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Evaluating the Cost-effectiveness of Health System Strengthening:

A Platforms Perspective

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1 Introduction

Health System Strengthening (HSS) is an important concept now widely discussed, but too often without sufficient structure or an adequate understanding of what actually is involved. The articles on which this seminar is based (Morton, Thomas and Smith, 2016; Smith and Yip, 2016) attempted to present more clearly just what health system strengthening might entail and whether that might be modelled.

The recent emphasis on HSS has arisen primarily at the international level, within intergovernmental organisations (IGOs) and in the field of global health. Greater emphasis is being placed on the idea that some targeted health programmes fail because they are designed and implemented without adequately considering the characteristics of the broader health system. This is important because services within a health care system are interdependent: "vertical" programmes that address one disease or health issue require sufficiently strong "horizontal" support and coordination across various health service sectors. This relationship always has been important, but the challenges of the Ebola crises in particular in the past few years have made that clearer. Although HSS discussions often focus on low- and middle-income countries, many of the ideas apply equally to countries such as the UK, specifically in planning for the future.

Delivery platforms, one aspect of HSS, are a major focus in the global health field at present. These include, for example, hospitals or a community network of nurses on which a range of services depend. What happens in one platform has a spill-over effect on others. Integrated care and economies of scope also are important considerations.

The emphasis in analyses of HSS is on interactions within a *system* — the recognition that a change in one aspect will, for better or worse, affect other aspects. Where health-focused activities interact, e.g. prevention and treatment, economies of scale and scope influence whether, how and how much activities interact. Policy choices, then, can affect a much wider range of interventions than anticipated — or intended.

Taking a systems-level focus in analysis and planning for health care has other advantages. It allows a longer term, strategic perspective that can explicitly include equity. A systems viewpoint also helps discern the interaction between health services and broader, social determinants of health.

Economists rarely have focused on health system design and the delivery of services. In a paper published last year, my colleague and I argue that: "an economic paradigm of constrained optimization adapted to the systemic nature of the health sector could provide an analytical and practical approach to policy-makers in assessing their health systems and deriving solutions" (Smith and Yip, 2016, p. 21). The other paper (Morton, Thomas and Smith, 2016) is a first attempt to do so.

2 Delivery Platforms

In our research, we adopted the idea of delivery platforms, a phrase common in the field of global health. "Delivery platform" has been defined in the Disease Control Priorities reports as "logistically related service delivery channels that collectively make up the organisational components of the healthcare system" (Watkins, et al., 2018, p.46). To state it differently, a delivery platform is a fixed health service resource on which a range of treatments depend; it may be something as large as a hospital, or as small as a GP's surgery. The crucial characteristic of a delivery platform is that its existence, organisation and efficiency can have an important effect on the costs and benefits of several services. The Disease Control Priorities programme identifies five types of platforms: population-based health interventions, community services, health centres, first level hospitals and referral hospitals (Watkins, et al., 2018).

Ultimately, delivery platforms affect health system cost. It might seem obvious, then, that cost-effectiveness analysis (CEA) should play a role in policy decisions about modifications of delivery platforms. But this is a difficult task, whether the approach is longitudinal or based on cross-country comparisons. Analyses based on one country's experience may not fit the situation in another or may not be considered relevant in our research, we use the principles underlying CEA to examine health systems and identify what changes to CEA methodology are required to evaluate strengthening initiatives. The idea, of course, is not new, but our approach is.

3 Three Approaches to HSS

Health System Strengthening may occur in three ways:

1. Investment in quality improvement for an existing shared platform generates benefits across a range of existing treatments, e.g. better IT or training for nurses.

2. Relaxing capacity constraints for an existing shared platform, lowers barriers to optimizing existing treatments, e.g. labour force changes.

3. Providing a new shared platform supports a number of existing treatments.

Our model respects the goal of CEA — i.e. maximising some concept of value subject to a budget constraint. We then model the interdependencies among treatments that are created by reliance on a common delivery platform. The basic model is shown in Figure 1.

$$maximize \sum x_i v_i$$

$$subject\ to \sum x_i c_i \leq B\ ;$$

$$all\ 0 \leq x_i \leq 1$$

- Marginal condition:

$$v_i/c_i \geq \lambda,$$

- where $1/\lambda$ is the cost-effectiveness threshold

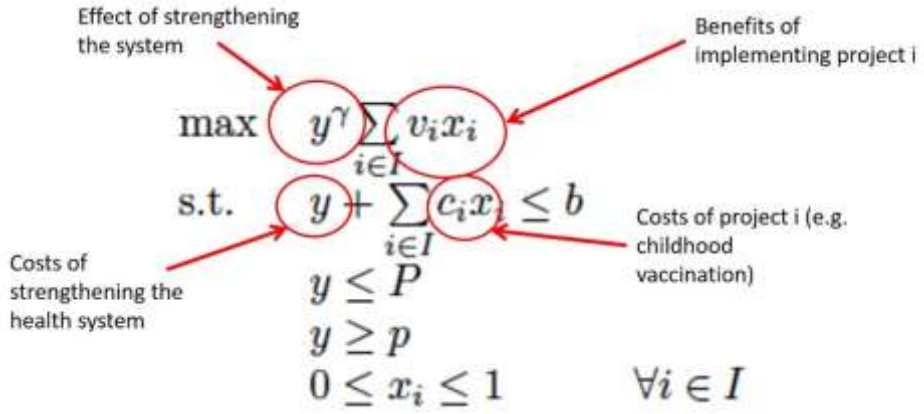
FIGURE 1: BASIC CEA MODEL

The important aspect of this model is that we have a set of interventions which are represented by the subscript i: each unit of delivery gives a value, v_i; each has a cost, c_i in the line below. Our decision variable is x_i, which typically would be 0 or 1, i.e. we either implement that treatment or not. However, an intermediate between 0 and 1 is possible in some situations where, say, the change implemented affects only a proportion of the population. So, a modification in the delivery system is desirable only if the value over the cost is greater than the inverse threshold. That is the typical model of cost effectiveness analysis and of course it assumes independence of interventions.

4 Improving the Quality of a Delivery Platform

The first adaptation of our model assumes an interest in improving the quality of an existing delivery platform. Since a range of treatments rely on the platform, improving its "quality" should improve the cost-effectiveness of all treatments, albeit perhaps to different extents. An example is a temperature-controlled supply chain for pharmaceutical products. The policy questions raised are (a) how much money to spend on such health system strengthening as opposed to the expansion of existing treatments — an important trade-off — and (b) whether quality improvement affects the optimal choice of treatments to be offered.

Figure 2 shows our model for this delivery platform modification. We have introduced variable y, which is the amount spent on health system strengthening. Spending more on y improves the benefits of all treatments, the v's. But the exponential gamma symbol after the y indicates diminishing returns, so gamma is between 0 and 1. At some point, health system strengthening will produce diminishing returns and gamma reflects that. Moreover, health system strengthening expenditure will encounter budget constraints, which is y.



Source: Morton, Thomas and Smith, 2016

FIGURE 2: IMPROVING EXISTING PLATFORM QUALITY

In one respect, this is a particularly naïve formulation because y has the same effect on all treatments i; the multiplicative effect is equal. It is easy to conceptualise a different impact—e.g. workforce improvement—on different projects so one could reformulate this with a differential impact.

This gives rise to a marginal condition expressed as follows:

$$\frac{v_i}{c_i} \geq \frac{\gamma \sum_i v_i x_i}{y}.$$

At the margin, the accepted interventions are at least as cost-effective as further investment in health system strengthening. In such cases, it makes no difference whether more is spent on the marginal project or on health system strengthening. Morton, Thomas and Smith (2016) has an example using HIV prevention projects, shown in Figure 3 below.

Intervention	Total Cost (US$)	Number of infections averted	Incremental cost-effectiveness ratio
	1	2	3
1. Peer group education-sex workers	39,575	2473	0.0625
2. Safe blood transfusion	50,000	595	0.0119
3. Peer group educationy-oung people	423,500	799	0.00189
4. Mass media and social marketing of condoms	1,300,000	2434	0.00187
5. Peer group education-high risk men	500,000	862	0.0017
6. Targeted AZT to pregnant women	300,000	319	0.0011
7. Voluntary counselling and testing	310,000	261	0.0008
8. Targeted advice for breast feeding	150,000	62	0.00041
9. Targeted treatment of STIs	560,000	204	0.00036

FIGURE 3: DATA FOR HIV PREVENTION PROJECTS

Source: Morton, Thomas and Smith, 2016, Table 1, p.99.

The data in Figure 3 are real data for a low-income country. Unknown, however, was the gamma, i.e. the diminishing-returns parameter. In the basic model, we assumed it to be 0.5 and we tested a range of other inputs. The parameters showed that the most cost-effective approaches, modelled with a gamma of 1.0, were implementing peer group education for sex workers, safe blood transfusion and the education of young people. Mass media outreach and social marketing of condoms had a gamma of 0.65 and were not implemented entirely. In total, $1.46m of the budget was spent on health system strengthening.

As another example, assume two treatments, T1 an T2, at a total expenditure of $15,450,000 with the total cost per QALY of $158, which is well under this country's fictitious threshold of $200 per QALY. Assume now that we have an additional $2 million and need to decide whether to spend that on new treatment T3. As Figure 4 shows, because T3 shares some of the fixed costs, that element of this platform is lower in cost than if none was shared. T3 is a high-volume intervention, but with low benefit and a cost per QALY of $250. However, when combined with T1 and T2, T3 reduced the cost of the package of treatments to $160, which is cost-effective, and only marginally higher than T1 and T2 alone.

Additional $2m spent on intervention T3

	T1	T2	T3			
Allocation fixed costs per case	294	294	294	294	Fixed costs	7,500,000
Variable costs per case	200	500	200	310	Variable costs	7,950,000
Incremental benefits (QALYs)	7	5	2.3	4.4	Total	15,450,000
Number of cases	6,000	9,500	10,000	25,500		
Total Cost/QALY	71	159	250	160		
Variable Cost/QALY	29	100	87	78		

Additional $2m spent on HSS

	T1	T2				
Allocation fixed costs per case	613	613		613	Fixed costs	9,500,000
Variable costs per case	200	500		384	Variable costs	5,950,000
Incremental benefits (QALYs)	8	6		6.8	Total	15,450,000
Number of cases	6,000	9,500		15,500		
Total Cost/QALY	102	185		153		
Variable Cost/QALY	25	83		61		

FIGURE 4: IMPROVING THE QUALITY OF AN EXISTING PLATFORM

Another option, also shown in Figure 4, would be to spend this new money on health system strengthening, in this case improving the quality of existing treatments. Say that calculations show we can achieve a total cost per QALY across the two treatments, T1 and T2, of $153; this is lower than adding in T3, which cost $160. This difference is not dramatic but still illustrates the principle of comparing the introduction of a new treatment to improving the quality of existing ones. The second option is the more cost-effective use of the additional money being spent in the health system on that platform.

5 Relaxing Capacity Constraints

Health system performance is affected negatively when the choice of treatment is limited by capacity constraints for some resources, e.g. human resources. This is a common issue in lower-income countries, but it also occurs in the NHS. If that constraint can be relaxed, the provision of high value treatments that rely on it, can be increased. The typical example in high-income country settings is the limited availability of nurses to deliver nurse-intensive treatments that are recognized as cost-effective.

The policy questions are, first, to what extent new funds should be spent on relaxing platform constraints rather than directly expanding treatment coverage and, second, how the optimal mix of treatments should change after constraints are relaxed.

Linear programming models of multiple constraints are well established. In our original cost-effectiveness formula, instead of having just one constraint we have two or more. Van Baal and colleagues (Thongkong, N et al. J.L., 2015) have formulated this, maximising x_{ivi}, as follows:

$$maximize \sum x_i v_i \ subject\ to \sum x_i c_i^L \leq B_L ; \sum x_i c_i^O \leq B_O; \ all\ 0 \leq x_i \leq 1$$

y is not a variable here, so quality improvement is not a concern, only constraints. The simplest way of representing this is with two budget constraints: labour — how much each treatment consumes in labour, which is the binding constraint (B_o); and residual expenditure — how much is required for each treatment (B_L). In effect, we have two opportunity costs, one for labour and one for the rest of the budget. These are not the same because the opportunity cost of labour is higher than the opportunity cost of residual money.

Figure 5 diagrams this relationship. Treatment 1 is labour intensive and relies heavily on fixed human resources. Treatment 2 requires far less labour because it is, say, pharma intensive. With given resources, the best QALY balance we can obtain for the two treatments is shown as point A. What happens if we relax the human resources constraint, the stronger of the two? In this example, to remain budget neutral, some of the residual money available for drugs, materials and other items is shifted to relax human resource constraints. This produces a higher number of QALYs, so the reallocation is worthwhile.

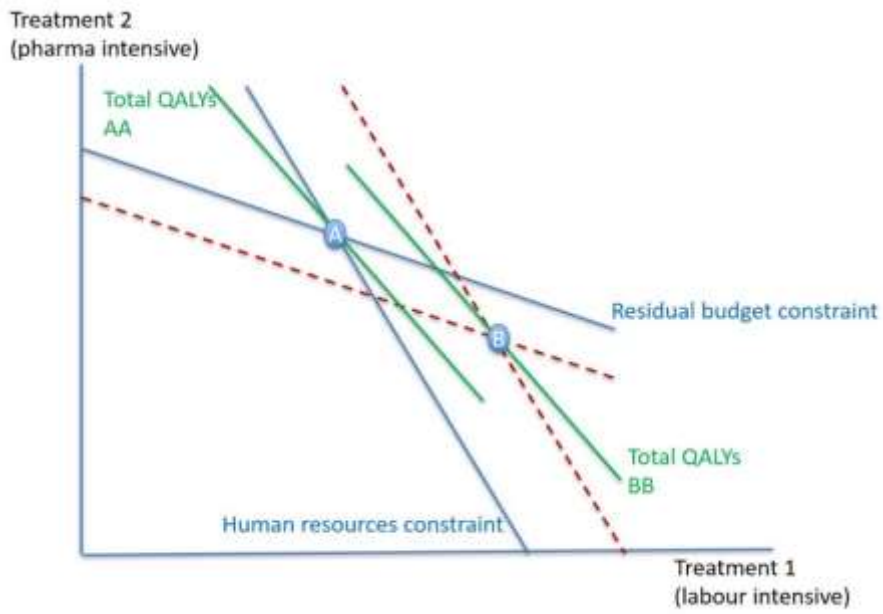


FIGURE 5: RELAXING A FIXED PLATFORM CONSTRAINT: CHANGE IN TREATMENT MIX AND IMPROVEMENT IN BENEFITS

Figure 6 provides another illustration, using a hypothetical example. Existing health care provision offers a single treatment, T1, at a cost per QALY of $180 with 8,500 people treated. A new treatment,

T2, uses fewer fixed resources. Assume that T1 originally could be delivered only by physicians, a constrained resource.

Suppose that treatment is now delivered by nurses. Incremental benefit then decreases from 6 to 4, but shifting resources saves enough money to allow a new treatment, T2, to be provided. Although the overall cost-effectiveness of both treatments improves, the number treated necessarily declines. The trade-off here is between allowing some degradation of quality in order to introduce new treatments and improve overall quality. Because some patients will be affected negatively, such trade-offs are highly controversial.

Existing health care provision

	T1	Total
Allocation fixed costs per case	882	882
Variable costs per case	200	200
Incremental benefits (QALYs)	6	
Number of cases	8,500	8,500
Total Cost/QALY	180	180
Variable Cost/QALY	33	33

Fixed costs	7,500,000
Variable costs	1,700,000
Total	9,200,000

Addition of intervention T2

	T1	T2	
Allocation fixed costs per case	682	682	682
Variable costs per case	200	100	155
Incremental benefits (QALYs)	4	7	
Number of cases	6,000	5,000	11,000
Total Cost/QALY	220	112	171
Variable Cost/QALY	50	14	34

Fixed costs	7,500,000
Variable costs	1,700,000
Total	9,200,000

FIGURE 6: AVAILBILITY OF NEW TREATMENT INCREASES COST-EFFECTIVENESS AT EXPENSE OF T1

6 Providing and Entirely New Shared Platform

The third approach to HSS is adding an entirely new shared platform. This would expand the range of treatments that could be provided or offer new methods of delivery for some existing treatments. Such expansion is costly, requiring new money rather than the reallocation of existing resources. The potential for improving the cost-effectiveness of both existing and added services exists. An example is introducing a network of community nurses to deliver a new treatment but in a way that may be more cost-effective by using that new network for other treatments as well. For example, in addition to making home visits to test for HIV, they also could screen for tuberculosis (TB).

The policy questions raised are, first, whether the new platform should be implemented at all; second, what mix of treatments would be optimal; and third, whether some existing treatments should be discontinued because the new platform would mean they no longer are cost-effective.

A new platform offers potential for new modes of service delivery, possibly for existing treatments. For example, say TB screening requires visits to the local hospital, which reduces the likelihood of both initial testing and follow up. The costs and the potential benefits of at-home or community-based delivery would change that calculation.

The simplest model is one that considers two scenarios, one with and one without the new platform infrastructure. Because this new platform is a far-reaching change, new money is required to implement it. Methodologically, the optimal portfolio of treatments under each scenario should be compared, considering the irreversible costs of investing in the new platform.

Figure 7 shows the models. The first formula is a standard cost-effectiveness model without the platform, i.e. maximising benefits subject to a budget constraint. Treatments would be ranked according to cost-effectiveness. The second formula includes the new platform. We now have decision variables z_i that capture whether services are now delivered by the new community nurses, the new platform. The existing treatments are retained in the formula, but since a treatment will not be delivered in both the old and the new settings, a choice must be made.

The budget constraint with the new platform includes the costs of implementation C_P, the cost of delivering in the existing system (the first summation) and the cost of delivery using the new platform (the second summation). The first inequality on the bottom line states that x_i plus z_i must be less than one, which means that a treatment can be delivered using only one platform, not both.

- **Without** the platform (set of interventions *S*)

$$maximize \sum_{i \in S} x_i v_i^S$$

$$subject\ to \sum_{i \in S} x_i c_i^S \leq B\ ; all\ 0 \leq x_i \leq 1,$$

- **With** the platform (set of interventions *P*, new decision variables $\{z_i\}$, cost of the platform C_P)

$$maximize \sum_{i \in S} x_i v_i^S + \sum_{i \in P} z_i v_i^P;$$

$$subject\ to\ C_P + \sum_{i \in S} x_i c_i^S + \sum_{i \in P} z_i c_i^P \leq B\ ;$$

$$all\ 0 \leq x_i + z_i \leq 1;\ 0 \leq x_i \leq 1;\ 0 \leq z_i \leq 1,$$

FIGURE 7: MATHEMATICAL MODEL

Figure 8 provides an illustration of introducing a new platform. T1 is delivering just the new treatment using the new platform — say, HIV treatment using a new community nurses platform. Fixed costs are $11 million, based on $200 for each household the nurse visits. On average QALYs improve by 7, but cost-effectiveness is $213, which is above our $200 threshold. The platform is not attractive, then, if nurses only visit to test for HIV. However, a second treatment — say, testing for TB — can use the same platform based on the same fixed costs. T2 alone does not have a desirable cost per QALY and would not have been implemented by itself. Delivering both T1 and T2, using the spare capacity

in this new platform, produces a cost per QALY of $164. Neither T1 nor T2 would have been cost effective on its own; delivering the two together is, because fixed costs are shared.

Note also that total costs increase, but these remain under the QALY threshold of $200. Unless this change is funded with entirely new money, it will produce opportunity costs somewhere else in the system; delivery of some other product or service may be decreased.

Provision of T1 alone

	T1	**Total**
Allocation fixed costs per case	1294	1294
Variable costs per case	200	200
Incremental benefits (QALYs)	7	
Number of cases	8,500	8,500
Total Cost/QALY	213	213
Variable Cost/QALY	29	29

Fixed costs	11,000,000
Variable costs	1,700,000
Total	12,700,000

Platform shared with T2

	T1	**T2**	
Allocation fixed costs per case	524	524	524
Variable costs per case	200	500	379
Incremental benefits (QALYs)	7	5	
Number of cases	8,500	12,500	21,000
Total Cost/QALY	103	205	164
Variable Cost/QALY	29	100	71

Fixed costs	11,000,000
Variable costs	7,950,000
Total	18,950,000

FIGURE 8: INTRODUCING A NEW PLATFORM

7 Conclusions

Approaching the idea of HSS from this viewpoint leads to the following conclusions. First, for many treatments, costs — and to some extent quality — can depend strongly on the existence and nature of health system infrastructure. Ultimately, the challenge is how to treat fixed costs, since the costs assigned to each treatment may be dramatically affected by whether and how they are shared with other treatments. As a result, "universal" estimates of cost-effectiveness, for many treatments, are simply not possible. That said, it is possible to develop appropriate analytic models that respect CEA principles and that can provide a guide for making choices.

Much of the debate on health systems and health system strengthening ultimately revolves around fixed costs and conventional CEA does not incorporate those adequately. One approach would be to disaggregate costs in CEA to specify spending on both variable costs, such as materials, drugs or service delivery, and fixed costs. This might help adapt CEA for local circumstances and counter the constraints in health care systems that compromise the use of a CEA threshold and favour zero-based notions of economic evaluation. Changing CEA, of course, entails its own costs, requiring more and different information and analytic resources, but the benefits likely would outweigh costs in the longer term.

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8.1 ACKOWLEDGEMENT

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