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Measuring health system efficiency and funding for net benefit maximisation: the health economics of quality of care

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Working Paper 1

Measuring health system efficiency and funding for net benefit maximisation: the health economics of quality of care

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1 Introduction

In June 2007 the South Australian Government undertook to implement a major reform in the delivery of health services across the State (Government of South Australia Department of Health 2007). Not only did this involve far reaching decisions about role delineation for hospital services, it also incorporated reforms for prevention and primary care. These initiatives are underpinned by a need to improve the health status of South Australians within a constrained budget.

In the past, evaluation methods and funding mechanisms for hospital services have concentrated quantitatively on resource utilisation per admission with qualitative attention to the outcomes of health care and limited consideration of their longer term impacts on the health system. However, while such methods create incentives to minimise cost per admission, they also create incentives for cream skimming, cost shifting and a quality of care that minimises cost per admission. These incentives have, in turn, expected impacts on patient health outcomes and health system use beyond separation (Evans 1981). Consequently, ignoring health effects in evaluation methods and funding mechanisms (e.g. cost per case-mix adjusted admission and case-mix funding) does not minimise the health system costs of treating patient populations over time and, in failing to trade-off the cost and value of effects of care, does not support evidence based medicine.

A recently developed method, the net benefit correspondence theorem, allows costs and health outcomes to be integrated in performance measurement and funding mechanisms consistent with maximising net benefit, the monetary value of net effects less net costs underlying evidence based medicine (Eckermann 2004; Eckermann 2006; Eckermann, Briggs and Willan 2008, Eckermann and Coelli 2008). This method overcomes several problems of current performance measures and funding mechanisms in providing both:

(1) provider incentives for net benefit maximising quality of care; and

(2) an explicit framework of comparability and coverage conditions to prevent cream skimming and cost shifting incentives.

The aim of this working paper is to outline and illustrate, in lay terms, how this method can be applied to construct performance measures that support the maximisation of net benefit underlying evidence based medicine. First, we describe how the correspondence theorem can be applied to incorporate effects in efficiency measurement consistent with maximising net benefit using existing frontier methods. Application is illustrated in comparing the performance of 45 New South Wales hospitals in treating respiratory infection DRG E62a patients, given their cost and mortality rate per admission. This illustration includes identifying technically efficient providers, the net benefit maximising peer and economic inefficiency relative to this peer at potential threshold values for effects, sources of inefficiency due to higher cost, size and relative value of quality (technical, scale and allocative inefficiency) and the implicit shadow price for quality in current industry behaviour. We then consider the three stage process of identification, measurement and risk adjustment to prevent cream skimming and cost shifting incentives, illustrated with a comparison of cardiovascular DRGs (F10Z and F15Z) for South Australian hospitals, before drawing policy implications and concluding. In a subsequent companion paper, the information generated by the performance measurement framework presented here is shown to simply extend to a funding mechanism that enables incentives for the highest quality of care attainable while maintaining current case-mix funding levels per admission.

2 The challenge

Current conventional measures of economic efficiency reflect cost per service, such as cost per admission in hospitals. This implicitly includes the costs of quality but excludes the value of effects of quality. Hence, effects of quality in hospitals are implicitly valued at 0 and incentives created for a quality of care that minimises cost per admission, rather than necessarily minimising costs to the health system in treating patient populations over time or, indeed, maximising net benefit of hospital activity. It is generally agreed that, to create appropriate incentives, economic efficiency measures need to include both the value from the effects as well as the costs of quality. The challenge is: how to specify the value of effects from quality in economic efficiency measures to be consistent with an appropriate underlying objective.

2.1 Maximising net benefit as the appropriate underlying objective

In allowing for costs and effects of alternative care, 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, O'Brien, Stoddard and Torrance 1997; Drummond, Stoddard and Torrance 1987; Drummond, Sculpher, Torrance, O'Brien and Stoddart 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, Henderson and Mooney 1988 p.32; Eckermann 2004 p. 134-135). That is, the impact on patients of a process of care requires consideration relative to alternatives (even if the alternative is doing nothing) and will usually be specific to the patient population receiving that care.

Decision making based on considering incremental health effects relative to the incremental cost of alternative strategies is equivalent to maximising the net value of incremental effects of a technology at a threshold value for effects minus incremental costs (Claxton and Posnett 1996). Stinnett and Mullahy (1998) described this net value of incremental effects less incremental costs for a strategy relative to a comparator as net benefit. Analogous to a profit objective, a net benefit (NB) objective attempts to maximise incremental value less incremental cost of activities. 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 a threshold value per unit of effect, E is effect per patient and C is cost per patient.

Consequently, maximising net benefit has been proposed by many authors (e.g. Claxton and Posnett 1996; Stinnett and Mullahy 1998; Tambour, Zethraeus and Johannesson 1998; Willan and Lin 2001; Drummond, Sculpher, Torrance, O'Brien and Stoddart 2005; Willan and Briggs 2006; Eckermann, Briggs and Willan 2008) as an appropriate objective in comparing costs and effects in processes of evidence based medicine and health care more generally.

2.2 *Measuring efficiency of health care providers consistent with maximising net benefit*

We would like economic efficiency measures across health care providers, such as hospitals, to be consistent with maximising net benefit so as to provide incentives supporting evidence based medicine and provide appropriate tradeoffs between the cost and value of quality in influencing effects from care. However, while the net benefit formulation in (1) represents an objective that can appropriately trade off the value of incremental effects and costs of care, it does not lend itself to efficiency measurement. Efficiency measurement requires ratio properties in comparing performance, which net benefit as specified in (1), with performance improving in increasing effects and reducing costs, does not permit. Hence, for efficiency measures from practice to support evidence based medicine requires a robust method to allow ratio measures incorporating health effects as well as costs (resource use) consistent with maximising net benefit.

A correspondence method, the net benefit correspondence theorem, has been shown to allow the incorporation of health effects in ratio measures of efficiency consistent with the maximisation of net benefit (Eckermann 2004). Formally, the net benefit correspondence theorem states that there is a one to one correspondence between maximising the net benefit of a bundle of health services (value of effects framed from a utility bearing perspective, e.g. survival, less costs) and minimising the cost plus effects framed from a utility reducing perspective (e.g. mortality) valued with the same metric per unit of effect as net benefit, where the following conditions are satisfied:

(i) The vector of quality variables framed from a disutility perspective covers effects included in net benefit (coverage condition);

(ii) Expected differences in costs and effects due to exogenous factors are adjusted for (common comparison condition).

Alternative proofs of this general theorem are provided in comparison of multiple providers by Eckermann (2004), with resource use represented by cost and single and multiple effects, and Eckermann and Coelli (2008) for comparison of multiple resource use and multiple effects, where cost of resources plus value of effects of a service bundle is described as quality inclusive cost (QIC). Eckermann Briggs and Willan (2008) provide an analogous proof in comparison of strategies in health technology assessment.

3 Applying the net benefit correspondence to efficiency measurement

The net benefit correspondence theorem provides a general method for comparing the efficiency of providers consistent with an economic objective of maximising net benefit on the cost-disutility plane (Eckermann 2004; Eckermann, Briggs and Willan 2008) or, more generally, with multiple inputs and/or effects in resource use and disutility space. To allow simple visual illustration of efficiency measurement applying this correspondence, comparison of 45 NSW hospitals for respiratory infection DRG E62A is initially considered, given their cost per admission and mortality rate, summary statistics for which are presented in Table 1.

Table 1 Summary statistics

	Admissions	Cost / admission	Mortality rate
Mean	63	$6,332	22.42%
Std dev	49	$1,851	10.56%
Minimum	10	$3,590	3.33%
Maximum	184	$13,128	40.00%

Comparison of all hospitals is depicted on the cost-disutility plane in Figure 1, with cost per admission on the vertical axis and mortality rate (deaths per admission as the effect framed from a disutility perspective) on the horizontal axis.

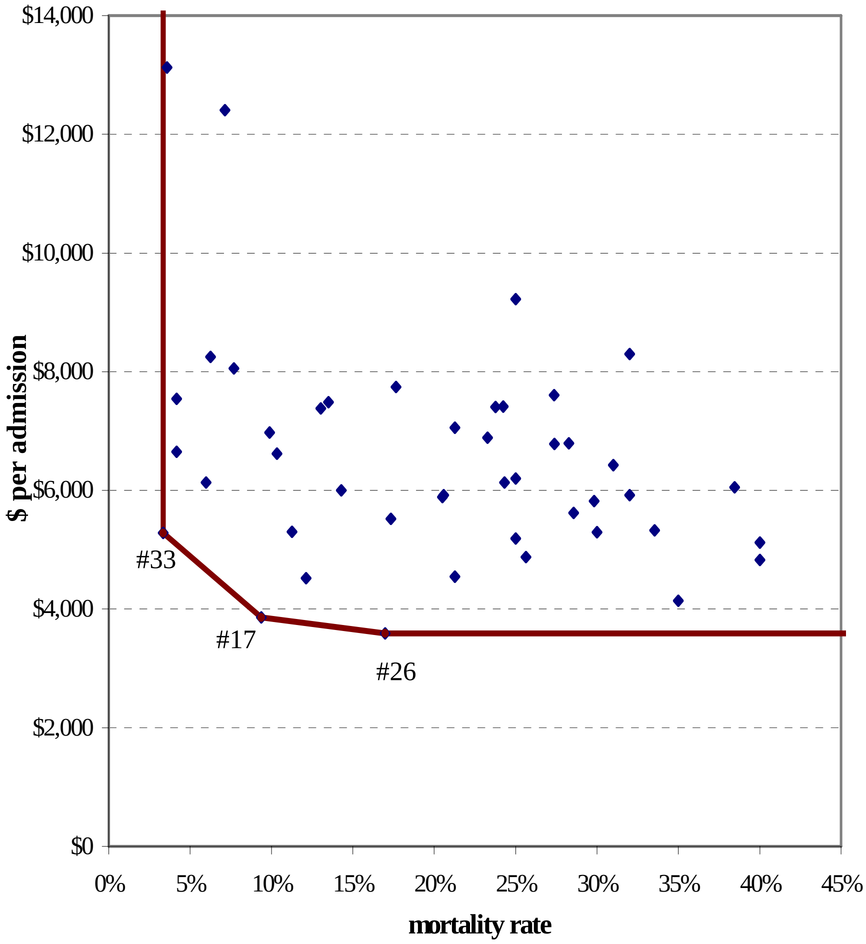

Figure 1 Cost & mortality rate for respiratory infection DRG E62A in 45 NSW hospitals

Performance improves in reducing cost per admission and reducing mortality rate and hence presentation on the cost-disutility plane naturally enables efficiency measures to be calculated in contracting towards the origin. Consequently, technically efficient providers who minimise cost for a given level of quality (mortality rate) or equivalently maximise quality (minimise mortality rate) for a given level of cost can be simply identified as those for whom no individual hospital or linear combination of hospitals have lower cost and mortality rate. For example, Hospitals 26, 17 and 33 are technically efficient in Figure 1. Drawing a line between adjacent technically efficient hospitals defines a technical efficiency frontier, relative to which the technical efficiency of hospitals can be estimated as the proportion to which costs and mortality per admission can be equi-proportionally contracted.

3.1 Comparing net benefit on the cost-disutility plane

Now consider the simple example in Figure 2, which is a generalisation of the example in Figure 1.

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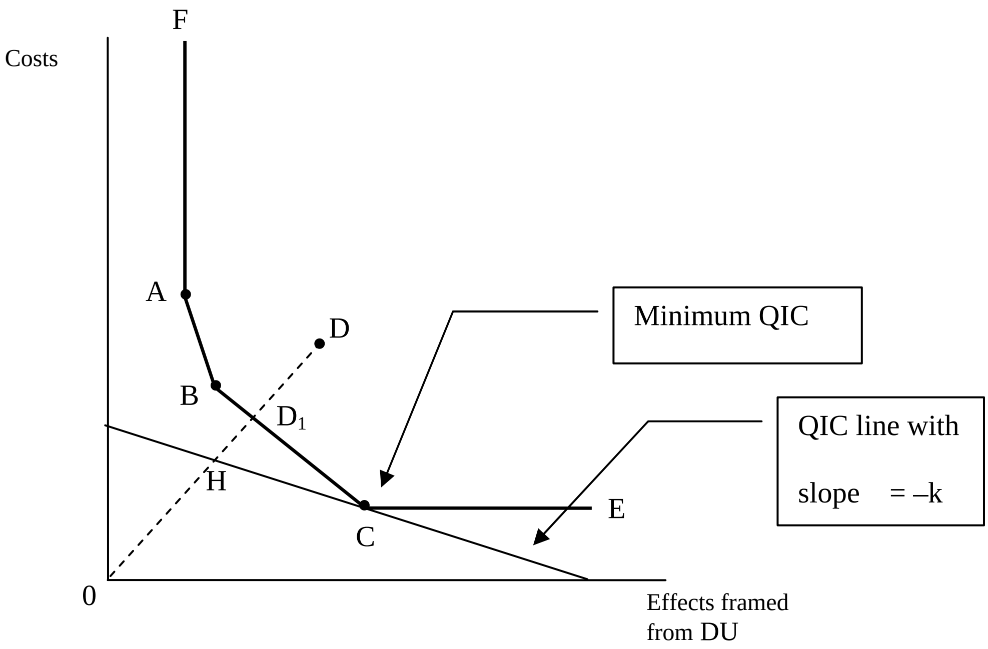

Figure 2 Net benefit efficiency decomposition

Comparing net benefit of hospitals on the cost disutility plane, quality inclusive cost (QIC) per admission (cost per admission plus effects framed from a disutility perspective, e.g. mortality rate valued at *k* as in net benefit) is simply represented by parallel lines with slope of -*k*. Such parallel lines closer to the origin represent lower QIC, corresponding to higher net benefit. In Figure 2, a QIC line has been inserted with a slope equal to –*k*.[1] *Minimum QIC* is obtained at point *C*, which is the point of tangency between the minimum QIC line and the frontier. For Hospital D, technical efficiency is equal to the ratio

[1] The value -*k* reflects the relative price of a quality effect relative to cost but can be simply generalised, as in Eckermann (2004), to multiple outputs (*k*s) or, as in Eckermann and Coelli (2008), to represent the value of multiple effect relative to multiple traditional inputs.

$TE = 0D_1 / 0D$. Economic efficiency and allocative efficiency for Hospital D can also be simply obtained using ratios in this diagram as $EE = 0H / 0D$ and $AE = 0H / 0D_1$.[2]

We now consider these concepts more generally. Of the technically efficient hospitals on the frontier, the hospital that maximises net benefit at a given threshold value is simply shown by the point of tangency between the frontier and the QIC line closest to the origin. The relative net benefit efficiency of hospitals can be measured relative to this net benefit maximising hospital as:

$$EE_i(inputs, admission, quality(E_{DU}), prices) = \frac{QIC^*}{QIC_i} \quad (2)$$

which is the ratio of minimum *QIC* to observed *QIC*. This economic efficiency (EE) measure will take a value between zero and one, with a value of one indicating full economic (net benefit) efficiency.

This economic efficiency measure can also be decomposed into technical and allocative components. For example, technical efficiency can be defined as:

$$TE(inputs, admissions, quality(E_{DU})) = \min_{\theta}\left\{\theta \mid \left(\theta \times inputs, admissions, \theta \times E_{DU}\right) \in T\right\} \quad (3)$$

where inputs and effects framed from a disutility perspective representing quality are proportionally reduced, for example to point D_1 for Hospital D in Figure 2. Consequently, a measure of allocative efficiency, which represents the extent to which providers have the right combination of cost and quality given relative prices, is simply calculated as a residual of economic and technical efficiency:

$$AE(inputs, admissions, E_{DU}, prices) = \frac{EE(inputs, admissions, E_{DU}, prices)}{TE(inputs, admissions, E_{DU})} \quad (4)$$

The *TE* and *AE* measures also take a value between zero and one.

Hence, returning to our example from Figure 1, the hospital that maximises net benefit at a given threshold value for effects will be that which lies on the iso-cost line closest to the origin, for example Hospital 17 in Figure 3 at a threshold value of $10,000 per mortality avoided.

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[2] The logic behind these ratios can be seen by noting that additional iso-cost lines could be drawn through points D_1 and D.

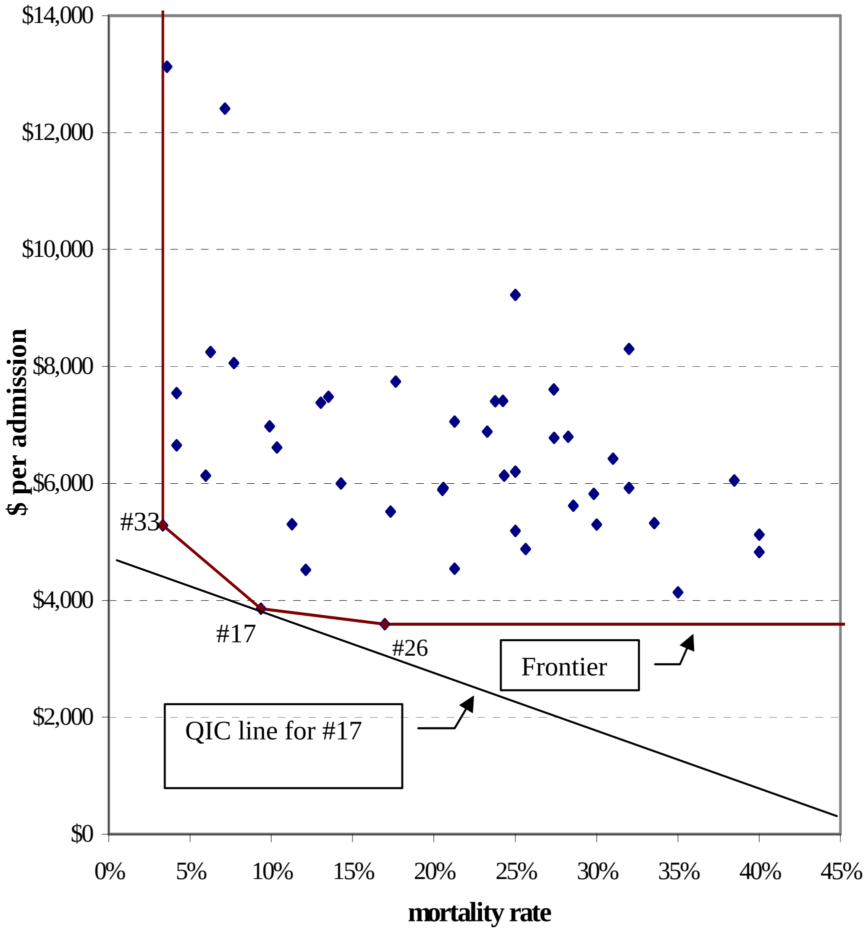

Figure 3 Net benefit efficiency decomposition in practice

The frontier is defined by Hospitals, 33, 17 and 26. These hospitals are technically efficient, in the sense that one cannot proportionally reduce the input variables (cost and quality indicator variable) of these hospitals without moving beyond the frontier (feasible set). At the given value of effects of $10,000 per mortality avoided in Figure 3, Hospital 17 is economically efficient, in the sense that quality inclusive cost (QIC) per admission is minimised[3], while all other hospitals are economically inefficient because they could potentially reduce their *QIC* per admission.

Economic efficiency (EE) measures, obtained using equation (2), are listed in Table 2 for each hospital for four different values of *k*: $0, $10,000, $25,000 and $50,000 per mortality avoided. Looking first at

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[3] Refer to equation (15).

the case of *k*=$10,000, we observe that Hospital 17 has an EE score of 1, as expected. The sample average EE score is 0.57, suggesting that the average hospital could reduce QIC by 43% per admission. The ranks indicate that Hospital 14 is the least efficient, with an efficiency score of 0.36, implying a potential 64% reduction in QIC.

In some instances, efficiency levels can vary with hospital size. For example, smaller hospitals in regional locations may have low capacity utilisation during certain periods.[4] If this were the case, a simple raw average measure may provide a misleading indication of the level of efficiency in the industry. As a consequence, we have also reported weighted means, where the weights are either number of admissions or total costs.

[4] Also note that, since constant returns to scale (CRS) has been imposed on the production technology in this empirical illustration, if scale economies do exist, it could be found that efficiency levels may vary with hospital size for this reason as well.

Table 2 Economic efficiency conditional on threshold value of mortality avoided

Hospital	$0	Rank	$10,000	Rank	$25,000	rank	$50,000	rank
1	0.74	7	0.54	29	0.41	41	0.28	44
2	0.39	43	0.41	43	0.4	43	0.32	40
3	0.45	40	0.54	28	0.61	15	0.58	12
4	0.29	44	0.37	44	0.43	39	0.43	22
5	0.7	8	0.53	31	0.4	42	0.28	43
6	0.44	41	0.54	27	0.62	14	0.61	8
7	***0.87***	***3***	***0.63***	***13***	***0.47***	***29***	***0.32***	***39***
8	0.6	20	0.65	10	0.64	11	0.53	13
9	0.49	33	0.55	24	0.57	16	0.5	14
10	0.54	27	0.68	8	0.8	5	0.8	3
11	***0.48***	***37***	***0.6***	***18***	***0.71***	***8***	***0.72***	***5***
12	0.43	42	0.42	42	0.38	45	0.29	42
13	0.59	23	0.48	40	0.39	44	0.27	45
14	0.27	45	0.36	45	0.44	37	0.47	17
15	0.54	26	0.63	12	0.66	9	0.59	9
16	0.58	24	0.55	23	0.49	25	0.37	28
17	**0.93**	**2**	**1**	**1**	**0.99**	**2**	**0.81**	**2**
18	0.48	36	0.49	39	0.45	34	0.36	30
19	0.79	5	0.84	4	0.81	3	0.66	6
20	0.59	22	0.56	21	0.5	23	0.38	27
21	0.48	35	0.54	26	0.56	18	0.49	16
22	0.74	6	0.64	11	0.54	20	0.39	25
23	0.61	19	0.6	17	0.56	17	0.43	21
24	0.68	12	0.58	19	0.48	28	0.34	34
25	0.79	4	0.72	6	0.62	13	0.46	18
26	**1**	**1**	**0.91**	**2**	**0.78**	**6**	**0.58**	**11**
27	0.59	21	0.71	7	0.8	4	0.76	4
28	0.46	39	0.5	37	0.5	22	0.43	20
29	0.68	11	0.75	5	0.75	7	0.64	7
30	0.61	18	0.53	30	0.44	36	0.32	38
31	0.65	14	0.66	9	0.62	12	0.49	15
32	0.53	29	0.5	36	0.45	33	0.34	33
33	**0.68**	**10**	**0.85**	**3**	**1**	**1**	**1**	**1**
34	0.51	32	0.6	16	0.65	10	0.58	10
35	0.48	34	0.49	38	0.46	31	0.36	29
36	0.69	9	0.62	14	0.53	21	0.39	24
37	0.62	16	0.54	25	0.46	30	0.34	32
38	0.52	30	0.52	33	0.48	27	0.38	26
39	0.56	25	0.5	35	0.43	38	0.32	37
40	0.61	17	0.6	15	0.55	19	0.43	19
41	0.64	15	0.57	20	0.48	26	0.35	31
42	0.51	31	0.52	32	0.49	24	0.39	23
43	0.67	13	0.55	22	0.45	32	0.31	41
44	0.47	38	0.46	41	0.42	40	0.33	36
45	0.53	28	0.5	34	0.44	35	0.33	35
Mean	**0.57**		**0.57**		**0.55**		**0.45**	
Admission wtd.	**0.59**		**0.58**		**0.54**		**0.43**	
Cost wtd.	**0.57**		**0.56**		**0.51**		**0.40**	

Table 2 contains EE scores corresponding to four different values of *k*. A value of *k*=$0 implies that quality has no value, with comparisons of *QIC* reverting to cost alone. This is equivalent to having an objective of cost minimisation, which can be visualised as having a horizontal QIC line to identify the net benefit maximising hospital in Figure 3. Where *k*=$0, Hospital 26, which has the lowest cost per admission, has the highest EE and mean EE across hospitals is 0.57. When *k* values of $25,000 and $50,000 are considered, the QIC line becomes steeper (higher negative slope in Figure 3), so that Hospital 33 has the highest EE and mean EE drops to 0.55 and 0.45 respectively. The rankings of the frontier hospitals (17, 26 and 33) do not change substantially as the value of *k* changes, but for some hospitals there are substantial changes. For example, as *k* increases, the rank of Hospital 7 worsens from 3rd to 39th while that of Hospital 11 improves from 37th to 5th. This makes clear that if quality is ignored in the efficiency analysis, when the true value of quality is say $50,000 per mortality prevented, very misleading relative efficiency measures and rankings can be obtained.

3.2 Identifying peer hospitals across potential threshold values for effect

In general, only hospitals on the technical efficiency frontier can maximise net benefit, given that a hospital can only lie on a minimum QIC line where such a line is tangent to the frontier, such as Hospital 17 in Figure 3. Consequently, only hospitals on the technical efficiency frontier can be net benefit maximising peers, in our case example Hospitals 26, 17 and 33. The regions of value for effects *k* over which these technically efficient hospitals (minimising cost and disutility events per admission) are economically efficient in minimising QIC can be simply identified by back-solving for adjacent technically efficient hospitals (*i*,*j*) on the frontier with:

$$QIC_i = QIC_j \Leftrightarrow k = (C_i - C_j)/(E_i - E_j) = (C_i - C_j)/(DU_j - DU_i) \quad (5)$$

In the case of Figure 3, regions of *k* over which Hospitals 26, 17 and 33 are economically efficient are:

Hospital 26 from $0 to $3,523 per mortality avoided;

Hospital 17 from $3,524 to $24,356 per mortality avoided;

Hospital 33 for $24,357 or more per mortality avoided.

In general, by using equation (5) decision makers can be informed of appropriate peers for any potential threshold value of effects (quality of care) in back-solving for threshold value between adjacent technically efficient hospitals.

3.3 Decomposing performance into technical and allocative efficiency

The economic efficiency (EE) measures in Table 2 can be decomposed into technical efficiency (TE) and allocative efficiency (AE) components, by calculating TE using equation (3) and then calculating AE in a residual manner using equation (4). These measures are reported in Table 3 for the case of k=$25,000.

Table 3 Technical, allocative and economic efficiency

Hospital	TE	AE (k=$25,000)	EE (k=$25,000)
1	0.74	0.55	0.41
2	0.41	0.98	0.40
3	0.61	1.00	0.61
4	0.47	0.91	0.43
5	0.70	0.57	0.40
6	0.62	1.00	0.62
7	***0.87***	***0.54***	***0.47***
8	0.65	0.98	0.64
9	0.58	0.98	0.57
10	0.80	1.00	0.80
11	***0.80***	***0.89***	***0.71***
12	0.44	0.86	0.38
13	0.59	0.66	0.39
14	0.93	0.47	0.44
15	0.67	0.99	0.66
16	0.59	0.83	0.49
17	**1.00**	**0.99**	**0.99**
18	0.51	0.88	0.45
19	0.85	0.95	0.81
20	0.60	0.83	0.50
21	0.57	0.98	0.56
22	0.74	0.73	0.54
23	0.63	0.89	0.56
24	0.68	0.71	0.48
25	0.79	0.78	0.62
26	**1.00**	**0.78**	**0.78**
27	0.80	1.00	0.80
28	0.51	0.98	0.50
29	0.76	0.99	0.75
30	0.61	0.72	0.44
31	0.68	0.91	0.62
32	0.54	0.83	0.45
33	**1.00**	**1.00**	**1.00**
34	0.65	1.00	0.65
35	0.51	0.90	0.46
36	0.69	0.77	0.53
37	0.62	0.74	0.46
38	0.54	0.89	0.48
39	0.56	0.77	0.43
40	0.63	0.87	0.55
41	0.64	0.75	0.48
42	0.54	0.91	0.49
43	0.67	0.67	0.45
44	0.49	0.86	0.42
45	0.54	0.81	0.44
Mean	**0.66**	**0.85**	**0.55**
Admission wtd.	**0.64**	**0.84**	**0.54**
Cost wtd.	**0.63**	**0.82**	**0.51**

The results indicate that TE is the main contributor to EE, with a mean of 0.66 for TE versus a mean of 0.85 for AE. The value of 0.85 suggests that, if the average hospital were technically efficient (operating on the frontier), it could reduce QIC by a further 15% if it were to use an optimal mix of inputs (traditional inputs and quality measures), given the specified price ratios. These additional savings would not have been identified if a value was not assigned to quality.

The importance of assigning a value to quality, instead of focusing on technical efficiency or average cost effectiveness (i.e. cost per survivor) is illustrated in Table 3, where the efficiency scores obtained using these three methods are listed along with the corresponding ranks. In some cases the ranks do not change significantly, while in other cases there are considerable changes. For example, in the case of Hospital 7, the rank is 5 and 7 for TE and average C/E, respectively, while it falls to 29 when EE is considered.

Hence in this case, and more generally, it should be clear that it does matter how the value of quality of care is included in relative performance measures. Technical efficiency (TE) and average cost effectiveness (C/E) ratios in Table 4 do not permit the value of quality to be incorporated. Incentives for net benefit maximising quality of care to support evidence based medicine will not be created by performance measures unless relative performance measures and peers are consistent with maximising net benefit, as they are in the middle EE column of Table 4.   Further, Eckermann (2004) and Eckermann and Coelli (2008) demonstrate that no other proposed alternative specifications of effects as quality variables allow performance measures consistent with maximising net benefit. Only specification of effects as quality variables under the net benefit correspondence theorem allows ranking consistent with maximising net benefit.

Table 4 Comparing TE, EE and average cost effectiveness

Hospital	TE	rank	EE (k=$25000)	rank	Average C/E	Rank
1	0.74	12	0.41	41	0.53	21
2	0.41	45	0.4	43	0.35	42
3	0.61	27	0.61	15	0.49	28
4	0.47	43	0.43	39	0.32	44
5	0.70	14	0.40	42	0.50	26
6	0.62	25	0.62	14	0.48	31
7	***0.87***	***5***	***0.47***	***29***	***0.67***	***7***
8	0.65	20	0.64	11	0.61	12
9	0.58	32	0.57	16	0.50	26
10	0.80	7	0.80	5	0.61	12
11	***0.80***	***7***	***0.71***	***8***	***0.54***	***19***
12	0.44	44	0.38	45	0.35	42
13	0.59	30	0.39	44	0.43	40
14	0.93	4	0.44	37	0.31	45
15	0.67	18	0.66	9	0.58	14
16	0.59	30	0.49	25	0.52	24
17	**1.00**	**1**	**0.99**	**2**	**1.00**	**1**
18	0.51	39	0.45	34	0.44	38
19	0.85	6	0.81	3	0.83	3
20	0.60	29	0.50	23	0.53	21
21	0.57	33	0.56	18	0.49	28
22	0.74	12	0.54	20	0.65	8
23	0.63	23	0.56	17	0.57	15
24	0.68	16	0.48	28	0.56	17
25	0.79	10	0.62	13	0.74	5
26	*1.00*	*1*	*0.78*	*6*	*0.98*	*2*
27	0.80	7	0.80	4	0.65	8
28	0.51	39	0.50	22	0.45	36
29	0.76	11	0.75	7	0.71	6
30	0.61	27	0.44	36	0.49	28
31	0.68	16	0.62	12	0.64	10
32	0.54	35	0.45	33	0.46	34
33	**1.00**	**1**	**1.00**	**1**	**0.78**	**4**
34	0.65	20	0.65	10	0.55	18
35	0.51	39	0.46	31	0.44	38
36	0.69	15	0.53	21	0.62	11
37	0.62	25	0.46	30	0.51	25
38	0.54	35	0.48	27	0.47	32
39	0.56	34	0.43	38	0.46	34
40	0.63	23	0.55	19	0.57	15
41	0.64	22	0.48	26	0.54	19
42	0.54	35	0.49	24	0.47	32
43	0.67	18	0.45	32	0.53	21
44	0.49	42	0.42	40	0.41	41
45	0.54	35	0.44	35	0.45	36
Mean	**0.66**		**0.56**		**0.55**	
Admission wtd.	**0.64**		**0.54**		**0.54**	
Cost wtd.	**0.63**		**0.51**		**0.52**	

3.4 Shadow prices

Analysts can use the above methods to advise policy makers regarding economic efficiency levels corresponding to different values for the quality of services. However, they can also obtain estimates of the implicit value being placed on quality, as reflected in the current behaviour of providers. That is, the shadow price for quality of each provider can be derived. In the illustrated comparison for NSW hospitals, the shadow price of quality for each hospital can be interpreted as the amount of money needed to reduce mortality if it were technically efficient. Estimated shadow prices are listed in Table 5. These shadow prices differ according to where on the frontier the hospital is projected. For individual hospitals they range from $0 (where hospitals are projected onto the horizontal part of the frontier with Hospital 26 as the only peer)[5] to more than $24,356 (i.e. arbitrarily large) where hospitals are projected onto the vertical portion of the frontier, with Hospital 33 as the only peer.

An estimate of the industry level shadow price for quality is found to be $3,523 per death avoided, calculated either as where industry economic and allocative efficiency are maximised (Eckermann 2004), or at the median cost and mortality rate across hospitals (Eckermann and Coelli 2008). This industry shadow price for quality may appear low. However, given that hospital administrators generally face strong budgetary pressure to minimise cost per admission, with only indirect (e.g. evidence based medicine or societal) pressures to seek quality outcomes, it is not surprising to find a shadow price not far from the zero price that would result from quality incentives being completely absent. However, it should also be noted that the second working paper demonstrates that the net benefit maximising value for quality (*k*) should reflect technical possibilities, bound above by the maximum shadow price within a given budget.

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[5] A "peer" hospital is one that forms part of the target frontier for a particular inefficient firm. An inefficient firm can have one or more peers, depending on the point of projection.

Table 5 Shadow prices

Hospital	Cost per admission	Mortality rate (%)	Peers	Shadow price
1	4,830	40.00%	26	$0
2	9,224	25.00%	26, 17	$3,523
3	8,056	7.69%	17, 33	$24,356
4	12,409	7.14%	33	>$24356
5	5,123	40.00%	26	$0
6	8,249	6.25%	17,33	$24,356
7	***4,138***	***35.00%***	***26***	***$0***
8	6,000	14.29%	17, 33	$24,356
9	7,382	13.04%	17, 33	$24,356
10	6,649	4.17%	33	>$24,356
11	***7,545***	***4.17%***	***33***	***>$24,356***
12	8,301	32.00%	26, 17	$3,523
13	6,052	38.46%	26	$0
14	13,128	3.57%	33	>$24,356
15	6,616	10.34%	17, 33	$24,356
16	6,199	25.00%	26, 17	$3,523
17	**3,858**	**9.38%**	**None**	**$3523 to $24356**
18	7,411	24.24%	26, 17	$3,523
19	4,520	12.12%	26, 17	$3,523
20	6,134	24.32%	26, 17	$3,523
21	7,484	13.51%	17, 33	$24,356
22	4,878	25.64%	26	$0
23	5,890	20.51%	26, 17	$3,523
24	5,296	30.00%	26	$0
25	4,543	21.28%	26, 17	$3,523
26	**3,590**	**16.98%**	**None**	**$0 to $3,523**
27	6,132	5.97%	17, 33	$24,356
28	7,744	17.65%	17, 33	$24,356
29	5,302	11.27%	17, 33	$24,356
30	5,920	32.00%	26	$0
31	5,518	17.33%	26, 17	$3,523
32	6,779	27.38%	26, 17	$3,523
33	**5,283**	**3.33%**	**None**	**$24,356 or more**
34	6,977	9.89%	17, 33	$24,356
35	7,407	23.76%	26, 17	$3,523
36	5,189	25.00%	26	$0
37	5,820	29.82%	26	$0
38	6,887	23.28%	26, 17	$3,523
39	6,424	31.01%	26	$0
40	5,921	20.59%	26, 17	$3,523
41	5,618	28.57%	26	$0
42	7,057	21.28%	26, 17	$3,523
43	5,324	33.55%	26	$0
44	7,605	27.37%	26, 17	$3,523
45	6,797	28.26%	26, 17	$3,523
Industry*	6,134	21.28%	**26, 17**	**$3,523**

* The Industry shadow price can be calculated either as where industry (cost share weighted) economic efficiency is maximised or at the mean or median values for cost and outcomes.

3.5 Limitations of NSW analysis – satisfying correspondence conditions

Application of the net benefit correspondence theorem has initially been presented illustratively in comparison of the 45 NSW hospitals with the explicit assumption that coverage and comparability conditions are satisfied. Satisfying the comparability condition in practice would require that costs and effects across hospitals are adjusted for differences in patient risk factors. Satisfying the coverage condition in practice would require that the scope of measured effects was widened and effects and costs beyond separation were accounted for, either directly with data linkage (Holman, Bass, Rouse and Hobbs 1999; Wolfson and Alvarez 2002) or by modelling expected costs and effects conditional on patient health stated at point of separation (Weinstein and Fineberg 1980; Petitti 2000; Hunink, Glasziou, Siegel, Weeks, Pilskin, Elstein and Weinstein 2001; Eckermann 2004).

Eckermann (2004; 2006) demonstrates that satisfying comparability and coverage conditions is necessary and sufficient to prevent efficiency measures creating incentives for choosing less complex patients (cream skimming) and cost (and outcome) shifting. Hence, the empirical findings in the illustration should be qualified to the extent that they fail to adjust for differences in patient risk and effects beyond separation and, hence, create incentives for cream skimming and cost shifting respectively. However, whatever specification of quality was used, satisfying coverage and comparability conditions would be required to avoid the cream skimming and cost shifting incentives that plague efficiency measures in health care.

In general, the net benefit correspondence theorem provides a simple and explicit framework to incorporate effects beyond point of separation in satisfying a coverage condition and adjusting for differences in patient risk factors to satisfy a comparison condition, using a three step process:

(i) Identify intervention effects (decision analytic methods);

(ii) Measure effects, including those beyond discharge (data linkage or expected effects conditional on health state at discharge), to satisfy the coverage condition;

(iii) Adjust rates for patient risk factors (key co-morbidities) at admission to satisfy the coverage condition.

In practice, the first two steps of this process can, depending on clinical specialty, involve measuring outcomes at discharge and modelling expected effects or linking directly to post separation data, such as state ISAAC data (e.g. all-cause mortality and readmission data to 12 months). The third step involves systematically collecting patient descriptors at admission, such ICD-10AM co-morbidity codes, and using them to adjust for patient level complexity and co-morbidity, using measures such as the Charlson Comorbidity Index (de Groot, Beckerman, Lankhorst and Bouter 2003). A simple example follows, where data linkage and risk adjustment was undertaken to standardise linked all-cause mortality, readmission and cost data to 12 months post date of admission across Cardiology patients undergoing PTCA procedures in South Australian hospitals.

4 SA Example: Comparing PTCA with standardised 12 month mortality, readmission and cost data

Application of the NBCT with linked data and adjustment for patient risk factors is illustrated with 2005-2007 South Australian hospital data for Cardiology patients treated with DRGs F10Z (Percutaneous Coronary Angioplasty with AMI) and F15Z (Percutaneous Coronary Angioplasty without AMI, with stent implantation). Patient level data for Charlson Comorbidity Index at index PTCA admission (2005-2006), effects of all-cause mortality and readmission to 12 months post date of index admission (2005-2007) and associated costs of index PTCA admission adjusted for length of stay[6] and readmissions were extracted for three major metropolitan South Australian hospitals. Analysis was restricted to patients with South Australian postcodes to allow adequate coverage in linking readmission and mortality data to 12 months. Twelve month mortality data were cross validated against the ACACIA study (Chew, Amerena, Coverdale, Rankin, Astley, Soman and Brieger 2008). There was a total of 1,438 separations among SA

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[6] Costs were adjusted based on LOS relative to that of case-mix weights for NHCDC public hospitals, using an average cost per bed day, which excluded non bed day costs in NHCDC subcategories. Bed day related costs were calculated, including ward and nursing medical costs, pharmacy, allied health, supplies, hotel, on costs and depreciation, while non bed day related costs (procedures, emergency care, critical care, prosthetics, pathology, imaging etc.) were excluded.

postcodes (F10Z n=695; F15Z n=743) with the rate of mortality to 12 months by DRG by hospital presented in Table 6.

Table 6 Summary of all-cause mortality within 12 months of admission.

Hospital	F10Z	F15Z
A	1.5%	0%
B	4.8%	2.1%
C	2.8%	3.1%
Total	21/695 (3.0%)	17/743 (2.3%)

The 12 month all-cause mortality rate across the three hospitals was 3.0% for F10Z (Percutaneous Coronary Angioplasty with AMI) and 2.3% for F15Z (Percutaneous Coronary Angioplasty without AMI, with stent implantation). These overall rates are lower than have been observed nationally in the ACACIA study (Chew, Amerena, Coverdale, Rankin, Astley, Soman and Brieger 2008), where overall mortality by 12 months among patients with PCI with MI was 3.5%. Hence findings of relatively higher mortality rates amongst hospitals A to C for DRG F10Z and F15Z are not necessarily of clinical concern, while lower relative mortality rates are likely to suggest high quality practice.

Several different analyses were conducted to examine the differences in 12 month all-cause mortality between the three metropolitan hospitals (A, B and C). First, logistic regression was used to examine the odds ratio across hospitals. Then analyses were adjusted for age and Charlson Comorbidity Index through their inclusion as covariates in the regression. This generally increased the size of the hospital effect, with, for example, in excess of a threefold risk of 12 month all-cause mortality for Hospital B compared with Hospital A for F10Z, increasing to almost fourfold when adjusted for age and Charlson Comorbidity Index.

Table 7 Summary of logistic regression analyses for all-cause mortality status within 12 months of admission

DRG	Unadjusted OR	Industry Stand. (1) Risk	Adjusted OR	Adjusted and (2) Industry Stand. Risk
F10Z				
Age	-	-	1.06 (p=0.003)	-
Charlson Comorbidity Index	-	-	1.58 (p=0.003)	-
Hospital A	0.31	0.0153	0.26	0.0136
Hospital B	1.00	0.0478	1.00	0.0507
Hospital C	0.57	0.0276	0.53	0.0267
Total		**0.0302**		**0.0302**
F15Z				
Age	-	-	1.06 (p=0.037)	-
Charlson Comorbidity Index	-	-	1.67 (p=0.002)	-
Hospital A (2)	0.00	0.00	0.00	0.00
Hospital B (referent)	1.00	0.0191	1.00	0.0249
Hospital C	1.55	0.0292	1.07	0.0267
Total		**0.0229**		**0.0229**

1: Industry standardised risk rates are back-solved in calibrating actual industry risk to the weighted average of hospital risk from applying the odds ratio for mortality over 12 months in each hospital.
2: No deaths occurred within 12 months of admission at Hospital A.

4.1 Readmissions

Re-admissions to 12 months post date of index admission by DRG by hospital are presented in Table 8 for the proportion of patients readmitted and the average number of readmissions per patient.

Table 8 Proportion of patients readmitted and average number of readmissions at 12 months

Proportion of patients with readmissions up to 12 months		
Hospital	**F10Z**	**F15Z**
A	30.1%	30.3%
B	25.9%	34.2%
C	32.4%	38.5%
Total	29.8%	35.9%
Average number of readmissions per person up to 12 months		
Hospital	**F10Z**	**F15Z**
A	0.4388	0.5606
B	0.4258	0.5474
C	0.5276	0.6247
Total	0.4719	0.5935

The effect of hospital on number of readmissions in the 12 months from the index admission was analysed using Poisson regression. As for the mortality analyses, separate regressions were initially run within each DRG and analyses were unadjusted and then adjusted for age and Charlson Comorbidity Index, as presented in Table 9.

Table 9 Summary of Poisson regressions for number of readmissions for F10Z and F15Z

	Unadjusted IRR	**Industry Standard. Rate**	**Adjusted IRR**	**Adjusted and Industry Standard. rate**
F10Z				
Age	-	-	1.02 (p<0.001)	-
Charlson	-	-	1.18 (p<0.001)	-
Hospital A	0.97	0.4388	0.99	0.4310
Hospital B	1.00	0.4258	1.00	0.4354
Hospital C	1.23	0.5276	1.21	0.5259
***F15Z*(1)**				
Age	-	-	1.00 (p=0.582)	-
Charlson	-	-	1.25 (p<0.001)	-
Hospital A	1.02	0.5606	1.02	0.5848
Hospital B	1.00	0.5474	1.00	0.5731
Hospital C	1.09	0.6247	1.07	0.6141

1: Industry standardised rates are back-solved in calibrating actual industry risk to the weighted average of hospital risk from applying relative risk for readmission over 12 months in each hospital.

4.2 Costs

Combined costs of index hospitalisation and readmissions to 12 months by DRG by hospital are presented in Table 10. Costs are presented unadjusted and age and Charlson Comorbidity Index standardised.

Table 10 Cost of admissions standardising for age and Charlson Comorbidity index

	LOS index admission	*Cost index admission**	*Cost of readmiss.*	*Total cost Unadjusted*	*Age, Charlson standardised*
F10Z					
Hospital A	5.00	$9,731	$2710	$12,441	$12,337
Hospital B	3.80	$8,935	$2313	$11,248	$11,034
Hospital C	4.98	$9,713	$2690	$12,403	$12,430
F15Z					
Hospital A	3.05	$7,772	$1976	$9,748	$9,739
Hospital B	2.15	$7,165	$2823	$9,988	$10,132
Hospital C	2.67	$7,513	$3660	$11,173	$11,009

* Costs adjusting for length of stay were calculated based on difference from mean NHCDC length of stay for F10Z as $9,279 + (LOS - 4.31) × $662.88 and for F15Z as $7,347 + (LOS - 2.42) × $667.36, see Footnote 7.

Based on these analyses, industry standardised all-cause mortality, readmission rates and costs are summarised in Table 11.

Table 11 Comparing hospitals by DRG with age and Charlson Comorbidity index standardised 12 month all-cause mortality, readmission and cost

	Std. mortality rate (12 moths)	*Std. rate of re-admission (12 months)*	*Std. cost of admissions (12 months)*
F10Z			
Hospital A	1.36%	0.4310	$12,337
Hospital B	5.07%	0.4354	$11,034
Hospital C	2.67%	0.5259	$12,430
F15Z			
Hospital A	0	0.5848	$9,739
Hospital B	2.49%	0.5731	$10,132
Hospital C	2.67%	0.6141	$11,009
F10Z and F15Z Combined			
Hospital A	0.66%	0.5105	$10,993
Hospital B	3.74%	0.5065	$10,568
Hospital C	2.66%	0.5714	$11,695

The average number of admissions across hospitals A, B and C for combined F10Z and F15Z is 479, with a minimum of 328 and maximum of 711. Their comparative cost and all-cause mortality rates are presented on the cost-disutility plane in Figure 4, with the cost implications of readmission rates included in the cost component of this presentation, but their potential implication as an indicator of morbidity not included in this presentation. Readmissions have been removed as a variable here to simplify graphical presentation, however it is later shown that, in this particular case, the non-cost value of avoiding readmission does not influence the threshold regions over which technically efficient providers maximise expected net benefit and have a shadow price of 0 implicit in current industry behaviour.

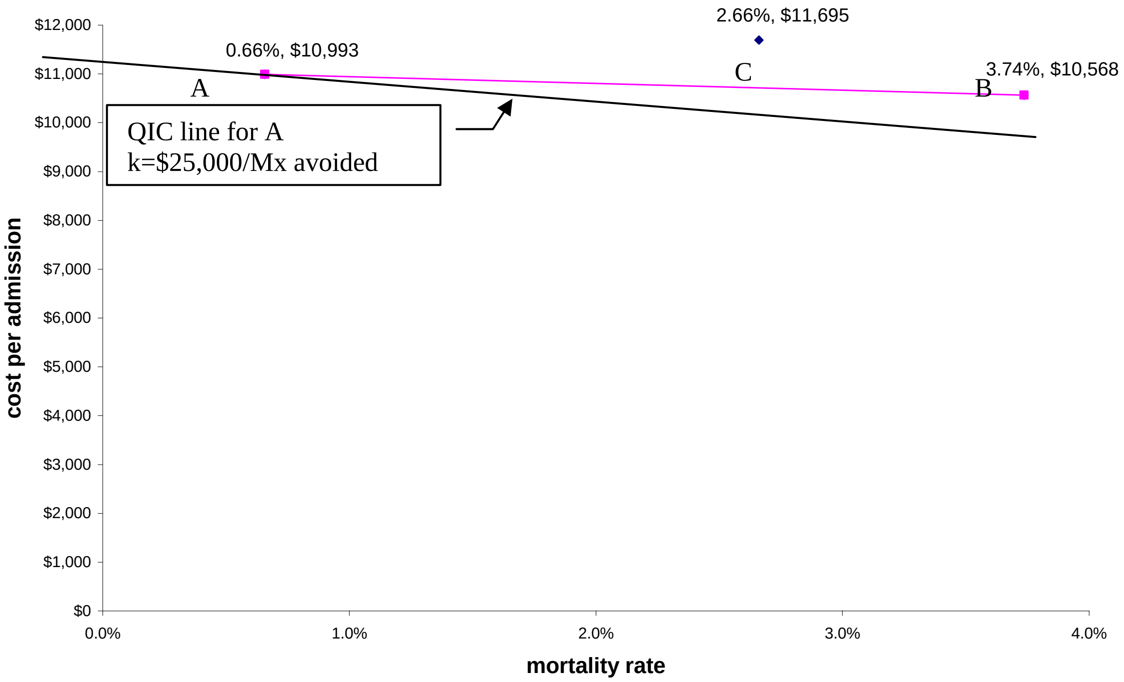

Figure 4 Standardised 12 month cost and all-cause mortality rates for SA hospitals combining F10Z & F15Z

The technical efficiency frontier is defined by hospitals A and B. These hospitals are technically efficient in the sense that one cannot proportionally reduce the input variables (cost and mortality as a quality variable) and still remain within the estimated frontier, and hence have technical efficiency of 1. Hospital C has a technical efficiency of 0.919, reflecting that it could reduce both its cost per admission and mortality rate by 8.1% to the technical efficiency frontier (a combination of cost and mortality for hospitals A and B).

At a given value of effects of $25,000 per mortality avoided, Hospital A is economically efficient (maximises net benefit), given quality inclusive cost (QIC) per admission is minimised, while the other hospitals are economically inefficient because they could potentially reduce their QIC (increase net benefit) per admission. Economic efficiency (EE) measures, obtained using equation (4), are listed in Table 12 for each hospital for four different values of *k*: $0, $10,000, $25,000 and $50,000 per mortality avoided.

Table 12 Economic efficiency conditional on threshold value of mortality avoided

Hospital	$0	$10,000	$25,000	$50,000
A	0.961	0.989	1.000	1.000
B	1.000	1.000	0.970	0.910
C	0.904	0.915	0.903	0.869

Looking first at the case of *k* = $25,000, we observe that Hospital A has an EE score of 1, as expected. Hospitals B and C have EE scores of 0.970 and 0.903, suggesting that they could reduce QIC by 3.0% and 9.7% per admission respectively. If there were no value given to avoiding mortality and *k* were 0, equivalent to minimising cost per admission, then Hospital B is the net benefit maximising hospital (EE of 1 and QIC minimised). This can be visualised as being equivalent to inserting a horizontal iso-cost line in Figure 4. When a value per mortality prevented of $50,000 is considered, QIC lines becomes steeper (negative slope increases), so that Hospital A has the lowest mortality rate as it continues to have EE of 1, while EE falls for B and C. This makes clear that if quality is ignored in the efficiency analysis, when the true value of quality is say $50,000 per mortality prevented, very misleading relative efficiency measures can be obtained. Hospital B, with the lowest cost over 12 months, would be suggested as the peer if quality is ignored, but Hospital A is clearly the peer if the value of avoiding a mortality is $50,000 and, indeed, even if $25,000.

4.3 Threshold regions

Applying equation (5) to cost and effects data in Table 11, the regions of threshold values for effects over which technically efficient Hospitals A and B are peers can be identified. If we only consider all-cause mortality and cost over 12 months (which includes costs of readmissions) and ignore the potential non-cost (morbidity) value of avoiding readmissions, then Hospital A is identified as preferred for threshold values of mortality of $13,800 and above and Hospital B for threshold values below this level. Explicitly, the threshold value for adjacent technically efficient Hospitals A and B on the frontier in Figure 4, beyond which A is preferred, is found from equating their QIC using equation (5) as:

$$10{,}993 + 0.0066k = 10{,}568 + 0.0374k \text{ and hence}$$

$$k = (\$10{,}993 - \$10{,}568) / (0.0374 - 0.0066) = \$13{,}800 \text{ / mortality avoided.}$$

If the potential non-cost morbidity value of readmission is now considered, then the threshold regions for the value of avoiding mortality and non-cost (morbidity) impacts of readmission, say $k1$ and $k2$ respectively, over which A is preferred, can be found applying equation (5) as:

$$10{,}933 + 0.0066k1 + 0.4310k2 < 10{,}568 + 0.0374k1 + 0.4354k2, \text{ which reduces to}$$

$$k1 + 0.129k2 > \$13{,}800$$

Interpreting this, if there is a positive non-cost value from avoiding a readmission then the threshold value at which Hospital A is preferred will fall below $13,800. Now, given the non-cost morbidity value of avoiding an admission will be less than avoiding a mortality, a lower bound for this can be set in the limiting case where the non-cost (morbidity) value of avoiding a readmission is equal to that of avoiding a mortality, in which case this value would fall to $13,800/1.129 = $12,200. Hence, Hospital A will be preferred for values above $13,800 per mortality avoided and Hospital B for values below $12,200 per mortality avoided, given feasible relative non-cost morbidity values of avoiding a readmission. For values of avoiding a mortality between $12,200 and $13,800 it would depend on the relative value of avoiding a readmission as to which of A and B is preferred. If there is no value associated with reduced morbidity from avoiding a readmission, then Hospital B is preferred over this region.

4.4 Shadow price

Industry economic efficiency across Hospitals A, B and C, calculated as the cost share weighted average economic efficiency across hospitals (Eckermann 2004), is maximised at values for avoiding mortality of $13,800 and a morbidity value of avoiding readmission of 0 (noting that the cost implications of readmission rates are already included in cost). That is, at a threshold value of avoiding mortality of $13,800, industry economic efficiency is reduced with any positive threshold value to avoiding readmission as an indicator of their morbidity value. Hence, current behavior across these three hospitals suggests some value to quality of care implicit at an industry level in avoiding mortality, while not necessarily a value in avoiding readmissions beyond their cost implications.

This industry value of quality in avoiding mortality is not supported under case-mix funding, which implicitly ascribes a 0 value to effects from quality of care in creating incentives for minimising cost per admission. However, in the next paper, we demonstrate how the performance measurement framework presented here can be extended to modify case-mix funding in creating incentives for net benefit maximisation, while maintaining budgets for case-mix funding. The current shadow price is shown to be an important starting point in managing this process, while ensuring budgetary control and accountability.

5 Conclusion

This working paper has illustrated, with NSW and SA examples, a robust method for including effects of care as quality indicators in performance measures to inform policy makers and create economic incentives for providers in practice, consistent with the maximisation of net benefit. Unlike previous methods this has been shown to allow policy makers to be informed of:

(1) the net benefit maximising peers at potential threshold values for quality;

(2) relative performance in maximising net benefit relative to the appropriate peer (economic efficiency at potential threshold values);

(3) the extent to which providers could improve quality (e.g. reduce mortality and readmission rates) and reduce resource use for a given number of admissions (technical efficiency);

(4) the extent to which providers' performance can be improved in aligning the value of quality with that of policy makers (allocative efficiency);

(5) the current value of quality implicit in industry behaviour (industry shadow price).

The South Australian examples have also shown how cost (and effect) shifting and cream skimming incentives can be prevented, with data linkage and risk adjustment respectively, to satisfy coverage and comparability conditions of the correspondence theorem underlying this method. In combination, this creates a performance measurement framework that overcomes limitations of previous separate clinical and cost based performance measures, to hold providers accountable for their cost and value of quality of care, while preventing perverse incentives for cream skimming and cost shifting. In a subsequent companion working paper, the information generated by this performance measurement framework is shown to simply extend to a funding mechanism, which modifies current case-mix funding to create active incentives for more appropriate quality of care within current budgets, while preventing cream skimming and cost shifting incentives.

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