How efficient are New Zealand's District Health Boards at producing life expectancy gains for Māori and Europeans?

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Abstract

Objective: Use data envelopment analysis (DEA) to measure the efficiency of New Zealand's District Health Boards (DHBs) at achieving gains in Māori and European life expectancy (LE).

Methods: Using life tables for 2006 and 2013, a two-output DEA model established the production possibility frontier for Māori and European LE gain. Confidence limits were generated from a 10,000 replicate Monte Carlo simulation.

Results: Results support the use of LE change as an indicator of DHB efficiency. DHB mean income and education were related to initial LE but not to its rate of change. LE gains were unrelated to either the initial level of life expectancy or to the proportion of Māori in the population. DHB efficiency ranged from 79% to 100%. Efficiency was significantly correlated with DHB financial performance.

Conclusion: Changes in LE did not depend on the social characteristics of the DHB. The statistically significant association between efficiency and financial performance supports its use as an indicator of managerial effectiveness.

Implications for Public Health: Efficient health systems achieve better population health outcomes. DEA can be used to measure the relative efficiency of sub-national health authorities at achieving health gain and equity outcomes.

Key words: life expectancy, efficiency, data envelopment analysis, Maori, New Zealand

Governments invest substantial resources in health in the expectation that these lead to increases in the length and quality of life. Technological and organisational advances have meant that population health status is now highly determined by the efficacy and efficiency of national health systems. Countries that invest more in health, particularly through public sector funding, tend to achieve better health outcomes[1] while macro socio-economic factors have become relatively less important over time.[2,3] It is self-evident that higher levels of health sector efficiency will produce greater health gains.

Data envelopment analysis (DEA) has been widely used to measure efficiency in the health sector, but this and most other frontier production analyses have focused on the performance of hospitals, health centres or specific services as decision-making units.[4] There are just a few examples of DEA being applied to measure the efficiency of semi-autonomous sub-national health authorities at achieving population health outcomes.[5,6]

Hospital productivity may be measured in terms of patient throughput or health interventions, but the productivity of health authorities should use broader measures consistent with their mandate to increase overall population health and to reduce inequalities in health outcomes. In many countries publicly funded health systems are decentralised or devolved to sub-national, geographically defined health authorities, although in most a governance and stewardship role is retained at central level. In Spain, for example, health sector budgets are controlled by the 17 Comunidades Autónomas; in Scotland, responsibility for health services rests with 14 Regional Health Boards; and in New Zealand (NZ) public sector health services are funded and provided (mainly) by 20 District Health Boards (DHBs).

The presence of multiple 'decision-making units' makes it possible to compare their performance but there has been some reluctance to make comparisons of outcomes between geographically defined health authorities on the grounds that the populations they serve differ considerably in socio-economic factors such as age, income, education and ethnicity that are themselves closely related to health outcomes. However, whilst acknowledging that these factors are important determinants of the baseline population health status, they are not necessarily of great importance as determinants of the velocity of change in population health status over time.

In this paper we first show that changes in life expectancy in NZ over the intercensal period from 2006 to 2013 were almost entirely unrelated to baseline socioeconomic and demographic factors. Rather, we posit that health change (specifically life expectancy

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for the purpose of this analysis) has been driven by changing patterns of exposure to risk factors, whose strength and impact on health outcomes has been modified by health sector intervention both at national and local level. Further, we suggest that subnational variation in ethnic-specific changes in life expectancy is partly determined by the efficiency with which individual DHBs have used need-weighted population-based funding to produce better health outcomes. We apply DEA as a widely used tool for the measurement of DHB efficiency.

NZ healthcare system organisation

It is important to begin by explaining some features that are specific to health in NZ. NZ has a multi-ethnic population divided broadly into: indigenous Māori (16% in 2013); Asians (12%); Pacific, who identify ethnically with one or other of the Pacific Islands (6%); and the rest (66%), who are overwhelmingly of European ethnicity and will be referred to here as European. The Māori and Pacific populations experience higher levels of deprivation and have lower life expectancies.

Equity in health in NZ is measured mainly in terms of the reduction or elimination of health inequalities between Māori and Pacific, and European (sometimes grouped with Asians). Considerable effort has been devoted to ensuring that ethnicity is measured completely and accurately in the census and in other national databases, including the mortality collection.[7] Individuals can have multiple ethnicities, however many analyses (and the population-based funding formula) apply a prioritisation to produce a single ethnicity code where Māori overrides all other ethnicities, Pacific overrides all but Māori, and Asian is recorded in priority to European.[8]

District Health Boards serve populations ranging (in 2013) from 33,000 to 552,000. They receive funding on a capitation basis with weightings and adjustments made to reflect variation in expected health-service costs due to: difference in the age-sex structure of the population in each ethnic group and deprivation decile; rurality; treatment of non-resident populations (e.g. tourists); and unmet health needs in Māori and Pacific.[9,10] The various cost-weights and adjustors mean that some DHBs receive up to 24% above the population average while others receive up to 12% less.[9]

Methods

The basic data used in this analysis were period lifetables produced by Statistics New Zealand for each ethnic group in each DHB using data from the 2006 and 2013 censuses in combination with mortality data from the periods 2005-07 and 2012-14.

The life tables were produced using a hierarchical Bayes model that copes with sparse data by sharing information across estimates, avoiding the need for manual smoothing. The methods yield explicit measures of uncertainty which are reflected in the 95% credibility limits provided with each table. A full description of the methods is provided by Statistics NZ.[11] We derived the change in Māori and European life expectancy for each DHB from these lifetables.

The first step in the analysis involved testing the hypothesis that the change in life expectancy in each DHB between 2006 and 2013 was unrelated to their baseline socioeconomic and demographic characteristics, and to the change in these over this period. Accordingly, the correlation between a wide variety of published indicators from the 2006 census and the change in DHB life expectancy was calculated and tested for statistical significance.

The second step of the analysis used output-oriented data envelopment analysis under the assumption of constant returns to scale to estimate the efficiency of each DHB at producing life expectancy gains in their Māori and European populations. With this tool we are effectively considering each DHB as a production unit whose main outputs are gains in population life expectancy. We restricted the analysis to Māori and European populations to avoid intractable complexity in the analysis. The implications of this restriction are addressed in the discussion.

The intercensal change in life expectancy at birth (LE) was chosen as the outcome of interest because it is a paramount goal of investment in healthcare, and as we demonstrate, it is largely unrelated to socioeconomic factors. It can be plausibly assumed to be attributable in a large part to investments in health where these are taken in a broad sense to include measures to modify risk factors and promote healthy lifestyles. The change in LE has the additional advantage that as an output, it exhibits constant returns to scale. This is evident from the fact that population LE is generally unrelated to the size of a country (the correlation coefficient for the association between population size and life expectancy at birth in 2010 for 188 countries listed on the Gapminder website is 0.02),[12] and here we test the possibility at a smaller scale by measuring its correlation with the size of the DHB. LE gains have the additional advantage that they are intuitively understood by both health sector managers and the general population. However, a more sophisticated analysis would also take into account health-related quality of life gains.

It was assumed that each DHB received equal inputs with which to increase LE. As noted above, the population-based funding formula (PBFF) is designed to compensate each DHB equitably for differences in costs to serve their respective populations. In a sense, the PBFF can be seen as a way of ensuring 'equality' of purchasing power among DHBs. The assumption that PBFF achieves equality in inputs among the DHBs was tested *post hoc* by examining whether there was any correlation between the calculated DHB efficiency scores and several factors related to healthcare costs that may or may not have been adequately adjusted for by the PBFF. These were: actual per capita DHB funding; the size of the DHB population; the proportion of Māori in the DHB population; the proportion of the population aged 85 and over; and DHB 'rurality' based on an indicator in recent review of the PBFF rural adjuster.[13] The efficiency scores of DHBs with tertiary services were also compared with those of DHBs without tertiary services to test that the PBFF adjusts adequately for this factor. If the PBFF has failed to adequately compensate for higher costs, then one might expect to see a negative correlation between actual per capita funding received and DHB efficiency. Conversely, if the PBFF overcompensates for cost differences then one might expect to see a positive correlation between the actual per capita funding and efficiency. Similarly, any significant correlation between the other variables and efficiency estimates would suggest that the assumption of equal health purchasing power may have been violated.

DEA estimates of efficiency were calculated using Stata and Excel. DEA is a widely used non-parametric method for assessing the efficiency of productive units and estimating production possibility frontiers. Although it does not rely on prior assumptions about the nature of the productive process, noise in measurement is known to bias efficiency estimates.[14] Kao and Liu have shown that if external estimates of measurement precision are available then Monte Carlo simulation methods can be used to produce unbiased 'stochastic' efficiency estimates.[14] A recent review of methods to perform DEA in the presence of measurement uncertainty recommended using Monte Carlo simulations where feasible.[15]

In this case we used the 95% credibility limits on the life table measures provided by Statistics New Zealand to simulate 10,000 replications of each DHB's gain in Māori and European life expectancy (assuming a normal distribution of the error in life expectancy estimates in each census year), thereby producing 10,000 estimates of efficiency along with 95% percentile limits for each DHB. Given their asymmetric distribution, median efficiency values were reported. Data on DHB financial deficits/supluses were drawn from the 2012/13 Annual Report of the Controller and Auditor-General.[16]

Excel was used to calculate correlation coefficients. Stata 13 was used to perform a t-test (unequal variance) of the difference in mean efficiency scores for DHBs with and without tertiary level hospitals.

Results

Table 1 shows the Māori and European life table estimates of life expectancy for each DHB, and the change in these between 2006 and 2013. Life expectancy has clearly improved for both European and Māori in all DHBs, but at a greater rate for the latter. The change of life expectancy among Māori from 2006 to 2013 was unrelated to the proportion of Māori in the DHB in 2006 (correlation coefficient r=-0.16; p=0.49). The change in Māori life expectancy was also not significantly associated with the starting LE in 2006 (r=0.19; p=0.42), suggesting that change was not limited at the upper end of the range. This was also true for Europeans (r=0.31; *p*=0.19).

Table 2 presents the correlation with LE in 2006 and the change by 2013 for a range of socioeconomic variables measured at DHB level. Although most of the indicators were significantly associated with the level of life expectancy in 2006, none of them was significantly associated with the improvement in life expectancy over the subsequent seven years.

A geometrical depiction of the classical DEA efficiency analysis is provided in Figure 1 where each DHB is represented as a point on the graph corresponding to its gain in LE from 2006 to 2013 for Māori (vertical axis) and Europeans (horizontal axis). The line enveloping the DHBs at the outer edge represents the (non-stochastic) production possibility frontier for these two outputs. The four DHBs sitting on and defining the PPF (Waikato, Counties Manukau, Hawkes Bay and Nelson Marlborough) have efficiencies of 100%. For the others, their efficiency can be represented graphically as the ratio of their distance from the origin to the distance from the origin to the PPF (passing through that point). So, in the case of Lakes DHB, the efficiency is the length of line OA divided by the length of line OB as shown in Figure 1.

The efficiency of each DHB calculated in this way is shown in Table 3. Table 3 also shows the median efficiency of each DHB derived from the Monte Carlo simulation, which effectively creates 10,000 different PPFs and calculates the DHBs' efficiency for each of them. A 95 percentile confidence limit is provided for each Monte Carlo efficiency estimate. It can be seen from Table 3 that the Monte Carlo efficiency estimates are consistently equal to, or smaller than, the non-stochastic DEA estimates. This is because deterministic DEA is known to overestimate efficiency when there is measurement error or noise.[17]

Table 2: Correlation of DHB socioeconomic indicators with LE in 2006 and the change in LE, 2006 to 2013.

Proportion of the DHB population / households	Correlation with 2006 LE	Correlation with change in LE (2006-13)
No educational qualification	-0.79***	0.08
University degree	0.68***	-0.15
Age-standardised unemployment rate	-0.34	0.30
Household income <$30,000	-0.70***	-0.06
Rental accommodation	0.26	0.26
Internet access	0.88***	-0.10
No motor vehicle	-0.15	-0.34
Age-standardised smoking rate	-0.89***	0.14
Rural residence	-0.55*	-0.06

** p<0.05 ** p<0.01 *** p<0.001*

The median efficiency in Table 3 was found to be positively correlated with the size of the financial surplus in 2012/13 (r=0.46; p=0.0498), with Canterbury excluded because its surplus/deficit was not reported (given that insurance receipts from earthquake damages made it incomparable). More than half the DHBs were apparently able to improve their LE comfortably within their PBFF allocations. Conversely, DHBs with deficits had lower efficiency scores. Efficiency scores were not significantly correlated with the funding to population ratio (r=0.06; *p*=0.81); the size of the DHB (r=0.05; *p*=0.85); the Māori proportion of its population

Table 1: Life expectancy at birth for Māori and European in 2006 and 2013 by DHB (with 95% credibility limits).

District Health Board	Māori			European		
	2006*	2013*	Change	2006	2013	Change
Auckland	77.1 (76.0-78.1)	79.4 (78.3-80.5)	2.3	83.5 (83.2-83.7)	84.5 (84.3-84.7)	1.0
Bay of Plenty	72.5 (71.8-73.2)	74.9 (74.2-75.6)	2.4	82.0 (81.7-82.2)	83.1 (82.9-83.4)	1.1
Canterbury	76.5 (75.5-77.7)	78.7 (77.6-79.9)	2.2	81.0 (80.8-81.2)	81.9 (81.8-82.1)	0.9
Capital and Coast	75.9 (74.8-77.1)	78.1 (77.0-79.3)	2.2	81.8 (81.5-82.1)	82.8 (82.5-83.0)	1.0
Counties Manukau	72.5 (71.8-73.2)	74.7 (74.1-75.4)	2.3	82.5 (82.2-82.7)	83.7 (83.4-83.9)	1.2
Hawke's Bay	71.2 (70.4-72.1)	73.9 (73.1-74.7)	2.7	80.8 (80.5-81.1)	81.9 (81.7-82.2)	1.2
Hutt	73.8 (72.6-75.0)	76.2 (75.0-77.4)	2.4	80.9 (80.5-81.2)	81.9 (81.5-82.2)	1.0
Lakes	71.6 (70.8-72.5)	73.6 (72.8-74.4)	2.0	80.8 (80.4-81.2)	81.8 (81.5-82.2)	1.0
Midcentral	73.5 (72.5-74.5)	75.7 (74.8-76.7)	2.2	80.7 (80.4-80.9)	81.8 (81.5-82.1)	1.1
Nelson Marlborough	77.7 (76.0-79.6)	80.3 (78.5-82.3)	2.6	81.0 (80.7-81.3)	82.2 (81.9-82.5)	1.2
Northland	71.2 (70.5-71.9)	73.5 (72.8-74.1)	2.3	81.6 (81.3-81.9)	82.6 (82.3-82.9)	1.0
South Canterbury	77.7 (74.9-81.0)	80.0 (77.2-83.6)	2.4	80.5 (80.1-80.9)	81.4 (81.0-81.8)	0.9
Southern	76.1 (74.9-77.2)	78.4 (77.2-79.6)	2.3	80.4 (80.2-80.6)	81.3 (81.1-81.5)	0.9
Tairawhiti	70.3 (69.4-71.2)	72.6 (71.7-73.5)	2.3	80.7 (80.1-81.3)	81.8 (81.3-82.4)	1.1
Taranaki	73.5 (72.4-74.8)	75.9 (74.7-77.1)	2.4	80.6 (80.3-81.0)	81.7 (81.4-82.1)	1.1
Waikato	72.3 (71.6-72.9)	74.4 (73.8-75.0)	2.1	81.0 (80.8-81.3)	82.3 (82.1-82.5)	1.2
Wairarapa	72.0 (70.3-73.8)	74.2 (72.5-76.0)	2.2	80.5 (80.0-81.0)	81.5 (81.0-81.9)	1.0
Waitemata	77.7 (76.7-78.6)	80.1 (79.1-81.1)	2.5	84.4 (84.2-84.6)	85.5 (85.3-85.7)	1.1
West Coast	75.3 (72.8-78.0)	77.6 (75.2-80.6)	2.4	79.9 (79.4-80.4)	80.9 (80.4-81.4)	1.0
Whanganui	71.0 (69.9-72.1)	73.4 (72.3-74.6)	2.5	80.5 (80.2-80.9)	81.6 (81.2-82.0)	1.0

Source: Statistics NZ

** Statistics NZ uses the period 2005-7 and 2012-4 since mortality data was used from that range of dates. For simplicity we use the year of the census which provided the population base for the life tables.*

(r=0.20; *p*=0.40); the proportion of its population aged 85 or over (r=-0.13; *p*=0.59); nor the rurality of the population it serves (r=-0.06; *p*=0.81). Although the mean efficiency of DHBs with a tertiary hospital was lower than DHBs without one (86.2% versus 90.6%) the difference was not statistically significant (*p*=0.23).

Discussion

This study has found reasonably high levels of efficiency in NZ DHBs. By means of comparison, Tigga and Mishra's DEA study of inter-state health outcomes in India found a mean technical efficiency score of 84%.[6] On the other hand, in a DEA comparison of health system efficiency in OECD countries all 28 countries studied were found to have efficiencies of 90% and over for life expectancy at birth and at 65 years (but it did not examine change in life expectancy and NZ was not one of the included countries).[18]

The 95% confidence limits for DHB efficiency all overlapped at some point, but that does not exclude the possibility there are in fact significant differences between them. Canterbury DHB had the lowest efficiency. Canterbury's efficiency was probably affected by the health impact and disruptive effects on service delivery of the 2011 earthquake. Capital and Coast also had a low efficiency score. It is notable that this DHB had four different Chief Executive Officers over the intercensal period, each attempting unsuccessfully to tackle its chronic budget deficit, perhaps to the detriment of population health outcomes. If the presence of a budget deficit is considered to be an indicator of managerial effectiveness, then the significant correlation between efficiency estimates and financial deficits/surpluses provides support for the validity of the efficiency estimates that we have calculated. Indeed, if the deficit were incorporated into the input measure (DHBs that run a deficit effectively receive greater inputs than the PBFF allocation), then the correlation between efficiency and financial results would have been even stronger (data not shown).

The generally high level of efficiency for all DHBs may reflect a relatively uniform standard of health sector management, but it could also be because policy directions and service guidelines provided by the Ministry of Health allow little scope for any particular DHB to shine over the rest, or because improvements in health outcomes are largely determined by national historical trends (such as the decline in smoking and the obesity epidemic), that affect all DHBs similarly, even if their starting levels of LE are quite different.

An obvious limitation of this study was its omission of Asian and Pacific life expectancy gains as outputs. Although DEA can readily cope with more than two outputs, the Monte Carlo simulation would have been far more difficult to conduct and its discriminatory power would have been reduced. Also, the Asian life tables are not subdivided into South Asians (predominantly of Indian, Sri Lankan, and Pakistani descent) and East Asians (mainly ethnic Chinese and Korean), whose distribution differs across DHBs and whose LE gains may also have differed considerably. Furthermore, Pacific and Asian populations in some DHBs are very low. Incorporating health-related quality of life measures into the outputs (perhaps as health expectancies) would be valuable in any future such analyses.

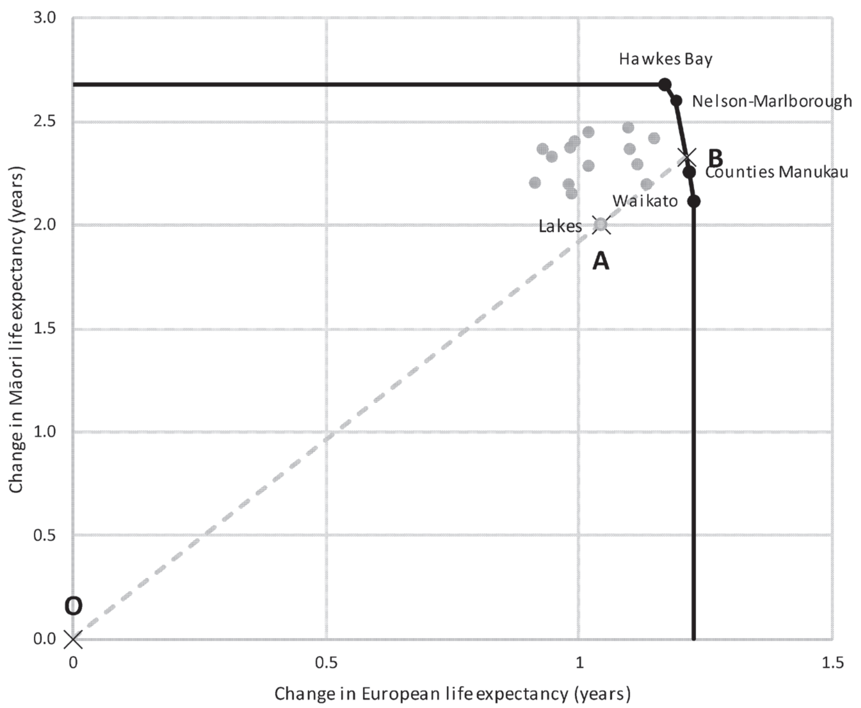
The approach used assumed that each DHB received equal levels of input based on the PBFF formula. Our tests of the validity of this assumption failed to identify any obvious violation and hence the observed differences in efficiency scores are unlikely to be due to differences in DHB funding.

In output-oriented DEA with two or more outputs the slope of the production possibility frontier defines opportunity costs and how these vary as life expectancy gains approach the maxima. In the flat and vertical segments there are no opportunity costs. A non-zero and non-infinite slope within

Table 3: Efficiency of District Health Boards at achieving life expectancy gains for their Māori and European populations.

District Health Board	Efficiency (%) Non-stochastic DEA	Efficiency (%) Stochastic DEA (95% confidence limits)
Auckland	86	86 (77–96)
Bay of Plenty	96	94 (86–100)
Canterbury	82	79 (71–93)
Capital and Coast	83	83 (74–94)
Counties Manukau	100	98 (90–100)
Hawke's Bay	100	100 (90–100)
Hutt	90	87 (76–100)
Lakes	86	84 (74–95)
Midcentral	93	92 (83–100)
Nelson Marlborough	100	100 (90–100)
Northland	86	86 (77–94)
South Canterbury	89	85 (67–100)
Southern	87	83 (74–99)
Tairawhiti	93	92 (79–100)
Taranaki	92	91 (82–100)
Waikato	100	98 (90–100)
Wairarapa	83	83 (70–100)
Waitemata	93	92 (84–100)
West Coast	89	88 (70–100)
Whanganui	91	89 (78–100)

Figure 1: Gain in Maori and European life expectancy by DHB 2006 to 2013.



this frontier implies opportunity costs such that gains for one ethnic group can only be attained at the expense of gains for the other ethnic group. One might challenge this feature of DEA on the grounds that it should always be possible to increase Māori life expectancy without sacrificing European life expectancy (and vice versa). There are many health interventions which increase both Māori and European life expectancy (e.g. water chlorination). However, many interventions have disproportionate life expectancy gains for one or other ethnicity: for example, rheumatic fever programmes; melanoma treatment; housing insulation subsidies; bowel screening; smoking cessation; hepatitis treatment, aortic aneurysm screening, etc. The actions of health service planners in having to make choices between these interventions demonstrates the very real opportunity costs to one ethnicity of making greater life expectancy gains for another.

By assessing efficiency in terms of Māori and European LE gains it was hoped that it would be possible to judge the extent to which DHBs are pursuing greater equity as well as overall population health gain, since both are fundamental health sector goals. DHBs operating at 100% efficiency can achieve different levels of LE gain for Māori and Europeans. Those achieving higher Māori LE gains could be considered to be pursuing higher degrees of equity. For example, although Hawkes Bay and Nelson Marlborough DHBs were both 100% efficient, the former achieved a LE gain for Māori of 2.68 compared with 2.60 for the latter. The opportunity cost of the 0.08-year greater gain in Māori life expectancy was a 0.02-year lower gain in European LE (1.17 versus 1.19). However, Māori make up 24.1% of Hawkes Bay's population but only 8.9% of Nelson Marlborough's. Thus the higher LE gain in Hawkes Bay will have a much higher impact on the actual number of years of life gained in Hawkes Bay than a similar gain for Māori would have had in Nelson Marlborough. Hence for any given DHB's mix of Māori and European population, there is probably only one point on the PPF that maximises total expected years of life gained.

To our knowledge this is the first study to formally quantify the efficiency of NZ's DHBs in achieving life expectancy gains. It has also demonstrated the feasibility of Monte Carlo based stochastic DEA. Future analyses could extend this work to incorporate health-related quality of life measures and other ethnic groups.

References

1. Barthold D, Nandi A, Mendoza Rodríguez JM, Heymann J. Analyzing whether countries are equally efficient at improving longevity for men and women. *Am J Public Health*. 2014;104(11):2163-9.
2. Preston SH. The changing relationship beween mortality and level of economic development. *Popul Stud*. 1975;29(2):231-48.
3. Riley JC. The timing and pace of health transitions around the world. *Popul Dev Rev*. 2005;31(4):741-64.
4. Hollingsworth B. The measurement of efficiency and productivity of health care delivery. *Health Econ*. 2008;17(10):1107-28.
5. Rouse P, Swales R. Pricing public health care services using DEA: Methodology versus politics. *Ann Oper Res*. 2006;145(1):265-80.
6. Tigga NS, Mishra US. On measuring technical efficiency of the health system in india an application of data envelopment analysis. *J Health Manag*. 2015;17(3):285-98.
7. Blakely T, Atkinson JN, Fawcett J. Ethnic counts on mortality and census data (mostly) agree for 2001-2004: New Zealand Census-Mortality Study update. *N Z Med J*. 2008;121(1281):58-62.
8. Ministry of Health. *Ethnicity Data Protocols for the Health and Disability Sector*. Wellington (NZ): Government of New Zealand; 2004.
9. Penno E, Gauld R. How are New Zealand's District Health Boards funded and does it matter if we can't tell?'. *N Z Med J*. 2013;126:e1376.
10. Ministry of Health. *Population-based Funding Formula Review: 2015 Technical Report*. Wellington (NZ): Government of New Zealand; 2016.
11. Statistics New Zealand. *New Zealand Period Life Tables: Methodology for 2012-14* [Internet]. Wellington (NZ): Government of New Zealand; 2015. [cited 2015 Oct 9]. Available from: http://www.stats.govt.nz/browse_for_stats/health/life_expectancy/period-life-tables.aspx
12. Gapminder. *Data in Gapminder World – Excel Data* [Internet]. Stockholm (SWE): Gapminder; 2016 [cited 2016 Mar 8]. Available from: http://www.gapminder.org/data/
13. Moore D, Blick G, Whelen C. *Review of the Rural and Tertiary Adjusters*. Wellington (NZ): Sapere Research Group; 2015.
14. Kao C, Liu S-T. Stochastic data envelopment analysis in measuring the efficiency of Taiwan commercial banks. *Eur J Oper Res*. 2009;196(1):312-22.
15. Dyson RG, Shale EA. Data envelopment analysis, operational research and uncertainty. *J Oper Res Soc*. 2010;61(1):25-34.
16. Controller and Auditor-General – Tumuaki o te Mana Arotake. *Annual Report 2012/13*. Wellington (NZ): Zealand Office of the Auditor-General; 2013.
17. Kao C, Liu ST. Measuring performance improvement of Taiwanese commercial banks under uncertainty. *Eur J Oper Res*. 2014;235(3):755-64.
18. Medeiros J, Schwierz C. *Efficiency Estimates of Health Care Systems*. Brussels (BEL): European Commission; 2015.