.

[9] Similarly, the issue of non-commitment to auditing strategies (i.e. non-commitment to audit probabilities) does not arise in this model either.

[10] Note, according to the assumption that an outside auditor monitors randomly and that upcoding behaviour is caught with a certain probability, ψ in fact represents an expected value of punishment.

tween inducing higher degree of effort and the costs (or agent's disutility) resulting from performing the effort (e.g. Laffont and Martimort, 2002), here the upcoding behaviour is the 'effort' the purchaser hopes to avoid. The value of the potential punishment is assumed to be known to both the purchaser and the provider. The incentive compatibility constraint ensures that the expected utility of the honest provider must not be less than the expected utility of a dishonest provider plus the value of the potential punishment. Thus, this incentive compatibility constraint implies the purchaser will *reward* the honest provider in order to induce zero upcoding behaviour. [11] While, we acknowledge that setting up this monitoring system will incur fixed costs, without any loss of generality, we ignore this fixed setting up cost as it does not alter our results.

To investigate the incentive effect of the mechanism, we consider two types of contractual environments. In the first one, the payment scheme is based on the realization of x and the treatment intensity is contractible, which means the intensity index y must be contingent upon the realization of x. The contract requires implicitly a monitoring system that ensures the resources used are consistent with the recorded diagnoses.[12] In the second one, the payment scheme is based on the realization of x but the treatment intensity is not contractible, which for instance is determined based on medical professionals' experiences during the previous periods.

The timing of the game is as follows. To start with, the purchaser designs a contract to induce honest behavior. If the provider chooses to accept the contract, he will decide whether or not to conduct upcoding and will treat patients with the chosen treatment intensities. Finally, the contracts are implemented. For the first contract, payment is based on both the realization of x and the treatment intensity y, and for the second contract, payment is made based on the realization of x.

[11] We show that in equilibrium, the honest provider receives the expected utility of exactly ψ ($\psi > 0$) whilst the dishonest one receives zero expected utility (see sections 5 and 6)

[12] In practice, the monitoring is conducted by comparing medical records with the use of resource records.

4. THE FULL INFORMATION BENCHMARK

In this case, since the provider's behavior is perfectly observable, the purchaser will require the provider to behave honestly. The distribution of x is hence affected only by the nature of the patients' medical conditions which are under scrutiny. We denote the (unconditional) density function by $f(x)$. The purchaser's problem is to maximize the expected benefit subject to the participation constraint that ensures that the provider is willing to provide the necessary care services. Namely, the maximization problem (P) is:

$$\max_{t(x),y(x)} \int_{\underline{x}}^{\overline{x}} \left[b\left(x,y\right) - t\left(x\right)\right] f\left(x\right) dx$$
$$s.t. \int_{\underline{x}}^{\overline{x}} U\left(t,y\right) f\left(x\right) dx \geq 0$$

Since in the purchaser's objective function the transfer $t(x)$ reduces her benefits and the provider's expected utility increases in $t(x)$, the purchaser will design the payment scheme such that participation constraint is binds: this is also verified in the proof of proposition 1 in the appendix. The properties of the optimal solution are summarized in the following proposition.

PROPOSITION 1. *Given that the provider's upcoding behavior is observable, the purchaser is able to design an optimal contract such that:*

1. *The first best trajectories of transfer $t(x)$ and intensity index $y(x)$ are determined by the following conditions:*

$$b_y\left(x,y\right) = -\frac{U_y\left(t,y\right)}{U_t\left(t,y\right)}$$

$$\int_{\underline{x}}^{\overline{x}} U\left(t,y\right) f\left(x\right) dx = 0$$

2. *Given the assumption that provider's ex-post utility is not negative when the realization of x reaches upper limit (i.e. $x = \overline{x}$), his ex-post utility function*

at the optimal is non-decreasing in x. That is, for any $x \in [\underline{x}, \overline{x}]$,

$$\begin{aligned} \frac{dU(t,y)}{dx} &\geq 0 \;\; \textit{if}\, \overline{U} \geq 0 \\ &= 0 \;\, \textit{if}\, \overline{U} = 0 \end{aligned}$$

3. *The sign of the slopes of the trajectory $t(x)$ and $y(x)$ depends on that of b_{yx}. That is,*

$$\frac{dt(x)}{dx}, \frac{dy(x)}{dx} \begin{cases} > 0 \;\textit{if}\; b_{yx}(x,y) > 0 \\ < 0 \;\textit{if}\; b_{yx}(x,y) < 0 \end{cases}$$

Proof. See the Appendix. ∎

Part 1 of the proposition states that the first best trajectory must satisfy the necessary condition that the marginal benefit of the treatment must be equal to the marginal rate of substitution between intensity $y(x)$ and transfer $t(x)$. When the boundary value $\overline{U}$ is larger than zero, the provider's utility monotonically increases in the realization of x, which indicates that the provider has the motivation in treating patients with worse medical conditions. Had the boundary value been set to zero, the ex-post utility would be extracted to zero for all values of x. Recall that b_{yx} indicates the change of marginal benefit resulting from treatment in medical conditions. Therefore, $b_{yx} > 0$ implies treating patients with worse medical conditions will produce more marginal benefit (or more marginal health status gain for population). Part 3 reveals that, while both of $t(x)$ and $y(x)$ change with x in the same direction, their slopes depend on the sign of b_{yx}. If the marginal benefit from treatment is larger for those with worse medical conditions the contract will allow more transfer to the provider, along with more intensive treatment, who provides services to patients with worse conditions. Similarly, if the marginal benefit from treatment decreases in x the payoff also decreases in x.

Obviously, the purchaser in practice prefers the former to the latter. We thereafter restrict our discussion on the case where treating worse patients results in a larger marginal benefit. Formally, we assume the purchaser's preference is characterized by $b_{yx} > 0$[13].

5. ASYMMETRY OF INFORMATION—CONTRACTIBLE TREATMENT INTENSITY

We now consider the situation where recording behavior is not observable to the purchaser. If the first best contract were to be offered, the provider would have an incentive to exert upcoding behavior that results in the right skew in AMI distribution. To solve this moral hazard problem, the purchaser must now solve the following problem:

$$\begin{aligned}
&\max_{t(x),y(x)} \int_{\underline{x}}^{\overline{x}} [b(x,y) - t]\, f(x|0)dx \\
&s.t. \int_{\underline{x}}^{\overline{x}} U(t,y)\, f(x|1)dx \geq 0 \\
&\int_{\underline{x}}^{\overline{x}} U(t,y)\, f(x|0)dx \geq \int_{\underline{x}}^{\overline{x}} U(t,y)\, f(x|1)dx + \psi
\end{aligned}$$

where the first constraint is the participation constraint that says that the provider's expected utility cannot be less than zero, while the second constraint is the incentive compatibility constraint that ensures that the provider's expected utility with no upcoding behaviour must not be less than that with upcoding.[14] Solution to the above problem is summarized in proposition 2.

PROPOSITION 2. *In the presence of moral hazard, the optimal contract offered to the provider with ex-post utility $U(t,y)$ entails:*

1. *The first best outcome for a provider with ex-post utility $U(t,y) - \psi$. That is, given the boundary condition $\overline{U} \geq \psi$, all features stated in proposition 1still hold except that*

[13] Henceforth, we restrict our discussion on the case where $b_{yx} > 0$ as this is, in practice, purchaser's preference. Similar approach could be applied to the assumption of $b_{yx} < 0$.

[14] Another participation constraint is $\int_{\underline{x}}^{\overline{x}} U(t,y)\, f(x|0)dx \geq 0$. We can check if this holds in equilibrium.

2. The optimal trajectories $t(x)$ and $y(x)$ are now determined by:

$$b_y(x, y) = -\frac{U_y(t, y)}{U_t(t, y)}$$

$$\int_{\underline{x}}^{\overline{x}} U(t, y) f(x|0)\, dx = \psi$$

Proof. See Appendix 4.B. ∎

There are two scenarios to the solution characterized by this proposition. In the first scenario, the provider is characterized by the ex-post utility function $U(t, y)$ and the information structure is asymmetric, while the second one is the full information contract offered to the provider with ex-post utility function $U(t, y)$ *minus* ψ. In other words, the first best contract designed for the provider with ex-post utility $U(t, y) - \psi$ can get rid of the moral hazard problem associated with the provider with ex-post utility $U(t, y)$. To see that, rewrite the equation in part 1 as:

$$\int_{\underline{x}}^{\overline{x}} [U(t, y) - \psi] f(x|0)\, dx = 0$$

Then define the following utility function:

$$W(t, y) = U(t, y) - \psi$$

Because $W_t(t, y) \equiv U_t(t, y)$ and $W_y(t, y) \equiv U_y(t, y)$, the solution (i.e. the equations in part 2 of proposition 2) are further rewritten as:

$$b_y(x, y) = -\frac{W_y(t, y)}{W_t(t, y)}$$

$$\int_{\underline{x}}^{\overline{x}} W(t, y) f(x|0)\, dx = 0$$

As indicated in proposition 1, these equations entail the first best mechanism for the provider with ex-post utility $W(t, y)$.

Figure 5-1 indicates how the trajectories $t(x)$ and $y(x)$ are distorted in the

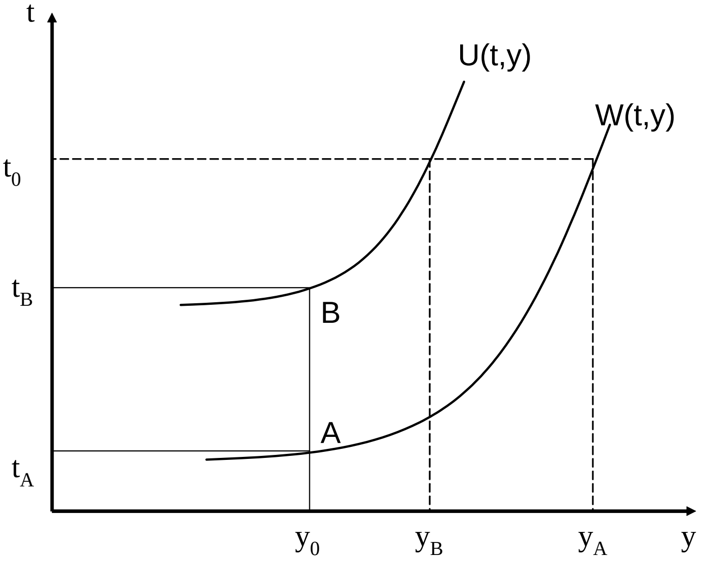

Figure 5-1

presence of moral hazard, compared to the full information case. From the definition of $W(t,y)$, we learn that, in $t-y$ space, the indifference curve of $U(t,y)$ is on North-West side of $W(t,y)$[15]. $U(t,y)$ stands for the indifference curve with moral hazard and $W(t,y)$ for that with full information. For a given realization of x, any intensity index, say $y_0(x)$, corresponds to transfers $t_A(x)$ on the curve $W(t,y)$ and $t_B(x)$ on the curve $U(t,y)$. As $t_B(x) > t_A(x)$, this indicates that the asymmetry of information distorts transfer towards the provider if he exerts honest behaviour. That is to say, the purchaser in the presence of moral hazard will make *more* transfers to the provider in an attempt to induce the honest behaviour. Similarly, any transfer, say $t_0(x)$, corresponds to two intensity indices $y_A(x)$, $y_B(x)$ with $y_A(x) > y_B(x)$. Synthetically, the second best outcomes in the presence of moral hazard are characterized by *raising* transfers to the provider and reducing treatment intensity, compared to the full information scenario.

We can understand the distortion by investigating the constraints. Binding participation and incentive compatibility constraints for the dishonest provider implies,

[15]The slopes of the indifference curves are positive: $dU(t,y) \equiv U_t(t,y)dt + U_y(t,y)dy = 0 \Rightarrow \frac{dt}{dy} = -\frac{U_y(t,y)}{U_t(t,y)} > 0$.

we have:

$$\int_{\underline{x}}^{\overline{x}} U\left(t, y\right) f\left(x|0\right) dx = \psi$$

i.e. the honest provider's expected utility must be equal to ψ rather than zero as under the full information case. The additional utility gain must result from more transfer or less treatment intensity or both.

6. ASYMMETRY OF INFORMATION—NON-CONTRACTIBLE TREATMENT INTENSITY

When the treatment is not contractible, transfer arrangement is the only instrument for the purchaser to cope with moral hazard. The determination of treatment intensity depends upon the provider's professional experiences. Professional reputation may be the main consideration in choosing treatment intensity. In this situation, the purchaser solves the following problem:

$$\begin{aligned}
\max_{t(x)} & \int_{\underline{x}}^{\overline{x}} \left[b\left(x, Y\right) - t\right] f(x|0) dx \\
s.t. & \int_{\underline{x}}^{\overline{x}} U\left(t, Y\right) f(x|1) dx \geq 0 \\
& \int_{\underline{x}}^{\overline{x}} U\left(t, Y\right) f(x|0) dx \geq \int_{\underline{x}}^{\overline{x}} U\left(t, Y\right) f(x|1) dx + \psi
\end{aligned}$$

where the treatment intensity Y is assumed to be of constant value.

As in the previous section, the first constraint is a participation constraint for the dishonest provider and the second one is incentive compatibility constraint. The participation constraint for the honest provider is omitted. To solve this problem we first introduce the following Lemma.

LEMMA 1. *Given that the density functions $f\left(x|0\right)$ and $f\left(x|1\right)$ satisfy the Monotone Likelihood Ratio Property (MLRP), i.e.* $\frac{d}{dx}\left(\frac{f(x|1)}{f(x|0)}\right) > 0$, *there exists a value of x,* *say* $x_0 \in (\underline{x}, \overline{x})$, *such that:*

$$\frac{f(x|1)}{f(x|0)} \begin{cases} < 1 \text{ } \textit{if } x \in [\underline{x}, x_0) \\ = 1 \text{ } \textit{if} \quad x = x_0 \\ > \textit{if } x \in (x_0, \overline{x}] \end{cases}$$

Proof. See in the Appendix. ∎

According to Proposition 2 by Milgrom (1981), *'the family of densities has the strict MLRP iff* $x_1 > x_2$ *implies that* x_1 *is more favorable than* x_2*.'* The assumption that $f(x|0)$ and $f(x|1)$ satisfy MLRP indicates that the distribution conditional upon behaviour 1 is skewed to the right. Lemma 1 implies $f(x|1)$ crosses $f(x|0)$ only once. The solution to the above maximization problem is summarized in proposition 3.

PROPOSITION 3. *In the presence of moral hazard the optimal contract with non-contractible treatment intensity entails that:*

1. *The second best trajectory* $t(x)$ *is determined from the equations:*

$$\frac{1}{U_t(t, Y)} = \lambda \frac{f(x|1)}{f(x|0)} + \mu \frac{f(x|0) - f(x|1)}{f(x|0)}$$

$$\int_{\underline{x}}^{\overline{x}} U(t, Y) f(x|0) \, dx = \psi$$

$$\int_{\underline{x}}^{\overline{x}} U(t, Y) f(x|1) \, dx = 0$$

2. *Given that MLRP holds, there exists a value of* x*, say* $x_0 \in (\underline{x}, \overline{x})$*, such that:*

$$t^{SB}(x) \begin{cases} < t^*(x) \text{ if } x < x_0 \\ = t^*(x) \text{ if } x = x_0 \\ > t^*(x) \text{ if } x > x_0 \end{cases}$$

   where $t^*(x)$ *and* $t^{SB}(x)$ *are the first and second best trajectories respectively.*

Proof. See in the Appendix. ∎

This proposition indicates that the second best trajectory $t^{SB}(x)$ is distorted in favour of the provider who delivers services to patients with worse medical conditions. This result is illustrated in Figure 5-2.

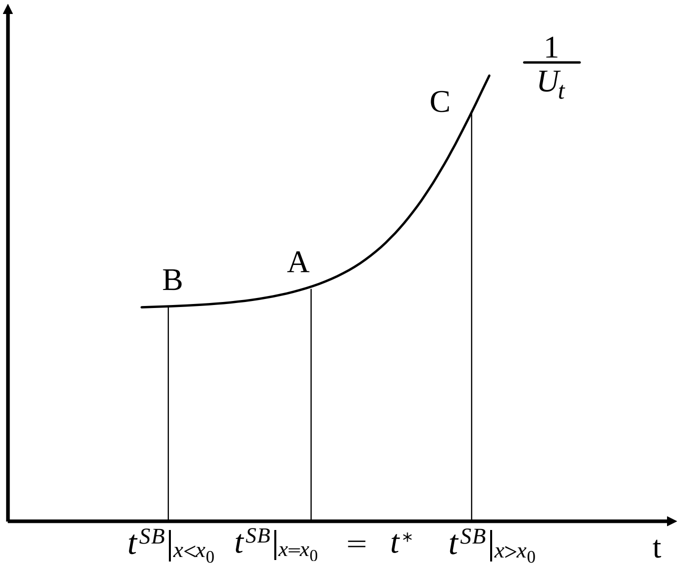

Figure 5-2

Point A corresponds the case that $x = x_0$, where the first best transfer is equal to the second best transfer, i.e. $t^*(x_0) = t^{SB}(x_0)$. If $x < x_0$, $\frac{1}{U_t}$ is on the left side of A, say point B, where the value of $\frac{1}{U_t}$ is less than that at A. Correspondingly, $t^{SB}(x)|_{x<x_0} < t^*(x)$. Similarly, at point C, the value of $\frac{1}{U_t}$ is larger than that at A and $t^{SB}(x)|_{x<x_0} > t^*(x)$.

Figure 5-3 presents the optimal trajectory for the transfer $t(x)$ under full and asymmetric information. The provider receives less transfer if $x < x_0$ and more if $x > x_0$, compared to the full information case. This contract distorts transfer in favour of those who provide services to patients with worse medical conditions.

This payment arrangement results in the incentive effect that induces honest behaviour. Under the asymmetry of information, the provider who behaves honestly is rewarded by receiving an expected utility that is equal to ψ, whilst under the full information his expected utility is brought down to zero. Formally, the expected utility under asymmetric information is given by $\int_{\underline{x}}^{\overline{x}} U(t,Y) f(x|0)\,dx = \psi$ and, that under full information is given by $\int_{\underline{x}}^{\overline{x}} U(t,Y) f(x|0)\,dx = 0$[16].

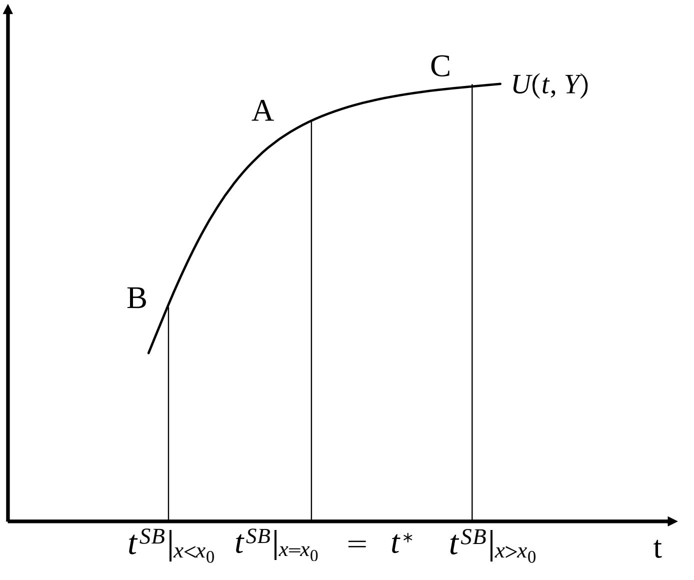

Figure 5-3

For $U_t(t,Y) > 0$, in comparison with the first best case, this contract characterizes that the ex-post utility curve is steeper. That is to say, the ex-post utility increases for any $x \in (x_0, \overline{x}]$ and decreases for any $x \in [\underline{x}, x_0]$. Whilst the expected utility for the honest provider has been raised to be equal to ψ, the ex-post utility he received will be less (or more) than that in the first best if the realization of x is small (or large) enough. This mechanism offers the provider with incentives to treat patients with worse medical conditions.

7. CONCLUSION

Risk selection is an important concern in health policy. The health authority, health insurance and private employers who purchase care services for their employees are all faced with risk selection challenges. In response, risk adjustment

[16] In section 4, density function is $f(x)$. For the purpose of comparison here we rewrite it as $f(x|0)$. This does not change the results because both represent the distribution without 'upcoding' behaviour.

methods are introduced in the reimbursement for services. Whilst the risk adjustment approach helps to ensure that the morbidity of individual patients is taken into account, the health care providers under this payment arrangement have the incentive to shift patients' diagnostic codes to ones that yield a greater payoff from the purchasers. This upcoding behavior is feasible because of the genuine uncertainty about inappropriate diagnoses.

In our framework, the purchaser uses some pieces of information to alleviate the moral hazard problem. ACG Morbidity Index, which is developed based on diagnostic information, is applied as a proxy for measuring morbidity burden and hence, as the risk adjuster. Although the index is a stochastic variable due to the influence of such factors as the uncertainty of medical conditions, the coding inaccuracy and so forth, its realization can be measured by collecting health care administrative data (e.g. ICD-9 codes). Another piece of information used in the models is the distribution of the index. Based on past experiences we assumed this pattern is common knowledge.

In this paper, we have demonstrated that the motivation for upcoding can be removed if an appropriate contract is offered to the provider. Two contracts have been developed: in the first contract the purchaser designs a payment scheme and imposes appropriate treatment intensity as the regulatory instruments, and the second contract is based only on the payment scheme. Both of the mechanisms offer the provider incentive to record diagnostic codes honestly. Under both incentive mechanisms, the rewards that the honest providers receive are the same, which is equal to the value of expected punishment, i.e.ψ $(\psi > 0)$. The value of ψ depends on how the society (i.e. the purchasers and the providers) evaluates the value of potential punishment once the behaviour manipulating diagnostic codes is detected. Therefore, in the sense of expected utility increase, both mechanisms have the same incentive effect.

From the incentive point of view, the first contract is accompanied by reducing the treatment intensity. This reduction may hurt the benefit from consuming health care services. On the other hand, the transfer distortion and ex-post utility effect under the second contract will lead the resources to be allocated to the patients with worse medical conditions.

In the sense of implementing contracts, however, we believe the mechanism based on both the payment scheme and treatment intensity is superior. Under this mechanism, the contract offered to the provider with ex-post utility $U(t, y)$ is equivalent to that offered under full information to a provider with ex-post utility $U(t, y) - \psi$. The problem with the presence of moral hazard is therefore converted into looking for solution to a problem under full information. As a result, the distribution conditional upon the upcoding behaviour is excluded in the mechanism design. The optimal payment scheme and treatment intensity depend only upon the distribution without upcoding. Because the distribution without upcoding reflects the nature of medical conditions it can be determined on the basis of population medical history.

The first contract requires that the treatment intensity must correspond to the realization of morbidity index (i.e. x). This condition implicitly assumed that the treatment intensity is observable. However, in practice, monitoring the intensity is necessary to ensure the treatment synchronizes with the diagnostic information, which will incur extra monitoring costs. The second mechanism is related to the distribution conditional upon upcoding behavior. Under the mechanism, the payment scheme depends not only upon the distribution without upcoding but also upon the conditional distribution, which is assumed to be known at the beginning of the game. However, the provider in practice still has the discretion to shift the conditional distribution through varying the degree of upcoding behavior, even after he has accepted the contract. This shift will result in the solution moving away from the equilibrium.

APPENDIX

Proof of Proposition 1. The purchaser solves the problem:

$$\max_{t(x),y(x)} \int_{\underline{x}}^{\overline{x}} [b(x,y) - t] f(x) \, dx$$
$$s.t. \int_{\underline{x}}^{\overline{x}} U(t,y) f(x) \, dx \geq 0$$

The combined functional $\pounds(x)$ is introduced as:

$$\pounds(x) = \int_{\underline{x}}^{\overline{x}} [b(x,y) - t] f(x) \, dx + \lambda \int_{\underline{x}}^{\overline{x}} U(t,y) f(x) \, dx$$

The optimal solution satisfies the functional derivative equations $\frac{\delta \pounds(x)}{\delta t(x)} = 0$ and $\frac{\delta \pounds(x)}{\delta y(x)} = 0$.Namely,

$$-f(x) + \lambda U_t(t,y) f(x) = 0 \tag{1}$$

$$b_y(x,y) f(x) + \lambda U_y(t,y) f(x) = 0 \tag{2}$$

Or

$$\lambda = \frac{1}{U_t(t,y)}$$

which indicates participation constraint is binding, i.e.

$$\int_{\underline{x}}^{\overline{x}} U(t,y) f(x) \, dx = 0 \tag{3}$$

From Eq.2 we have

$$b_y(x,y) = -\frac{U_y(t,y)}{U_t(t,y)} \tag{4}$$

Next, we investigate the slops of trajectory $t(x)$ and $y(x)$. Integrating Eq.3 by part yields:

$$U(t,y) F(x) \Big|_{\underline{x}}^{\overline{x}} - \int_{\underline{x}}^{\overline{x}} F(x) \left[U_t(t,y) \frac{dt}{dx} + U_y(t,y) \frac{dy}{dx} \right] dx = 0$$

Note that $F(\underline{x}) \equiv 0$ and $F(\overline{x}) \equiv 1$, we have:

$$\int_{\underline{x}}^{\overline{x}} F(x) \left[U_t(t, y) \frac{dt}{dx} + U_y(t, y) \frac{dy}{dx} \right] dx = \overline{U}$$

where $\overline{U} \equiv U(t(\overline{x}), y(\overline{x}))$ is the ex-post utility as $x = \overline{x}$. And $\overline{x} \geq 0$ by assumption. Because of $F(x) > 0$ for any $x \in (\underline{x}, \overline{x}]$, we have:

$$U_t(t, y) \frac{dt}{dx} + U_y(t, y) \frac{dy}{dx} \geq 0 \tag{5}$$

We recognized that the left hand side of 5 is $\frac{dU(t,y)}{dx}$,and hence

$$\frac{dU(t, y)}{dx} \geq 0$$

From 5 we have:

$$\frac{dt}{dx} \geq b_y \frac{dy}{dx} \tag{6}$$

Doing derivative of Eq.4 with respect to x, we get:

$$\left\{ \begin{array}{c} U_{yy}(t, y) \frac{dy}{dx} + U_{yt}(t, y) \frac{dt}{dx} + b_y \left[U_{tt}(t, y) \frac{dt}{dx} + U_{ty}(t, y) \frac{dy}{dx} \right] \\ +U_t(t, y) \left[b_{yy}(t, y) \frac{dy}{dx} + b_{yx}(x, y) \right] \end{array} \right\} = 0$$

or

$$\left\{ \begin{array}{c} \frac{dy}{dx} \left[U_{yy}(t, y) + b_y U_{ty}(t, y) + U_t(t, y) b_{yy}(t, y) \right] \\ +\frac{dt}{dx} \left[U_{yt}(t, y) + b_y U_{tt}(t, y) \right] \end{array} \right\} = -U_t(t, y) b_{yx}(x, y)$$

Substituting 6 into the equation above, we have:

$$\frac{dt}{dx} \left[\frac{U_{yy}(t, y) + b_{yy}(t, y)}{b_y} + 2U_{ty}(t, y) + b_y U_{tt}(t, y) \right] \geq -U_t(t, y) b_{yx}(x, y) \tag{7}$$

or

$$\left\{ \frac{dy}{dx} \left[\begin{array}{c} U_{yy}(t, y) + b_y U_{ty}(t, y) + U_t(t, y) b_{yy}(t, y) \\ +b_y U_{yt}(t, y) + b_y^2 U_{tt}(t, y) \end{array} \right] \right\} \leq -U_t(t, y) b_{yx}(x, y) \tag{8}$$

Note that by assumption each term in the square bracket in 7 and 8 are negative. Therefore, from 6 and 8, we have:

$$\frac{dy}{dx} > 0 \text{ and hence } \frac{dt}{dx} > 0 \text{ if } b_{yx}(x,y) > 0$$

From 6 and 7, we have:

$$\frac{dt}{dx} < 0 \text{ and hence } \frac{dy}{dx} < 0 \text{ if } b_{yx}(x,y) < 0$$

Q.E.D.

Proof of Proposition 2. Let us introduce a combined functional to find the necessary conditions of this problem:

$$\pounds(x) = \left\{ \begin{array}{c} \int_{\underline{x}}^{\overline{x}} [b(x,y) - t] f(x|0)\, dx + \lambda \int_{\underline{x}}^{\overline{x}} U(t,y) f(x|1)\, dx \\ +\mu \int_{\underline{x}}^{\overline{x}} U(t,y) [f(x|0) - f(x|1)]\, dx - \mu\psi \end{array} \right\}$$

The first order conditions are $\frac{\delta \pounds(x)}{\delta t} = 0$ and $\frac{\delta \pounds(x)}{\delta y(x)} = 0$.Namely,

$$-f(x|0) + \lambda U_t(t,y) f(x|1) + \mu U_t(t,y) [f(x|0) - f(x|1)] = 0$$

and

$$\left\{ \begin{array}{c} b_y(x,y) f(x|0) + \lambda U_y(t,y) f(x|1) \\ +\mu U_y(t,y) [f(x|0) - f(x|1)] \end{array} \right\} = 0$$

Rewriting the first order conditions, we have:

$$\frac{1}{U_t(t,y)} = \lambda \frac{f(x|1)}{f(x|0)} + \mu \frac{f(x|0) - f(x|1)}{f(x|0)} \tag{9}$$

and

$$\frac{b_y(x,y)}{U_y(t,y)} = -\lambda \frac{f(x|1)}{f(x|0)} - \mu \frac{f(x|0) - f(x|1)}{f(x|0)} \tag{10}$$

Next we show that $\lambda, \mu > 0$. Integrating Eq.9:

$$\int_{\underline{x}}^{\overline{x}} \frac{f(x|0)}{U_t(t,y)} dx = \lambda \int_{\underline{x}}^{\overline{x}} f(x|1)\, dx + \mu \int_{\underline{x}}^{\overline{x}} [f(x|0) - f(x|1)]\, dx$$

Note that $\int_{\underline{x}}^{\overline{x}} f(x|0)\, dx = \int_{\underline{x}}^{\overline{x}} f(x|1)\, dx = 1$ and $\int_{\underline{x}}^{\overline{x}} \frac{f(x|0)}{U_t(t,y)} dx \equiv E\left(\frac{1}{U_t(t,y)}\right)$, we have:

$$\lambda = E\left(\frac{1}{U_t(t,y)}\right) > 0 \tag{11}$$

Substituting Eq.11 into 9, we have:

$$\frac{1}{U_t(t,y)} = E\left(\frac{1}{U_t(t,y)}\right) \frac{f(x|1)}{f(x|0)} + \mu \frac{f(x|0) - f(x|1)}{f(x|0)} \tag{12}$$

Multiplying both sides of the equation by $U(t,y)$ and $f(x|0)$, and then integrating it, we have:

$$\int_{\underline{x}}^{\overline{x}} \frac{U(t,y)}{U_t(t,y)} f(x|0)\, dx = \left\{ \begin{array}{c} \int_{\underline{x}}^{\overline{x}} E\left(\frac{1}{U_t(t,y)}\right) U(t,y)\, f(x|1)\, dx \\ +\mu \int_{\underline{x}}^{\overline{x}} U(t,y)\, [f(x|0) - f(x|1)]\, dx \end{array} \right\} \tag{13}$$

From Kuhn-Tucker condition, we have:

$$\mu \left\{ \int_{\underline{x}}^{\overline{x}} U(t,y)\, [f(x|0) - f(x|1)]\, dx - \psi \right\} = 0$$

or

$$\mu\psi = \mu \int_{\underline{x}}^{\overline{x}} U(t,y)\, [f(x|0) - f(x|1)]\, dx \tag{14}$$

Eq.13 and 14 yield:

$$\mu\psi = \int_{\underline{x}}^{\overline{x}} \frac{U(t,y)}{U_t(t,y)} f(x|0)\, dx - E\left(\frac{1}{U_t(t,y)}\right) \int_{\underline{x}}^{\overline{x}} U(t,y)\, f(x|1)\, dx$$

According to the definition covariance[17], we have:

$$\begin{aligned}
\mu\psi &= \int_{\underline{x}}^{\overline{x}} \frac{U(t,y)}{U_t(t,y)} f(x|0)\,dx - E\left(\frac{1}{U_t(t,y)}\right) \int_{\underline{x}}^{\overline{x}} U(t,y) f(x|1)\,dx \\
&> \int_{\underline{x}}^{\overline{x}} \frac{U(t,y)}{U_t(t,y)} f(x|0)\,dx - E\left(\frac{1}{U_t(t,y)}\right) \int_{\underline{x}}^{\overline{x}} U(t,y) f(x|0)\,dx \\
&= E\left(\frac{U(t,y)}{U_t(t,y)}\right) - E\left(\frac{1}{U_t(t,y)}\right) E\left(U(t,y)\right) \\
&= Cov\left(U(t,y), \frac{1}{U_t(t,y)}\right)
\end{aligned}$$

Here we note that, from incentive compatibility constraint, $\int_{\underline{x}}^{\overline{x}} U(t,y) f(x|1)\,dx < \int_{\underline{x}}^{\overline{x}} U(t,y) f(x|0)\,dx$. Taking into account the fact that $U(t,y)$ and $\frac{1}{U_t(t,y)}$ change in the same direction, we have:

$$\mu\psi = Cov\left(U(t,y), \frac{1}{U_t(t,y)}\right) > 0$$

That is,

$$\mu > 0$$

Therefore, both the participation constraint and incentive compatibility constraint are binding. The parameter λ and μ, and trajectory $t(x)$ and $y(x)$ can be determined by using the constraints in equality and the first order condition Eq.9 and 10.

To determine trajectories $t(x)$ and $y(x)$, let's refine Eq.9 and 10.

Eq.9 plus 10 yields:

$$b_y(x,y) = -\frac{U_y(t,y)}{U_t(t,y)} \tag{15}$$

Both constraints taking in equality imply that:

$$\int_{\underline{x}}^{\overline{x}} U(t,y) f(x|0)\,dx = \psi \tag{16}$$

[17] The covariance between random variables ξ, η is defined as

$$cov(\xi,\eta) = E\left[(\xi - E\xi)(\eta - E\eta)\right] = E(\xi\eta) - E\xi E\eta$$

Trajectories $t(x)$ and $y(x)$ are determined by using the equation above.

Next we show this solution is equivalent to the first best. Rewriting Eq.16, we have:

$$\int_{\underline{x}}^{\overline{x}} [U(t,y) - \psi] f(x|0)\,dx = 0$$

Defining a utility function:

$$W(t,y) \equiv U(t,y) - \psi$$

and note that $W_t(t,y) \equiv U_t(t,y)$ and $W_y(t,y) \equiv U_y(t,y)$. Hence the optimal trajectories are determined by the equations below:

$$\int_{\underline{x}}^{\overline{x}} W(t,y) f(x|0)\,dx = 0$$

$$b_y(x,y) = -\frac{W_y(t,y)}{W_t(t,y)}$$

Considering the discussion last section and noting that $f(x|0) \equiv f(x)$ because both represent the density function without upcoding behaviour, we see the first best mechanism can be used in the case. Therefore, given the boundary condition $\overline{W} \equiv \overline{U} - \psi \geq 0$, all of the results from proposition 1 are achieved here.

Q.E.D.

Proof of Lemma 1. Given that MLRP holds, i.e. $\frac{d}{dx}\left(\frac{f(x|1)}{f(x|0)}\right) > 0$, there are three possible relations between $f(x|1)$ and $f(x|0)$, as listed below:

1. $f(x|1) > f(x|0)$ for any $x \in [\underline{x}, \overline{x}]$
2. $f(x|1) < f(x|0)$ for any $x \in [\underline{x}, \overline{x}]$
3. There exists $x_0 \in (\underline{x}, \overline{x})$, such that:

$$\frac{f(x|1)}{f(x|0)} \begin{cases} < 1 \text{ if } x \in [\underline{x}, x_0) \\ = 1 \text{ if } \quad x = x_0 \\ > \text{ if } x \in (x_0, \overline{x}] \end{cases}$$

Obviously, 1 and 2 are not true. Indeed, in case 1 for example, integrating both sides obtain:

$$\int_{\underline{x}}^{\overline{x}} f(x|1)\, dx > \int_{\underline{x}}^{\overline{x}} f(x|0)\, dx$$

However, according to the definition of density function, both sides must equal 1. Hence, the above cannot be true. By similar argument, case 2 cannot occur. Therefore, only case 3 must hold.

Q.E.D.

Proof of Proposition 3. The purchaser solves the problem:

$$\begin{aligned}
&\max_{t(x)} \int_{\underline{x}}^{\overline{x}} [b(x, Y) - t]\, f(x|0) dx \\
&\quad s.t. \int_{\underline{x}}^{\overline{x}} U(t, Y)\, f(x|1) dx \geq 0 \\
&\quad \int_{\underline{x}}^{\overline{x}} U(t, Y)\, f(x|0) dx \geq \int_{\underline{x}}^{\overline{x}} U(t, Y)\, f(x|1) dx + \psi
\end{aligned}$$

The first order condition is:

$$-f(x|0) + \lambda U_t(t, Y)\, f(x|1) + \mu U_t(t, Y)\, [f(x|0) - f(x|1)] = 0$$

i.e.

$$\frac{1}{U_t(t, Y)} = \lambda \frac{f(x|1)}{f(x|0)} + \mu \frac{f(x|0) - f(x|1)}{f(x|0)} \tag{17}$$

Using the same approach as that in the proof of proposition 2, we see $\lambda, \mu > 0$. Therefore, parameters λ and μ, and trajectory $t(x)$ can be determined by using Eq.17 and the constraints hold with equality.

Next we examine the relation between the first best trajectory $t^*(x)$ and the second best one $t^{SB}(x)$. Rewriting Eq.17, we have:

$$\frac{1}{U_t(t, Y)} = \lambda + (\mu - \lambda) \left[1 - \frac{f(x|1)}{f(x|0)}\right] \tag{18}$$

or

$$\frac{1}{U_t(t,Y)} - E\left(\frac{1}{U_t(t,Y)}\right) = (\mu - \lambda)\left[1 - \frac{f(x|1)}{f(x|0)}\right] \tag{19}$$

We will show $\mu - \lambda < 0$ if $x \neq x_0$, where x_0 is the value discussed in appendix C. Using the same approach as in the proof of proposition 1, we can show $\frac{dt}{dx} > 0$. Considering this and the assumption $U_{tt}(t,Y) < 0$, we immediately learn that $\frac{1}{U_t(t,Y)} - E\left(\frac{1}{U_t(t,Y)}\right)$ monotonously increases in x. We also know from Lemma 12 that $f(x|1) = f(x|0)$ if $x = x_0$, which implies $\frac{1}{U_t(t,Y)} - E\left(\frac{1}{U_t(t,Y)}\right) = 0$ at the point $x = x_0$. Therefore, we have:

$$\frac{1}{U_t(t,Y)} - E\left(\frac{1}{U_t(t,Y)}\right)\begin{cases} < 0 \text{ if } x < x_0 \\ > 0 \text{ if } x > x_0 \end{cases}$$

This combining with Lemma 12 and Eq.19 implies $\mu - \lambda < 0$ if $x \neq x_0$.

Obviously, the first order condition in the full information case can be written as:

$$\frac{1}{U_t(t,Y)} = \lambda \tag{20}$$

Comparing Eq.18 with Eq.20, we therefore conclude:

$$t^{SB}(x)\begin{cases} < t^*(x) \text{ if } x < x_0 \\ = t^*(x) \text{ if } x = x_0 \\ > t^*(x) \text{ if } x > x_0 \end{cases}$$

Q.E.D.

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