Measuring efficiency consistent with maximising net benefit

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Abstract

Conventional methods of specifying effects or quality of service variables in economic efficiency measures as outputs framed from a utility bearing perspective reflect underlying economic objectives such as minimising average cost per unit of effect. However, in service industries such as health care where effects of services are incremental and non-tradable once received, an economic objective of minimising average cost per unit effect has been rejected in favour of maximising (incremental) net benefit. More generally, the maximisation of net benefit, which explicitly values effects at willingness to pay threshold, has previously been shown to provide a necessary and sufficient condition for pareto improvement with public expenditure under uncertainty.

In this paper a correspondence method is identified which allows the incorporation of effects in ratio measures of efficiency consistent with the maximisation of net benefit. Framing effects from a disutility perspective and comparing service providers on the cost-disutility plane, with an input specification of effects is demonstrated to allow measures of economic, technical, allocative and scale efficiency and identification of peers consistent with maximising net benefit. This method is illustrated in comparing the relative efficiency of 45 hospitals in New South Wales.

Explicit coverage and comparability conditions of the net benefit correspondence theorem underlying this method are also shown to provide necessary and sufficient conditions for efficiency measures to avoid the inclusion of cream-skimming and cost-shifting. Hence, efficiency measurement should be qualified as including and creating incentives for cost-shifting and cream skimming where these conditions are not satisfied. Consequently, the proposed method is suggested to provide a robust framework to measure efficiency consistent with maximising net benefit and avoid cost-shifting and cream-skimming incentives. Applications are suggested in allowing for the value of effects in efficiency measurement for industries such as health, education and corrective services and more globally for valuing pollution abatement in comparing performance.

Keywords: efficiency measurement; quality of services; maximizing net benefit; cost-shifting; cream-skimming.

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1. Introduction

In public services such as hospitals, costs of services across providers are increasingly compared in countries such as Australia, Canada and the United Kingdom. Parallel to this effects of services, such as mortality, morbidity and readmission in hospitals, are also increasingly being collected in countries including Australia, Canada and the UK (Australian Council on Healthcare Standards 2001, National Health Performance Committee 2000, Wolfson et al. 2002, National Health Service 2002).

When these same countries compare alternative treatment strategies in processes of health technology assessment (National Institute for Clinical Excellence 2001, Australian Government Department of Health and Ageing 2002, Ministry of Health of Ontario 1994), effects are integrated with costs consistent with an objective of maximising net benefit (Claxton et al. 1996, Stinnett et al. 1998). However, a method for integrating the value of effects in ratio measures of economic efficiency consistent with the maximising of net benefit has not been identified. Rather, economic efficiency measures across such providers have either:

(i) ignored effects of care in efficiency measurement, for example with cost per (case-mix adjusted) admission for hospitals;

(ii) modelled effects as exogenous parameters in efficiency measurement (e.g. Zuckerman et al. 1994), and hence been unable to include the value of such effects in estimating economic or allocative efficiency; or

(iii) specified effects as utility bearing outputs in efficiency measurement (Gregan et al. 1997, Puig-Junoy 1998, Dawson et al. 2005), representing, where identifiable, objectives such as average cost per unit effect (average cost effectiveness).

The objective of this paper is to identify a systematic method for including effects in ratio measures of economic efficiency consistent with maximising net benefit. The paper is structured as follows. A correspondence is identified between

(1) maximising net benefit, and

(2) minimising costs plus effects framed from a disutility perspective valued at the same monetary amount per unit of effect as net benefit.

This correspondence is shown to allow economic efficiency measures consistent with maximising net benefit on the cost-disutility plane. This method is illustrated in comparing relative efficiency of 45 hospitals based on their means cost and mortality rate per admission. The relative merits of the proposed method to previous methods for including effects as quality of service indicators are discussed and consequently conclusions are drawn on the usefulness of the proposed approach.

2. Measuring economic efficiency consistent with an appropriate objective

When comparing service providers such as hospitals, economic performance measures have historically ignored quality of care indicators concentrating on ‘homogenous’ intermediate measures of output such as “case-mix” (relative service cost intensity) adjusted admissions. This concentration on intermediate outputs has been: “largely because measurement problems are less constraining.” (McGuire et al. 1988) p.218.

However, economic performance measures such as cost per case-mix adjusted admission, which include costs of (implicitly), but ignore effects of, quality of services, do not create appropriate incentives for service quality. Effects and costs of services are jointly influenced by quality and hence including the cost but not the value of quality in efficiency measurement will create incentives for cost minimising quality of services. The importance of considering the joint relationship between value and cost of quality in considering efficiency was highlighted by Harris in his paper on the internal organisation of the hospital, split between clinicians with an objective of health maximisation, and administrators with an objective of cost minimisation:

> "The failure to recognize that doctors and hospitals are linked by a strong bond of joint production is the basis of many of the hospitals inefficiencies." (Harris 1977 p.475).

The desirability of taking into account value (of effects) as well as costs of quality of services is reinforced when considering the impact of quality of services on expected costs and effects post service. Health systems are characterised by incomplete vertical integration across health services (Evans 1981) and hence, quality of hospital care within an admission can have significant impacts beyond post separation on the wider health system.

Where hospitals are not held accountable for the expected effects of their care beyond separation, perverse economic incentives are created for practices such as quicker-sicker care, cost-shifting and quality-skimping (Smith 2002). For example, with performance measured by cost per case-mix adjusted separation, performance improves when within admission costs per patient fall and hence providers can improve performance by earlier release of sick patients (quicker-sicker care). However, while such practices can reduce cost per admission, they have expected negative effects on health effects beyond hospital separation (effect or outcome shifting) and consequently increase expected demands for and use of care post-discharge (cost-shifting). Such cost-shifting may manifest in increasing rates of readmission to hospitals, treatment in other institutional settings (general practice, specialist and aged care services), or informal care in non-institutional settings. More generally, accounting for effects over time in efficiency measurement would appear to be necessary to avoid perverse incentives and create incentives for appropriate quality of services. However, the question remains as to how effects should be included in efficiency measurement.

Health economists have stressed the importance of evaluating strategies relative to a comparator and informing decision makers of incremental rather than average cost–effectiveness ratios (Drummond et al. 1997, Drummond et al. 1987, Drummond et al. 2005). This rejection of average cost effectiveness ratios in favour of incremental cost effectiveness ratios is based on the incremental and non-tradable nature of health effects of care in treated populations (McGuire et al. 1988) p.32 (Eckermann 2004) pp.134-135. Hence in service industries such as health care, effects of a process of care or intervention require consideration relative to counterfactual alternatives (even if doing nothing), and cannot simply be scale up in a treated population by repeating services..

Decision making based on considering incremental health effects relative to the incremental cost of alternative strategies in processes of health technology assessment, was suggested by Claxton and Posnett (1996) as equivalent to maximizing the net value of incremental effects of a technology at a threshold willingness to pay (WTP) for effects minus incremental costs. Stinnett and Mullahy (1998) described this net value of incremental effects less incremental costs for a strategy relative to a comparator as incremental net benefit. Formally, incremental net monetary benefit (*INMB*) per patient can be represented for a given strategy (*i*), relative to a comparator (*c*), as:

$$INMB_i = k(E_i - E_c) - (C_i - C_c) \qquad (1)$$

where k represents the threshold willingness to pay per unit of effect, E is effect per patient, and C is cost per patient.

The maximisation of net benefit has therefore been established in health technology assessment as the appropriate objective underlying public decision making in comparing alternative health care strategies. More generally, the maximisation of net benefit in equation (1) is shown by Graham (1981,1992) to provide a necessary and sufficient condition to for pareto improvement, ensuring marginal benefit equals marginal cost under uncertainty in cost-benefit analysis. Graham (1992) also established net benefit criteria necessary and sufficient for pareto efficient public expenditure under uncertainty. Hence, if efficiency measurement for public services such as health care are to align with pareto improving solutions to public expenditure under uncertainty an objective function for including effects in efficiency measurement of maximising net benefit is suggested.

However, historically, methods proposed to include effects of services, (such as mortality, morbidity and readmission) in efficiency measurement have attempted to specify them under the ‘quality-quantity trade-off’ suggested by Newhouse (Newhouse 1970). Methods previously suggested for specifying effects in performance measurement under this trade-off can be broadly characterised as:

(i) Exogenous methods: Conditioning of activity-based measures of performance on rates of effects, for example in the study of Zuckermann et al.(1994) conditioning cost per case-mix adjusted admission on whether case-mix-adjusted mortality rate was in the upper or lower decile;

(ii) Endogenous methods: Specifying health effects framed from a utility bearing perspective as outputs, for example use of survival in Puig-Junoy (1998) and effects more generally (survival, life years, quality adjusted life years) in Dawson et al. (2005).

However, as Eckermann (2004, pp.136-138) describes in detail neither of these approaches to specifying health effects in efficiency measures represent the underlying economic objective of maximising net benefit underlying health technology assessment. The first set of specifications, conditioning performance on rates of effects, effectively treat effects as exogenously determined environmental variables (outside the control of the hospital), rather than endogenously determined variables representing quality of care. The inability of such specifications to represent effects as quality of care indicators is made clear in the study of Zuckermann (1994). Expected costs were adjusted upwards for hospitals that had mortality rates in either the lower or upper decile (low or high quality of care) in comparison to hospitals in the tenth to ninetieth percentile. Consequently, the exogenous treatment of effects resulted in the ten percent in both the highest and lowest quality providers having their performance (expected relative to actual costs at their level of mortality) increased relative to other providers. In general, specifying health effects as exogenous variables prevents their value being included in economic or allocative efficiency measurement. Hence, an exogenous specification of health effects cannot represent maximisation of net benefit.

The second set of endogenous specifications framing effects from a utility bearing perspective (e.g. survivors, reduction in morbidity, reduction in re-admission) and specifying them as outputs in efficiency measurement recognises an interaction between quality and quantity of care However, even, in the simplest case with one measure of effect, if a value is attached per unit of effect as proposed in Dawson et al (2005), these values cancel in comparing relative performance. Hence the implicit underlying objective from an output specification of effects from a utility-bearing perspective is at best minimising average cost per unit effect, as demonstrated by Eckermann (Eckermann 2004, Eckermann et al. 2006). For example, if the average cost per survivor between two hospitals is 1.1 then the ratio will remain 1.1 if effects are valued, regardless of the value. Endogenous specifications of effects of care framed from a utility-bearing perspective, like endogenous output specifications of effects have problems of invariance to the value attributed to effects of care in comparing performance. Consequently, neither specification of health effects as outputs framed from a utility bearing perspective or exogenous specification of can reflect an objective of maximising net benefit.

3. Measuring economic efficiency consistent with maximizing net benefit

Economic efficiency measures across public service such as hospitals should be consistent with maximising net benefit to provide incentives encouraging pareto efficiency. However, while the net benefit formulations in equation (1) represents an objective which can appropriately trade off the value of incremental effects and costs of (quality of) care, they do not have radial (ratio) properties required for economic efficiency measurement.

The lack of radial properties in (1) is evident in comparison of strategies on the incremental cost effectiveness plane, where incremental costs and effects can be positive or negative. Consequently there are 4 rather than one quadrant for consideration with equation (1), with performance only unequivocally improving in contracting to a vertex in the quadrant where incremental cost is positive and incremental effect is negative. However, a linear transformation of the net benefit statistic in equation (1) could permit radial properties, while retaining an underlying objective of maximizing net benefit.

Consider a bilateral comparison between service providers *i* and *j*, where incremental effect per service for provider *i* can be expressed by differences in a single rate of effect, which framed from a utility bearing perspective we label E^u (e.g. survival rate).We let *k* be the associated decision maker's threshold WTP per unit effect. Without loss of generalization (order is arbitrary in establishing a correspondence), let

$INMB_i > INMB_j$

Then from equation (1), when two providers with a common comparator (no difference in expected rate of health outcome and costs of care) are compared, the comparator terms cancel.

$$\Leftrightarrow k \times E_i^u - C_i > k \times E_j^u - C_j \qquad (2)$$

Now, if we multiply both sides of equation (2) by minus 1, the sign changes and we translate from maximizing net benefit per service to minimizing net loss per service:

$$\Leftrightarrow C_i - k \times E_i^u < C_j - k \times E_j^u \qquad (3)$$

Adding *k* to both sides of equation (3) and re-arranging with common factors we obtain:

$$\Leftrightarrow C_i + k \times (1 - E_i^u) < C_j + k \times (1 - E_j^u) \qquad (4)$$

Now, if E^u is rate of effect framed from a utility bearing perspective (e.g. survival rate) then $(1 - E^u)$ represents the rate of services framed from a disutility bearing perspective, E^{DU} (e.g. mortality rate).

$$\Leftrightarrow C_i + k \times E_i^{DU} < C_j + k \times E_j^{DU} \qquad (5)$$

Therefore, where effects are currently represented by the rate of an event framed from a utility bearing perspective (survival, absence of morbidity, functional ability), maximising net benefit is equivalent to minimising costs plus the value of this effect framed from a disutility perspective (mortality, morbidity, functional limitation). The necessary and sufficient conditions required for this relationship to hold are that providers face a common comparator (differences in expected cost and effect are adjusted for) and that effects framed from a disutility perspective cover the effects of care in net benefit framed from a utility bearing perspective (coverage condition).

Now, consider whether this correspondence can generalises to multiple effects and differences between providers in expected costs and effects of people receiving services. Let all potential combinations of effects framed from a disutility perspective be represented by ($E_1^{DU}, E_2^{DU}, .., E_m^{DU}$), and associated values of units of effects by ($k_1, ..., k_m$). Then, under the coverage condition of the correspondence theorem, net benefit for any hospital (*i=1,…,n*) can be presented relative to a comparator representing expected costs and effects as:

$$\begin{aligned} INMB_i &= k_1(E_1^{DU}{}_{ci} - E_1^{DU}{}_i) + .. + k_m(E_m^{DU}{}_{ci} - E_m^{DU}{}_i) - (C_i - C_{ci}) \\ &= (k_1 \times E_1^{DU}{}_{ci} + .. + k_m \times E_m^{DU}{}_{ci} + C_{ci}) - (k_1 \times E_1^{DU}{}_i + .. + k_m \times E_m^{DU}{}_i + C_i) \end{aligned} \tag{6}$$

Without loss of generalization, let $INMB_i > INMB_j$, then from (6) $\Leftrightarrow$

$$-(k_1 \times E_1^{DU}{}_i + .. + k_m \times E_m^{DU}{}_i + C_i) > -(k_1 \times E_1^{DU}{}_j + .. + k_m \times E_m^{DU}{}_j + C_j) + z \tag{7}$$

Where: $z = -(k_1 \times E_1^{DU}{}_i + .. + k_m \times E_m^{DU}{}_i + C_i)$

Multiplying both sides of (7) by minus 1, the sign changes and we translate from maximizing net benefit to minimizing net loss per admission:

$$\Leftrightarrow \quad k_1 \times E_1^{DU}{}_i + .. + k_m \times E_m^{DU}{}_i + C_i < k_1 \times E_1^{DU}{}_j + .. + k_m \times E_m^{DU}{}_j + C_j \tag{8}$$

Now, if absolute differences in expected costs and disutility events are adjusted for, this is equivalent to adding the term z to the right-hand side of equation (8) in any bilateral comparison. Hence, provided absolute differences in expected costs and disutility event rates are adjusted for, a one-to-one correspondence is maintained between:

(i) maximizing net benefit and

(ii) minimizing the sum of cost and effects framed from a disutility perspective ($E_1^{DU},..,E_m^{DU}$), valued per unit effect as in net benefit ($k_1,..,k_m$).

Now, consider whether this correspondence can be extended further to cases where effects are measured by time dependant variable such as life years or quality adjusted life years in health care. The proof for the case of multiple strategies established that satisfying the common comparator assumption is equivalent to adjusting for differences in expected costs and effects (patient risk factors) across providers. We make use of this result to simplify the proof for cases where effects are measures by life years or quality adjusted life years.

Let incremental net monetary benefit be represented incremental to the highest observed QALYS and to satisfy the common comparison condition let Q and C represents QALYs and cost per patient adjusted for expected differences in patient risk factors. Then the incremental net monetary benefit of each provider can be represented by:

$$INMB_i = k \times (Q_i - Q_{Q\max}) - (C_i - C_{Q\max}) \quad (10)$$

Without loss of generalisation, let $INMB_i > INMB_j$

$$\Leftrightarrow k \times (Q_i - Q_{Q\max}) - (C_i - C_{Q\max}) > k \times (Q_j - Q_{Q\max}) - (C_j - C_{Q\max}) \quad (11)$$

$$\Leftrightarrow k \times (Q_{Q\max} - Q_i) + C_i < k \times (Q_{Q\max} - Q_j) + C_j \quad (12)$$

Now, let E^{DU} be life years or quality adjusted life year lost relative to the highest attained.

$$E_i^{DU} = Q_{Q\max} - Q_i \quad (13)$$

$$\Leftrightarrow k \times E_i^{DU} + C_i < k \times E_j^{DU} + C_j \quad (14)$$

QED

Hence, If the net benefit for services of provider *i* is greater than that of provider *j*, then the sum of cost per service and effects per service, framed from a disutility perspective and valued per unit effect as in net benefit ($k \times E_i^{DU} + C_i$), are less for *i*, under correspondence conditions of coverage and comparability. The cases of effects represented by a single event rate, multiple event rates, and time dependent effects such as life years illustrate that this is the case regardless of how effects are measured. This relationship can be formally stated as the net benefit correspondence theorem (Eckermann 2004).

3.1 The net-benefit correspondence theorem

There is a one-to-one correspondence between maximising net benefit, and minimising cost plus the value of effects in net benefit framed from a disutility perspective (e.g. mortality, morbidity, functional limitation, life years lost or QALYS lost), where the following conditions are satisfied:

(i) Effects framed from disutility perspective cover effects of services (coverage condition);

(ii) Expected differences in costs and disutility are adjusted for (comparison condition).

Figure 1 graphically illustrates the correspondence between maximizing net benefit and minimizing $k \times E^{DU} + C$. In figure 1 a lower rate of E^{DU} (e.g. mortality, morbidity, functional limitation, loss of life years or loss of QALYs) per admission represents increasing quality of care under correspondence conditions. The efficiency frontier (ABC) represents the technically feasible trade-off between cost and E^{DU}, which *a priori* is expected to reflect diminishing returns to resources (costs), as E^{DU} approaches 0 (quality of services increases).

Incremental net benefit is the value of incremental effects less incremental costs relative to a comparator. For providers in figure 1 the value of incremental effects conditional on rate of disutility is represented by DE, a line whose slope represents the threshold value of effects (k), and is positive for rates of disutility below that of the comparator and negative for rates of disutility above that of the comparator. For providers on the efficiency frontier ABC, incremental costs relative to a common comparator are represented by FGH, a parallel shift down in the vertical plane of this frontier by the cost per service of a common comparator. Therefore, incremental net benefit for providers on the frontier is shown by the curve IJ, equivalent to the value of incremental health effect (DE) conditional on rate of disutility, less incremental cost (FGH). This incremental net benefit curve is maximised where the marginal cost of reducing disutility

(|slope of FGH|) equates with the marginal value of reducing disutility (|slope of DE|, k).

Now, the efficiency frontier ABC and incremental cost curve of providers on the frontier FGH have the same slope at the same level of disutility as there is a constant vertical distance between them equivalent to the cost of the comparator. Hence, the quality of care (E^{DU}) at which net benefit is maximised will correspond to where the efficiency frontier ABC has slope –k, point E in figure 1. At E, level lines of the form cost plus disutility events valued at the decision makers threshold (k) equals a constant, have their value minimised across the feasible set of convex cost-disutility combinations. Hence for providers on the frontier there is a correspondence between maximising incremental net benefit and minimising incremental cost plus the value (at k per unit of effect) of incremental effects framed from a disutility perspective.

More generally, differences in net benefit between providers can be measured on the cost-disutility plane under correspondence conditions as distances between level net benefit lines, with providers closer to the origin having higher net benefit. Therefore, a complete ordering across providers consistent with that of maximising net benefit can be established in the cost-disutility plane for any given value of effects by considering the relative position of such level lines that providers lie on. Distances measured between net benefit lines on the cost axis represent differences in net monetary benefit per admission while distances measured on the disutility axis represent differences in net effect benefit.

4. Applying the net benefit correspondence to efficiency measurement

The net benefit correspondence theorem provides a general method for comparing efficiency of providers consistent with an economic objective of maximizing net benefit. The net benefit formulation in equation (1) on the incremental cost effectiveness plane does not permit efficiency measures. However, a linear transformation onto the cost-disutility plane in equation (6) allows efficiency measures consistent with maximising net benefit. Equi-proportionally reducing costs and effects framed from a disutility perspective, E^{DU} increases net benefit, allowing radial properties and ratio measures of performance consistent with maximising net benefit. Hence, efficiency measurement methods based on ratio measures such as index or frontier methods can be applied to estimate economic efficiency consistent with maximising net benefit on the cost-disutility plane. Such methods applied on the cost-disutility plane also permit decompositions of economic efficiency consistent with maximising net benefit into scale, technical and allocative efficiency on the cost-disutility plane, to allow a richer story of sources of inefficiency to be told.

4.1 Decomposition of net benefit efficiency with frontier methods

Figure 1 illustrated that to maximise net benefit in the cost-disutility plane it is necessary to be on the convex efficiency frontier representing minimum cost per service conditional on E^{DU} or, equivalently, minimum E^{DU} conditional on cost. Net benefit is maximised at the point of tangency between a net benefit line closest to the origin (with slope -k representing the value of a unit of effect) and the frontier representing the boundary of feasible convex combinations of strategies on the cost-disutility plane (at B in figure 1). Therefore, being on the efficiency frontier (technically efficient) is a necessary, while not sufficient, condition for net benefit maximization under correspondence conditions, which additionally depends on the value of effects.

Consequently, reductions in net benefit can be simply decomposed into sources of technical and allocative inefficiency on the cost disutility plane using existing methods based on radial properties, such as data envelopment analysis (DEA). DEA allows estimation of technical inefficiency on the cost disutility plane under constant returns to scale (Charnes et al. 1978) as the proportion by which cost and E^{DU} per patient can be reduced to a frontier constructed as a convex piecewise linear hull of observed best practice. Figure 2 illustrates efficiency measurement relative to such a DEA frontier in the cost disutility plane, where all conventional inputs per admission are represented by cost per patient and effects by E^{DU} (e.g. mortality, morbidity, functional limitation, life years lost or quality adjusted life years lost).

For a provider at *P* in figure2, technical efficiency of net benefit under constant returns to scale (CRS) is estimated relative to the unit isoquant (*TT'*) minimizing cost and rate of disutility per admission as *OQ/OP*. This estimate of technical efficiency does not depend on the value of effects represented by the rate of disutility. At a decision maker's value for effects of *k*, economic efficiency can be measured consistent with maximising net benefit, relative to the level net benefit line at the point of tangency to the frontier. For example, for a provider at P in Figure 2, economic (net benefit) efficiency is estimated as *OR/OP*.

Consequently, allocative efficiency of net benefit (the appropriateness of factor proportions for inputs given decision makers value of effects) can also be estimated as the residual of economic efficiency and technical efficiency under constant returns to scale, equivalent to *OR/OQ* for a provider at P.

Technical efficiency can also be estimated with DEA formulations under variable returns to scale (Banker et al. 1984) and not increasing returns to scale (Färe et al. 1994). Hence, scale efficiency can be estimated as the residual of technical efficiency under VRS and CRS, while comparison of not increasing returns to scale and CRS formulations allow an indication of whether scale inefficiency is attributable to increasing or decreasing returns to scale (Coelli et al. 1998).

4.2 Identification of best practice conditional on value of effects

To maximise net benefit at any given value for effects of care it is necessary for providers to be on the technical efficiency frontier where no equi-proportional reduction in cost and E^{DU} is possible. The regions of threshold WTP for effects of care over which each of these technically efficient hospitals maximise net benefit are simply identified by back-solved between adjacent technically efficient providers with:

$$C_i + k \times DU_i = C_j + k \times DU_j \Leftrightarrow k = (C_j - C_i)/(DU_j - DU_i) \qquad (13)$$

4.3 Implicit industry value of quality (shadow price)

Economic efficiency for each provider compared can be estimated conditional on k, the threshold WTP of effects, by simply changing the slope of net benefit lines in the cost-disutility plane and altering the point of tangency to the frontier in figure 2. Therefore, weighting economic efficiency for each provider by their industry share of costs, an industry economic efficiency can be estimated. Mapping industry economic efficiency against potential values for a unit of effect, the shadow price of effects (quality) of care in industry behaviour can be simply identified as the value that maximizes industry economic (and allocative) efficiency.

5. Illustrating efficiency measurement in the cost-disutility plane

We compare performance of forty-five Australian acute care public hospitals in treating patients for DRG E62a (respiratory infection). This comparison is based on cost and admission data collected by the Australian National Hospital Cost Data Collection (NHCDC) as part of the annual sample used to construct DRG weights (Australian Government Department of Health and Aged Care 2000), and data provided by the New South Wales Health Department on in hospital mortality rate. The cost per admission and mortality rate for these forty-five hospitals in treating patients for DRG E62a are shown in figure 3, with cost per admission on the horizontal axis and mortality rate on the horizontal axis.

Technical inefficiency of providers reflects the degree of radial contraction to the frontier possible, while economic inefficiency reflects the degree of radial contraction to the net benefit level line tangent to the frontier, illustrated at a value of $30,000 per life saved in figure 3. Where the value of effects is uncertain, economic efficiency can be conditioned on potential (plausible) values for effects of care. In table 1 economic efficiency across the 45 hospitals are reported:

1. with the proposed method at potential WTP thresholds of $0 (corresponding to current methods with an implicit objective of minimizing cost per admission), $10 000, $25 000 and $50 000 per life saved, and;
2. for an alternative output specification of health effects, where economic efficiency measurement is based on minimising cost per survivor.

The alternative specification applies the method suggested by Dawson et al (2005) and Puig-Junoy (1998) for including health effects in efficiency measures as utility bearing outputs.

Using the proposed method, peers (economic efficiency of 1) and relative ordering of economic efficiency are conditional on the WTP threshold for the effect of survival in table 1. At $0 per life saved (corresponding to minimising cost per admission), hospital 26 is a peer and benchmark with the lowest cost of $3590 per admission, while hospital 33 with a cost per admission of $5283 has economic efficiency of 0.70. However, at $50,000 per life saved, hospital 33 with a 3.3% mortality rate is the peer, while hospital 26 with a 17.0% mortality rate has economic efficiency of 0.58. Differences between the ordering at a value of effects of 0 and that of a decision maker reflects the divergence between minimising cost per admission and maximising net benefit.

Using the alternative method based on average cost effectiveness, economic efficiency minimising cost per survivor (last column of table 1) is invariant to the value of survival. Regardless of the value of survival, hospital 17 would be identified as economically efficient (cost per survivor of $4258), while hospital 26 would have economic efficiency of 0.98 (cost per survivor of $4325) and hospital 33 0.78 (cost per survivor of $5463). Hence, an output specification of effects framed form a utility-bearing perspective has an inability to incorporate the value of health effects in estimating economic efficiency and cannot be consistent with maximising net benefit, unlike the proposed method,.

Having empirically illustrated the advantages of the proposed method in representing economic efficiency measures consistent with maximising net benefit we now empirically consider its decomposition. Technical efficiency under CRS and VRS, scale efficiency as the residual of CRS technical efficiency divided by VRS technical efficiency, and an indicator of whether scale inefficiency is attributable to increasing or decreasing returns to scale are presented in table 2 for the 45 compared hospitals. Hospitals 26, 17 and 33 are technically efficient under constant returns to scale, reflecting those hospitals on the frontier in figure 3. Their cost and mortality per admission cannot be equi-proportionally reduced in comparison with convex combinations of all other hospitals. Technically efficiency calculated under a variable returns to scale formulation of DEA, has a more restrictive comparison of peers. This is reflected in fourteen of the hospitals identified as technically efficient under a variable returns to scale DEA formulation.

Applying the back solving formulae in equation 13, hospitals 26, 17 and 33 which are technically efficient under constant returns to scale are economically efficient for value per additional survivor of $0 to $3523, $3524 to $24356 and greater than $24356, respectively. The industry cost share weighted economic efficiency is maximised at $3523 per life saved, as illustrated in figure 3. This shadow price for the value of survival across the 45 compared hospitals reflects the economic incentive for cost minimising quality of care under case-mix funding, rather than the objective of net benefit maximisation implicit in processes of health technology assessment.

In summary, applying the proposed correspondence method to compare hospital efficiency on the cost-disutility plane has been illustrated to, unlike alternative methods, allow:

(i) economic efficiency consistent with maximising net benefit and its decomposition into technical, allocative and scale efficiency;

(ii) values for health effects over which providers are peers; and

(iii) the shadow price of health effects (quality of care) in industry behaviour.

However, in applying the net benefit correspondence theorem with available data in our case example, assumptions are required in each case that comparability and coverage conditions were satisfied. The assumption that these conditions were satisfied would also be implicitly made with application of other methods, but are explicit with the net benefit correspondence theorem underlying the proposed method. Comparability and coverage conditions are clearly not met with the cost and mortality data used in comparing the forty-five Australian hospitals for DRG E62a, as they were not adjusted for differences in patient risk across hospitals and did not allow for cost and health effects beyond point of discharge or non-survival effects within admission. This raises complementary questions of:

1. What are the requirements to robustly satisfy coverage and comparability conditions?
2. What are the implications where these requirements are not satisfied?

5.1 Efficiency measurement where coverage and comparability conditions are not met

To apply the net benefit correspondence theorem to efficiency measurement without qualification requires coverage and comparability conditions are met in practice. However, satisfying coverage and correspondence conditions are also necessary and sufficient to prevent incentives for cost-shifting and cream-skimming respectively, and would be required to prevent these incentives whatever method were applied. To illustrate why this is the case, consider what is required to avoid cream-skimming and cost-shifting being measured as performance improvement, and hence perverse incentives for these activities being created by performance measures.

Incentives to choose patients with lower expected costs and higher expected effects (cream-skim) will be created by performance measures unless differences in the expected cost and effects of care (patient risk factors), at point of admission, are adjusted for. Adjustment of costs and effects for patient risk factors at point of admission are also required to satisfy the common comparison condition. Therefore, adjusting rates of costs and effects per admission across compared providers for predictive patient risk factors satisfies the common comparator condition and prevent incentives for cream-skimming. However, if risk adjustment of costs and effects is not undertaken, as in the illustrated comparison across forty-five hospitals, the common comparison condition is not satisfied and relative performance measures include, and hence create incentives for, cream-skimming. Hence, satisfying the common comparator condition is necessary and sufficient to prevent cream-skimming being measured as improved performance, and prevent incentives being created by performance measures for cream-skimming.

Similarly, in considering the coverage condition, incentives are created for cost-shifting and health outcome-shifting with hospital economic efficiency measurement unless costs and health effects beyond separation are adjusted for in performance measurement. However, adjusting for these effects beyond point of separation are also required to satisfy the coverage condition of the net benefit correspondence theorem. In our hospital example, adjustment of within admission mortality rates and costs per patient to a common time point with data linkage or modelling expected effects conditioning on expected health state at point of separation would be required to satisfy the coverage condition and prevent incentives for cost, and outcome, shifting. In the absence of adjustment for actual or expected costs and mortality beyond point of separation, relative performance measurement should be qualified as incorporating and hence creating incentives for, cost and outcome, shifting. Hence, satisfying the coverage condition is necessary and sufficient to prevent incentives for cost, and outcome, shifting.

In summary, efficiency measurement should be qualified as reflecting and creating incentives for cost, and outcome, shifting and cream-skimming to the extent that correspondence conditions of coverage and comparability are respectively not met. The lack of risk adjustment or data linkage in the illustrated example clearly qualifies efficiency measurement as including and creating incentives for cream-skimming and cost, and mortality, shifting. However, these qualifications would be present given the available cost and mortality data and should be identified whatever efficiency measurement method was employed.

Hence, while application of the net benefit correspondence theorem does not overcome cream-skimming and cost-, and outcome-, shifting incentives, comparability and coverage conditions create an explicit and systematic framework to account for them, a framework absent with alternative methods. Application of the correspondence theorem where coverage and comparability conditions are satisfied avoids cream-skimming and cost-shifting in addition to allowing economic efficiency measurement consistent with maximising net benefit, unlike alternative methods.

6. Discussion

Newhouse, when critiquing the use of frontier methods to estimate efficiency of hospitals at an aggregate level (such as that of Zuckerman, Hadley and Lezzioni, 1994), raised concerns about their ability to adequately model quality of care and allow for heterogeneous hospital activities (Newhouse 1994). Implicitly, these concerns relate to questions of the appropriateness of the underlying objective function that efficiency measures represent and the appropriate level of analysis.

In this section we compare the specification of effects as quality of care variables under the proposed method with previously suggested methods. Previously proposed methods, where health effects are specified as exogenous variables, or as utility bearing endogenous outputs, do not allow the relative value of health effects are not able to be included in economic efficiency measures. In comparison, specification of health effects as endogenous inputs framed from a disutility perspective under the correspondence theorem allows the value of effects to be included in economic and allocative efficiency measurement consistent with maximising net benefit. Consequently, the proposed input specification has been demonstrated to provide distinct advantages over output specifications in allowing:

(i) estimation of economic and allocative as well as technical efficiency consistent with maximising net benefit and;

(ii) estimation of a monetary shadow price of quality in the absence of prices for admissions *per se* in public hospitals.

An alternative specification of disutility effects such as pollution or other negative externalities have previously been proposed for technical efficiency measure under the hyperbolic method of Färe, Grosskopf, Lovell and Parsuka (Färe et al. 1989). The hyperbolic method measures technical efficiency in equi-proportionally contracting 'weakly disposable undesirable outputs' and expanding 'strongly desirable outputs'. However, the assumption of weakly disposable undesirable outputs under this hyperbolic method is unable to reflect the value of effects in an economic efficiency measure, effectively treating effects of care as exogenously determined. Figure 4 illustrates technical efficiency measured under the hyperbolic method relative to an efficiency frontier OABCD in equi-proportionally expanding strongly disposable desirable outputs (v, e.g. electricity), and contracting weakly disposable undesirable outputs (w, e.g. pollution). Technical efficiency estimated relative to regions of the frontier such as CD in figure 4, becomes meaningless as a performance measurement where disutility event reflect quality of care, rather than differences in patient populations or other external influences. This is particularly problematic, as output-orientated economic efficiency can not be estimated in the absence of prices for admissions *per se*, and hence technical efficiency measurement effectively becomes the only measure of relative performance. Hence, the proposed method is also simpler and allows greater explanation of hospital efficiency than the hyperbolic method of Färe, Grosskopf, Lovell and Parsuka (Färe et al. 1989)The related method of Färe, Grosskopf, Lovell and Yaisawarang (Färe et al. 1993) for estimating a monetary shadow price of 'undesirable outputs' also cannot be employed in comparing public hospitals in the absence of a price for admissions *per se*.

In summary there are distinct advantages to hospital efficiency comparison from specifying effects framed from a disutility perspective as inputs over alternatively proposed utility bearing output, exogenous or hyperbolic disutility bearing weakly disposable output specifications. Previous studies in environmental economics have also applied and noted the appropriateness of specifying undesirable products such as pollution as inputs in estimating technical efficiency. Pittman (Pittman 1981), Cropper and Oates (Cropper et al. 1992), Haynes et al (Haynes et al. 1993, Haynes et al. 1994) and Rheinhardt, Lovell and Thjissen (Reinhard et al. 1999) have all included undesirable by-products such as pollutants and waste as inputs in technical efficiency measurement. As Pittman (1981) and Reinhardt et al. (1999) suggest, the relationship between a negative variable and an output looks like the relationship between conventional input and output. However, these studies did not consider economic or allocative efficiency, where the method outlined in this paper provides the theoretical support for specifying effects from a disutility perspective as inputs to represent value of effects in efficiency measurement consistent with maximising net benefit. While this has been illustrated in comparing hospitals in this paper, the proposed method is general and can equally be applied to measure efficiency allowing for effects consistent with maximising net benefit wherever the valuing of effects and objective of maximising net benefit is appropriate. Natural applications are suggested in service industries such as education (lack of employment), corrective services (recidivism) but also industries with external effects, such as pollution in energy generation (Eckermann 2004 pp. 274-278).

In addition to advantages related to representing a more appropriate objective in specifying effects, the coverage and comparison conditions of the net benefit correspondence theorem also provide an explicit theoretical framework to account for cost-shifting and cream-skimming. Performance measures should be qualified when these conditions are not satisfied, regardless of which efficiency measures are employed. To satisfy correspondence conditions and avoid incentives for cream-skimming and cost and event shifting, a three stage approach is suggested:

1. Identify the effects of care using decision-analytic methods (as in health technology assessment).
2. Measure effects of care identified in stage 1 in their natural unit, allowing for costs and effects beyond service either with data linkage, or modelling expected effects conditional on surrogates such as health state at point of discharge.
3. Standardise providers' effects (cost and effects) for differences in baseline population risk factors across providers.

The resulting standardised measures (costs and effects) can then be robustly applied in efficiency measurement. The first two steps are aimed at satisfying the coverage condition and preventing incentives for cost and effect shifting, while the third step is required to prevent incentives for cream skimming and satisfy the comparison condition.

In applying the net benefit correspondence theorem some standardised rates of effects across providers may need to be reframed from a disutility perspective.

In health care many effects are naturally measured from as disutility event rates, whether as rates of mortality, morbidity, functional limitation or readmission. However, where they are naturally measured from a utility bearing perspective they can be simply reframed from a disutility perspective. Utility translates to disutility, life years to life years lost and quality adjusted life years (QALYs) to QALYs lost. Framing health effects from a disutility perspective can always be undertaken regardless of how effects have been measured from a utility bearing perspective, as demonstrated in the correspondence theorem proof. For example, utility bearing effects outside of health effects, such as those related to process of care and the sovereignty of the patient could also be robustly included in efficiency measurement under the net benefit correspondence theorem. Where required, reframing of such standardised measures from a disutility perspective to apply the net benefit correspondence theorem can be undertaken wherever they are naturally measured from a utility-bearing perspective.

7. Conclusion

The maximisation of net benefit has previously been established as an appropriate, pareto improving, economic objective wherever value of effects are important considerations (Graham 1981, 1992). In health technology assessment maximising net benefit has been established as preferred to average cost effectiveness in reflecting and accounting for incremental and patient specific characteristics of health service effects in treated populations (Drummond 1987, 1997). However, current methods for specifying effects in comparing economic efficiency of health care providers, such as hospitals, in practice do not represent an underlying objective of maximising net benefit. The objective of this paper was to identify a systematic method for comparing economic efficiency of providers in practice consistent with maximising net benefit. The paper has made two main contributions with respect to this objective. First, a correspondence method has been identified for specifying effects in ratio measures of performance, consistent with an economic objective of maximising net benefit. An input specification of effects framed from a disutility perspective has been illustrated to, unlike alternative specifications, allow:

1. estimation of economic efficiency, its decomposition into technical, scale and allocative efficiency and peer identification consistent with maximising net benefit and;
2. estimation of the shadow price for quality of care, in the absence of prices for admissions *per se*.

Second, coverage and comparability conditions of the net benefit correspondence theorem underlying the proposed method have been shown to provide an explicit framework to account for cost-shifting, and cream-skimming in performance measurement. Satisfying the coverage and common comparison conditions are necessary and sufficient to prevent performance measures creating incentives for cost-shifting and cream-skimming, respectively. Therefore, while coverage and correspondence conditions are explicit in applying the net benefit correspondence theorem to relative performance measurement, they are also implicit in accounting for cost-shifting and cream skimming with alternative methods. Whatever performance measurement framework is applied, performance measures should be qualified where these conditions are not satisfied, and more generally they support risk adjustment and data linkage to prevent cost-shifting and cream-skimming incentives.

In conclusion, the approach outlined in this paper links the advantages of an appropriate economic objective function in maximising net benefit with radial properties of efficiency measurement to allow a story in explaining sources of inefficiency. The correspondence theorem underlying this method offers a framework to avoid incentives for cream-skimming and cost-, and effect-, shifting while creating incentives for net benefit maximising quality of care.

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Table 1: Economic efficiency of 45 hospitals treating patients with respiratory infection (DRG E62a) conditional on value of survival (k)

Hospital	Cost per Admission (A$1998)	Mortality rate	Minimum cost per admission plus mortality rate multiplied by k (value of health outcome) k=$0	k=$10,000	k=$25,000	k=$50,000	Minimum cost per survivor
1	4830	40.0%	0.74	0.54	0.41	0.28	0.53
2	9224	25.0%	0.39	0.41	0.4	0.32	0.35
3	8056	7.7%	0.45	0.54	0.61	0.58	0.49
4	12409	7.1%	0.29	0.37	0.43	0.43	0.32
5	5123	40.0%	0.7	0.53	0.4	0.28	0.50
6	8249	6.3%	0.44	0.54	0.62	0.61	0.48
7	4138	35.0%	0.87	0.63	0.47	0.32	0.67
8	6000	14.3%	0.6	0.65	0.64	0.53	0.61
9	7382	13.0%	0.49	0.55	0.57	0.5	0.50
10	6649	4.2%	0.54	0.68	0.8	0.8	0.61
11	7545	4.2%	0.48	0.6	0.71	0.72	0.54
12	8301	32.0%	0.43	0.42	0.38	0.29	0.35
13	6052	38.5%	0.59	0.48	0.39	0.27	0.43
14	13128	3.6%	0.27	0.36	0.44	0.47	0.31
15	6616	10.3%	0.54	0.63	0.66	0.59	0.58
16	6199	25.0%	0.58	0.55	0.49	0.37	0.52
17	**3858**	**9.4%**	**0.93**	**1.00**	**0.99**	**0.81**	**1.00**
18	7411	24.2%	0.48	0.49	0.45	0.36	0.44
19	4520	12.1%	0.79	0.84	0.81	0.66	0.83
20	6134	24.3%	0.59	0.56	0.5	0.38	0.53
21	7484	13.5%	0.48	0.54	0.56	0.49	0.49
22	4878	25.6%	0.74	0.64	0.54	0.39	0.65
23	5890	20.5%	0.61	0.6	0.56	0.43	0.57
24	5296	30.0%	0.68	0.58	0.48	0.34	0.56
25	4543	21.3%	0.79	0.72	0.62	0.46	0.74
26	**3590**	**17.0%**	**1.00**	**0.91**	**0.78**	**0.58**	**0.98**
27	6132	6.0%	0.59	0.71	0.8	0.76	0.65
28	7744	17.6%	0.46	0.5	0.5	0.43	0.45
29	5302	11.3%	0.68	0.75	0.75	0.64	0.71
30	5920	32.0%	0.61	0.53	0.44	0.32	0.49
31	5518	17.3%	0.65	0.66	0.62	0.49	0.64
32	6779	27.4%	0.53	0.5	0.45	0.34	0.46
33	**5283**	**3.3%**	**0.68**	**0.85**	**1.00**	**1.00**	**0.78**
34	6977	9.9%	0.51	0.6	0.65	0.58	0.55
35	7407	23.8%	0.48	0.49	0.46	0.36	0.44
36	5189	25.0%	0.69	0.62	0.53	0.39	0.62
37	5820	29.8%	0.62	0.54	0.46	0.34	0.51
38	6887	23.3%	0.52	0.52	0.48	0.38	0.47
39	6424	31.0%	0.56	0.5	0.43	0.32	0.46
40	5921	20.6%	0.61	0.6	0.55	0.43	0.57
41	5618	28.6%	0.64	0.57	0.48	0.35	0.54
42	7057	21.3%	0.51	0.52	0.49	0.39	0.47
43	5324	33.5%	0.67	0.55	0.45	0.31	0.53
44	7605	27.4%	0.47	0.46	0.42	0.33	0.41
45	6797	28.3%	0.53	0.5	0.44	0.33	0.45

Table 2: Technical efficiency of net benefit minimising cost and disutility event per admission under constant, variable and non-increasing returns to scale and scale efficiency

Hospital	Technical efficiency (constant returns to scale)	Technical efficiency (variable returns to scale)	Scale efficiency	Technical efficiency (NIRS)*
1	0.74	1.00	0.74	IRS
2	0.41	0.74	0.56	IRS
3	0.61	1.00	0.61	IRS
4	0.47	1.00	0.47	IRS
5	0.70	0.84	0.83	IRS
6	0.62	1.00	0.62	IRS
7	0.87	0.98	0.88	IRS
8	0.65	0.82	0.79	IRS
9	0.58	0.68	0.86	IRS
10	0.80	1.00	0.80	IRS
11	0.80	1.00	0.80	IRS
12	0.44	0.48	0.93	IRS
13	0.59	0.64	0.92	IRS
14	0.93	1.00	0.93	IRS
15	0.67	0.73	0.92	IRS
16	0.59	0.62	0.96	IRS
17	**1.00**	**1.00**	**1.00**	
18	0.51	0.52	0.98	IRS
19	0.847	0.849	0.998	IRS
20	0.60	0.61	0.98	IRS
21	0.57	0.57	0.99	IRS
22	0.74	0.76	0.97	IRS
23	0.633	0.634	0.999	IRS
24	0.68	0.70	0.97	IRS
25	0.79	0.80	0.99	IRS
26	**1.00**	**1.00**	**1.00**	
27	0.80	0.81	0.99	DRS
28	0.51	0.58	0.88	DRS
29	0.76	0.87	0.88	DRS
30	0.61	0.74	0.82	DRS
31	0.68	0.84	0.82	DRS
32	0.54	0.70	0.77	DRS
33	**1.00**	**1.00**	**1.00**	
34	0.65	0.75	0.87	DRS
35	0.51	0.70	0.73	DRS
36	0.69	0.98	0.71	DRS
37	0.62	0.88	0.70	DRS
38	0.54	0.79	0.69	DRS
39	0.56	0.83	0.68	DRS
40	0.63	1.00	0.63	DRS
41	0.64	0.97	0.66	DRS
42	0.54	0.98	0.55	DRS
43	0.67	1.00	0.67	DRS
44	0.49	1.00	0.49	DRS
45	0.54	1.00	0.54	DRS

* scale inefficiency due to increasing returns to scale (IRS) or decreasing returns to scale (DRS)

Figure 1: Correspondence between maximising net benefit per admission and minimising costs plus disutility events valued as in net benefit (k)

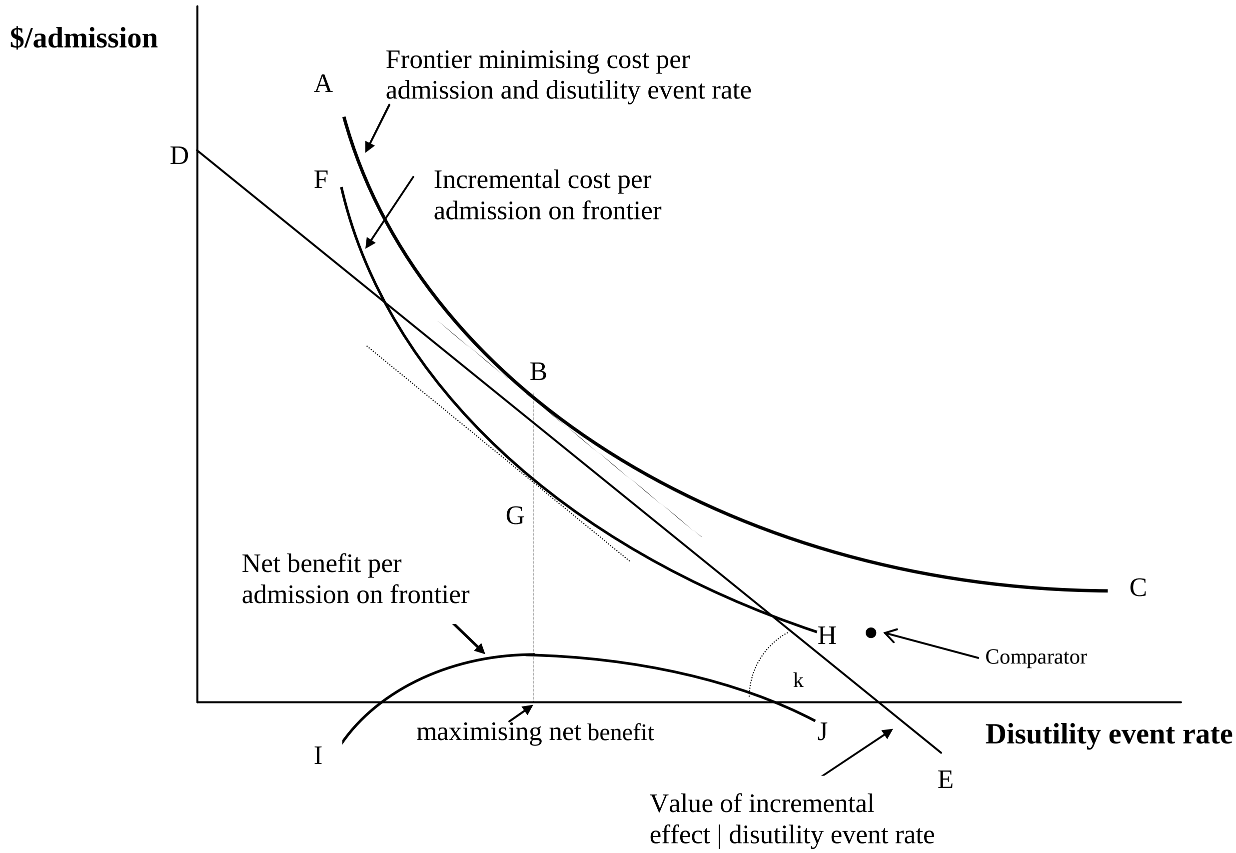
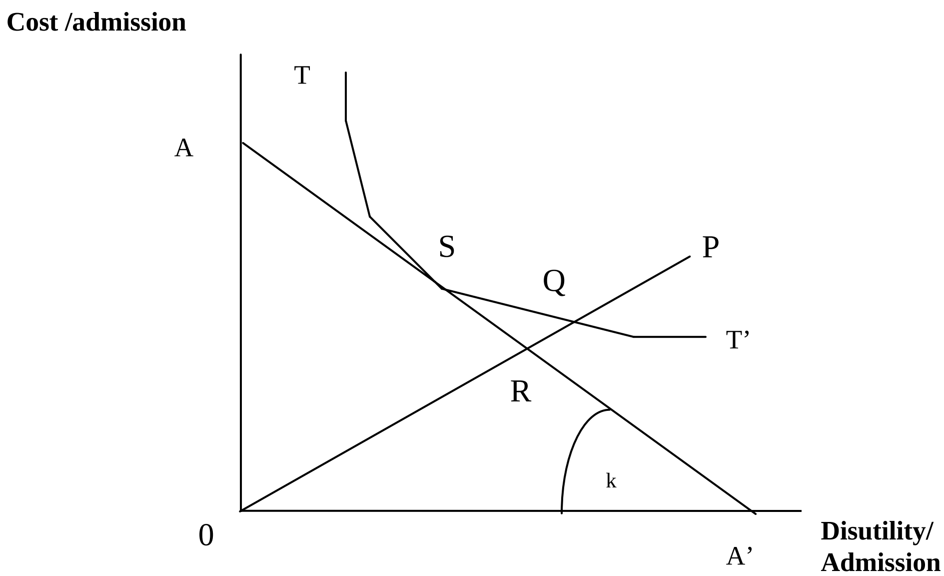


Figure 2: Decomposing net benefit efficiency into technical efficiency of net benefit (minimising cost per admission conditional on disutility event rate) and allocative efficiency



technical efficiency of provider at P=OQ/OP
with value of disutility events k:
economic efficiency for provider at P=OR/OP
allocative efficiency for provider at P=OR/OQ

Figure 3: Applying the correspondence theorem to efficiency measurement across 45 Australian public hospitals for DRG E62a

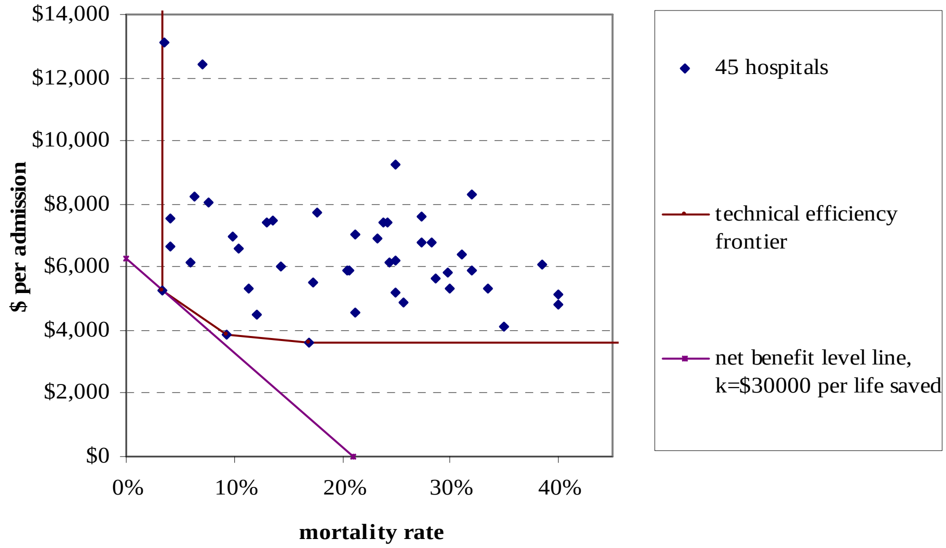


Figure 4 Technical efficiency under the hyperbolic method with undesirable events as a weakly disposable output