Estimating Costs of Achieving Global Goals

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Estimates of the costs of achieving intermediate or long-term global development goals are subject to uncertainties that go well beyond those in applied economic contexts, and exceed the level that is tolerable. It therefore seems inappropriate that such estimates should be relied on heavily to determine global resource mobilisation targets and priorities for action for lengthy planning horizons. Consequently, an alternative planning and resource allocation framework that is flexible and learning-oriented is needed. In this note, we explore one important class of reasons for uncertainties concerning the validity of recent estimates of the intermediate or long-term cost of achieving global goals, which stem from the unknown nature of the "development production function" and its (dual) cost function.

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In recent years, there has been considerable interest in intermediate or long-term global development goals, most notably the Millennium Development Goals (or MDGS).[1] Various estimates have been produced of the cost of achieving these goals, by the World Bank, United Nations, and the Millennium Project, directed by Jeffrey Sachs. Such cost estimates are thought necessary to facilitate the raising of adequate resources and the allocation of the available resources among different ends and interventions.

Unfortunately, estimates of the costs of achieving intermediate or long-term global development goals are subject to uncertainties that go well beyond those which are accustomed in applied economic contexts and exceed the level that is tolerable. It therefore seems inappropriate that such estimates should be relied on as much as they have in determining global resource mobilisation targets and priorities for action. These uncertainties point to the requirement for a flexible and learning-oriented planning and resource allocation framework of the kind described in Reddy and Heuty (2005). An alternative framework of this kind would periodically reassess the resource requirements of attaining development goals on the basis of current information and cumulated experience and redeploy resources accordingly.

In this paper, we explore one important class of reasons for uncertainties concerning the validity of recent estimates of the intermediate or long-term cost of achieving global goals, which stem from the unknown nature of the "development production function" and its dual cost function.

We use data from the influential Commission on Macroeconomics and Health to explore the impact of erroneous assumptions. Although the case we examine is specific, the lessons that may be drawn from it are general.

1 Development Goals

A subtle but profound obstacle to producing estimates of the cost of achieving individual development goals is that this concept is not well-defined. The reason is that, as has been widely recognised, the distinct development goals are likely to be "jointly produced". The interventions that help promote a given development goal are likely to very often also promote other development goals. To take just one example, better nutrition may promote both the ability of children to learn and to survive. In such circumstances, it is not feasible, unambiguously, to identify the cost of achieving the goals associated with education and with good health. The reason is that it is not possible to unambiguously identify the share of the cost of an intervention (serving as a joint input to more than one development goal) that should be attributed to each of the goals. Only the cost of achieving development goals jointly can, properly speaking, be identified.

The cost of achieving individual development goals can be specified by arbitrarily attributing the cost (or a share of the cost) of a particular input to a specific development goal. However, under this approach (which, for example, is that taken by the UN Millennium Project in its recent estimates of the cost of achieving the MDGS[2]) the presumed cost of achieving the development goals jointly (i e, the sum total of the costs attributed to each development goal) will not equal the true cost of achieving the development goals jointly. All of the existing efforts to estimate the total global cost of achieving development goals, which have simply added estimates of the presumed costs of achieving individual development goals are invalid.[3]

Efforts to identify the cost of achieving development goals jointly require an adequate understanding of the joint production function for development goals. However, the requirements for understanding the causal pathways by which development goals are interrelated can be immense and can severely strain the limits of existing knowledge. Problems in the estimation of costs that arise due to the presence of joint production, which are conveniently ignored in many empirical economic analyses, cannot be ignored in the context of development goals in view of the highly interdependent causal processes that are likely to underlie aggregate social and economic achievements in developing countries.

2 Uncertain Unit Costs

Existing methodologies for estimating the cost of achieving major development goals (for instance those related to education and to health) rely on the generalisation of unit cost estimates derived from rather limited evidence. A major issue concerns the accuracy of these unit cost estimates. Often, it is not made clear whether they refer to average or marginal costs, and what is their source (for example, national average data or on a specific local observation that has been generalised). Estimates of marginal costs are based on assumptions regarding counterfactuals (for instance, concerning what factors of production are fixed and what factors of production are flexible in the short run). These can be specified in many different ways. The methodologies used are rarely made clear and may well be mutually incompatible.

Generalisation of unit cost estimates across countries is invariably done (for instance, by Kumaranayake, Kurowski and Conteh (2001) in their report for the Commission on Macroeconomics and Health and by recent country studies concerning the cost of achieving the MDGs on the part of the World Bank and the UN Millennium Project) by using general purchasing power parity (PPP) conversion factors, which may be based on poor underlying information in poor countries as mask considerable diversity of relative prices across different types of commodities. The resulting estimates of the cost of expanding development achievements could be potentially quite incorrect. It can be shown that the relative costs of the components of healthcare (such as drugs or the services of physicians) across countries can be widely divergent from the relative costs of general consumption .

Table 1, which draws on the data examined more fully in Reddy and Heuty (2004), demonstrates that the relative price structure across different components of health expenditure is widely divergent even among poorer countries. It may easily be checked that these divergences exist even between pairs of countries in the same region. This suggests that the use of general consumption PPPs (or even existing disaggregated PPPs) to predict overall costs of achieving health improvements in poor countries may lead to non-negligible errors.

Table 1: Correlation between PPP for All Consumption and for Components of Healthcare (for poor countries)

Drugs	Medical Supplies	Therapeutic Appliances	Hospital Care	Physicians' Services	Dentists' Services	Nurses' Services
0.943861	0.94096333	0.44176484	0.64295312	0.64568034	0.60078694	0.94344501

Source: Reddy and Heuty (2004).

It has been widely noted that existing PPPs are based on data drawn from price points in major cities (and often from capital cities alone). As a result, they are unlikely to accurately reflect the costs of purchasing goods and services in small towns and in rural areas, in which both the level and structure of prices are likely to be different, in ways that vary from country to country. This is an additional reason that estimates of unit and total costs based on these PPPs are unlikely to be especially accurate.

Quite apart from the difficulties involved in generalising cost estimates across countries, recent country studies from different sources have made unit cost estimates for the extension of particular services in the same country that vary widely. Table 2,[4] comparing estimates of

Table 2: Unit Costs of Universal Primary Education in Uganda

Study	Estimated Annual Cost Per Pupil
UNICEF 2001	$13 (1998 prices)
EPRC 2001	$46 (2001 prices)
World Bank 2003	$27.5 (2000 prices)
Millennium project 2003	$53 (2000 prices)

Source: Delamonica, Mehrotra and Vandemoortele (2001); EPRC (2002); Bruns, Mingat and Rakotomalala (2003); Millennium Project (2004).

the cost of achieving universal primary education in Uganda from different sources, is illustrative.

Although these cost estimates are phrased in dollars of different years, it is clear that they are widely discrepant (indeed, they vary by a factor of about four). Of course, this variation may, in part, appropriately reflect differences in the understanding of the goal and in detailed analytical premises. From this standpoint, the existence of discrepancies is not necessarily embarrassing (although, in the absence of adequate explanation, it is still worrying). Deficiencies in the quality of unit cost estimates can certainly be diminished over time. However, at the present time, these deficiencies are rather severe.

3 Uncertainties Concerning Extrapolation of Unit Costs

Should unit costs be taken as likely to remain fixed even as the goal is progressively attained, as is done in all of the recent estimates of the cost of achieving the individual goals? There are strong a priori reasons to think that decreasing or increasing marginal costs (economies and diseconomies of scale) may play an important role in relation to development goals. For instance, in poor countries, those who are not already the beneficiaries of relevant services may be those who are most difficult to reach, for geographical or social reasons. The limited supply of skilled personnel and the impact of overseas development assistance on the exchange rate may make it increasingly costly to extend services. Contrarily, positive externalities may lower barriers to service provision as more units of a service are provided. Transformations in social norms and transmission of relevant knowledge within social networks are likely to be among the reasons for such phenomena [see, for example, Foster and Rosenzweig 2004]. Although it is difficult to know in advance what the scale of such effects is and what form they take, it seems entirely plausible that they exist. Similarly, there are strong a priori reasons to think that there are significant complementarities between distinct development goals. For instance, it seems likely that greater access to safe drinking water and literacy will both improve health outcomes.

On the other hand, achieving certain goals may increase the cost of achieving others. For instance, reductions in child mortality will increase the school-age population and thereby increase the cost of achieving universal primary education. Similarly, pecuniary externalities associated with the achievement of a given development goal (such as the effects on wages and exchange rates mentioned above) may also raise the cost of achieving other development goals. It is not difficult to think of these and other connections, or indeed to imagine that the magnitude of their impact may be sizeable. Such quantitative work as exists on the complementarities between distinct development achievements suggests that this is indeed the case. We may refer to such complementarities as "economies of scope" (and their opposite as "diseconomies").

How accurate is a cost estimate likely to be if it assumes that unit costs are fixed when (in fact) there exist economies (or diseconomies) of scope or scale? In order to answer this question, we have undertaken a simple numerical exercise (reported in the Appendix, p 71), drawing on actual data, from a background paper of the Commission on Macroeconomics and Health, which appears to have played a critical role in the cost estimates of the commission and to have influenced those of the UN Millennium Project.[5] For a variety of health interventions, we have inferred the unit costs of coverage extensions (i e, the costs of expanding the percentage of the population covered by one percentage point) that are implicitly assumed in this background paper, which assumes a linear and separable cost function (i e, that there are no economies or diseconomies of scale or scope). We have also used the actual baseline coverage levels and the targets (for 2007 and 2015) specified in the paper. Whether the unit cost estimates of the Commission on Macroeconomics and Health are accurate is not in itself of great importance, as the purpose of the exercise is merely to show that the impact of divergence from the assumption that there are no economies of scale or scope can be large over realistic coverage ranges. In particular, the numerical exercise shows that the impact of the presence of (dis)economies of scale or scope by themselves on total cost estimates is significant. Moreover, the impact of the interaction of even moderate levels of (dis)economies of scale and scope is to generate truly massive discrepancies in total cost estimates. As shown in Tables A9 and A10 (p 73) in the Appendix, the inclusion of reasonable economies of scale and scope can lead to variation in total cost estimates of more than an order of magnitude!

The conclusion we would draw is that in the absence of far greater knowledge concerning the causal processes at work, we should be greatly wary of current cost estimates, which almost universally depend upon simple linearity assumptions (which preclude economies and diseconomies of scale) and separability assumptions (which preclude inter-goal externalities in production – economies or diseconomies of scope). Indeed, even if the assumptions

Table 3: Total Health Costs Per Year under Different Assumptions (in billions of (2002) dollars)

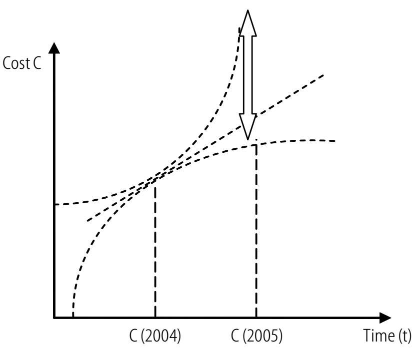
Neither Economies of Scale nor Scope	Economies of Scale Alone	Diseconomies of Scale Alone	Economies of Scope Alone	Diseconomies of Scope Alone	Economies of Scale and Scope	Diseconomies of Scale and Scope
4.3	1.442	17.215	2.213	6.387	0.737	25.516

Health costs include tuberculosis treatment and malaria diagnosis.
The figures presented in the table are taken from Tables A9 and A10 of the Appendix. The results represent the values obtained for the highest and lowest magnitude of the parameters used in the exercises (i e, beta = +/- 0.5 and delta = +/- 1).

were to be relaxed, the sensitivity of total cost estimates to the assumptions made should be cause for great concern. Some of the results of these exercises are summarised in Table 3 (p 70).

The figure graphically demonstrates how estimates that fail to take account of economies or diseconomies of scale and scope (represented in the diagram by the straight line extrapolation) can lead to potential errors in the estimation of total costs. Ex ante, there is insufficient knowledge with which to conclude that the cost function for achieving development goals of interest has a particular form. The resulting uncertainty undermines the credibility of long-range cost estimates.

Figure: Potential Error from Disregarding Economies of Scale or Scope



The existence of potentially large but unknown economies and diseconomies of scale and scope is reason to doubt the credibility and accuracy of current development goal cost estimates. The World Bank (2003, box 1, p 3) acknowledges the "inter-dependence of MDGs" without assessing – explicitly and transparently – the impact of this interdependence on the cost of achieving them. The Millennium Project (2004: 24) makes a partial and unsatisfactory attempt to estimate complementarities between the different goals. Synergies between and within the MDGs are only assessed in the health sector – where most complementarities are assumed to occur, and "estimated" (by what means is unclear) to "have the potential to save 20-35 per cent of the total health costs" (ibid: 105). Despite these flaws, the UN Millennium Project forcefully insists that "our treatment of synergies is not comprehensive, but we feel confident that our analysis captures some of the most important savings that can be realised by 2015 through implementing an integrated package of interventions" (ibid: 24-25).

4 Conclusions

The unknown nature of the development production function and its dual cost function implies significant uncertainties about the actual intermediate or long-term cost of achieving global development goals. These uncertainties make estimates of the cost of achieving these goals falsely precise and potentially enormously misleading. The resulting potentially significant errors in resource allocation may have large adverse implications. The severe limitations of knowledge faced by policymakers ought to lead them away from attempts to identify ex ante the policies and resource allotments that are sufficient to achieve global development goals and rather to adopt flexible and learning-oriented approaches to planning and resource allocation [see for example, Reddy and Heuty 2005]. An alternative framework of this kind would periodically reassess the resource requirements of attaining development goals, and the appropriate allocation of resources, on the basis of new information and recent experience.

NOTES

1 The text of this paper overlaps partially with that of Reddy and Heuty (2008).

2 See Millennium Project (2005).

3 We are very grateful to Sudhir Anand for bringing our attention to this point.

4 We would like to thank Lynn McDonald of UNICEF for this comparison.

5 In this connection see also Sachs (2005).

6 It may be checked that the marginal cost of producing a single output (say x), holding the other output constant, is influenced by the level of the other output (say y) in two ways. First, the level of y decrease (or increase, depending on the sign of delta) the marginal cost of producing x by a multiplicative proportion, given by the magnitude of delta. Second, the level of y decreases (or increases, depending on the sign of delta) the marginal cost of producing x by an additive constant, also given by the magnitude of delta.

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Appendix: Potentially Erroneous Estimates of the Cost of Achieving Global Development Goals

We explore the sensitivity of cost estimates to the assumptions of joint production and nonlinearity of the cost function. We take unit cost and population in need (PIN) data from Kumaranayake Kurowski, and Conteh (2001).

Let c = $ unit cost for increasing coverage of a health treatment by 1 per cent, and

x = increase in prevalence of the treatment in per cent (i e, if it is desired to increase coverage from 10 per cent to 80 per cent, then n = 70). We compare the following two cost functions:

Linear cost: = cx

Non-linear cost: $= \frac{cx^{\beta+1}}{\beta+1}$; $\beta \in R$, $\beta \neq -1$

The interventions include tuberculosis treatment, malaria prevention and treatment, and HIV/AIDS care + treatment (HAART) for (i) poor countries (GPD per capita < 1,200 US$ in 1999 US$), including all sub-Saharan Africa; (ii) excluding countries with less than 1,50,000 population; and (iii) sample of 83 countries.

The CME paper (ibid) assumes that the incidence/prevalence of diseases/risks are constant over the time period through 2015,

Table A1: Current Coverage Rates and Future Targets (in %)

Disease	Year	2002 Baseline	2007A Min Target	2007B Min Target	2015 Min Target
Tuberculosis	Treatment	44	50	60	70
Malaria	Diagnosis	31	50	60	70
	Prevention	2	30	50	70
HIV/AIDS	Care of OI	10	25	40	70
	Treatment (HAART)	1	10	45	65

These figures are averages of coverage across relevant countries.

and so are unit costs of providing the health interventions defined.

First Exercise: (Dis)economies of Scale

Nonlinear cost: $= \frac{cx^{\beta + 1}}{\beta + 1}$; $\beta \in R, \beta \neq 1$ where x is the increase in coverage of the intervention, c is the initial unit cost, and β is a parameter. For β = 0, the cost function becomes linear = cx and there are no economies of scale.

Table A2: Implied Annual Unit Costs (in 2002 US$)

Disease	Year	2007A	2007B	2015
Tuberculosis	Treatment	6,66,66,667	3,12,50,000	3,46,15,385
Malaria	Diagnosis	6,31,57,895	6,89,65,517	8,71,79,487
	Prevention	1,07,14,286	1,04,16,667	1,47,05,882
HIV/AIDS	Care of OI	10,66,66,667	9,33,33,333	10,66,66,667
	HAART	11,11,11,111	11,36,36,364	12,50,00,000

Source: Kumaranayake, Kurowski and Conteh (2001).

It is assumed that the unit cost, c, identified by the CME background paper is correct for the last (observed) unit (1 per cent) of the coverage. For the next unit (1 per cent) of coverage produced, we have: $MC = \frac{c}{\beta + 1} (\beta + 1)\, x^{\beta} = cx^{\beta}$. At the first additional unit produced, x=1, (1 per cent additional coverage of the intervention), the MC is exactly c (the unit cost).

A positive value of β implies rising marginal costs, and a negative value of β implies falling marginal costs. A value of zero implies constant marginal costs, in line with the linearity assumption of the background paper.

A value of 0.5 (the maximum value considered here) implies that the one-hundredth unit costs 10 times as much to produce as does the first. A value of -0.5 (the minimum value considered in the estimates) implies that the one-hundredth unit costs one-tenth as much to produce as does the first. A value of 0.2 implies that the one-hundredth unit costs 2.5 times as much to produce as does the first. A value of -0.2 implies that the one-hundredth unit costs less to produce than does the first unit by a factor of 2.5. A value of 0.1 implies that the one-hundredth unit costs 1.6 times as much to produce as does the first. A value of -0.1 implies that the one-hundredth unit costs less to produce than does the first unit by a factor of 1.6.

Economies of scale in service delivery may exist due to phenomena such as, for instance, informational externalities and fixed costs of health infrastructure development. Diseconomies of scale in service delivery may exist due to, for instance, increasing difficulty in reaching underserved (for example geographically and socially marginalised) populations.

Second Exercise: (Dis)economies of Scope

What is the cost of achieving the development goals concomitantly? Are there spillovers between interventions? Are there economies or diseconomies of scope?

Table A3: Comparison between Linear and Non-linear Costs: Dis/Economies of Scale
(Figures are in '000 000 000 US$)

		Linear	Non-linear					
		Beta >	0.000	0.001	0.005	0.01	0.05	0.1
Scenario 2007A								
Tuberculosis	Treatment	0.40	0.400	0.400	0.402	0.403	0.417	0.435
Malaria	Diagnosis	1.20	1.200	1.202	1.212	1.224	1.324	1.464
	Prevention	0.30	0.300	0.301	0.304	0.307	0.338	0.381
HIV/AIDS	Care of OI	1.60	1.600	1.603	1.614	1.628	1.745	1.907
	HAART	1.00	1.000	1.001	1.006	1.012	1.063	1.132
Scenario 2007B								
Tuberculosis	Treatment	0.50	0.500	0.501	0.504	0.509	0.547	0.600
Malaria	Diagnosis	2.00	2.000	2.005	2.024	2.048	2.254	2.546
	Prevention	0.50	0.500	0.501	0.507	0.515	0.578	0.669
HIV/AIDS	Care of OI	2.80	2.800	2.807	2.834	2.868	3.161	3.577
	HAART	5.00	5.000	5.014	5.070	5.141	5.754	6.636
Scenario 2015								
Tuberculosis	Treatment	0.90	0.900	0.902	0.910	0.921	1.009	1.133
Malaria	Diagnosis	3.40	3.400	3.409	3.446	3.492	3.889	4.459
	Prevention	1.00	1.000	1.003	1.016	1.033	1.176	1.386
HIV/AIDS	Care of OI	6.40	6.400	6.420	6.500	6.601	7.480	8.762
	HAART	8.00	8.000	8.025	8.127	8.257	9.380	11.023

Delta = 0, beta varies.

Table A4: Comparison between Linear and Non-linear Costs: Dis/Economies of Scale
(Figures are in '000 000 000 US$)

		Linear	Non-linear					
		Beta >	0.000	- 0.001	-0.005	- 0.01	- 0.05	- 0.1
Scenario 2007A								
Tuberculosis	Treatment	0.40	0.400	0.400	0.398	0.397	0.385	0.372
Malaria	Diagnosis	1.20	1.200	1.198	1.188	1.177	1.090	0.993
	Prevention	0.30	0.300	0.299	0.297	0.293	0.267	0.239
HIV/AIDS	Care of OI	1.60	1.600	1.597	1.586	1.573	1.471	1.356
	HAART	1.00	1.000	0.999	0.994	0.988	0.943	0.892
Scenario 2007B								
Tuberculosis	Treatment	0.50	0.500	0.499	0.496	0.491	0.458	0.421
Malaria	Diagnosis	2.00	2.000	1.995	1.976	1.953	1.779	1.587
	Prevention	0.50	0.500	0.499	0.493	0.486	0.434	0.377
HIV/AIDS	Care of OI	2.80	2.800	2.793	2.767	2.734	2.486	2.214
	HAART	5.00	5.000	4.986	4.931	4.863	4.356	3.805
Scenario 2015								
Tuberculosis	Treatment	0.90	0.900	0.898	0.890	0.880	0.805	0.722
Malaria	Diagnosis	3.40	3.400	3.391	3.355	3.311	2.980	2.619
	Prevention	1.00	1.000	0.997	0.984	0.968	0.852	0.729
HIV/AIDS	Care of OI	6.40	6.400	6.380	6.302	6.205	5.490	4.722
	HAART	8.00	8.000	7.975	7.875	7.752	6.840	5.864

Delta = 0, beta varies.

Table A5: Comparison between Linear and Non-linear costs: Dis/Economies of Scale
(Figures are in '000 000 000 US$)

		Linear	Non-linear				
		Beta >	0.15	0.20	0.30	0.40	0.50
Scenario 2007A							
Tuberculosis	Treatment	0.40	0.455	0.477	0.527	0.585	0.653
Malaria	Diagnosis	1.20	1.623	1.802	2.233	2.783	3.487
	Prevention	0.30	0.430	0.487	0.627	0.813	1.058
HIV/AIDS	Care of OI	1.60	2.089	2.292	2.773	3.376	4.131
	HAART	1.00	1.209	1.293	1.487	1.720	2.000
Scenario 2007B							
Tuberculosis	Treatment	0.50	0.659	0.725	0.884	1.083	1.333
Malaria	Diagnosis	2.00	2.882	3.268	4.225	5.494	7.180
	Prevention	0.50	0.777	0.904	1.229	1.680	2.309
HIV/AIDS	Care of OI	2.80	4.055	4.607	5.975	7.796	10.224
	HAART	5.00	7.670	8.881	11.969	16.226	22.111
Scenario 2015							
Tuberculosis	Treatment	0.90	1.276	1.439	1.840	2.366	3.059
Malaria	Diagnosis	3.40	5.122	5.895	7.850	10.514	14.155
	Prevention	1.00	1.637	1.938	2.728	3.863	5.497
HIV/AIDS	Care of OI	6.40	10.285	12.096	16.814	23.513	33.049
	HAART	8.00	12.981	15.316	21.429	30.160	42.667

Delta = 0, beta varies.

Table A6: Comparison between Linear and Non-linear Costs, Dis/Economies of Scope
(Figures are in '000 000 000 US$)

		Non-linear				
Scenario 2007A	Delta >	-0.1	-0.05	-0.01	-0.005	-0.001
		1.624	1.612	1.602	1.601	1.600
Total linear costs: $ 1.6 B	Delta >	0.001	0.005	0.01	0.05	0.1
		1.600	1.599	1.598	1.588	1.576
Scenario 2007B	Delta >	-0.1	-0.05	-0.01	-0.005	-0.001
		2.578	2.539	2.508	2.504	2.501
Total linear costs: $ 2.5 B	Delta >	0.001	0.005	0.01	0.05	0.1
		2.499	2.496	2.492	2.461	2.422
Scenario 2015	Delta >	-0.1	-0.05	-0.01	-0.005	-0.001
		4.509	4.404	4.321	4.310	4.302
Total linear costs: $ 4.3 B	Delta >	0.001	0.005	0.01	0.05	0.1
		4.298	4.290	4.279	4.196	4.091

Beta = 0, delta varies.
Two interventions: tuberculosis treatment and malaria diagnosis.

Table A7: Comparison between Linear and Non-linear Costs, Dis/Economies of Scope
(Figures are in '000 000 000 US$)

		Non-linear				
Scenario 2007A	Delta ⇒	0.15	0.25	0.35	0.40	0.45
		1.564	1.540	1.516	1.505	1.493
Total linear costs: $ 1.6 B	Delta ⇒	0.50	0.55	0.60	0.65	0.70
		1.481	1.469	1.457	1.445	1.433
Scenario 2007B	Delta ⇒	0.15	0.25	0.35	0.40	0.45
		2.383	2.305	2.226	2.187	2.148
Total linear costs: $ 2.5 B	Delta ⇒	0.50	0.55	0.60	0.65	0.70
		2.109	2.070	2.031	1.992	1.953
Scenario 2015	Delta ⇒	0.15	0.25	0.35	0.40	0.45
		3.987	3.778	3.569	3.465	3.361
Total linear costs: $ 4.3 B	Delta ⇒	0.50	0.55	0.60	0.65	0.70
		3.256	3.152	3.048	2.943	2.839

Beta = 0, delta varies.
Two interventions: tuberculosis treatment and malaria diagnosis.

Table A8: Comparison between Linear and Nonlinear Costs, Dis/Economies of Scope
(Figures are in '000 000 000 US$)

		Non-linear				
Scenario 2007A	Delta ⇒	-0.15	-0.25	-0.35	-0.4	-0.45
		1.636	1.660	1.684	1.695	1.707
Total linear costs: $ 1.6 B	Delta ⇒	-0.5	-0.55	-0.6	-0.65	-0.7
		1.719	1.731	1.743	1.755	1.767
Scenario 2007B	Delta ⇒	-0.15	-0.25	-0.35	-0.4	-0.45
		2.617	2.695	2.774	2.813	2.852
Total linear costs: $ 2.5 B	Delta ⇒	-0.5	-0.55	-0.6	-0.65	-0.7
		2.891	2.930	2.969	3.008	3.047
Scenario 2015	Delta ⇒	-0.15	-0.25	-0.35	-0.4	-0.45
		4.613	4.822	5.031	5.135	5.239
Total linear costs: $ 4.3 B	Delta ⇒	-0.5	-0.55	-0.6	-0.65	-0.7
		5.344	5.448	5.552	5.657	5.761

Beta = 0, delta varies.
Two interventions: tuberculosis treatment and malaria diagnosis.

Table A9: Comparison between Linear and Non-linear Costs, Dis/Economies of Scale and of Scope
Delta Positive (economies of scope), (figures are in '000 000 000 US$)

		Non-linear				
	Delta ⇒	0.00	0.15	0.40	0.70	1.00
	Beta ⇓					
Scenario 2015						
Total linear costs: $4.3B	0.000	4.300	3.987	3.465	2.839	2.213
	0.001	4.311	3.997	3.474	2.846	2.218
	0.005	4.356	4.039	3.510	2.876	2.242
Diseconomies of scale	0.01	4.413	4.091	3.556	2.913	2.271
	0.05	4.898	4.541	3.948	3.235	2.522
	0.1	5.592	5.185	4.508	3.694	2.881
	0.2	7.334	6.802	5.914	4.849	3.784
	0.5	17.215	15.970	13.894	11.404	8.913
Scenario 2015						
Total linear costs: $4.3B	0.000	4.300	3.987	3.465	2.839	2.213
	- 0.001	4.245	3.977	3.456	2.832	2.207
	- 0.005	4.245	3.936	3.421	2.802	2.184
Economies of scale	- 0.01	4.191	3.886	3.377	2.767	2.156
	- 0.05	3.785	3.509	3.049	2.498	1.946
	- 0.1	3.341	3.097	2.691	2.204	1.717
	-0.2	2.629	2.437	2.117	1.733	1.349
	-0.5	1.442	1.336	1.160	0.948	0.737

Beta, delta varies.

Table A10: Comparison between Linear and Non-linear Costs, Dis/Economies of Scale and of Scope
Delta Negative (diseconomies of scope), (figures are in '000 000 000 US$)

		Non-linear				
	Delta ⇒	0.00	- 0.15	- 0.40	- 0.70	- 1.00
	Beta ⇓					
Scenario 2015						
Total linear costs: $4.3B	0.000	4.300	4.613	5.135	5.761	6.387
	0.001	4.311	4.625	5.148	5.776	6.404
	0.005	4.356	4.673	5.202	5.836	6.470
Diseconomies of scale	0.01	4.413	4.734	5.269	5.912	6.554
	0.05	4.898	5.254	5.848	6.561	7.274
	0.1	5.592	5.998	6.676	7.489	8.302
	0.2	7.334	7.867	8.755	9.820	10.885
	0.5	17.215	18.460	20.535	23.026	25.516
Scenario 2015						
Total linear costs: $4.3B	0.000	4.300	4.613	5.135	5.761	6.387
	- 0.001	4.245	4.601	5.122	5.746	6.371
	- 0.005	4.245	4.554	5.069	5.687	6.306
Economies of scale	- 0.01	4.191	4.496	5.005	5.615	6.225
	- 0.05	3.785	4.061	4.520	5.072	5.623
	- 0.1	3.341	3.585	3.991	4.478	4.965
	-0.2	2.629	2.821	3.141	3.525	3.909
	-0.5	1.442	1.548	1.724	1.935	2.147

Beta, delta varies.

An Example Involving Two Goals: Take tuberculosis treatment and malaria diagnosis, and denote the interventions by x and y.

In general, let the total cost function identifying the minimum cost of providing a given level of outputs (jointly) be represented by TC(x,y), where x and y denote the improvements in intervention coverage to be attained (by 2007 or 2015).

$$TC(x,y) = \frac{c_1 x^{\beta_1+1}}{\beta_1+1}\left(1-\delta_1\frac{y}{y_{max}}\right) + \frac{c_2 y^{\beta_2+1}}{\beta_2+1}\left(1-\delta_2\frac{x}{x_{max}}\right),$$

where $\beta \in R, \beta \neq -1, \delta \in [-1, 1]$.

The δ parameters will generate economies/diseconomies of scope. Y_{max} and X_{max} are defined as follows: $y_{max} = 100 - y_{baseline}$, and similarly $x_{max} = 100 - x_{baseline}$ (the coverage extensions which are required to attain complete coverage, beginning at the empirical baseline).

In what follows, assume that $\delta_1 = \delta_2 = \delta$ and $\beta_1 = \beta_2 = \beta$ for simplicity. $\delta = 0$ means that there are no economies of scope. Note that $\delta>0$ yields economies of scope and $\delta<0$ yields diseconomies of scope.

An interpretation of delta is that it corresponds to the percentage decrease (or increase, depending on the sign of delta) in the total cost of producing both outputs to the maximum extent feasible (i e, covering the population entirely with both interventions) that arises as a result of the existence of economies (diseconomies) of scope.[6] For example, a value for delta of 0.5 implies that the total cost of covering the entire population is 50 per cent lower (due to the presence of economies of scope, or complementarities) than it would have been if there had not been any complementarities.

Economies of scope may exist in the health sector due to the presence, for instance, of positive spillovers in diagnosis. Diseconomies of scope may exist due to the presence, for instance, of "congestion effects" or crowding out in the utilisation of health service infrastructure.

In the exercises below, we have tried to use what we believe to be plausible values of both beta and delta. In particular, we consider maximum values of $\beta = 0.5$, and $\delta = 1$ and minimum values of $\beta = -0.5$, and $\delta = -1$. The assumption that $\delta = -1$, which suggests that the total cost of achieving both goals completely is zero, is not as implausible ex ante as it may first appear. One reason it is not implausible is that the cost concept employed by Kumaranayake, Kurowski and Conteh (2001) is that of "incremental expenditure" above and beyond existing health expenditures. A second reason is that complete coverage of the population by the diagnostic, preventative and treatment interventions considered entails substantial decreased disease prevalence (indeed possibly to zero). Such substantial decreases in disease prevalence will entail substantial reductions in costs actually incurred.