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Measuring hospital efficiency consistent with maximising net benefit

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Abstract

Health effects of care are increasingly being reported in comparing hospital performance. However, conventional methods of specifying health effects in economic efficiency measures reflect underlying objectives such as average cost effectiveness rather than the maximisation of net benefit established in health technology assessment. In this paper a correspondence method is identified which allows the incorporation of health effects in ratio measures of efficiency consistent with the maximisation of net benefit. The satisfaction of correspondence conditions of coverage and comparability are also shown to provide a robust theoretical framework to avoid cost-shifting and cream-skimming incentives.

Keywords: hospital performance; quality of care; maximizing net benefit; cost-shifting; cream-skimming.

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1. Introduction

Costs are increasingly compared across hospitals in countries such as Australia, Canada and the United Kingdom. Parallel to this, health and other effects of care such as mortality, morbidity and readmission are also increasingly being collected and used to assess aspects of clinical performance across hospitals (e.g. clinical audit, outlier identification) 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), health 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 health 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 health effects of care with measures such as cost per case-mix adjusted separation;

(ii) modelled health 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 health 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 health effects of care 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 the sum of costs and 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 a method of economic efficiency measurement in the cost-disutility plane consistent with maximising net benefit. This method is then applied to compare relative efficiency of hospital activities. Finally the differences between methods to allow for quality of care in efficiency measurement proposed previously and that proposed in this paper are clarified and their relative merits discussed in conclusion.

2. Measuring economic efficiency of hospitals consistent with an appropriate objective

Economic performance measures across hospitals have historically ignored health effects and other quality of care indicators and concentrated on ‘homogenous’ intermediate measures of hospital output such as case-mix
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 health effects of, quality of care, do not create appropriate incentives for quality of care. Health effects and costs of care are jointly influenced by quality of care and hence including the cost but not the value of quality in efficiency measurement creates incentives for cost minimising, rather than a clinically neutral quality of care. The importance of considering the joint relationship between value and cost of quality was suggested by Harris (1977) 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 care is further reinforced when considering the impact of quality of hospital services on costs and health effects of patients post hospital separation. Health systems are often characterised by incomplete vertical integration across health services (Evans 1981). Consequently, quality of hospital care within an admission can have significant impact 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. Accounting for the health effects of patients over time in efficiency measurement would therefore appear to be necessary to avoid perverse incentives and create incentives for appropriate quality of care. However, while accounting for health effects is suggested to be desirable in creating appropriate incentives for quality of care and such health effects of care over time are increasingly being measured, the question remains as to how they 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 reflects the incremental and non-tradable nature of health effects of care in treated populations (McGuire et
al. 1988 p.32, Eckermann 2004 p. 134-135). The impact on patients of a process of care or intervention require consideration relative to alternatives (even if doing nothing) and generally will be specific to, and not repeatable in, the patient population receiving them.

Decision making based on considering incremental health effects relative to the incremental cost of alternative strategies was suggested by Claxton and Posnett (1996) as equivalent to maximizing the net value of incremental effects of a technology at a threshold value 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 net benefit. Net benefit under these definitions can either be represented as incremental net monetary benefit where incremental effects are measured in monetary terms or equivalently as incremental net effect benefit where incremental costs are measured in terms of equivalent units of effect. Formally, incremental net monetary benefit (INMB) per patient and incremental net effect benefit (INEB) per patient can be represented for a given strategy (i), relative to a comparator (c), as:

\[
INMB_i = k(E_i - E_c) - (C_i - C_c)
\]

\[
INEB_i = (E_i - E_c) - \frac{1}{k}(C_i - C_c)
\]

where \(k\) represents the decision makers’ willingness to pay per unit of effect, \(E\) is effect per patient, and \(C\) is cost per patient.

Historically, methods proposed to include effects of care such as mortality, morbidity and readmission in efficiency measurement have attempted to specify them under the ‘quality-quantity trade-off’ suggested by Newhouse (Newhouse
Methods previously suggested for specifying health 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 health effects, for example in the study of Zuckermann et al. (1994) adjusting comparison of cost per case-mix adjusted admission for whether case-mix-adjusted mortality rates were in the upper decile, lower decile or tenth to ninetieth percentile;

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

However, neither of these approaches to specifying health effects in efficiency measures hold health care providers accountable for the costs and effects consistent with the objective of maximising net benefit underlying process of HTA for evidence based medicine (Eckermann 2004, pp. 136-138).

The first set of specifications, conditioning of performance on rates of health effects, treats these 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 health 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. Hence, the
exogenous treatment of effects resulted in the ten percent in both the highest and lowest quality providers having their performance (expected costs conditional on mortality rate relative to actual costs) increased relative to other providers. This clearly illustrates that specifying health effects as exogenous variables prevents their value being included in economic or allocative efficiency measurement. Consequently, 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, for the simplest case of one effect framed from a utility perspective (survival say) an output specification represent an underlying economic objective of minimising average cost per unit of health effect framed from a utility bearing perspective (e.g. average cost per survivor) or average cost effectiveness. As HTA has established in comparing health care performance, average cost effectiveness does not allow for the incremental nature of health effects or the inability to scale up health effects by repeating care in defined populations.

Further, even if a value is attached per unit of effect as proposed in Dawson et al (2005), these values cancel in comparing relative performance for the simplest case of one effect. Hence the underlying objective remains minimising average cost per unit effect, as demonstrated by Eckermann (2004; 2006). For example, if the average cost per survivor between two hospitals is 1.5 then the ratio will
remain 1.5, regardless of the value for effects. Hence, endogenous specifications of effects of care framed from a utility-bearing perspective, like exogenous 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**

For economic efficiency measures to support health technology assessment, we require an economic efficiency measure consistent with maximising net benefit. The net benefit formulations in equations (1) and (2) represent an objective which can appropriately trade off incremental effects and costs of care, but do not have radial (ratio) properties required for economic efficiency measurement. In health technology assessment this is evident in comparison of strategies on the incremental cost effectiveness plane, where incremental costs and effects can be positive or negative and performance improves by moving in a south-east direction rather than contracting to a vertex.

However, a linear transformation of the net benefit statistic in equation (1) could permit radial properties, while retaining an underlying objective of maximising net benefit. Consider a bilateral comparison between hospitals \(i\) and \(j\), where incremental health outcome per admission for hospital \(i\) 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 value 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 hospitals with a common comparator (there is no difference in expected rate of health outcome and costs of care) are compared, the comparator terms cancel.

$$\iff k \times E_i^u - C_i > k \times E_j^u - C_j$$

(3)

If we multiply both sides of equation (3) by minus 1, the sign changes and we translate from maximizing net benefit per admission to minimizing net loss per admission:

$$\iff C_i - k \times E_i^u < C_j - k \times E_j^u$$

(4)

Adding $k$ to both sides of equation (4) and re-arranging with common factors we obtain:

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

(5)

Now, if $E$ is survival rate, then $(1 - E)$ is mortality rate, or more generally if $E$ is the rate of admissions without a disutility-bearing event then $(1 - E)$ is the rate of admissions with effects framed from disutility-bearing perspective, $E_{DU}$.

$$\iff C_i + k \times E_i^{DU} < C_j + k \times E_j^{DU}$$

(6)

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 of patients treated 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 we consider whether this correspondence can generalises to multiple effects and differences between providers in expected costs and effects of patients treated. Let all potential combinations of effects framed from a disutility perspective be represented by \((E_{DU}^{1}, E_{DU}^{2}, \ldots, E_{DU}^{m})\), and associated values of units of health effects by \((k_{1}, \ldots, k_{m})\). Then, under the coverage condition of the correspondence theorem, net benefit for any hospital \((i=1, \ldots, n)\) can be presented relative to a comparator representing expected costs and effects for patients treated, as:

\[
\text{INMB}_{i} = k_{i}(E_{DU}^{1}_{ci} - E_{DU}^{1}_{i}) + \ldots + k_{m}(E_{DU}^{m}_{ci} - E_{DU}^{m}_{i}) - (C_{i} - C_{ci})
\]

\[
= (k_{1} \times E_{DU}^{1}_{ci} + \ldots + k_{m} \times E_{DU}^{m}_{ci} + C_{ci}) - (k_{1} \times E_{DU}^{1}_{i} + \ldots + k_{m} \times E_{DU}^{m}_{i} + C_{i})
\]

(7)

Without loss of generalization, let \(\text{INMB}_{i} > \text{INMB}_{j}\), then from (7) \(\Leftrightarrow\)

\[
-(k_{1} \times E_{DU}^{1}_{i} + \ldots + k_{m} \times E_{DU}^{m}_{i} + C_{i}) > -(k_{1} \times E_{DU}^{1}_{j} + \ldots + k_{m} \times E_{DU}^{m}_{j} + C_{j}) + z
\]

(8)

Where: \(z = -(k_{1} \times E_{DU}^{1}_{j} + \ldots + k_{m} \times E_{DU}^{m}_{j} + C_{j})\)

Multiplying both sides of (8) by minus 1, the sign changes and we translate from maximizing net benefit to minimizing net loss per admission:

\(\Leftrightarrow\)

\[
k_{1} \times E_{DU}^{1}_{i} + \ldots + k_{m} \times E_{DU}^{m}_{i} + C_{i} < k_{1} \times E_{DU}^{1}_{j} + \ldots + k_{m} \times E_{DU}^{m}_{j} + C_{j}
\]

(9)

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 (9) 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 we consider whether this correspondence can be extended further to cases where effects are measured by life years or quality adjusted life years. 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:

\[
INMB_i = k \times (Q_i - Q_{\text{max}}) - (C_i - C_{\text{max}})
\]

Without loss of generalisation, let \(INMB_i > INMB_j\)

\[
\Leftrightarrow k \times (Q_i - Q_{\text{max}}) - (C_i - C_{\text{max}}) > k \times (Q_j - Q_{\text{max}}) - (C_j - C_{\text{max}})
\]

\[
\Leftrightarrow k \times (Q_{\text{max}} - Q_i) + C_i < k \times (Q_{\text{max}} - Q_j) + C_j
\]
Now, let $E_{DU}^i$ be life years or quality adjusted life year lost relative to the highest attained.

$$E_{DU}^i = Q_{max} - Q_i$$

(13)

$$\Leftrightarrow k \times E_{DU}^i + C_i < k \times E_{DU}^j + C_j$$

(14)

QED

If the net benefit of treatment at hospital $i$ is greater than that of hospital $j$, then the cost per admission plus effects per admission, framed from a disutility perspective and valued per unit effect as in net benefit ($k \times E_{DU}^i + C_i$), are less for hospital $i$, under correspondence conditions of coverage and comparability. The cases of health effects represented by a single event rate, multiple event rates, and quality adjusted life years illustrate that this is the case regardless of how health 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 care (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 disutility (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 the cost per admission and disutility per admission, which \textit{a priori} is expected to reflect diminishing returns to resources (costs), as the rate of disutility 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 the sum of incremental cost and 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 also allow decompositions of economic efficiency consistent with maximising net benefit into scale, technical and allocative efficiency on the cost-disutility plane, to tell a richer story of sources of inefficiency.

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 admission conditional on disutility per admission or, equivalently, minimum rate of disutility 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 health 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 figure 2, 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 \( \frac{OR}{OP} \).

Efficiency related to the choice of quality given the decision makers WTP for effects (allocative efficiency) can also be estimated as the residual of economic efficiency and technical efficiency under constant returns to scale, equivalent to \( \frac{OR}{OQ} \) 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 hospitals to be on the technical efficiency frontier where no equi-proportional reduction in cost and disutility events per admission is possible. The values 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 \( i \) and \( j \) with:

\[
C_i + k \times DU_j = C_j + k \times DU_j \iff k = (C_j - C_i)/(DU_j - DU_i)
\]  

(13)
4.3 Implicit industry value of quality (shadow price)
Economic efficiency for each compared hospital can be estimated conditional on \( k \), the value of health outcome, 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 hospital by their industry share of costs, an industry economic efficiency can be estimated. The shadow price of effects (quality) of care in industry behaviour can then 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 the mortality rate in hospital. 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 is reported at values 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, with the proposed method.

Peers (economic efficiency of 1) and relative ordering of economic efficiency are conditional on the value 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.

Efficiency measures are also presented for an alternative output specification of health effects, where economic efficiency measurement is based on minimising cost per survivor. This alternative specification applies the specification suggested by Dawson et al (2005) and Puig-Junoy (1998) for including health effects in efficiency measures as utility bearing outputs. 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).

In general output specifications of effects framed from a utility-bearing perspective have an inability to incorporate the value of health effects in estimating economic efficiency and hence, unlike the proposed method, cannot be consistent with maximising net benefit.

Table 2 present application of the proposed method to estimate technical efficiency under CRS and VRS, scale efficiency and an indicator of whether scale inefficiency is attributable to increasing or decreasing returns to scale for the 45 compared hospitals. Hospitals 26, 17 and 33 on the frontier in figure 3 are technically efficient under CRS. The cost and mortality per admission cannot be equi-proportionally reduced for these hospitals relative to convex combinations of any other hospitals. Technically efficiency under VRS has a more restrictive comparison of peers, with fourteen of the hospitals identified as technically efficient under VRS.

Applying the back solving formulae in equation 13, technically efficient hospitals 26, 17 and 33 are economically efficient for value per additional survivor of $0 to $3523, $3524 to $24356 and greater than $24356, respectively. The shadow price for the value of survival across the 45 compared hospitals is estimated as $3523 where the industry cost share weighted economic efficiency is maximised, as illustrated in figure 4. This shadow price reflects the economic incentive for cost minimising quality of care under current case-mix.
performance measures and funding mechanisms, rather than the value of effects from net benefit implicit in HTA. 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 were made in each case that comparability and coverage conditions are satisfied. These assumptions would also be implicitly made with application of other methods, but are explicit in applying 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 is 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. 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, in critiquing the use of frontier methods to estimate efficiency of hospitals (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.

Previously proposed methods, where health effects are specified as exogenous variables, or as utility bearing endogenous outputs, the relative value of health effects are not able to be included in economic or allocative 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. Hence, 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.

Consideration of effects framed form a disutility perspective is not strictly new in efficiency measurement for applications outside of health care. Färe, Grosskopf, Lovell and Parsuka proposed a hyperbolic method measuring technical efficiency in equi-proportionally contracting ‘weakly disposable undesirable outputs’ and expanding ‘strongly desirable outputs’ (Färe et al. 1989). 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 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) under the hyperbolic method. 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. 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.

Hence, in summary there are distinct advantages to hospital efficiency comparison from specifying effects framed from a disutility perspective as inputs over alternatively proposed output, exogenous or hyperbolic 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 (1981), Cropper and Oates (1992), Haynes et al (1993, 1994) and Rheinhardt, Lovell and Thjissen (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 method can equally be applied to measure efficiency consistent with maximising net benefit across providers in any service or industry where this is an appropriate objective (Eckermann 2004 pp. 274-278; Eckermann 2007).
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 effects (costs and health effects) beyond separation either with data linkage, or modelling expected effects conditional on health state at point of discharge.

3. Standardise providers’ effects (cost and health effects) for differences in baseline patient risk factors across providers.

The resulting standardised measures (costs and health 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.
Many health effects of care such as mortality, morbidity, functional limitation or readmission are naturally measured as disutility event rates. However, if effects 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 or Disability adjusted life years (DALYs). 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. Similarly, 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.

7. Conclusion

Processes of health technology assessment underlying evidence based medicine have established the maximisation of net benefit as the appropriate economic objective, in reflecting incremental and patient specific characteristics of health effects of treated populations. However, current conventional methods for specifying health effects in comparing 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 processes of health technology assessment and evidence-based medicine. The paper has made two main contributions with respect to this objective.
First, a correspondence method has been identified for specifying health effects in ratio measures of performance, consistent with an economic objective of maximising net benefit. An input specification of health 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 incentives being created by performance measures for cost-shifting and cream-skimming, respectively. Hence, 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 objective function from health technology assessment 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.

Acknowledgements

The paper is drawn from research undertaken as part of my dissertation at the University of New South Wales. I am grateful to advice from Kevin Fox, Brita Pekarsky and helpful comments at invited seminars at McMaster, York, Oxford, Aberdeen and Newcastle in 2003 and 2004, as well as related papers presented at conferences in 2003 and 2005 for the International Health Economic Association (IHEA), in 2005 for Medical Decision Making (MDM) and in 2006 for Health Technology Assessment International (HTAI) and the International Conference on Health and Social Care Modelling and Applications (HSCM).
References


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* Scale inefficiency due to increasing returns to scale (IRS) or decreasing returns to scale (DRS)
Figure 1: Correspondence between maximising net benefit and minimising the sum of 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 service $E^{DU}$) and allocative efficiency

Cost/service ($S$)

Technical efficiency of provider at $P=OQ/OP$ with value of effects $k$:
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

Shadow price for industry where economic efficiency weighted by cost share maximised

[Graph showing economic efficiency across hospitals against willingness to pay to avoid death]
**Figure 5** Technical efficiency under the hyperbolic method with undesirable events as a weakly disposable output