Developing new approaches to measuring NHS outputs and productivity

NON-TECHNICAL SUMMARY OF THE FINAL REPORT

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1 Introduction

1.1 The research remit

In March 2004 the Department of Health commissioned a research team from the Centre for Health Economics at the University of York and the National Institute for Economic and Social Research to develop new approaches to measuring NHS outputs and productivity. The research objectives were development of:

- A comprehensive measure of NHS outputs and productivity
- Methods to facilitate regular in-year analysis of NHS productivity
- Output measures capable of measuring efficiency and productivity at sub-national levels.

The research team was also asked to co-operate with the Atkinson Review on measurement of government output and productivity for the national accounts.

The background to the research remit referred to the Public Service Agreement (PSA) following the 2002 Spending Review that "set a 'value for money' (productivity) target of 2%". The target required information on quality improvement that had not previously been measured for the NHS as a whole. Quality adjusted measures of NHS output were also required for monitoring the performance of Trusts and identifying the scope for efficiency gains.

Three interim reports were produced (July 2004, November 2004 and June 2005), as well as memoranda on data requirements (September 2004) and methodology (January 2005, August 2005). The work was presented for scrutiny at two expert workshops (7 July 2004 and 17 June 2005). The research team presented work in progress to four meetings of the NHS Outputs Steering Group (7 July 2004, 2 February 2005, 10 May 2005, 20 July 2005). The Final Report was submitted on 31 August. This is a non-technical summary of the Final Report.

The research team has delivered:

1. A methodology for producing a comprehensive quality adjusted index of NHS output. This is referred to as the "value weighted output index". Data

necessary to estimate this index are not currently available for all NHS activities but are feasible to collect.

2. Methodologies for calculating quality adjusted NHS output indices with existing data. These are cost weighted indices that incorporate varying combinations of changes in survival, health effects, waiting times, patient satisfaction, readmissions and MRSA. We present estimates of experimental indices which examine sensitivity to different ways of measuring waiting times, survival, and to different assumptions about the health effect, discount rates and other parameters.
3. For the small set of hospital based treatments where there are some data on health outcomes before and after treatment, we have produced "specimen" indices that illustrate the use and importance of incorporating data on health outcomes.
4. We have suggested data that are feasible to collect which would not only improve future measurement of NHS output but would also be of value in managing the NHS.
5. We have constructed a new index of labour input in the NHS. It combines data from a range of sources to calculate a volume measure of total hours worked in the hospital sector and includes an adjustment for increases in the skills of the workforce.
6. Using the cost weighted quality adjusted index of outputs and inputs, we have produced provisional estimates of Labour Productivity Growth and Total Factor Productivity Growth for the period 1998/99-2003/04.
7. The methodology and data used in these indices can be applied to sub-national groups of institutions (e.g. NHS Trusts).
8. For many purposes, quality adjusted measures of output and productivity growth for particular diseases and across institutional settings will be of more value to the NHS than a comprehensive index. We indicate how, with planned changes to NHS data collection, it will be feasible to produce disease specific output and productivity indices with the methodology presented in this report.

Although key data used in our output indices, predominantly from the Hospital Episode Statistics (HES), are available on a quarterly basis, we do not recommend publication of within year estimates of output growth for the time being. The quarterly

HES data are subject to significant revision and use of quarterly index numbers could be misleading. Moreover the quarterly HES data do not currently contain information on deaths within 30 days which is our preferred hospital mortality measure.

1.2 Relevant concepts

There are significant differences between the concepts of efficiency, value for money, productivity and productivity growth with implications for methods of measurement and policy relevance of the resulting indices.

- **Efficiency** is the ratio of output produced with given inputs relative to the maximum feasible output, often referred to as technical efficiency.
- **Value for money** is the value placed on output relative to the costs of production. This often corresponds to a cost-benefit analysis.
- **Productivity** is the ratio of a measure of total output to a measure of total inputs.
- **Productivity growth** is the change in output relative to the change in inputs. It is often interpreted as reflecting the effect of technical change on production.

Figures 1.1 and 1.2 illustrate the relationships between these four concepts. In Figure 1.1, production at point **B** is more efficient than at point **A** but productivity is lower at **B** than at **A**. The welfare indifference curve shows combinations of output and input with the same social value. 'Value for money' defined in welfare terms is higher at **B** than at **A** even though productivity is lower.

Figure 1.1 Productivity, efficiency and welfare

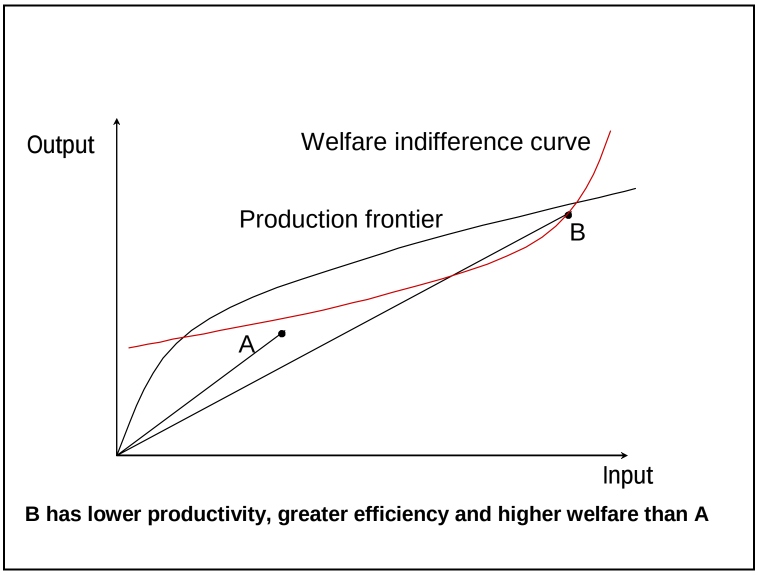
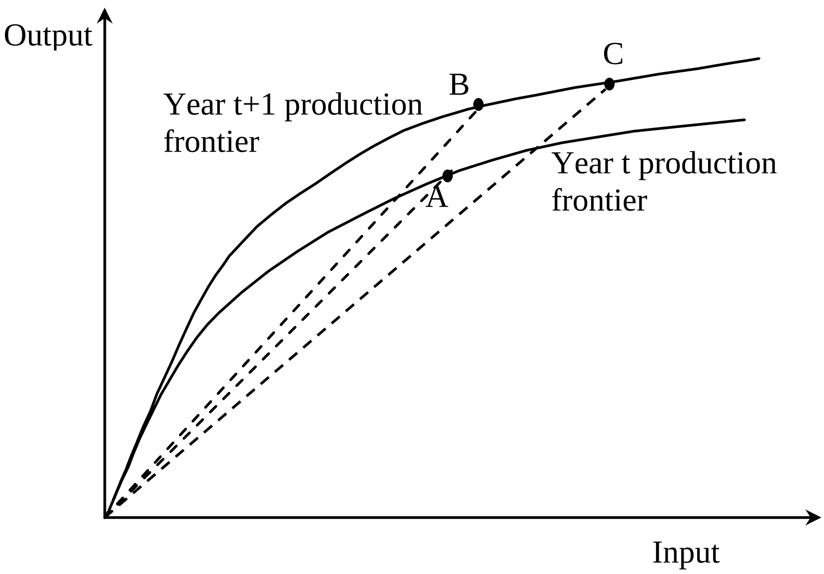


Figure 1.2 shows a change in production possibilities over time with the output producible from a given level of input increasing. Even if the health care system fully exploits the new opportunities and produces efficiently, the effect on measured productivity depends on whether **B** or **C** is the new level of output. At **B** productivity will have increased relative to the previous year. At **C** productivity will have decreased relative to the previous year. Negative productivity growth when moving from **A** to **C** or from **B** to **C** reflects neither inefficiency nor failure to secure value for money but is a consequence of the technology exhibiting diminishing returns.

Figure 1.2 Productivity growth, input growth and diminishing returns



Indices that measure changes in productivity do not measure changes in efficiency and can diverge from changes in “value for money”.

1.3 Quality

We distinguish *activities* (operative procedures, diagnostic tests, outpatient visits, consultations…), *outputs* (courses of treatment for a patient which may require a bundle of activities), and *outcomes* (the characteristics of output which affect utility).

We define the quality of treatment as the level of the characteristics valued by patients and changes in quality as the rate of change of these characteristics.

Since improving the health of patients is a primary objective of the NHS, improved health *outcomes* are the most important characteristic of treatment. The main impact of technical change in health care has been to improve health outcomes—e.g. the expected health outcomes from heart surgery or management of diabetes are better today than ten years ago. There is little data on health outcomes in the NHS and hence it has not been possible to measure quality improvement, productivity growth and technical change.

The main available health outcomes data are hospital mortality rates. This is a severe limitation on any attempt to measure the quality of output or productivity since only 3% of NHS patients die soon after treatment. There are no routine data to measure improvements in health due to treatment for the 97% of patients who survive. The DH is considering collecting data on health outcomes and in the full report we make a number of suggestions about how this might be done. In section 4 of the Final Report we present output and productivity indices that should be used if and when data on health outcomes become available, either generally or for a subset of outputs.

It follows from our definition of quality that the unit for measuring NHS output should be the treated patient. This makes it necessary to link the *activities* delivered to each patient during their “journey” through the full course of treatment. For example, a patient undergoing treatment for heart disease might receive prescriptions for various drugs, attend outpatient clinics, have diagnostic tests, surgery and follow-up care from a GP. At present it is not possible to identify the set of activities delivered to NHS patients with particular conditions. The Department of Health plans to introduce a patient identifier that in future will permit analysis of the care delivered to a patient across activities, institutions and over time. For the present it is necessary to continue to use counts of activities as proxies for output. However, the indices we have devised could readily be adapted to a patient-based definition of output when linked data become available.

1.4 Value for money and technical change

Recent US literature illustrates how, with data on outcomes and an ability to link activities/inputs to patients with particular conditions, it is possible to obtain approximate disease specific measures of value for money and technical change. Cutler *et al*. (2001), for example, examine improved survival rates for patients admitted with acute myocardial infarction (AMI). By placing a monetary value on quality adjusted additional years of life expectancy and dividing by the cost of inputs, estimates can be produced of the growth in value for money. Similar US research has been done for depression, schizophrenia and cataract surgery.

The DH requested the research team to devise indices and estimates for overall NHS output and productivity growth. When data become available that identify the set of inputs used to treat particular conditions and the monetary value of output, the approach we outline in section 5 can be applied to studies of individual conditions as in the US work.

2 Key issues

An NHS output index should capture the valuable things that the NHS produces. Operationalising this idea is not straightforward because of the difficulties of defining NHS outputs, attaching values to the outputs, and obtaining the relevant data.

We have defined *outputs* as courses of treatment that may require a bundle of *activities* (prescribing pharmaceuticals, surgery, etc.) and *quality* as the characteristics of output valued by individuals (health improvement, waiting time, relationship with the doctor, etc.).

It is more difficult to construct quality adjusted output indices for the NHS than for the private sector. Because there are no prices to reveal patients' marginal valuations of NHS outputs, we have to find other means of estimating their value. We can do so in two equivalent ways: we can measure the outputs and attempt to estimate the marginal valuations attached to them or we can measure the outcomes produced by each unit of output and attempt to estimate marginal valuations of the outcomes. The bundle of outcomes produced by a unit of output is likely to change over time in the NHS because of, among other things, changes in technology or treatment thresholds. In a private market the price of output would change to reflect this. But in the absence of market prices for NHS outputs it is likely to be easier to calculate the change in the marginal value of output by focusing on the change in the basket of outcomes.

2.1 Measuring health gain

Given the objectives of the NHS, it is important to measure the health gain accruing to patients as a consequence of treatment. A unit of measurement used in a number of countries, and in the UK by NICE, is the Quality Adjusted Life Year (QALY). This measures the change in the quality of life and the duration of the benefit. It therefore allows for both treatments that improve the quality of life without affecting life expectancy and treatments that improve life expectancy. Health gains accruing over time are discounted and appear as the present value of the benefit of treatment. In theory the health outcome consequent on treatment is the difference between QALYs with treatment and without treatment. In Figure 2.1, the area under the "with treatment" curve less the area below the "without treatment" curve gives the health benefit of the treatment. In practice, even with routinely collected data on health outcomes, it will not be possible to measure this true treatment effect. First, for ethical reasons, few patients are left without treatment. All we will observe is the difference between health state before treatment and after treatment. Second, even routinely collected outcomes data would not provide a continuous monitoring of post treatment health state. We would only have snapshot estimates at particular points in time.

We have suggested in our full report that the NHS should collect data on the health of patients before and after treatment. An outcome measure based on the difference between snapshot measures of health status before treatment h^b and after treatment h^a is an imperfect measure of the change in the discounted sum of QALYs due to treatment. It does not measure health with and without care but health before and after care. It will therefore underestimate the benefit of NHS treatment but will give a better indication of the value of treatment than the present practice of assuming benefit is zero.

Reliance on observational data that provide information on post treatment health state at a particular point in time (three months or one year after treatment) will be an imperfect measure of benefit over time. It is reasonable to assume that the benefit of a cataract operation may last for the life expectancy of individuals of the age/sex of the patient. However, a treatment for cancer may affect the life expectancy of the patient. Current work by DH/ONS linking patient records with deaths should make it possible to incorporate the impact of treatment on long term survival.

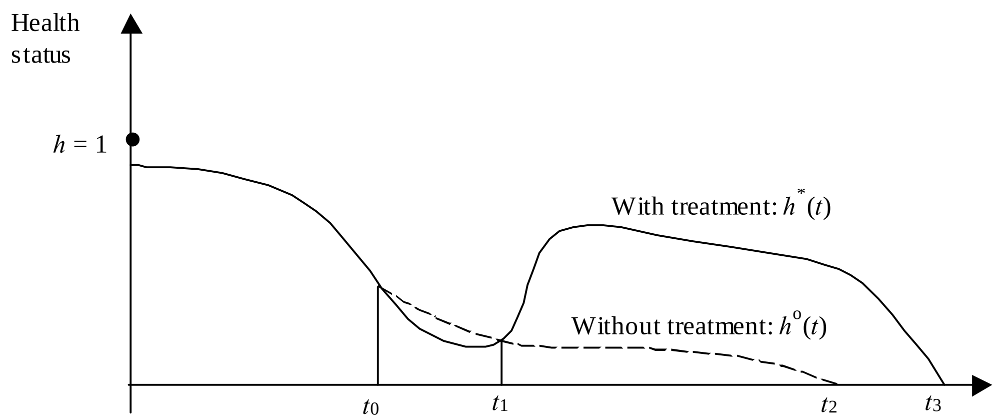
For some long-term conditions the effect of treatment is to slow down the rate of decline in health status, so that $h^a - h^b < 0$ even though the treatment increases the sum of QALYs compared with no treatment. For these patients, estimates of benefit from NHS care could be made using expert opinion on prognoses without treatment. This may be a valuable way forward when making key decisions on resource allocation—e.g. by NICE or in national service frameworks. However, reliance on expert opinion is less suitable for construction of a comprehensive output index that is to record annual changes in quality adjusted output. The number of treatments to be covered is large, regular updates of prognoses would be required and for some uses of the output index (national accounts) there may be a requirement for reliance on more “objective” sources of data.

Lack of data on without treatment health states for long-term conditions may present less of a problem for construction of a quality adjusted output index than for NHS resource allocation decisions. The output index is to measure the *rate of growth* of quality adjusted output. If over time improved treatment for chronic conditions results in after treatment health state h^a in year t+1 being higher than in year t, an index using observational data will record an increase in quality adjusted output. Where the aim is to measure the *rate of growth* of output we are interested in whether the rate of growth of $\Delta h = h^a - h^b$ is a reasonable approximation to the rate of growth of the effect of treatment on the discounted sum of QALYs. The important issue is how well the rate of change in measures based on the snapshots h^b, h^a approximates the rate of change in the areas under the two time profiles of health streams with treatment $h^*(s)$ and without treatment $h^o(s)$

Both the level of health before treatment h^b and the health of treated patients if not treated depend on the patient population selected for treatment and on the general health of the population. It is not unreasonable to suggest that the rates of change of h^b and the discounted value of the without treatment health profile $h^o(s)$ over time will be similar. Both the snapshot level of health after treatment h^a and the discounted value of the time profile h^* will be measured on the same population and hence are affected by the same factors including any technological change.

Hence, despite the imperfections of the difference between snapshots of before and after treatment heath status for calculating the *level* of productivity, we suggest that rates of change of measures based on h^b, h^a will improve estimates of NHS output growth compared to estimates where such information is not used.

Figure 2.1 With and without treatment health profiles



2.2 A value weighted NHS output index

To measure NHS productivity requires a measure of output growth which reflects changes in quality. The *value weighted output index* that we seek to measure is

$$I_{yt}^{xq} = \frac{\sum_j x_{jt+1} \sum_k \pi_{kt} q_{kjt+1}}{\sum_j x_{jt} \sum_k \pi_{kt} q_{kjt}} \qquad (1)$$

where x_{jt} is the volume of output j in period t, q_{kjt} is the amount of outcome k produced by a unit of j, and π_{kt} is marginal value of outcome k. The index measures changes in the volume of outputs and their characteristics but does so holding the value of the characteristics constant. π_{kt} is held constant in calculating the quality adjusted output growth rate because changes in π_{kt} are due to changes in social preferences over time which are not attributable to the NHS. For example as incomes increase health may become more valuable. Notice that holding π_{kt} constant in the output index does *not* mean that changes in marginal social values over time should not affect decisions within the NHS on the mix of outputs.

Estimating the value weighted output index requires data on both the characteristics produced (e.g. health outcomes) and on the marginal social value of these characteristics. The data are required if we are to construct weights that permit aggregation of the many outputs of the NHS into a single index number.

The *value weighted output index* is our preferred way to measure NHS output. The data required to construct weights for a value weighted index are not presently available but are feasible to collect. The index can then be estimated for the NHS as a whole or for particular conditions and diseases. New technologies which improve health outcomes will be reflected in the real growth of NHS output. When the NHS adopts more cost effective treatments, use of the value weighted output index in productivity growth measures will show a rise in productivity.

The standard assumption in the national accounting literature is that marginal social values are measured by the unit costs of production. The assumption has been questioned by Atkinson (2005). It requires that unit costs measure marginal costs and that resources are cost-effectively allocated in the NHS so that the marginal costs of different outputs are proportional to their marginal social values. Both assumptions are highly questionable. Even if these assumptions were satisfied, a cost weighted index would still fail to adjust adequately for quality in calculating growth. For example, when the NHS adopts more cost effective ways of treating patients, a cost weighted output index may record a *fall* in output. This would not occur with a value weighted index.

In the absence of data on health effects of treatment we have no alternative to using unit costs to weight outputs. Hence we suggest indices that make use of currently available data to quality adjust cost weighted outputs. This was the only option given our remit to produce comprehensive index numbers with existing data and is in line with Eurostat recommendations for measuring public sector output.

2.3 The unit of output

We have argued that the correct unit of output is the treated patient and hence it is necessary to know what services were delivered to patients with particular conditions. Until the NHS introduces a patient identifier, it is not possible to track patients across all of the settings in which they receive care. However, for hospital activity, we have been able to calculate Continuous Inpatient Spells (CIPS), which capture the full package of inpatient care, including instances where patients are transferred to different providers.

There are two competing sources of data for patients admitted to hospital, the Reference Cost return and the Hospital Episode Statistics (HES). We recommend the use of HES data in preference to the Reference Cost returns for the following reasons: (1) HES contains patient level data extracted from the medical record which can be summarised in a variety of ways, whereas Reference Cost data aggregates diverse procedures into single HRGs; (2) CIPS cannot be derived from Reference Cost data; (3) HES data undergo a more thorough process of validation; (4) HES contains information allowing activity to be quality adjusted, notably to take account of waiting times and survival.

The Reference Cost returns are the primary data source for NHS activities outside hospital.

3 Feasible quality adjusted indices of NHS output

The scope for quality adjusting an NHS output index with existing data is very limited:

- The only routinely collected data on health outcomes that can be linked to NHS activities are hospital inpatient mortality rates. Mortality rates are quite low, around 3% of patients. There are no outcomes data that can be used to quality adjust for the health outcomes of the 97% of hospital inpatients who survive.
- There is information on waiting times, measures of patient satisfaction and performance indicators such as readmission rates.

We first describe our suggested quality adjustments for changes in short term hospital survival rates and then show how they can be combined with quality adjustments for changes in waiting times. In the full version of the Final Report we give the formal derivations of each index, spelling out the required assumptions, and examine variants of all the main indices, looking at the sensitivity of results to key parameters. In this summary report we simply set out the key elements of each index and present some sample results. The annex provides a flow chart showing the relationship of the various indices estimated in the report.

For the present we do not recommend the use of data on patient satisfaction and performance indicators to quality adjust the cost weighted output index because of lack of essential data on the valuation of such characteristics. But we have explained how such data could be used in principle and have made some crude assumptions to produce illustrative indices incorporating these adjustments.

Information from the new GP contract introduced in April 2004 should make it possible to incorporate measures of quality change in primary care in the near future.

However, in the absence of a run of such data, the only part of NHS output for which we suggest a quality adjustment is the hospital sector.

3.1 Output indices with short term survival adjustments

Pure survival adjusted cost weighted output index

For each HRG we have data on in-hospital and 30 day mortality. Annual changes in survival rates are used to scale activity so that an improvement in survival is recorded as an increase in real output.

The effect of the simple survival adjustment on the rate of growth of NHS productivity will not be great since the vast majority of NHS patients survive their treatment and the survival rate does not change rapidly. The simple survival adjustment will be an underestimate of improvement in quality.

Survival adjusted cost weighted output index incorporating a uniform estimate of health effects

The simple survival adjustment implies that the patient would have zero quality adjusted life years if not treated. We investigated the difference it would make to a survival adjusted output index if we could take account of the improved quality of life of patients when survival rates increase. The very limited evidence available (mostly for elective procedures) suggested the ratio of health state before treatment to health state after treatment (k) was on average 0.8. In section 4 we present results that show the sensitivity to a range of values of this uniform adjustment.

The fact that we do not have comprehensive data on before and after treatment outcomes means that our uniform adjustment understates health outcomes for some HRGs and overstates health outcomes for others. Most especially, some patients are admitted to hospital when the expectation of death is very high. For HRGs where the mortality rate is high, we make no health effect adjustment and use only the change in survival. We consider in some detail in section 5 the adjustments using actual values of the health effect for a sub-sample of HRGs. Following this we make a recommendation on the values for the health effect and then show the impact of this on the CWOI in section 6.

Survival adjusted cost weighted output index incorporating uniform health effects and life expectancy

In addition to survival of patients we also know their age and gender and so can estimate the average life expectancy for different treatments. The index suggested in the preceding section assumes that there is no change in life expectancy over time. But, whilst we can argue that for some treatments, changes in life expectancy after treatment and without treatment are primarily due to factors outside the control of the NHS and so should not affect the calculation of the growth rate of health output from one period to the next, the age structure of patients treated may change over time. Thus if younger patients are treated they will have longer to enjoy the increased health status post treatment. In this index we take account of such changes in life expectancy of patients treated.

Output indices with waiting time adjustments

Waits for diagnostic tests and treatment may affect individuals in two ways. First, they may dislike waiting per se irrespective of the effect of treatment on the discounted sum of their quality adjusted life years. Thus waiting time is regarded as a separate *characteristic* of health care, distinct from its effect on health to which we can attach a monetary value. This is the approach used in the value weighted index. With available data we were not able to use this approach to estimate a comprehensive output index but did investigate the impact on a specimen index for a limited number of procedures.

Second, longer waits can reduce the health gain from treatment and the waiting adjustment is akin to a *scaling factor* multiplying the health effect. Delay may be associated with deterioration in the patient's condition and the pain and distress while waiting for treatment results in a loss of quality adjusted life years for the patients affected.

A recent survey of the literature on the cost of waiting (Hurst and Siciliani, 2003) found some evidence on deterioration and premature death associated with waiting for cardiology treatment but little for other procedures. If the NHS begins the routine collection of data on health related quality of life, the QALY improvement due to reduced waiting time should be captured by trend changes in QALYs.

The main variant of our suggested scaling waiting time adjustment has a charge for waiting which represents the welfare lost as a result of not having been treated immediately. This is an offset against the benefit of the treatment which applies for the residual life span. Interest is charged on the cost of waiting and the marginal disutility of waiting increases with the length of the wait. We refer to this as *'discounting to date of treatment with charge for waiting'*. An alternative model assumes waiting has a cost in units of health which increases with the length of the wait but at a decreasing rate. This model is discussed in section 5 of the Final Report and referred to as *'discounting to date placed on list'*.

We calculate indices using alternative measures of inpatient waiting time. The first is the mean waiting time. The second is the "certainty equivalent wait". This reflects the possibility that the disutility of being on a waiting list depends not just on the average wait but also the risk of a longer than average wait. We measure the certainty equivalent wait as the waiting time for patients at the 80th percentile of the waiting time distribution for each elective HRG. Reductions in these relatively high waiting times deliver benefits to all patients on the waiting list by reducing the uncertainty of a long wait.

Readmissions and MRSA

Readmissions have been used as a performance indicator for NHS hospitals and we have constructed a quality adjustment based on the assumption that the cost of readmissions is a deadweight loss which reduces the value of treatment. A similar approach is applied to cases of MRSA. However the calculations are illustrative since there is no information on the actual costs of readmissions and MRSA.

Patient experience

Patients may also be concerned with characteristics of hospital care such as the quality of food, cleanliness and the respect and dignity accorded them by staff. We calculate indicators from responses to surveys of patient experience and combine them with the output index adjusted for survival and waiting times. Once again these calculations are illustrative since we do not have the data on the relative valuations of health and satisfaction needed.

3.2 Atkinson principles and quality adjustment

The Atkinson Review published its final report in January 2005 setting out recommendations for improving the measurement of government output and productivity (Atkinson, 2005). In major respects Atkinson recommended a methodology for measuring NHS output growth that had been advocated in our earlier interim reports. Atkinson also points to distortions introduced into output indices weighted by average costs. Different outputs should be weighted by the marginal value of the outputs to individuals. We are in complete agreement.

4 Experimental indices of NHS output: results

4.1 General trends, index form and data sources

Our starting point is the set of activities used by the DH in its cost weighted output index (CWOI). For inpatient hospital care we use the Hospital Episode Statistics (HES) (data on non-elective, elective and day case activity). This is then combined with information on activities such as outpatient treatments, accident and emergency, mental health, GP consultations, prescribing plus a range of other activities from a variety of sources. In 2002/03 the data consisted of 1913 groups of activities. Table 4.1 gives a summary of the main divisions of this dataset.

The main quality adjustments discussed in this report are for survival and waiting times. Mortality rates are only available for HES activity (non-elective, elective and day case hospital activity). Waiting times are available for electives and day cases and some outpatient activities. This means our quality adjustments will only apply to 47% of the activity currently included in the CWOI. We therefore first report results showing the effects of quality adjustments for the HES activities and then add other activities at the end of the section.

Table 4.1 Activities and cost shares 2002/03

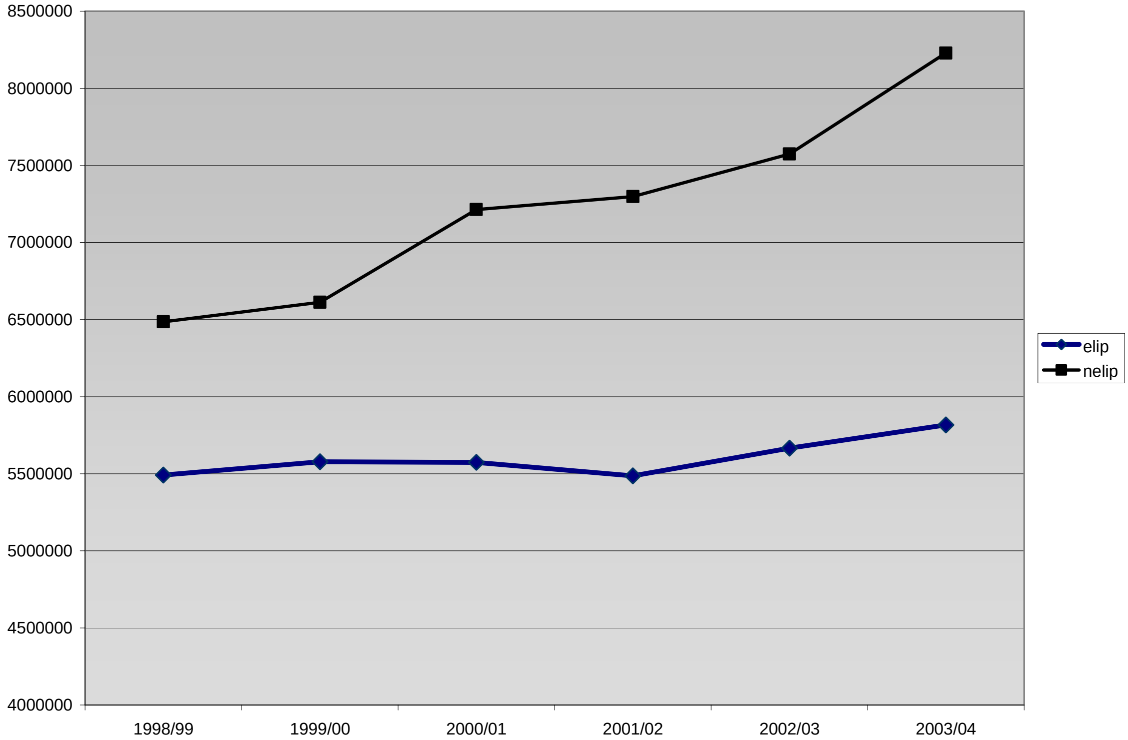
	Number of activities (millions)	Cost shares[1]
Electives+ day cases	5.58	13.38
Non-electives	5.96	22.1
Outpatients	53.43	11.15
Other activities[2]		53.37
Total		100.00

Notes: 1. Derived by multiplying activities by unit costs; 2.These activities are measured in non-comparable units so total numbers of activities are meaningless. A division of costs shares with this category is shown in Table 3.1 in the Final Report.

In order to highlight the impact of quality adjustment for the activities where the data permit adjustment, in section 4.3 we compare our quality adjusted indices to an unadjusted index restricted to the same set of activities. In the tables this truncated version of CWOI is labelled “unadjusted”. In section 6 we examine how quality adjusting for this subset of activities affects the value of the complete CWOI.

The HES data are grouped according to procedures comprising 574 Healthcare Resource Groups (HRGs), with an additional separation into electives and day cases and non-electives. Figure 4.1 graphs the number of episodes for each year from 1998/99 to 2003/04. It shows little change in electives up to 2001/02 with some growth thereafter. Non-electives show more significant growth, with high growth in the final year.

Figure 4.1 Number of FCEs, electives+day cases (elip) and non-electives (nelip), 1998/99 – 2003/04



Within these broad categories there is considerable variation in number of procedures and in growth by HRG. For example, comparing 2002/03 with 2001/02, the arithmetic mean growth in episodes for elective HRGs was 3.8% but with a standard deviation of 15.9% – growth across HRGs was even more variable for non-electives.

Unit costs from the Reference Costs database are employed to aggregate these diverse activities. The unit costs also show considerable variation across procedures, from over £20,000 for transplant procedures to under £500 for ophthalmic and ear procedures. In 2002/03 the mean unit cost across HRGs for electives was about £1,700 with a standard deviation of £2,220, (£2,200 and £2,600 for non-electives).

The cost weighted output index combines activity growth by weighting by unit costs, equivalent to multiplying the ratio of activities by cost shares. Cost shares are concentrated in a few HRGs. Treating electives and non-electives as separate sets of activities, in 2002/03, 25% of expenditure was accounted for by only 20 HRGs with 50% accounted for by 74 HRGs.

We compared the Laspeyres (base period weighted) index with Paasche (current period weights) index and the geometric mean Fisher index formula. The results (see section 5 of the Full Report) show that the index number formula used has only a small impact on the indices. In this summary report we follow ONS in reporting only Laspeyres indices.

4.2 Spells versus episodes

Hospital output can be measured as finished consultant episodes (FCEs) or continuous inpatient spells (CIPS) which consist of sets of consecutive FCEs. We argue that CIPS are a better approximation to the patient journey and therefore a more appropriate measure of output. We use CIPS for our calculation of the effects of quality adjustments.

Although there are around 8% fewer CIPS than FCEs this should have essentially no effect on the calculation of a cost weighted output index since we constructed our unit costs for CIPS from the underlying FCE unit costs. Table 4.2 compares FCE based and CIPS based CWOIs as a check on our calculations of unit costs of spells. The only reason for a divergence between the two indices is that some of the FCEs assigned to a particular year in the FCE index may be assigned to a different year in a CIPS index since a CIPS is assigned to a year only if its last FCE finished in that year.

We would however expect to see differences in FCE and CIPS based indices once the outputs are adjusted for survival and mortality since these adjustments are applied to the different distributions of HRG types generated by the FCE and CIPS volume measures.

Table 4.2 Comparison of cost weighted output indices for hospitals based on finished consultant episodes and continuous inpatient spells

	CWOI index		
	Episodes	CIPS	pp diff
1998/99-1999/00	1.84	1.87	-0.03
1999/00-2000/01	0.90	0.91	-0.01
2000/01-2001/02	0.93	0.95	-0.02
2001/02-2002/03	4.41	4.44	-0.03
2002/03-2003/04	5.75	5.81	-0.06
Average	2.75	2.78	-0.03

4.3 Survival adjustments: hospital output

Simple survival adjustment

Mortality can be measured as in-hospital deaths or as deaths within 30 days. In-hospital deaths are those most directly attributable to the NHS but are likely to underestimate survival changes due to medical treatment since many patients die within a short time after discharge. Using 30 day mortality rates runs the risk of attributing deaths from extraneous influences to the NHS. In the period under consideration 30 day mortality rates were about 25% higher than in-hospital deaths (Table 4.3). Both indicators show a downward trend with similar rates of decline.

Table 4.3 Mortality rates, (deaths/CIPS), 1998/99-2003/04

	In-hospital	30 day
1998/99	0.0239	0.0308
1999/00	0.0238	0.0306
2000/01	0.0229	0.0293
2001/02	0.0236	0.0299
2002/03	0.0228	0.0286
2003/04	0.0222	0.0276

Death rates are considerably higher for non-elective procedures than for electives and have declined more rapidly in the former. High death rates are associated with a minority of procedures; very high death rates, say greater than 0.4, are the exception, and very rare amongst electives.

Table 4.4 reports calculations of the pure short term survival adjusted cost weighted output index (section 4.8.1, Final Report)

$$\frac{\sum_j x_{jt+1}\left(\frac{a_{jt+1}}{a_{jt}}\right)c_{jt}}{\sum_j x_{jt}c_{jt}} \qquad (2)$$

where *a* is the survival rate. The first column of results is the unadjusted CWOI. The second and third columns are the survival adjusted indices calculated with 30 day and in-hospital death rates. The adjustments are non-trivial, though generally quite small in percentage point terms. They increase output growth in three out of the five years, and on average over the period. 30 day survival gives a higher adjustment than in-hospital survival in all but the first year.

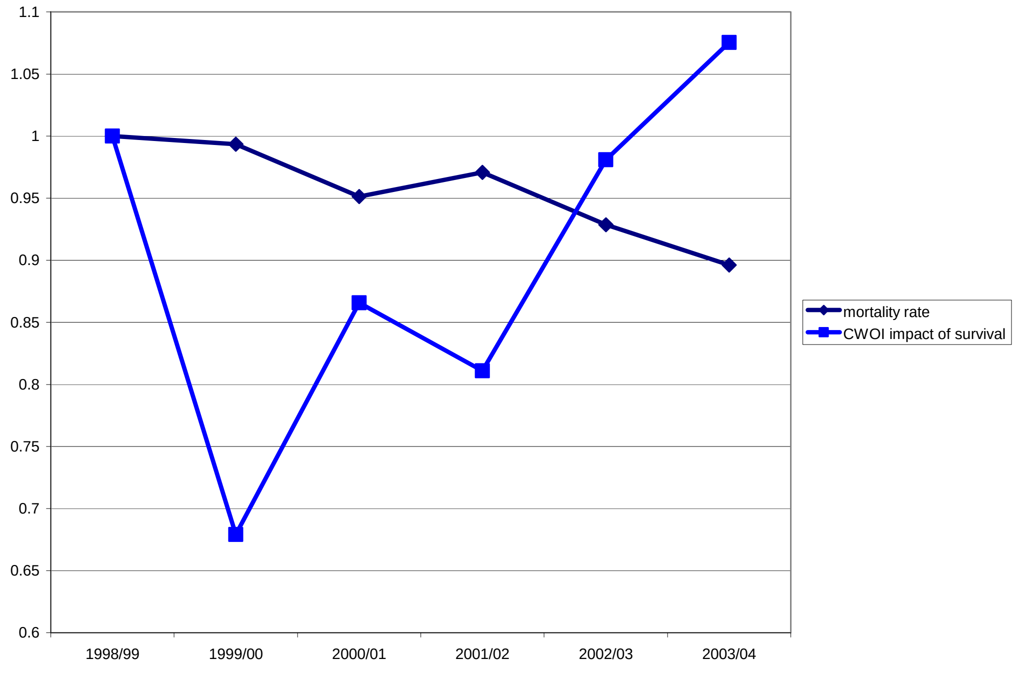
Table 4.4 Laspeyres CWOI index, CIPS, adjusted for survival

	Laspeyres CWOI		
	Unadjusted	Adjusted for survival	
		30 day	In-hospital
1998/99-1999/00	1.87	1.27	1.37
1999/00-2000/01	0.91	1.16	1.08
2000/01-2001/02	0.95	0.89	0.86
2001/02-2002/03	4.44	5.37	5.14
2002/03-2003/04	5.81	6.37	6.22
Average all years	2.78	2.99	2.91

The impact of the survival adjustment depends on both the rate of change of survival across HRGs and their cost shares. The latter turn out to have a large impact since, as stated earlier, the majority of procedures show little change in survival but these tend to be concentrated in low cost procedures. To illustrate this point Figure 4.2 shows the change in average (unweighted) mortality rates (from Table 4.3) and the change in the CWOI adjusted for survival minus the unadjusted CWOI (the second column in Table 4.4 minus the first column in Table 4.4), both indexed at 1998 =1. The mortality rate shows a relatively smooth pattern, generally declining but with a small upward shift comparing 2000/01 and 2001/02. In contrast the impact on the CWOI is much more variable, and not always in the inverse direction to the change in the mortality rate.

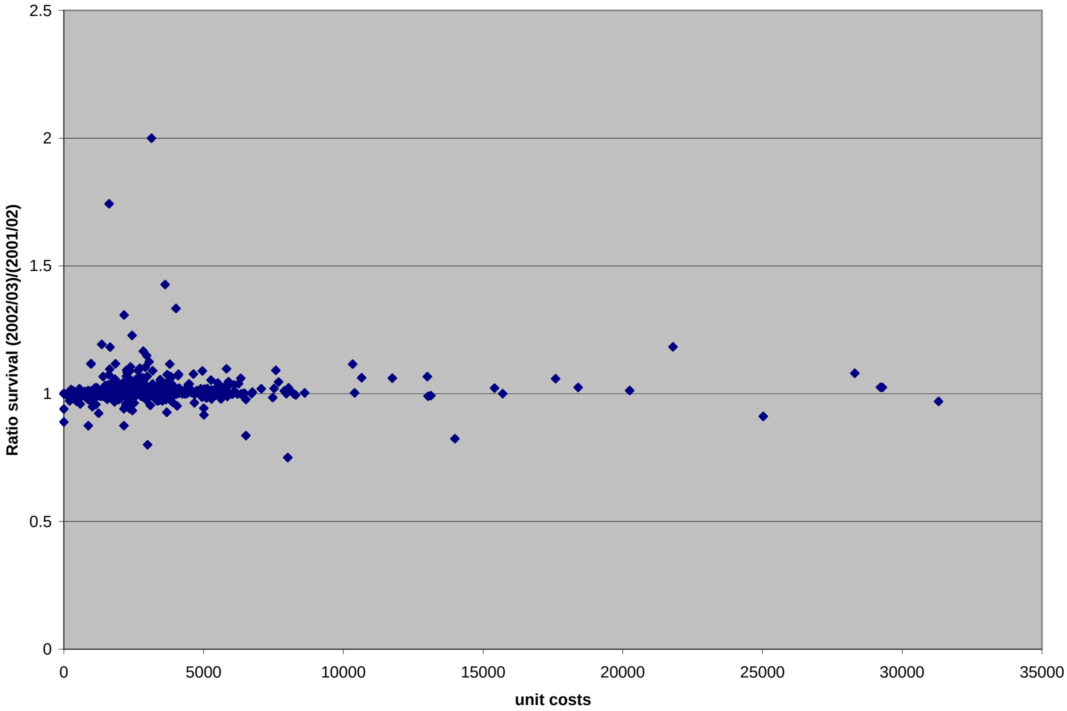
Figure 4.3 plots changes in survival rates against unit cost for one of the growth periods, 2001/02-2002/03. Most changes in survival are small, ranging around the value 1 on the y-axis and the majority of these are in the lowest unit cost range. Year on year changes in the CWOI are driven largely by variations in survival rates in the relatively few procedures with very high unit costs, plus a few cases where changes in survival rates are very high in the low unit cost range.

Figure 4.2 Mortality rates and the impact of the survival adjustment*, Index 1998/99=1



* calculated as the difference between the 30 day survival adjusted CWOI and the unadjusted CWOI

Figure 4.3 Growth in survival (ratio) and unit costs, 2001/02-2002/03, (electives and non-electives)



To understand the sensitivity of the results to cost shares we estimated the change in the index when survival was assumed unchanged for the top 25 high cost share HRGs, pooled across electives and non-electives, which represented just over 30% of total expenditure. The impact of this was to reduce the 30 day survival adjustments by about 60%. Thus the calculations depend heavily on the survival rates of a small number of HRGs. Within this high cost share group, comparing 1999/00 with 1998/99, 17 of the 25 HRGs showed reductions in survival rates and these are responsible to a large extent for the big negative impact of the survival adjustment on the CWOI in that growth period. In contrast in the final two growth periods the majority of high cost share HRGs witnessed increases in survival rates – 19 HRGs in 2001/02-2002/03 and 20 HRGs in 2002/03-2003/04.

Over time, both the number of HRGs with positive growth in survival rates and the share of expenditure accounted by these procedures has increased as shown in Table 4.5. If the percent of HRGs with increases in survival rates is lower than the cumulative expenditure share (in percent) of these procedures, then increased survival is concentrated in relatively high cost procedures. Table 4.5 shows that this is the case in each growth period except the first and that the discrepancy has increased through time.

Table 4.5 Changes in 30 day survival rates and expenditures shares

	Percent of procedures* with change in survival rates >1	Expenditure shares of procedures* with change in survival rates >1
1998/99-1999/00	42.8	37.8
1999/00-2000/01	55.5	62.0
2000/01-2001/02	49.5	50.7
2001/02-2002/03	62.9	75.4
2002/03-2003/04	63.0	77.7

* Total number of procedures = 1148, with electives and non-elective HRGs treated as separate procedures.

We demonstrate in the full Final Report that under plausible assumptions the simple survival adjustment produces an underestimate of growth in the health effect of treatment. We next consider how making strong assumptions about the health effect alters the results.

Survival and estimated health effects adjustment

We calculate the survival and health effects adjusted index

$$\frac{\sum_j x_{jt+1}\left(\frac{a_{jt+1}-k_j}{a_{jt}-k_j}\right)c_{jt}}{\sum_j x_{jt}c_{jt}} \qquad (3)$$

where k_j = q^0_{jt} / q^*_{jt} is an estimate of the proportionate effect of treatment conditional on survival to no treatment which, in the absence data on actual health effects, we assume is constant over time. (q^*_{jt} is the sum of discounted quality adjusted life years accruing to patients who survive treatment. q^o_{jt} is the sum of quality adjusted life years for untreated patients.) With k = 0, which implies that the patient would have zero quality adjusted life years if not treated, we have the pure survival adjusted index. We examine the impact of assuming that k is positive. The rather sketchy available evidence suggests a value of around $k = 0.8$ for non life threatening procedures. When the treatment has a high mortality we set $k = 0$. If we used $m = 0.2$ for the cut-off mortality rate for setting $k = 0$ this would ensure that term $a - k$ is never negative which would correspond to treatment having a negative effect on health. But this would make the index very sensitive to change in mortality when the rate is close to 0.2. We therefore set the cut off value for mortality which leads to $k = 0$ so that $a - k$ is never smaller than 0.05. Thus for HRGs with high mortality we use the simple survival adjustment.

Table 4.6 shows that including the crude health effects adjustment via $k = q^o/q^*$ generally increases the growth rate compared with no adjustment (first column) and with a simple survival adjustment (Table 4.4). The table also shows the sensitivity of the index to the uniform value of k. Averaged across the five yearly growth rates, the impact ranges from adding about 1.0 to 0.4 percentage points to the growth rate. Contrast this with an average impact of 0.22 for the simple survival adjustment using 30 day survival rates. Thus a survival adjustment which incorporates crude but not implausible adjustments for health effects is capable of significantly adding to the growth rate of hospital output. Note, as with the simple survival adjustment, much of the impact is due to the behaviour of survival rates in the high cost share HRGs. For example in the case where k=0.8 with cut off = 0.10, nearly 70% of the adjustment can be attributed to the 25 HRGs with the highest cost shares.

Table 4.6 CWOI index, CIPS, adjusted for survival, 30 day mortality rates

	Unadjusted	q^0/q^*=0.8 if m<0.10, q^0/q =0 otherwise	q^0/q^*=0.8 if m<0.15, q^0/q =0 otherwise	q^0/q^*=0.7 if m<0.15, q^0/q =0 otherwise	q^0/q^*=0.7 if m<0.10, q^0/q =0 otherwise	q^0/q^*=0.9 if m<0.05, q^0/q =0 otherwise
1998/99-1999/00	1.87	0.78	0.09	0.73	1.02	1.26
1999/00-2000/01	0.91	1.58	1.97	1.51	1.36	1.54
2000/01-2001/02	0.95	0.91	1.01	0.93	0.90	1.01
2001/02-2002/03	4.44	6.59	7.72	6.34	5.97	6.27
2002/03-2003/04	5.81	7.15	8.04	7.10	6.76	7.09
Average all years	2.78	3.36	3.77	3.28	3.20	3.43

Survival adjustments with health effects and life expectancy

We argue that including a term reflecting life expectancy of patients treated would improve the crude adjustment for the health effect and propose the index

$$\frac{\sum_j x_{jt+1} c_{jt} \frac{\left(a_{jt+1} - k_j\right)}{\left(a_{jt} - k_j\right)} \left(\frac{1 - e^{-rL_{jt+1}}}{1 - e^{-rL_{jt}}} \right)}{\sum_j x_{jt} c_{jt}} \qquad (4)$$

where L_{jt} is the life expectancy at the average age of patients getting treatment j and r is the discount rate on quality adjusted life years (the units in which health effects are measured).

Table 4.7 CWOI index, CIPS, adjusted for survival, life expectancy, 30 day mortality rates, r=1.5

	Unadjusted	q^0/q^*=0.8 if m<0.10, q^0/q =0 otherwise	q^0/q^*=0.8 if m<0.15, q^0/q =0 otherwise
1998/99-1999/00	1.87	1.12	0.74
1999/00-2000/01	0.91	1.37	1.76
2000/01-2001/02	0.95	0.76	0.89
2001/02-2002/03	4.44	6.31	7.44
2002/03-2003/04	5.81	7.13	8.03
Average all years	2.78	3.30	3.72

Comparing the results of this table with those in Table 4.6 this calculation leads to lower growth rates for comparable assumptions in all years except the first and reflects the increasing age of patients treated by the NHS.

Waiting time and survival adjustments: hospital output

We calculated the mean wait (after truncating very long waits to four years) and the 80th percentile wait for treatment. Table 4.8 shows mean waits across all patients and the mean 80th percentile wait across HRGs for electives in the period under study. There was only a small decline in both waiting times measures over the period, suggesting that waiting time quality adjustments will have relatively little impact on the output index.

Table 4.8 Trends in waiting time, days, averages across HRGs

	Mean wait	
	Truncated mean	80th percentile
1998/99	88.7	132.2
1999/00	80.8	117.7
2000/01	82.3	119.0
2001/02	85.2	124.4
2002/03	88.5	128.9
2003/04	85.9	126.8

Effect of waiting time adjustments

We examined two main forms of waiting time adjustment:

discounting to date placed on the waiting list,

$$\frac{\sum_j x_{jt+1} c_{jt} \left\{ \dfrac{k_j \left[\dfrac{(1-e^{-r_w w_{jt+1}})}{r_w} - \dfrac{(1-e^{-r_L w_{jt+1}})}{r_L} \right] + \left(a_{jt+1} - k_j\right) \dfrac{e^{-r_L w_{jt+1}} \left(1-e^{-r_L L_{jt+1}}\right)}{r_L}}{k_j \left[\dfrac{(1-e^{-r_w w_{jt}})}{r_w} - \dfrac{(1-e^{-r_L w_{jt}})}{r_L} \right] + \left(a_{jt} - k_j\right) \dfrac{e^{-r_L w_{jt}} \left(1-e^{-r_L L_{jt}}\right)}{r_L}} \right\}}{\sum_j x_{jt} c_{jt}} \quad (5)$$

and *discounting to date of treatment with a charge for waiting*

$$\frac{\sum_j x_{jt+1} c_{jt} \left(\dfrac{a_{jt+1} - k_j}{a_{jt} - k_j} \right) \dfrac{\left[\dfrac{\left(1-e^{-r_L L_{jt+1}}\right)}{r_L} - \dfrac{\left(e^{r_w w_{jt+1}} - 1\right)}{r_w} \right]}{\left[\dfrac{\left(1-e^{-r_L L_{jt}}\right)}{r_L} - \dfrac{\left(e^{r_w w_{jt}} - 1\right)}{r_w} \right]}}{\sum_j x_{jt} c_{jt}} \quad (6)$$

where we allow for the possibility that patients apply a different discount (r_w) to future health whilst waiting for treatment than after they are treated (r_L).

None of the waiting time adjustments had any marked effect on growth rates. We report summary results in Table 4.9 in the form of average annual growth rates over the period 1998/99 to 2003/04. All are based on the same survival adjustment with $k = q^0/q^*$=0.8 and the mortality cut off set to m = 0.10. Other uniform survival adjustments made little difference to the effects of the waiting time adjustments.

Table 4.9 Laspeyres CWOI index, CIPS, adjustments for changes in waiting times. Average annual growth rates 1998/9 to 2003/4

Form of waiting time adjustment	Measure of waiting time	$r_W = r_L$ = 1.5%	r_W =10%, r_L =1.5%
Discount to date treated, with charge for waiting	80th percentile	3.33	3.34
Discount to date treated, with charge for waiting	mean wait	3.32	3.32
Discount to date on list,	80th percentile	3.24	
Discount to date treated, with charge for waiting	individual data	3.48	3.49
Discount to date treated, with charge for waiting	mean wait, optimal wait = 15 days	3.33	3.34
Survival adjustment only		3.30	

Note: All columns have the same survival adjustment: k = 0.8 if a_{jt} - k > 0.10, 0 otherwise

The first and third rows show that there is little difference in the effect of the forms of the waiting time adjustment. Comparison of the first and second row shows that the choice of waiting time measure has no impact.

Since the waiting times and life expectancy factors are non-linear and there is a variation in waiting times and in ages within an HRG in a given year it is possible that our use of a single waiting time and life expectancy estimate for each HRG may lead to misleading results. We therefore computed the equivalent of the waiting time adjustment with discounting to date of treatment with a charge for waiting with individual level data. The results are in the fourth row and again differ little from the same index form using the 80th percentile wait in the first row.

We were asked to consider how an adjustment for waiting times could allow for optimal waiting times – it was suggested that some patients might find too short a wait inconvenient. In the absence of any information on what an optimal wait might be we investigated the implications of assuming that the effect of an optimal waiting time w^* was to replace the actual wait in our waiting time adjustments with the $\hat{w} = w - w^*$ if $w > w^*$ and 0 otherwise. Thus reductions in waiting time below w^* would have no effect whereas the proportionate effect of reductions above w^* would be increased. We experimented first with $w^* = 30$ days but found that this resulted in a large number of HRGs where $\hat{w} = 0$. The results are in row five in Table 4.9 and are very similar to the same index using the 80th percentile wait.

The results show little or no impact from adjusting for changes in waiting times, regardless of the formulae or measures of waiting time employed. The small effects of waiting time adjustments are largely driven by the lack of change in waiting times rather than the methods used. To see this suppose waiting times for the 80th percentile were reduced by 10% for all HRGS comparing 2003/04 with 2002/03. Then the discount to date of treatment with charge for wait and low discount rates equal to 1.5% would add 0.16 percentage points. With the same discount rates, reducing waits at the 80th percentile by 50% would add 1.12 percentage points to the growth rate in that year. While further significant reductions in waiting time will increase the growth of NHS output, it is important to note that the index measures changes in *both* health gain through treatment and reduced waiting time. Treatment may generate improved quality of life for ten years while a reduction in waiting from six months to three months will add only a fraction to the overall gain in output.

In addition the impact of changes in waiting times is dependent on the cost share weights. In this case however, large increases in waiting times tend to be concentrated in low unit cost procedures. This is illustrated for the final two growth periods in Figure 4.4 and Figure 4.5 but a similar pattern is also apparent for earlier years.

Figure 4.4 Percentage changes in waiting times (days) and unit costs, 2001/02-2002/03

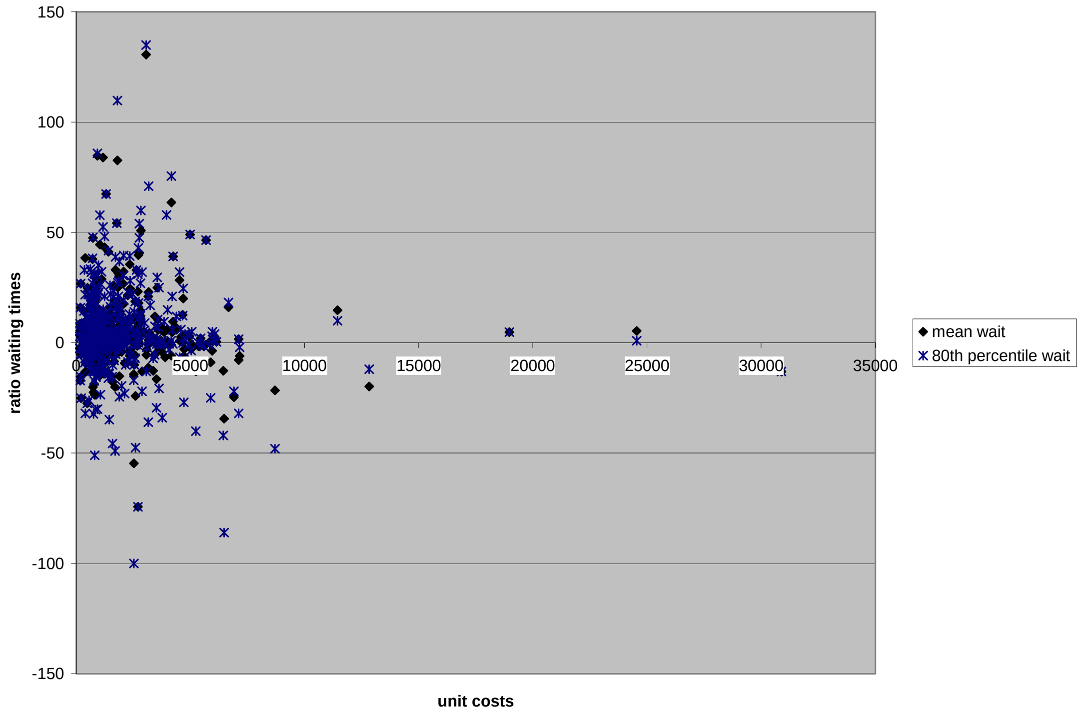
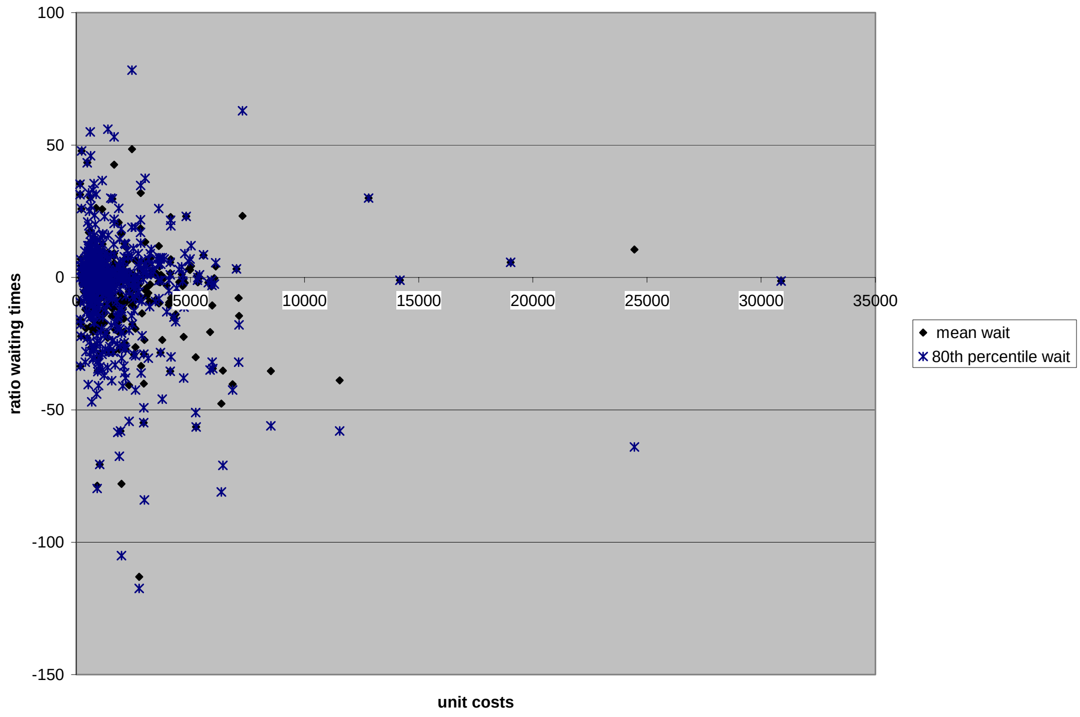


Figure 4.5 Percentage changes in waiting times (days) and unit costs, 2002/03-2003/04



Again it is useful to summarise the relationship between cost and changes in waiting times by the number of HRGs that show reductions and their expenditure shares. Table 4.10 shows that for three of the five growth periods the majority of HRGs show increases in waiting times with higher proportions in the first and final period. In general the percent of HRGs with reductions in waiting times are about equal to their expenditures shares so that reductions tend to be concentrated at the low unit cost end.

Table 4.10 Changes in waiting times and expenditures shares

	Mean wait		80^{th} percentile wait	
	Per cent of electives* with reduction in waiting time	Expenditure shares of electives* with reduction in waiting time	Per cent of electives* with reduction in waiting time	Expenditure shares of electives* with reduction in waiting time
1998/99-1999/00	62.3	68.7	55.1	65.8
1999/00-2000/01	32.4	37.3	34.2	37.7
2000/01-2001/02	31.9	30.4	33.9	35.2
2001/02-2002/03	32.3	33.3	29.9	29.8
2002/03-2003/04	63.4	63.9	51.5	51.7

* Total number of electives = 563

We did not estimate the alternative characteristics waiting time adjustment for all HRGs because of lack of data on health effects. However, we report in section 5 results from using this approach to waiting times with a small specimen set of HRGs for which we have better health data.

Outpatient waits

Data on waiting times for first outpatient attendances are only available for four of the years considered in this report. Average days wait for outpatients were 64 days in 1999/00 and 2000/01 but then declined by about 10% in 2002/03 to 58 days and a further 7% to 54 days in 2003/04. We used the discount to date of treatment formula as for electives above, assuming all outpatients had remaining life expectancy of 26 years, the average across electives. The cost weights for changes in waiting times for outpatients was assumed to be the sum of the cost share of first attenders and follow up appointments to be consistent with the spells approach employed in previous calculations. The effect of this adjustment was to increase the cost weighted output index for outpatient first attenders from 4.47% to 4.59% in 2001/02 and from 6.48% to 6.56% in 2002/03. These adjustments become very small when all outpatients including follow-ups are included in the index.

4.4 Additional quality adjustments

We were asked to examine the possibility of making further quality adjustments based on data for:

- Readmission rates
- Incidence of MRSA
- Surveys of patient experience

Readmission rates

It was argued that emergency readmission within 28 days of discharge may reflect poor quality of care during the previous episode of treatment. If true, these admissions could be excluded from the count of admissions thus reducing total output and the costs instead treated as a continuation of earlier treatment. There are two problems with using existing data to make this adjustment. First, it is not possible to identify the proportion of readmissions due to poor care. Some readmissions are for treatment of patients with long standing or complex conditions. It has also been suggested that A&E waiting time targets have increased readmission rates. Second, there is no information on the costs of readmissions related to poor care.

Incidence of MRSA

It is argued that the number of MRSA cases reflects poor quality of NHS hospital services. The cost of these cases should be deducted from total NHS output. As with readmissions, there are serious problems with available data. There is no data on

MRSA cases prior to 2001/2 and no routine data for estimating the cost of an MRSA case.

Patient experience surveys

If patient experience surveys measure characteristics of NHS care valued by patients but not reflected in other quality measures such as health outcome or waiting time, then they could be used to quality adjust output. The available data is limited and only permit comparison of 2004 or 2004/5 with 2003. There is also the problem of identifying a patient valuation or cost weight to use when incorporating this aspect of quality into an output index. In future, if discrete choice data is obtained by the DH, this information can be used to weight changes in patient experience in an output index.

Our full analysis of data and methods for incorporating these additional quality adjustments is in Section 5.7 of the Final Report and in Appendix A. **With current data we do not recommend these quality adjustments be included in the NHS output index.** However, given DH interest in these adjustments, we illustrate how inclusion might affect estimates of output. To do this is necessary to employ a number of arbitrary assumptions:

- All readmissions reflect poor quality care; assume cost per case is an average of A&E cost per case.
- Readmissions incur £500 of wasted costs and MRSA £1000 at 2002/03 prices.
- Responses of patient experience surveys on cleanliness and food weighted by share in total expenditure; responses on non-clinical care weighted by 5% or 10% of total expenditure.

The results of these illustrative calculations are given in Table 4.11.

Table 4.11 Illustrative calculations of hospital CWOI with adjustments for survival, waiting times, patient satisfaction as measured in patient surveys, readmissions and MRSA. Average annual growth rates 2001/2 to 2003/4

Average Growth Rates 2001/2 to 2003/4	% p.a.
Unadjusted CWOI	4.34%
Quality Variant 1	5.74%
With Adjustment for Patient Satisfaction (5% weight on non-clinical care satisfaction)	5.71%
With adjustment for MRSA, Readmissions and Patient Satisfaction (5% weight on non-clinical care satisfaction)	5.71%
With Adjustment for Patient Satisfaction (10% weight on non-clinical care satisfaction)	5.69%
With adjustment for MRSA, Readmissions and Patient Quality and Satisfaction (10% weight on non-clinical care satisfaction)	5.69%

These purely illustrative results suggest that the difference between giving a 5% weight and a 10% weight to patient satisfaction has little effect on the overall illustrative index growth. In either case the adjustments for waiting and mortality have an important impact which is little affected when account is also taken of MRSA and readmission.

4.5 Conclusions

Applying our quality adjustments to the cost weighted output index we found that

- the pure survival adjustment raises the average annual growth rate of the hospital sector between 1999/00 and 2003/04 from 2.78% to 2.99% using 30 day survival and 2.91% when using in-hospital survival.
- combining the survival adjustment with an assumed uniform proportional health effect further increase the average growth rate by around 0.4% to 1.0%.
- adding a life expectancy adjustment to the survival and health effect adjustment had little additional effect on the growth rate.
- the effect of the waiting time adjustment was insensitive to very large variations in discount rates on waiting times, to the use of individual rather than HRG level data, to the form of the adjustment, and to the measure of waiting time (mean wait or 80th percentile wait).

- the small waiting time effects are due to the small changes in waiting times over the period rather than to the form of the waiting time adjustment and the particular parameter values used.
- a crude illustrative adjustment for readmissions and MRSA (all that is possible with current data) in addition to the survival, assumed health effect, life expectancy and waiting times adjustments, had no perceptible effect on the average annual growth rate (2001/2 to 2003/4).
- a similarly crude illustrative adjustment for patient satisfaction with food, cleanliness and non-clinical care reduced the growth rate very slightly, (2001/2 to 2003/4) by less than 0.1 percentage point.

5 Specimen output indices

In section 2.2 we set out our preferred index of NHS output, a value weighted output index. It is not possible to estimate a comprehensive value weighted index because of a lack of data on the most important characteristic: improvement in health for patients who survive treatment. In section 2.2 we also pointed to the stringent assumptions necessary to justify using cost weights in the output index and the perverse effects when more cost effective treatments are introduced. In section 4 of the Final Report we looked at the sensitivity of the output index to an estimate of health gain based on the assumption that health gain was constant across all activities and did not vary over time.

For a small set of HRGs we identified data on health outcomes which permit the calculation of our preferred value weighted output index. The data are similar to what would be produced by sampling patients before and after treatment and are used to drop the restrictive assumption that health gain is constant across activities. While the conditions for which we have outcomes data are not representative of all NHS activities, we are able to compare a number of "specimen" indices with the equivalent cost weighted output index for the same sub-set of conditions. The data are fully discussed in section 6 and Appendix C of the Final Report.

We use the data on health outcomes along with that on survival and waiting times to examine:

- A value weighted output index assigning monetary weights to improvements in health and reductions in waiting times
- The impact on an index of substituting cost weights with value weights
- The effect on health effect adjusted cost weighted indices of allowing health gain to vary by treatment

5.1 The data

Table 5.1 lists the procedures used in the specimen index along with available estimates of health state with and without treatment. h^o, h^* are estimates of outcomes with and without treatment, based in some cases on data after and before treatment

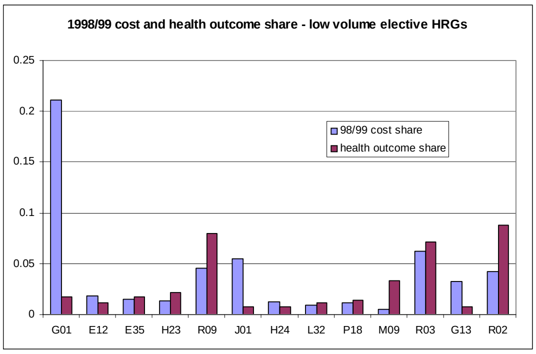
Table 5.1 Estimated health outcomes by procedure

HRG description	Source	HRG	Health outcome h_j^0	h_j^*
Intermediate Pain Procedures	BUPA	A07	0.41	0.57
Phakoemulsification Cataract Extraction with Lens Implant	BUPA	B02	0.73	0.76
Other Cataract Extraction with Lens Implant	BUPA	B03	0.70	0.72
Mouth or Throat Procedures - Category 2	BUPA	C14	0.87	0.95
Nose Procedures - Category 3	BUPA	C22	0.83	0.91
Mouth or Throat Procedures - Category 3	BUPA	C24	0.77	0.93
Coronary Bypass	BUPA	E04	0.50	0.73
Acute Myocardial Infarction w/o cc	EQ5D	E12	0.68	0.72
Percutaneous Transluminal Coronary Angioplasty (PTCA)	BUPA	E15	0.54	0.79
Chest Pain >69 or w cc	EQ5D	E35	0.63	0.69
Inguinal Umbilical or Femoral Hernia Repairs >69 or w cc	BUPA	F73	0.64	0.69
Inguinal Umbilical or Femoral Hernia Repairs <70 w/o cc	BUPA	F74	0.74	0.81
Liver Transplant	EQ5D	G01	0.53	0.59
Biliary Tract - Major Procedures >69 or w cc	BUPA	G13	0.63	0.66
Biliary Tract - Major Procedures <70 w/o cc	BUPA	G14	0.68	0.81
Primary Hip Replacement	BUPA	H02	0.37	0.62
Primary Knee Replacement	York	H04	0.35	0.54
Soft Tissue Disorders >69 or w cc	BUPA	H23	0.77	0.84
Soft Tissue Disorders <70 w/o cc	BUPA	H24	0.72	0.74
Inflammatory Spine, Joint or Connective Tissue Disorders <70 w/o cc	EQ5D	H26	0.41	0.53
Complex Breast Reconstruction using Flaps	BUPA	J01	0.93	0.96
Non-Malignant Prostate Disorders	EQ5D	L32	0.81	0.85
Upper Genital Tract Major Procedures	BUPA	M07	0.70	0.80
Threatened or Spontaneous Abortion	BUPA	M09	0.72	0.83
Psychiatric Disorders	EQ5D	P18	0.36	0.41
Varicose Vein Procedures	EQ5D	Q11	0.77	1
Surgery for Degenerative Spinal Disorders	BUPA	R02	0.37	0.67
Spinal Fusion or Decompression Excluding Trauma	BUPA	R03	0.36	0.62
Revisional Spinal Procedures	BUPA	R09	0.32	0.60

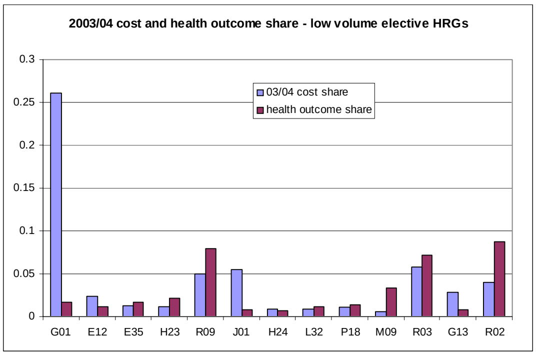
Figures 5.1 and 5.2 illustrate the difference in relative costs and relative health outcomes. We would expect the difference for high volume HRGs to dominate changes in the value of an output index that uses health gain rather than costs to weight activities.

Figure 5.1 Cost and health outcome weights, elective HRGs

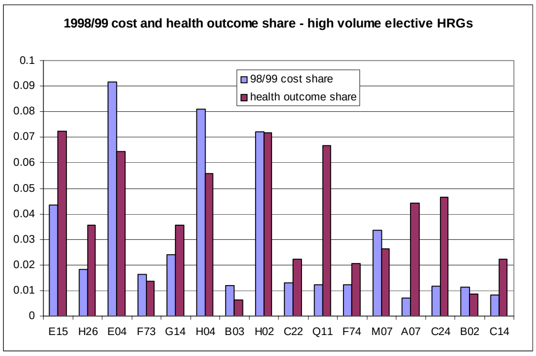
(a) 1998/99 costs, low volume HRGs



(b) 2003/04 costs, low volume HRGs



(c) 1998/99 costs, high volume HRGs



(d) 2003/04 costs, high volume HRGs

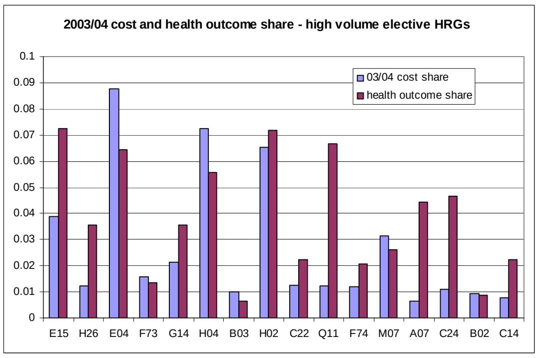
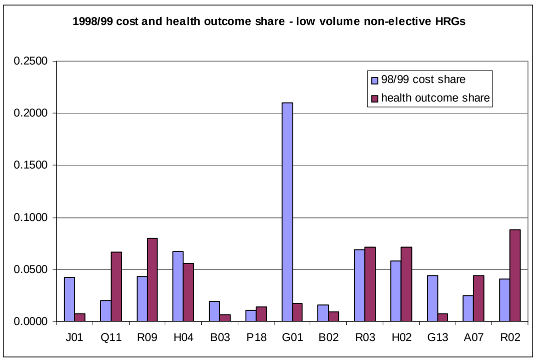
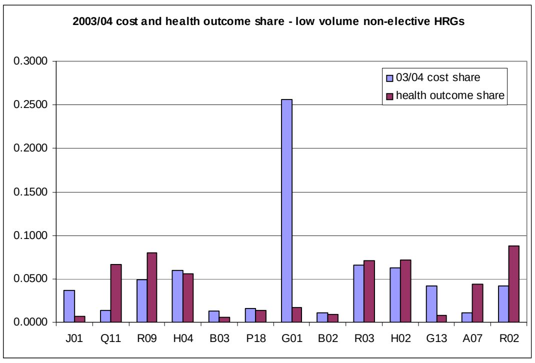


Figure 5.2 Cost and health outcome weights, non-elective HRGs

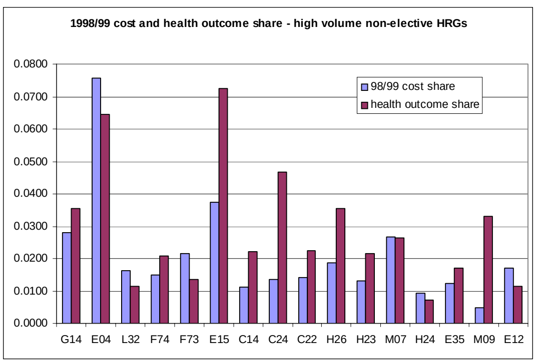
(a) 1998/99 costs, low volume HRGs



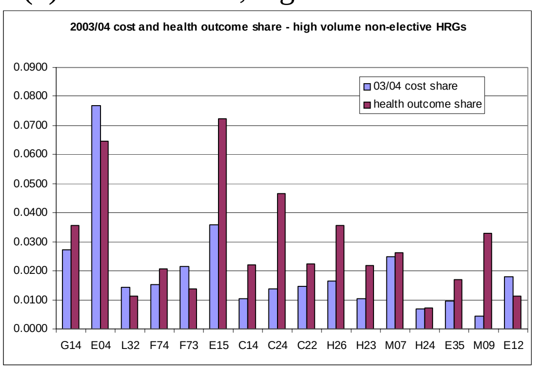
(b) 2003/04 costs, low volume HRGs



(c) 1998/99 costs, high volume HRGs



(d) 2003/04 costs, high volume HRGs



5.2 Health outcome weighted output indices

This section presents the results from calculation of health outcomes weighted output indices (HOWOI). For comparative purposes with the CWOI, we first estimate a version of HOWOI in which the impact of treatment on life expectancy is ignored. In effect, this amounts to comparing the use of cost and survival-adjusted before and after health outcomes as weights:

$$\frac{\sum_j x_{jt+1}(a_{jt+1}h_j^* - h_j^0)}{\sum_j x_{jt}(a_{jt}h_j^* - h_j^0)} \qquad (7)$$

This equation is estimated both with *k* varying by HRG (column (ii) Table 5.2) and for a value of *k*=0.8 (column (iii) Table 5.2). Output growth appears lower than in this formulation of a HOWOI than the corresponding cost weighted output index (figures from Table 6.6 in main report reproduced in column (i) of Table 5.2).

As can be seen, substitution of cost for health outcome weights leads to a reduction in estimated output growth for this group of HRGs. The extent to which an index is sensitive to the choice of cost and health outcome weights depends on three factors:

- Whether cost weights are disproportionate to health outcome weights;
- The volume of activity in those HRGs where the relative weights are most disproportionate;
- The change in activity over time in those HRGs where the relative weights are most disproportionate.

For a handful of HRGs, cost weights are greater than health outcome weights. This is particular evident for G01 liver transplants, which are costly (the non-elective cost was £23,000 in 2003/04) but their estimated contribution to health outcome is about average for the sample of HRGs considered here. However, because this is a low volume HRG and there is little change in the amount of activity over time, the impact of changing the valuation basis for G01 exerts little influence on the overall index.

In contrast, elective activity categorised to A07 (intermediate pain procedures) contributes 7.4% of total 2003/04 activity, and elective activity in this HRG grew by 17.5% over the period captured by the index. Its cost share in 2003/04 is only 0.6% whereas its health outcome share is 4.43%. All else equal, the growth in activity in this high volume HRG would lead to an index based on health outcome shares having a higher value than one based on cost shares.

There is little difference between the cost and health outcome weights for B02 (cataract extractions), but they are accorded slightly less weight (-0.06%) when relative values are based on health outcomes. However, despite this minimal difference, B02 exerts considerable influence on the overall index, contributing 20.7% of total volume in 2003/04. There has also been a volume increase of 81% in this activity over the period captured by the index. Thus, this HRG exerts downward influence on the index.

Table 5.2 Health outcome weighted output index

	CWOI	HOWOI		HOWOI	
		No LE	No LE	With LE	
discount rate			k=0.8		
life expectancy				1.50%	5%
	(i)	(ii)	(iii)	(iv)	(v)
1998/99 - 1999/00	-1.19%	-2.96%	-1.88%	-4.75%	-4.06%
1999/00 - 2000/01	2.79%	0.16%	1.87%	-3.78%	-2.20%
2000/01 - 2001/02	2.18%	1.41%	1.04%	0.27%	0.48%
2001/02 - 2002/03	9.14%	10.17%	9.11%	8.43%	8.85%
2002/03 - 2003/04	6.30%	4.62%	5.07%	1.95%	2.73%
Average	**3.84%**	**2.68%**	**3.04%**	**0.42%**	**1.16%**

Properly health outcome weights should incorporate the effect of treatment on life expectancy, so that they measure QALYs:

$$\frac{\sum_j x_{jt+1}(a_{jt+1}h_j^* - h_j^0)(1-e^{-r_L L_{jt+1}})}{\sum_j x_{jt}(a_{jt}h_j^* - h_j^0)(1-e^{-r_L L_{jt}})} \qquad (8)$$

Estimates are presented from this index in columns (iv) and (v) Table 5.2, with life expectancy discounted at 1.5% and 5%. The impact of including life expectancy is a substantial reduction in estimated output growth. The reason for this is that life expectancy declined gradually over the period, the main reason for this probably being that increasingly older people were receiving treatment, as demonstrated in column. Table 5.3 provides evidence.

Table 5.3 Average age and life expectancy

	Age	Life expectancy
1998/99	45.71	25.83
1999/00	45.76	25.34
2000/01	46.17	24.12
2001/02	46.3	23.91
2002/03	46.93	23.59
2003/04	47.9	22.98

The health outcomes weighted output index is also estimated after incorporating waiting times to date placed on list:

$$\frac{\sum_j x_{jt+1}\left\{h_j^o\left[\frac{(1-e^{-r_w w_{jt+1}})}{r_w}-\frac{(1-e^{-r_L w_{jt+1}})}{r_L}\right]+\left(a_{jt+1}h_j^*-h^o\right)\left[\frac{e^{-r_L w_{jt+1}}\left(1-e^{-r_L L_{jt+1}}\right)}{r_L}\right]\right\}}{\sum_j x_{jt}\left\{h_j^o\left[\frac{(1-e^{-r_w w_{jt}})}{r_w}-\frac{(1-e^{-r_L w_{jt}})}{r_L}\right]+\left(a_{jt}h_j^*-h^o\right)\left[\frac{e^{-r_L w_{jt}}\left(1-e^{-r_L L_{jt}}\right)}{r_L}\right]\right\}} \quad (9)$$

to date of treatment, with a charge for waiting:

$$\frac{\sum_j x_{jt+1}\left(a_{jt+1}h_j^*-h_j^o\right)\left[\frac{\left(1-e^{-r_L L_{jt+1}}\right)}{r_L}-\frac{\left(e^{r_w w_{jt+1}}-1\right)}{r_w}\right]}{\sum_j x_{jt}\left(a_{jt}h_j^*-h_j^o\right)\left[\frac{\left(1-e^{-r_L L_{jt}}\right)}{r_L}-\frac{\left(e^{r_w w_{jt}}-1\right)}{r_w}\right]} \quad (10)$$

The sensitivity of these two variants of the HOWOI are assessed with respect to:

- Discounting life expectancy at 1.5% or 5%
- Discounting waiting time at 1.5%, 5% or 10%

When waiting time is discounted to date placed on the list, estimates of output growth are slightly higher than those when no waiting time adjustment is made reported in Table 5.2, with the difference increasing at higher discount rates. Compared to discounting to date placed on list, discounting to date of treatment results in lower estimates of output growth, decreasing at higher discount rates.

Table 5.4 HOWOI, adjusted for waiting time

HOWOI health, waiting time and life expectancy adjustment, 80% percentile waiting time						
discount rate life expectancy		1.5%			5%	
discount rate waiting time	1.5%	5%	10%	1.5%	5%	10%
Discount to date on list	0.46%	0.47%	0.50%	1.25%	1.28%	1.32%
Discount to date of treatment	0.48%	0.48%	0.49%	1.29%	1.29%	1.30%

5.3 Value weighted output index

Our "preferred" index takes the form specified in equation (1) in which activities are valued according to their associated health outcomes and waiting times are considered a characteristic of health care. The index takes the form:

$$I_{yt}^{xq} = \frac{\sum_j x_{jt+1}[(a_{jt+1}h_j^* - h_j^0)[(1-e^{-r_L L_{jt+1}})\pi_h]/r_L - w_{jt+1}\pi_W]}{\sum_j x_{jt}[(a_{jt}h_j^* - h_j^0)(1-e^{-r_L L_t})\pi_h]/r_L - w_{jt}\pi_W]} \qquad (11)$$

We estimate this index assuming that the monetary value in 2002/03 of a QALY (π_h) is £30,000, and explore the sensitivity of results to:

- the cost of a day spent waiting (π_W) - either £3.13[1] or £50 at 2002/03 values
- discounting life expectancy at 1.5% and 5%

The estimated value of a QALY and of a day waited are adjusted in line with money GDP growth for years before 2002/3. Estimates of output growth are presented in Table 5.5. These imply lower rates of output growth than a CWOI for these HRGs, the main reason being because of the influence of treating an increasing older population (leading to decreasing life expectancy). The effect of applying a higher value to the cost of a day spent waiting is to increase estimated output growth, but not substantially.

[1] This estimate is taken from the review by Ryan, Odejar and Napper (2004), see section 4.5.5 of the Final Report.

Table 5.5 Value weighted output index

	Value weighted output index			
cost of day spent waiting	£3.13		£50	
discount rate life expectancy	1.50%	5%	1.50%	5%
	(i)	(ii)	(iii)	(iv)
1998/99 - 1999/00	-4.71%	-4.00%	-3.39%	-1.54%
1999/00 - 2000/01	-3.86%	-2.32%	-4.22%	-2.53%
2000/01 - 2001/02	0.23%	0.41%	-0.29%	-0.42%
2001/02 - 2002/03	8.41%	8.82%	8.27%	8.70%
2002/03 - 2003/04	2.00%	2.82%	2.90%	4.59%
Average	**0.41%**	**1.15%**	**0.65%**	**1.76%**

5.4 Conclusion

In this section we have applied various formulations of an output index to a limited set of HRGs for which data were available on health status before and after treatment. The main conclusions are that:

- Estimates of output growth are sensitive to whether *k* is assumed constant across treatments. In view of this, it would be advisable to ascertain before and after health status for a larger sample of NHS treatments.
- Although relative cost and health outcome weights differ to some extent for our specimen set of HRGs, the difference does not lead to dramatic changes in the estimates produced by the specimen index. It cannot be assumed, however, that there will not be greater divergence between indices using costs and health outcome weights for other NHS activities.
- Unable to estimate QALYs directly, we have had to rely upon life tables from the general population to generate estimates of life expectancy. With an increasingly older population being treated over time, this leads to decreasing life expectancy, which in turn implies declining output growth in indices where life expectancy is included. This is because our index formulations make the value judgement that an additional quality adjusted life year should have the same value whatever the age of the person it accrues to.
- Cost weighted indices with waiting time adjustments are sensitive to whether waiting time is discounted to the date placed on the list or to the date of treatment, and to the choice of discount rate.

- The health and waiting time outcomes index, for the HRGs considered here, is not particularly sensitive to which point in the distribution is chosen to measure waiting time (mean or 80% percentile) or to the cost applied to a day spent waiting (£3.13 or £50).

6 Effects of quality adjustments on hospital and NHS output indices: summary

In Section 4 we argued that it was important to include estimates of health effects in a quality adjusted output index. This should be done by regular collection of health outcomes data for a representative range of NHS activity. In the absence of this data, in Section 4 we used available information on outcomes for 29 HRGs and made the assumption that the average health gain observed could be applied uniformly to all hospital activity.

For the specimen quality adjusted output index discussed in Section 5, it was possible to test the sensitivity of results to the assumption of a uniform effect. For the specimen index we were able to estimate quality adjusted output using data for actual health effects and compare the result with estimates using a uniform health effect. As expected, the move from uniform to actual values does affect the result.

We recommend that wherever possible actual health effects data be used to estimate quality adjusted output indices. Over the next few years the number of HRGs for which actual data will be available should increase. This will gradually reduce the proportion of activity where it is necessary to make assumptions about health effects. A consequence of this recommendation is that for the next few years a quality adjusted output index would have to be based on a mix of actual and assumed values.

In this section we examine the impact of departing from the assumption of uniform fixed health effect (k = 0.8) and instead use actual values where they exist and assumed values where data is absent.

- For the 29 elective procedures for which we have data, *k* varies by HRG as in the specimen index.
- For all other elective procedures we assume $k = 0.8$ as suggested by the mean of the *k* for the elective HRGs where there are estimates
- For non-elective HRGs we assume $k = 0.4$ on the grounds that non-elective patients may have worse health (q^o) if not treated so that the ratio of health if not treated to health if treated ($k = q^o/q^*$) is smaller.

Given that non-elective activity is growing more rapidly than elective, the lack of knowledge of health state and health gain for non-elective patients is a serious problem.

We compare our recommended variant (Q2) based on a health effects adjustment which varies by HRG with a variant (Q1) with the same health effect adjustment for all HRGs, elective and non-elective.

Quality variant 1 assumes $k = q^0/q^* = 0.8$ if $a - k > 0.05$ and $k = 0$ otherwise for all elective and non-elective HRGs, discounts to date of treatment with charge for wait, with discount rates on waits and health equal to 1.5% and the waiting time variable is the 80th percentile wait in each HRG.

Quality variant 2 is our recommended quality variant. This sets $k = q^0/q^* = 0.8$ for electives, $k = 0.4$ for non-electives, k = actual k for those HRGs included in the specimen index where this is known, provided $a - k > 0.10$ and $k = 0$ otherwise. This quality variant discounts to date of treatment with charge for wait, with discount rates on waits and health equal to 1.5% and uses 80th percentile waits.

We show the effects of these two quality adjustments variants on the HES hospital output in Table 6.1, to all hospital output including outpatients and accident and emergency in Table 6.2 and to all NHS output in Table 6.3.

Table 6.1 shows that the Q1 quality adjustment variant, with survival, health effects, life expectancy and waiting time adjustments adds just under one percentage point to the HES hospital unadjusted index average across the five growth periods. The recommended variant Q2 results in a smaller upward adjustment of just over 0.5%

Table 6.1 HES hospital cost weighted output index with hospital sector quality adjustments

	Unadjusted	Quality variant 1		Quality variant 2	
		Survival and health effect only	Survival, health effect, life expectancy and waiting	Survival and health effect only	Survival, health effect, life expectancy and waiting
1998/99-1999/00	1.87	0.09	0.49	0.63	1.04
1999/00-2000/01	0.91	1.97	1.73	1.50	1.25
2000/01-2001/02	0.95	1.01	0.87	0.82	0.65
2001/02-2002/03	4.44	7.72	7.48	6.77	6.52
2002/03-2003/04	5.81	8.04	8.15	7.21	7.31
Average	2.80	3.77	3.74	3.38	3.35

Table 6.2 shows the effect of the two variants on a broader definition of hospital activity. All variants have faster growth than for the narrower HES output indices in Table 6.1. The main reason for this is the faster growth in the activities not captured by HES, such as A&E and outpatients, which are excluded from Table 6.1. However, because fewer of the quality adjustments apply to these non-HES activities the proportionate effect of Q1 and Q2 is smaller than in Table 6.1. Thus Q1 increases average annual growth by 0.44% instead of nearly 1% and Q2 increases growth by 0.25% instead of 0.55% over the period.

Table 6.2 Hospital sector cost weighted output index with hospital sector quality adjustments

	Unadjusted	Quality variant 1		Quality variant 2	
		Survival and health effect only	Survival, health effect, life expectancy and waiting	Survival and health effect only	Survival, health effect, life expectancy and waiting
1998/99-1999/00	2.03	0.43	0.79	0.91	1.28
1999/00-2000/01	1.54	2.35	2.16	1.99	1.80
2000/01-2001/02	4.48	4.52	4.43	4.40	4.31
2001/02-2002/03	3.94	5.71	5.57	5.19	5.06
2002/03-2003/04	4.78	5.94	6.00	5.51	5.56
Average	3.35	3.79	3.79	3.60	3.60

Finally Table 6.3 shows the impact of the quality adjustments to the hospital sector output on the cost weighted output index for the NHS as a whole. We first show the CWOI without quality adjustments and then add variants of the adjustments for survival and waiting times for the hospital sector. Overall NHS output growth is higher than either of the hospital sector output growth rates because of the more rapid growth in some non-hospital activities such as prescribing and consultation rates, and because of increasing coverage of NHS activity. Quality adjustment variant Q1 increases average annual growth by 0.29% and Q2 increases it by 0.17%. Notice that for 2001/02 to 2002/03 both variants have a much larger effect (1.04% for Q1 and 0.71% for Q2) but rather small effects in the middle years and actually reduce growth from 1998/99 to 1999/00. This negative adjustment is due, as we noted in section 5.4.1, to the fall in survival for a small number of high activity high cost HRG. Notice also that from 1998/99 to 1999/00 when both Q1 and Q2 lead to downward adjustments our recommended variant Q2 has a smaller negative effect. Thus in general variant Q2 has a smaller positive or negative effect than Q1 because it uses smaller assumed health effects for emergency activities.

Table 6.3 Aggregate NHS cost weighted output index with hospital sector quality adjustments

	Unadjusted	Quality variant 1		Quality variant 2	
		Survival and health effect only	Survival, health effect, life expectancy and waiting	Survival and health effect only	Survival, health effect, life expectancy and waiting
1998/99-1999/00	2.61	1.77	1.96	2.03	2.22
1999/00-2000/01	2.11	2.57	2.46	2.36	2.26
2000/01-2001/02	3.85	3.88	3.82	3.80	3.74
2001/02-2002/03	5.07	6.20	6.11	5.87	5.78
2002/03-2003/04	4.43	5.17	5.20	4.89	4.93
Average	3.62	3.92	3.91	3.79	3.79

We next examine input changes over the period and then in section 8 combine our output indices and input indices to calculate productivity growth rates.

7 Labour input in the NHS

Labour is by far the most important input used in producing health services, accounting for about 75% of total hospital expenditures. Current practice by DH and ONS is to calculate labour input by deflating payments to labour by a wage index. This is an indirect measure of the volume of labour input. It is more usual to estimate labour inputs based on direct measures, such as the number of persons engaged or hours worked. In particular, the OECD productivity manual recommends the use of annual actual hours worked, to allow for time paid but not worked such as overtime, holidays and sick leave. It was therefore considered useful to devote effort in the project to this alternative method of measuring of labour input.

In addition the Atkinson Report recommended that labour input should be adjusted to take account of variations in types of workers employed, in particular the changing use of skilled workers. The productivity of highly skilled workers is clearly greater than that of less skilled workers. While skill is not the only factor to consider in a quality adjusted measure of labour input, with other factors such as age and experience also of importance, most research has suggested that skill is the most important dimension.

The standard growth accounting formula for adjusting for skills divides labour hours by skill type and then weights the growth in hours of each type by their wage bill shares. This captures the fact that more highly skilled workers get paid more than the unskilled, and under competitive market conditions, the wage paid reflects the marginal productivity of workers of different types. Merely calculating growth in total hours worked is equivalent to weighting worker types by their share in employment. Hence if there is general upskilling of the workforce so that growth in hours is greater for skilled relative to unskilled workers, weighting by wage bill shares leads to higher aggregate labour input growth.

A number of data sources relating to labour input were reviewed during the course of the project. From this, two principal sources emerged as most useful for our purposes – the NHS workforce census, an annual census carried out by the Department of Health, and the Labour Force Survey, a quarterly sample survey carried out by ONS. Data from the NHS Census was used to obtain a headcount measure of labour input, while data from the LFS was used to incorporate hours worked, to incorporate quality adjustments, as well as to adjust for agency staff.

To construct a quality adjusted measure of labour input, data on the proportion of workers in each skill group and their wage rates from the LFS were combined with the NHS Census data, which acted as control totals. The data show evidence of upskilling across the NHS workforce, not only among doctors, nurses and other health professionals, but also at the lower end of the skill distribution. There has also been a marked decline in the share of the workforce with no skills.

A comparison with the total economy revealed that the NHS employs proportionally more workers at the high end of the skill distribution. The NHS has experienced higher growth in the proportion of the workforce with the highest qualifications (degree and above) than in the total economy or market services, and the decline in the use of unskilled workers has been greater.

Changes in the skill use pattern however will only impact if there are also significant differences in wage rates across skill groups. This appears to be the case in the NHS – on average those with higher degrees were earning about 4 times the average unskilled wages. Combining the information on skill use and wages gives growth in quality adjusted labour. For the total NHS, this quality adjustment raised labour input growth from about 2.7% annual average growth over the period 1995-03 to about 3.5%, a significant upward adjustment. Considering differences across broad occupational groups, the impact was greatest for managers, followed by healthcare assistants. Quality adjustments were found to be similar in percentage points to those in the total economy and greater than in the more comparable market services sector.

Some additional refinements to the quality adjusted index were also carried out. First, a further disaggregation of doctors was carried out using data from the NHS staff earnings survey – this resulted in growth in quality adjusted doctors about 30% above numbers employed, suggesting the qualification data alone (which resulted in an increase of about 4%) are not sufficient to capture all quality change. However, with doctors representing less than 1.5% of the NHS Trusts wage bill this leads to only a very small adjustment for the hospital sector.

Secondly, an adjustment for training received by an individual in addition to their certified qualifications was also made. In 2003/04, for example, LFS data showed that just over 50% of staff in the NHS had received some form of job related training. Clearly, the impact of training on workers productivity will vary considerably depending on the type of training in question. The results of adjusting for job related training were to raise the quality adjusted labour input growth rate on average from 1999/2000 by about 5%, a small but not insignificant impact. Therefore our estimates of quality adjusted labour were scaled up to reflect the impact of on the job training. Finally two additional calculations were tried using a division by region and by country of birth but neither significantly altered the results.

The following charts show annual estimates of both the volume of labour input and quality adjusted labour input, for both the total NHS and the hospital sector.

Figure 7.1 Total NHS, volume and quality adjusted labour input, annual estimates

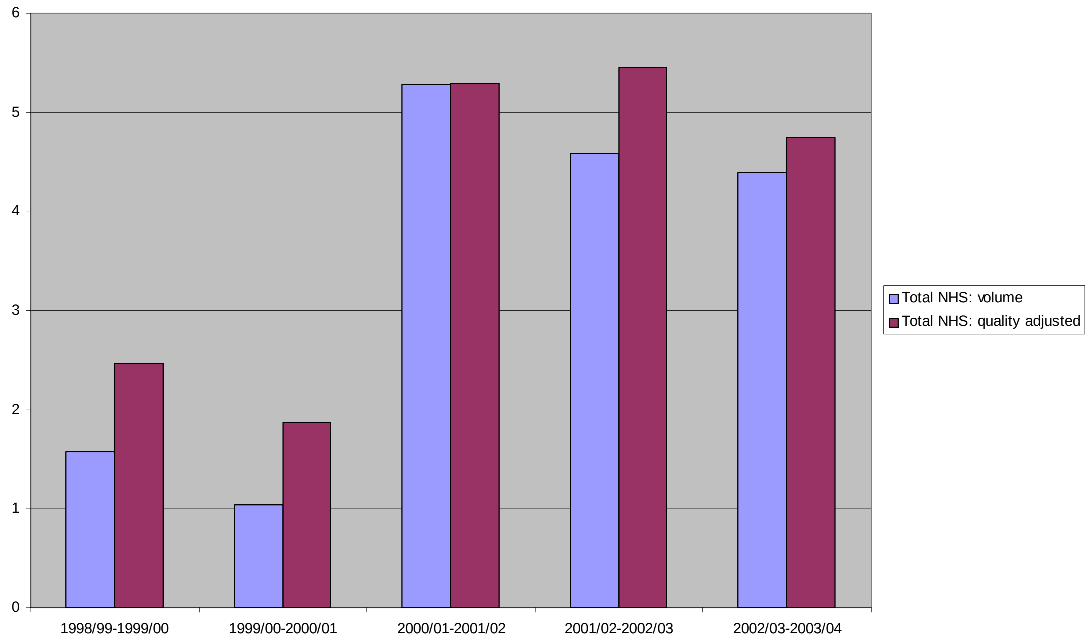
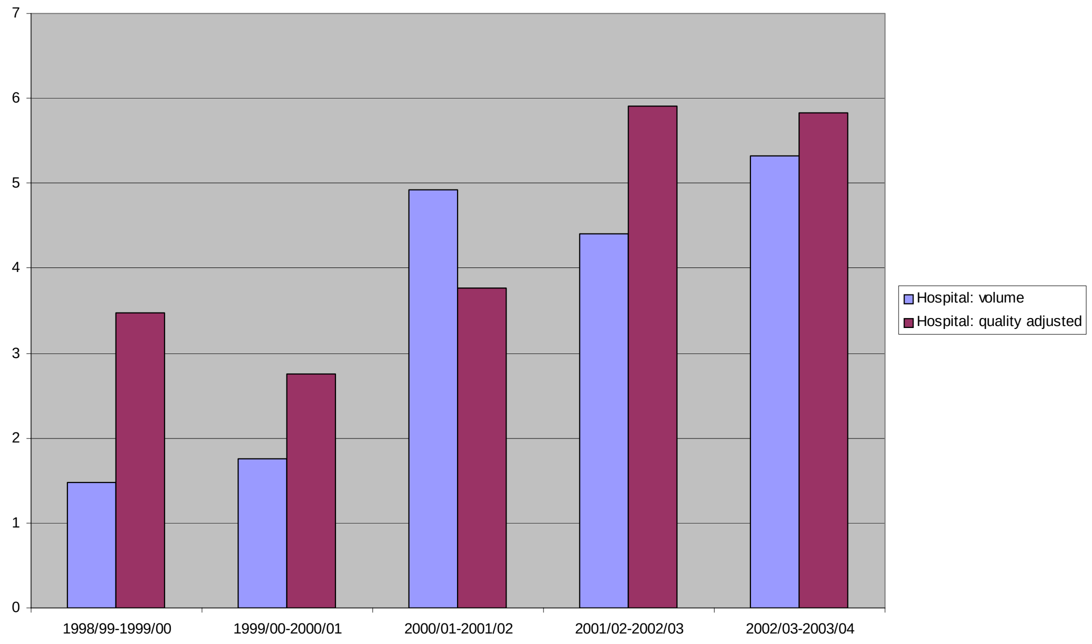


Figure 7.2 Hospital sector, volume and quality adjusted labour input, annual estimates



In conclusion, labour input growth has been rising very rapidly in recent years, mainly due to growth in the numbers of workers employed but there is also a significant contribution from upskilling of the workforce. The latter is important in understanding why expenditure on the NHS has been increasing rapidly in recent years. Thus a crude calculation suggests some 20% of payments to labour is due to paying for higher skilled workers.

8 Experimental productivity estimates

8.1 Labour productivity growth

Converting to an annual hours basis and adjusting for agency workers, using LFS data, growth in volume and quality adjusted labour input for the total NHS were calculated. These measures can then be combined with the aggregate and hospital output measures to calculate labour productivity growth rates.
Labour productivity growth rates are derived by taking the growth in output minus the growth in labour input. Here we show calculations for unadjusted cost weighted output and the quality variants chosen for illustrative purposes in section 6 adjusting for survival and waiting times. We also present estimates for the hospital sector which in this context is broadened to include non HES hospital activities such as A&E and outpatients. This in turn is to ensure a correspondence between input and output measures. Denote these two variants by Q1 and Q2.

The first panel in Table 8.1 presents labour productivity estimates based on volume of labour and shows positive average labour productivity growth across the period for all output variants for the total NHS and for the Q1 variant for hospital output but a small negative number for unadjusted hospital output. When quality adjusted labour is used instead, average labour productivity growth becomes negative in the total NHS when output is not quality adjusted, but is approximately zero using the Q1 variant of quality adjusted output. Hospital labour productivity growth is negative for all output variants when quality adjusted labour is used. Note negative labour productivity growth in health services is not unusual in international comparisons. Data from the US national accounts suggests labour productivity growth, unadjusted for labour quality changes, was -0.31% on average from 1999 to 2002. Adjusting for labour quality would reduce this further.

Table 8.1 Labour productivity growth

	Total NHS				Hospital		
	Unadjusted	Q1	Q2		Unadjusted	Q1	Q2
Labour volume							
1998/99-1999/00	1.02	0.38	0.63		0.53	-0.69	-0.20
1999/00-2000/01	1.05	1.40	1.20		-0.23	0.38	0.03
2000/01-2001/02	-1.49	-1.51	-1.59		-0.54	-0.58	-0.70
2001/02-2002/03	0.35	1.35	1.04		-0.55	1.02	0.53
2002/03-2003/04	-0.05	0.69	0.42		-0.65	0.51	0.09
Average	0.17	0.46	0.34		-0.29	0.13	-0.05
Quality adjusted labour							
1998/99-1999/00	0.08	-0.56	-0.30		-1.40	-2.60	-2.12
1999/00-2000/01	0.65	1.00	0.79		-1.18	-0.57	-0.92
2000/01-2001/02	-1.38	-1.41	-1.48		0.68	0.64	0.52
2001/02-2002/03	-0.48	0.51	0.20		-1.87	-0.32	-0.81
2002/03-2003/04	-0.48	0.26	-0.01		-0.99	0.16	-0.25
Average	-0.32	-0.04	-0.16		-0.95	-0.54	-0.72

Notes: Q1 is the 'high' quality adjustment variant with $k = q^0/q^* = 0.8$ if $a - k > 0.05$, and $k = 0$ otherwise, discounts to date of treatment with charge for wait, discount rates on waits and life expectancy equal to 1.5% and where the waiting time variable is the 80th percentile wait in each HRG. Q2 is our recommended quality variant and sets $k = q^0/q^* = 0.8$ for electives, $k = 0.4$ for non-electives, k = actual k for those HRGs where known, if $a - k > 0.10$, and $k = 0$ otherwise; discounts to date of treatment with charge for waits, discount rates on waits and life expectancy equal to 1.5% and uses 80th percentile waits.

8.2 Intermediate and capital inputs

Intermediate input for the hospital sector comes from Trust Financial Returns (TFR) and is deflated by a modified version of the DH Health Services Cost Index to derive a volume measure. Intermediate input was defined as all current non pay expenditure items in the TFR, and hence excluded all purchases of capital equipment and capital maintenance expenditures as these items cannot be allocated to a particular year's output. The share of hospital drugs in intermediate expenditure has been rising rapidly, from about 24% in 1998/99 to 34% in 2003/04. The share of external purchase of health care from non-NHS bodies has also increased share through time but remains small at about 6% of total intermediate expenditure in 2003/04.

These numbers for intermediate input were deflated by an aggregate price index, derived as a chain linked index of corresponding HSCI items. This resulted in a very small upward adjustment in the intermediate input deflator than one using all items in the HSCI, as the prices of capital items have been growing more slowly than current items and in the case of computers have been falling. Capital input for the hospital sector is measured by depreciation reported in the Trust Financial Returns, deflated by the ONS capital consumption deflator, plus an allowance for depreciation of capital purchases in the current year, deflated by a chain linked deflator for capital items in the HSCI.

Calculating input shares is more difficult for the total NHS since we attempt to combine data from different sources. For the aggregate NHS we use TFR data on payments to labour in the hospital sector and use ONS data for payments to labour in other parts of the NHS. Similarly, intermediate inputs are derived combining expenditures from TFR and PFR with ONS data on other parts of the NHS. Capital inputs are those employed by ONS in their measures of Health Sector Productivity. Family Health Drugs are deflated by the cost of all items rather than the ONS quality adjusted Paasche variant. The estimates for the NHS should be treated with considerable caution since data are being taken from a number of sources which may need further reconciling.

Table 8.2 shows average period input shares and average growth in the three inputs where labour input is the quality adjusted variant.

Table 8.2 Average period input shares and average growth in inputs

	NHS		Hospital	
	Shares	Input growth	Shares	input growth
Labour	0.61	3.95	0.72	4.34
Intermediate	0.33	8.58	0.20	4.93
Capital	0.06	3.12	0.08	4.76

Labour represents a lower share in the total NHS than in the hospital sector, mainly due to the inclusion of family health prescribing in the former. Growth in intermediate input is very large in the total NHS, while all three inputs show similar average growth rates in the hospital sector.

8.3 Total factor productivity growth

Combining the input shares with growth in real inputs allow the calculation of total input growth and subtracting this from output growth yields total factor productivity growth rates, shown in Table 8.3. Average TFP growth rates are strongly negative for the total NHS for all quality variants. The numbers based on quality adjusted output are similar to those calculated by ONS reported in Lee (2004). The ONS estimates using the most comparable methods to measure inputs suggest average TFP declining by 1.34% per annum over the same period. However it should be noted that ONS output measures use reference cost activities which are not directly comparable with the HES based data employed in this report's calculations. Average TFP growth is also negative for the hospital sector but less so than for the total NHS.

Table 8.3 Total factor productivity growth

	Total NHS				Hospital		
	Unadjusted	Q1	Q2		Unadjusted	Q1	Q2
1998/99-1999/00	-2.33	-2.95	-2.71		-2.82	-4.00	-3.53
1999/00-2000/01	0.55	0.89	0.69		0.30	0.91	0.56
2000/01-2001/02	-2.12	-2.15	-2.22		0.17	0.13	0.01
2001/02-2002/03	-1.86	-0.88	-1.19		-2.01	-0.46	-0.95
2002/03-2003/04	-2.97	-2.25	-2.51		-1.13	0.02	-0.39
Average	-1.75	-1.48	-1.59		-1.11	-0.70	-0.87

The finding that TFP growth is negative is not unusual in the private sector. For example Bank of England estimates show negative gross output based annual average TFP growth rates for a number of sectors in the 1990s including insurance and business services. Similar results have frequently been reported by the US Bureau of Labour Statistics. Negative TFP growth is mostly likely to occur in service sectors where output is poorly measured and quality adjustment is minimal. TFP growth rates for the private sector using comparable measurement methods are not yet available for the period under consideration in this report.

When inputs are measured correctly, with adjustments for quality change then the TFP residual is close to a measure of pure technical change so long as output is also measured correctly. But as emphasised in many parts of this report, we are only capturing part of the improvement in quality of care via our proposed adjustments for survival, health effects and waiting times. Because of this incomplete adjustment for quality change we expect to underestimate TFP growth. There are also reasons why in the short term at least we might expect negative growth rates. The literature on the impact of information technology on productivity in the private sector points to an important role of organisational changes in facilitating benefits from new technology, with the suggestion that we could observe declining TFP in the short run due to disruption of production processes. There is no doubt that the NHS is undergoing significant organisational change.

Of more consequence for the health sector is the notion that there are diminishing returns as increased activity allows treatment of more complex and hence most costly cases. Activity rates have been increasing more rapidly in recent years. Some evidence in support of this is provided by the increased average age of patients treated in hospitals, from 48.6 years in 1999/00 to 50 years in 2003/04. In addition there has been some increase in the expenditure shares of HRG categories with the title ‘complex elderly’ from 3.4% of expenditures to 4.2% over the same period. Changes in the case mix are likely to be larger within than across HRGs but we lack the necessary data to examine this. Data that identified the characteristics of patients would also be useful in identifying the extent to which changes in NHS productivity are affected by diminishing returns.

9 Conclusions and recommendations

9.1 Methods

9.1.1 The preferred approach

Economic theory suggests that the preferred way of measuring NHS output is with a value weighted output index.

- The unit of output is the patient treated, the characteristics of output valued by individuals indicate quality and the weight attached to each characteristic reflects the marginal social value of the characteristic.
- The index overcomes the serious problem of a cost weighted index where movement to more cost-effective ways of treating patients appears as a reduction in output.
- Data necessary to estimate this index are not currently available but are feasible to collect.
- A condition specific value weighted index can be constructed as data on major diseases becomes available.

Not only is the value weighted index theoretically correct, it would allow measurement of improvements in delivery of services intended to raise both productivity and patient satisfaction.

9.1.2 Methods using existing data

It is not possible to calculate a value weighted index with current data. It is possible to quality adjust the hospital component of a cost weighted NHS output index using existing data combined with some assumptions. We have

- spelt out the methods for quality adjustment with existing data in some detail, taking care to emphasise the necessary assumptions and their implications, rather than merely presenting plausible ad hoc adjustments which may in fact contain dubious assumptions or value judgements.
- shown how it is possible to use routine data on short term survival and waiting times, coupled possibly with an explicit assumption about the proportionate

effect of treatment on health, to calculate quality adjusted cost weighted output indices.

- presented experimental calculations of these indices to compare their effects on a simple cost weighted output index and to investigate the empirical implications of the assumptions about important parameters which are required.
- used data on the health effects of a limited set of treatments to illustrate the construction of a value weighted index for the set and to shed further light on the implications of making possibly inaccurate assumptions about the health effects when constructing an index for all hospital treatments.
- described how it is possible in principle to use data on other aspects of care (readmissions, MRSA, patient satisfaction with food, cleanliness and non-clinical care) to provide an additional quality adjustment and have produced some illustrative examples of such adjustments based on the current unsatisfactory data on these characteristics of care.
- described a method of quality adjustment using the information on longer term survival which will become available in the near future.

9.2 Results

9.2.1 Results for the hospital sector

Results are reported for a cost weighted quality adjusted output index over the period 1999/00 – 2003/04. It was only possible to quality adjust for hospital activity, 47% of expenditure covered in the DH cost weighted output index. In section 5 of the Final Report we examine sensitivity to discount rates and key assumptions. Table 9.1 summarises the central results.

Table 9.1 Hospital sector cost weighted output index with quality adjustments (growth rates %)

	No adjustment	Survival and health effects adjustment[1]	With survival, health effects, and waiting time adjustments[2]
1998/99-1999/00	2.03	0.91	1.28
1999/00-2000/01	1.54	1.99	1.80
2000/01-2001/02	4.48	4.40	4.31
2001/02-2002/03	3.94	5.19	5.06
2002/03-2003/04	4.78	5.51	5.56
Average p.a.	3.35	3.60	3.60

[1] This sets $k = q^0/q^* = 0.8$ for electives, $k = 0.4$ for non-electives, k = actual k for those HRGs included in the specimen index where this is known, provided $a - k > 0.10$ and $k = 0$ otherwise.
[2] Recommended quality variant 2. As note 1 plus discounts to date of treatment with charge for wait, with discount rates on waits and life expectancy equal to 1.5% and uses 80th percentile waits.

Table 9.2 shows the impact of incorporating quality adjustments for the hospital sector into the overall NHS cost weighted output index.

Table 9.2 Aggregate NHS cost weighted output index with hospital sector quality adjustments (growth rates %)

	Unadjusted CWOI	CWOI with hospital survival and waiting time adjustments[1]
1998/99-1999/00	2.61	2.22
1999/00-2000/01	2.11	2.26
2000/01-2001/02	3.85	3.74
2001/02-2002/03	5.07	5.78
2002/03-2003/04	4.43	4.93
Average p.a.	3.62	3.79

[1] Recommended quality variant 2. This sets $k = q^0/q^* = 0.8$ for electives, $k = 0.4$ for non-electives, k = actual k for those HRGs included in the specimen index where this is known, provided $a - k > 0.10$ and $k = 0$ otherwise; discounts to date of treatment with charge for wait, with discount rates on waits and life expectancy equal to 1.5% and uses 80th percentile waits.

Overall, our results show that quality adjustment with existing data can make an impact on measures of NHS output and as more routinely collected data becomes available, the quality adjustment can be improved.

9.2.2 Other quality indicators

We were asked to explore the use of indicators such as patient satisfaction, readmission rates, clinical errors and incidence of MRSA. The data are not at present suitable for inclusion in an output index but some "illustrative" adjustments are reported in Table 9.3.

Table 9.3 Illustrative calculations of hospital CWOI with adjustments for survival, waiting times, patient satisfaction as measured in patient surveys, readmissions and MRSA. Average annual growth rates 2001/2 to 2003/4

Average Growth Rates 2001/2 to 2003/4	% p.a.
Unadjusted cost weighted output index	4.34%
With adjustment for survival and waiting times[1]	5.74%
With adjustment for adjustment for satisfaction with food, cleanliness, and non clinical care[2]	5.71%
With adjustment for MRSA, readmissions satisfaction with food, cleanliness, and non clinical care[2]	5.71%

[1] Variant 1 (k = 0.8, mortality cut off 0.15, discounting to date of treatment, discount rate on waits 10%, on life expectancy 1.5%, 80th percentile waiting time measure).
[2] 5% weight on non-clinical care

9.3 Total factor productivity growth

Employing a new quality adjusted index of labour input in the hospital sector, provisional estimates of productivity growth are reported. Key results appear in Table 9.4. They highlight the importance of quality adjustments to output in evaluating NHS performance.

Table 9.4 Total factor productivity growth (%)

	Total NHS			Hospital	
	Unadjusted	Recommended Quality Variant		Unadjusted	Recommended Quality Variant
1998/99-1999/00	-2.33	-2.71		-2.82	-3.53
1999/00-2000/01	0.55	0.69		0.30	0.56
2000/01-2001/02	-2.12	-2.22		0.17	0.01
2001/02-2002/03	-1.86	-1.19		-2.01	-0.95
2002/03-2003/04	-2.97	-2.51		-1.13	-0.39
Average p.a.	-1.75	-1.59		-1.11	-0.87

9.4 Recommendations

Recommendations for improving quality adjustment were made throughout the report. We summarise the main ones here.

For the medium term improvement of the output index improvements to the data are required. We recommend:

- Routine collection of outcomes data for a range of NHS treatments. The programme should start with a few high volume elective and medical conditions that would permit sampling rather than complete coverage. The data would also be immensely useful for other purposes including monitoring of Trust performance and improved cost-effectiveness analysis of particular treatments.
- Collection of longer term survival data by linkage of HES and ONS records to produce estimates of patient life expectancy.
- A patient identifier that will permit grouping NHS activities across institutions and by disease. The DH has plans to implement this change.
- Stated preference studies of patients to establish their relative valuations of the characteristics of NHS output from waiting times to being treated with courtesy and dignity by staff. The studies should also include a cost characteristic so that monetary valuations can be inferred and all characteristics can be valued in a common unit. The studies will enable the data from patient satisfaction studies to be utilised for quality adjustment as well as informing decision making in the NHS.

For the short run improvement of the output index with available data:

- We recommend the use of short term survival coupled with life expectancy to quality adjust hospital output.
- The short term survival adjustment will underestimate output growth. We recommend that it be coupled with an estimated health effect derived from an estimate of the proportionate effect of treatment:
    - As the data become available from surveys of patient health before and after treatment and elsewhere, treatment specific estimates of $k_j = q^o_{jt} / q^*_{jt}$ should be used.

- Where there are no treatment specific estimates, k_j should be estimated as the volume-weighted mean of existing treatment specific estimates for the relevant class (electives and non-electives).
- In the absence of any estimates of treatment specific *k* for non-electives the estimate for non-electives should be equal to half the volume-weighted mean *k* of the electives.
- The health effects adjustment should be used only for treatments with a mortality rate of 0.10 or less.

- We recommend the use of a waiting time adjustment based on discounting to date of treatment, with a charge for waiting. Theoretical considerations suggest that the discount rate on waits should be the same as the discount rate on QALYs. We suggest 1.5%.
- We do not recommend quality adjustments based on patient satisfaction with food, cleanliness, and non-clinical care until there are data on the relative marginal values of these outcomes. If it is felt that estimates of the costs of cleaning and food derived from Trust accounts reasonably reflect marginal social values then it would be possible to include an adjustment just for these satisfaction indicators.
- We do not recommend quality adjustments based on readmission rates and MRSA because of data problems and because they may reflect aspects of care which are better captured in the other quality adjustments.
- We recommend the use of 30 day mortality, rather than in hospital mortality, as the measure of short term survival, since we believe its greater theoretical merits outweigh the difficulties in calculating it. As data linkage methods are improved the advantage of the 30 day mortality will increase.
- The waiting time measure should be a certainty equivalent wait, to avoid the need to calculate adjustments on individual data. The 80th percentile wait seems a reasonable value.
- Quality adjustments of hospital output should use CIPS rather than FCEs as the unit of output.
- HES rather than the Reference Cost data base should be the source of data on hospital outputs.

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Annex: How should NHS output be measured?

Value weighted output index

The *value weighted output index* is our preferred way to measure NHS output:

$$I_{yt}^{xq} = \frac{\sum_j x_{jt+1} \sum_k \pi_{kt} q_{kjt+1}}{\sum_j x_{jt} \sum_k \pi_{kt} q_{kjt}}$$

where x_{jt} is the volume of output *j* in period *t*, q_{kjt} is the amount of outcome or characteristic *k* produced by a unit of *j*, and π_{kt} is marginal value of outcome *k*.[2]
The index requires data on both the characteristics produced and on their marginal social value. Since improving the health of patients is a primary objective of the NHS, improved health outcomes are one of the most important characteristics of treatment. But other characteristics of treatment also affect utility, e.g. the length of time waited for treatment, the degree of uncertainty attached to the waiting time, relationship with doctors, hospital food and safety. These can be incorporated in the value weighted output index when the necessary data are available.

Cost weighted output index

Continuous inpatient spells (CIPS) →

If the data needed to calculate the value weighted output index are not available, we can instead use unit costs to weight outputs, and make use of available data to quality adjust these cost weighted outputs. The *cost weighted output index* is:

$$I_{ct}^{x} = \frac{\sum_j x_{jt+1} c_{jt}}{\sum_j x_{jt} c_{jt}}$$

↓

Information on survival can be used to adjust the cost weighted output index

30 day mortality rates →

Data on short term survival can be used to adjust the index as follows:

$$\frac{\sum_j c_{jt} x_{jt+1} \left(\frac{a_{jt+1}}{a_{jt}}\right)}{\sum_j c_{jt} x_{jt}}$$

Information on long term survival (not currently available for most treatments) could be used to adjust the index as follows:

$$\frac{\sum_j x_{jt+1} c_{jt} \frac{a_{jt+1}}{a_{jt}} \sum_{s=1}^{S} \left(\frac{\sigma^*_{jt+1}(s)}{\sigma^*_{jt}(s)}\right)\left(\frac{\sigma^*_{jt}\delta^s}{\sum_{s=1}^{5} \sigma^*_{jt}(s)\delta^s}\right)}{\sum_j x_{jt} c_{jt}}$$

↓

2 Please refer to the table of notation at the end of this report for further details of the notation used here.

The simple survival adjustment above implies that the patient would have zero quality adjusted life years if not treated. It is possible to introduce an additional term into the formula to include a uniform estimate of the difference between health before and after treatment, giving the *health effect survival index*:

$$\frac{\sum_j x_{jt+1}\left(\frac{a_{jt+1}-k_j}{a_{jt}-k_j}\right)c_{jt}}{\sum_j x_{jt}c_{jt}}$$

Note that for HRGs where the mortality rate is high, we make no health effect adjustment and use only the change in survival.

↓

Information on changes in the life expectancy of patients treated can also be included as follows:

$$\frac{\sum_j x_{jt+1}c_{jt}\frac{\left(a_{jt+1}-k_j\right)}{\left(a_{jt}-k_j\right)}\left(\frac{1-e^{-rL_{jt+1}}}{1-e^{-rL_{jt}}}\right)}{\sum_j x_{jt}c_{jt}}$$

↓

Certainty equivalent wait – measured as the waiting time for patients at the 80th percentile of the waiting time

- - - →

Information on waiting times can be used to quality adjust the cost weighted output index. This approach regards reductions in the wait for treatment as valuable because of their effect on the discounted value of the health gain from treatment

↓

There are two main forms of waiting time adjustment

↓

Discount to date of treatment with charge for waiting

$$\frac{\sum_j x_{jt+1}c_{jt}\left(\frac{a_{jt+1}-k_j}{a_{jt}-k_j}\right)\frac{\left[\frac{\left(1-e^{-r_L L_{jt+1}}\right)}{r_L}-\frac{\left(e^{r_w w_{jt+1}}-1\right)}{r_w}\right]}{\left[\frac{\left(1-e^{-r_L L_{jt}}\right)}{r_L}-\frac{\left(e^{r_w w_{jt}}-1\right)}{r_w}\right]}}{\sum_j x_{jt}c_{jt}}$$

This is the form of the CWOI that we recommend should be used in the interim, where;

- $r_L = r_W = 0.015$,
- k_j = actual k_j if known, = mean k for known electives if not k_j known and elective, = ½ mean k for electives if non-elective,
  - if $(a_{jt+1} - k_j)$ and $(a_{jt} - k_j) < 0.10$ then $k_j = 0$.
  - w_{jt}, w_{jt+1} are 80th percentile waits

↓

Discount to date placed on list

$$\frac{\sum_j c_{jt}x_{jt+1}\left(\frac{a_{jt+1}-k_j}{a_{jt}-k_j}\right)\left(\frac{e^{-rw_{jt+1}}\left(1-e^{-rL_{jt+1}}\right)}{e^{-rw_{jt}}\left(1-e^{-rL_{jt}}\right)}\right)}{\sum_j c_{jt}x_{jt}}$$

(assumes $r_W = r_L = r$)

Additional quality adjustments can also be made to the CWOI. A lack of appropriate data means that only illustrative adjustments for these additional aspects of quality could be calculated at present.

A quality adjustment for readmissions and MRSA can be incorporated based on the assumption that their cost is a deadweight loss which reduces the value of treatment. Hence the CWOI (ignoring other quality adjustments for illustrative purposes) can be adjusted as follows,

$$\frac{\sum_j x_{jt+1}c_{jt} - \sum_j x^b_{jt+1}c^b_{jt}}{\sum_j x_{jt}c_{jt} - \sum_j x^b_{jt}c^b_{jt}}$$

where x^b denotes the number of readmissions or cases of MRSA and c^b their costs.

Patient satisfaction can also be incorporated in the CWOI, using measures of patient experience, derived from patient satisfaction surveys, as summary indicators of characteristics that patients value.
This can be incorporated as follows;

$$I_t^{Comp} = \sum_{k=0}^{n} \omega_k I_t^k$$

where I_t^{Comp} is calculated as the weighted sum of the growth rate of one of the quality adjusted output indices and the growth rates of the other indicators. We denote the growth rate of indicator k by I_t^k. If there are n such indicators, and the relevant weights are denoted by ω_k then the overall index is given by the formula above.

Table of Notation

Notation	Interpretation
x_{jt}	quantity of output *j* at time *t* (units of *j*)
π_{kt}	marginal social value of characteristic *k* at time *t*
q_{jkt}	quantity of characteristic *k* produced by one unit of output *j* at time *t*
I_{yt}^{xq}	value weighted output index
I_{ct}^{x}	cost weighted output index CWOI
c_{jt}	unit (average) cost of output *j* at time *t* (£s per unit of *j*)
m_{jt}	mortality rate from NHS output *j* in period *t*
a_{jt}	survival rate (1-m_{jt})
$\sigma_{jt}^{*}(s)$	probability of surviving *s* periods given that the patient survived treatment *j* at date *t*
$h_{jt}^{*}(s)$	expected level of health conditional on surviving *s* periods
δ	discount factor
$q_{jt}^{*}=\sum_s \delta^{s-t}\sigma_{jt}^{*}(s)h_{jt}^{*}(s)$	discounted sum of quality adjusted life years produced by the treatment if the patient survives treatment
$h_{j}^{o}(s)$	expected health *s* periods hence if the patient does not receive treatment *j* conditional on surviving *s* periods
$\sigma_{j}^{o}(s)$	probability of surviving without treatment
$q_{jt}^{o}=\sum_s \delta^{s}\sigma_{j}^{o}(s)h_{j}^{o}(s)$	discounted sum of quality adjusted life years if patient not treated
$q_{jt}=(1-m_{jt})q_{jt}^{*}-q_{jt}^{0}$	expected increase in discounted QALYs from treatment *j* at time *t*
I_{ct}^{xa}	survival adjusted cost weighted output index
π_{wjt}	value of a reduction of one day in waiting time for treatment *j* in year *t*
π_{ht}	value of health gain
r_W, r_L	discount rates on the wait for treatment, QALYs
w_{jt}	waiting time for treatment *j* in year *t*
L_t	life expectancy with treatment