THE LANCET Diabetes & Endocrinology

Supplementary appendix

This appendix formed part of the original submission and has been peer reviewed. We post it as supplied by the authors.

Table of Contents

Appendix 1: Systematic search of the monetary value of an IQ point for an unborn cohort in a UK setting

This appendix aims to identify and evaluate papers which can be used to estimate the monetary value of an IQ point increment. To properly reflect the true cost of IQ loss/gain from a programme applicable to the target population, careful consideration is needed on the sourcing and methodology behind the estimation of the monetary value of an IQ point. The findings are then applied to estimate the value of an IQ point for the unborn UK cohort in the iodine supplementation model.

Methods

Systematic search of the literature on the monetary value of IQ points

A systematic search of the literature to determine the monetary value of an IQ point was undertaken following the UK Centre for Review and Dissemination guidelines for methods and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for reporting, where appropriate.[1,2]

Inclusion Criteria

Articles were included if they met the following criteria: the study reports primary or secondary research on the monetary value of an IQ point gain/loss, or the study looks at the economic cost associated with IQ gain/loss.

Search Strategy

Four electronic databases were searched (EMBASE, MEDLINE, EconLit, and NHS Economic Evaluation Database) up to August 2014. In addition, the reference lists of potentially relevant articles were then manually searched and an exploration of grey literature consisting of internet searches with Google and Google scholar was conducted to identify additional studies. Search words included "Intelligence", "IQ", "cost benefit analysis", "cognitive ability", "willingness to pay", "willingness to accept", "economic evaluation", "earnings", and "income". One author did the study selection and data extraction.

A three stage process determined studies fit for inclusion, using methods described in detail elsewhere.[3] The initial screening process used the title and abstract of an article to sort them into five groups A-E based on the relevance of each study to the systematic search:

A. The study reports primary research on the monetary value of IQ point decrement/increment.
B. The study reports secondary research on the monetary value of IQ point decrement/increment.
C. Study found via grey literature searches.
D. The study looks at the economic cost associated with IQ loss but do not in terms of IQ point decrements /increments.
E. This study is not relevant to this systematic search.

All studies categorised as A, B, C, or D were further classified after reading the full text into the following categories by type of study:

1. Primary Research which details the methodology behind the monetary value of an IQ point.
2. Secondary Research which details the methodology behind the monetary value of an IQ point.
3. Only provides a reference from other literature on the monetary value of IQ point loss.
4. Review of the literature which includes the costs associated with IQ loss.
5. Decision analysis model using the cost of IQ loss as a parameter.
6. Other, such as the costs associated with the shift in the population IQ distribution policy. decisions related to low IQ or the economic burden of neurodevelopmental disorders.
7. The cognitive measure in the study cannot be used to determine the monetary value of an IQ point.
8. Not applicable to this systematic search.

Only studies that reported primary research on an IQ point were eligible for the quality criteria stage (A1s, B1s, & C1s). Finally, the following quality assessment criteria were applied to the studies to determine robust estimates of IQ point valuations for the iodine supplementation decision model:

1. An individual's IQ is used and is not a proxy.
2. Variables are clearly specified.
3. IQ measure follows a conventional normal distribution with a mean of 100 and standard deviation of 15 or sufficient information is included in the study to allow the IQ measure's distribution to be converted into one (for cross study comparability).
4. The results reported in currency form have the applicable year stated.

Studies fulfilling the quality criteria were eligible for inclusion. For each included study, data were extracted on the study characteristics, the intelligence measure used, the main results reported and covariates, if any. The data were tabulated, and the themes faced by the individual studies when estimating the value of an IQ point were compared narratively.

Results

The electronic database search identified 1361 published articles, of which 390 were rejected as duplicates. Appendix 1 Figure 1 shows a flow diagram of the articles identified, retrieved, and retained or excluded at each stage and the categorization of the articles. Eight studies passed all the quality criteria and were therefore considered for use in calculating the monetary value of an IQ point. The included studies are listed in Appendix 1 Table 1.

One study looked at people's willingness to pay (WTP) for an additional IQ point.[4] Five studies used econometric regressions to determine the individuals IQ's effect on their subsequent income,[5-9] whereas two studies were cost benefit analysis on reducing lead exposure.[10,11] Only one of the studies included in the systematic literature search was not set in the USA.[5]

Direct or otherwise, all the econometric and cost benefit analysis studies valued an IQ point solely from its impact on earnings. Excluding the willingness to pay study, none of the studies considered IQ's effect on health outcomes in its valuation.

IQ's effect on an individual's future earnings

When determining IQ's causal effect on income, the included covariates are important. If a covariate is indirectly affected by someone's intelligence, IQ's effect on earnings will be understated. For example, Fletcher's[9] study inclusion of an academic achievement variable along with other cognitive related variables is likely to contribute to IQ not being a significant predictor of earnings in his model.

The issue of whether to include number of years in education as a covariate is not clear-cut. Higher education leads to higher earnings which would overestimate IQ's effect on earnings if not controlled for. However, education to a certain extent is a choice variable and dictated by someone's intelligence.[12] Thus, controlling for education ignores IQ's indirect contribution on earnings via more years of schooling undertaken. Schwartz[10] recognized that IQ's indirect effects on earnings originate from the positive effect of a person's IQ on years of schooling which subsequently affects the worker participation rate and earnings. He concluded that IQ's total effects gave an additional 1.76% in earnings per additional IQ point.

The earnings returns for an additional IQ point are not uniform across genders. Using more recent data than Schwartz's[10] estimates, Salkever[11] found that the total effect on earnings per additional IQ point is 2·09% for men and 3·63% for women. In contrast, Mueller reported higher earnings returns from an additional IQ point for males rather than females. Salkever and Schwartz's relatively high figures compared to other microeconomic papers on IQ and earnings have led to concerns that their reported effect of IQ on earnings is overstated;[13,14] Salkever[15] has since responded to these concerns pointing out, among other things, the generalizability issues of the other studies and endogenity problems with studies using hourly wages as a dependent variable.

Non cognitive ability is shown to have a significant effect on earnings.[7-9] Non cognitive ability here relates to personality traits, social skills, motivation, and perseverance. Mueller & Plug[7] utilised the Big Five Inventory (BFI) to capture personality traits and assess its effects in conjunction with IQ on earnings. After unstandardizing the IQ regression coefficient and controlling for personality traits, an additional IQ point increases hourly earnings by 0·69% and 0·48% for men and women respectively. Zagorsky[8] reported that IQ score along with the Rotter locus of control, Rosenberg Self-esteem scale and Pearlin mastery scale were all significant in a robust income regression with an extensive array of covariates. An additional IQ point increases annual household income on average by $202 (2004 US dollars), around 0·56% of median household income in the study.

Heckman and colleagues[12] reported a positive correlation between cognitive and non-cognitive ability which would overestimate cognitive ability's effect on earnings if non-cognitive ability is omitted from the regression. Unfortunately, their study did not pass the quality criteria as their standardized cognitive measures inhibited a valuation of an IQ point.

The strength of IQ as a predictor of earnings appears to increase as people get older. In Zax and Rees' study,[6] an additional IQ point raised 35 year old male earnings by 0·75% whereas an additional IQ point raised earnings by 1·4% when they were measured when the participants were in their fifties. After adjusting for years of education, the 35 year old earnings IQ coefficient falls to 0·46% and the 53 year old earnings falls to 0·61% respectively.

Valuation of an IQ point based on people's willingness to pay

A product or service should be valued by how much people are willing to pay for it. The willingness to pay study assigned a much lower valuation of an IQ point (1996 USD $1,100-$1,900) than the econometric papers. This may reflect high discounting of the future by their respondents and/or the lack of awareness of the implications of IQ loss on future earnings and health states. Lutter[4] also suggests that the low valuation may partly be due to the parents expecting poor returns in investing in their child's human capital.

Monetary Value of an IQ point to be used in the model

In keeping with the conservative nature of the model, the relatively high earnings premium from IQ points from Schwartz [10] and Salkever [11] are excluded on the basis that the effect may be overstated. The base case percentage is taken to be 1%, a rough average of the IQ's effect on earnings at the two timepoints, not controlling for education, in the Zax and Rees[6] study. A lower bound estimate of IQ's effect on earnings for the sensitivity analysis is taken to be £1135 – an updated lower bound WTP for an IQ point in Lutter's[4] study. The lower bound WTP estimate was calculated by updating the study figure into 2013 US dollars and converting it to British pound sterling based on the 2013 rate of purchasing powers parities ($1 is equal to £0·70).[16]

To estimate the value of the extra lifetime earnings for the unborn infants with higher IQ points, the average UK wage in 2013 —£24687— was taken from the labour force survey.[17] Assuming real wages rises by 1% per annum and the UK Economically Active Rate (EAR) for 16-64 year olds stays constant (0·72),[17] the Present Value of Lifetime Earnings (PVLE) for the infants, evaluated at time of birth, discounted at the recommended 3·5% ,[18] is £337736. The formula for estimating the PVLE for the unborn infants is displayed below:

PVLE for unborn cohort = (PVLE up to 64 yrs. − PVLE up to 16 yrs.)× EAR

Taking 1% as the base case percentage of the effect of an additional IQ point on earnings, this translates to a £3377 monetary value of an IQ point for this unborn cohort. Since not everyone survives until the age of 65, UK life tables are used in conjunction with the projected earnings to calculate a revised estimate of the value of an IQ point for this unborn cohort.[19] This gives an adjusted estimate of £3297 for an IQ point value.

Discussion

The systematic search identified eight studies for the purposes of extracting a monetary value of an IQ point for the iodine supplementation model. Twelve other studies which contained primary research behind the monetary value of an IQ point did not pass all the quality criteria and therefore were excluded from the final analysis. One problem that prevented a lot of the papers from being included in the final analysis was the inability of using their cognitive measure due to scaling issues. The reported coefficients for the studies are standardized so as to convey the relative importance of each coefficient in comparable units. Insufficient information is given by the studies to enable transforming the IQ score coefficient back to the conventional IQ distribution. Adopting the standardizing approach is surprising, given that standardizing coefficients has attracted its share of criticism.[20]

The monetary value of an IQ point assumes a linear effect on earnings that is not dependent on where on the IQ distribution an individual gaining an additional IQ point would start. Intuitively, we would expect an additional IQ point to be worth more for someone who has a borderline intellectual disability than someone from a higher IQ category. The Zax and Rees[6] study participants were restricted to high school graduates and therefore, the IQ's impact on earnings is likely to be an underestimate for people of lower educational ability who never progress to that educational attainment level.

With questions about how much the participants are aware of the implications of an additional IQ point, the representativeness of the study sample to the general population and its applicability in a UK setting, using the willingness to pay figure for the iodine supplementation model would be far from ideal.
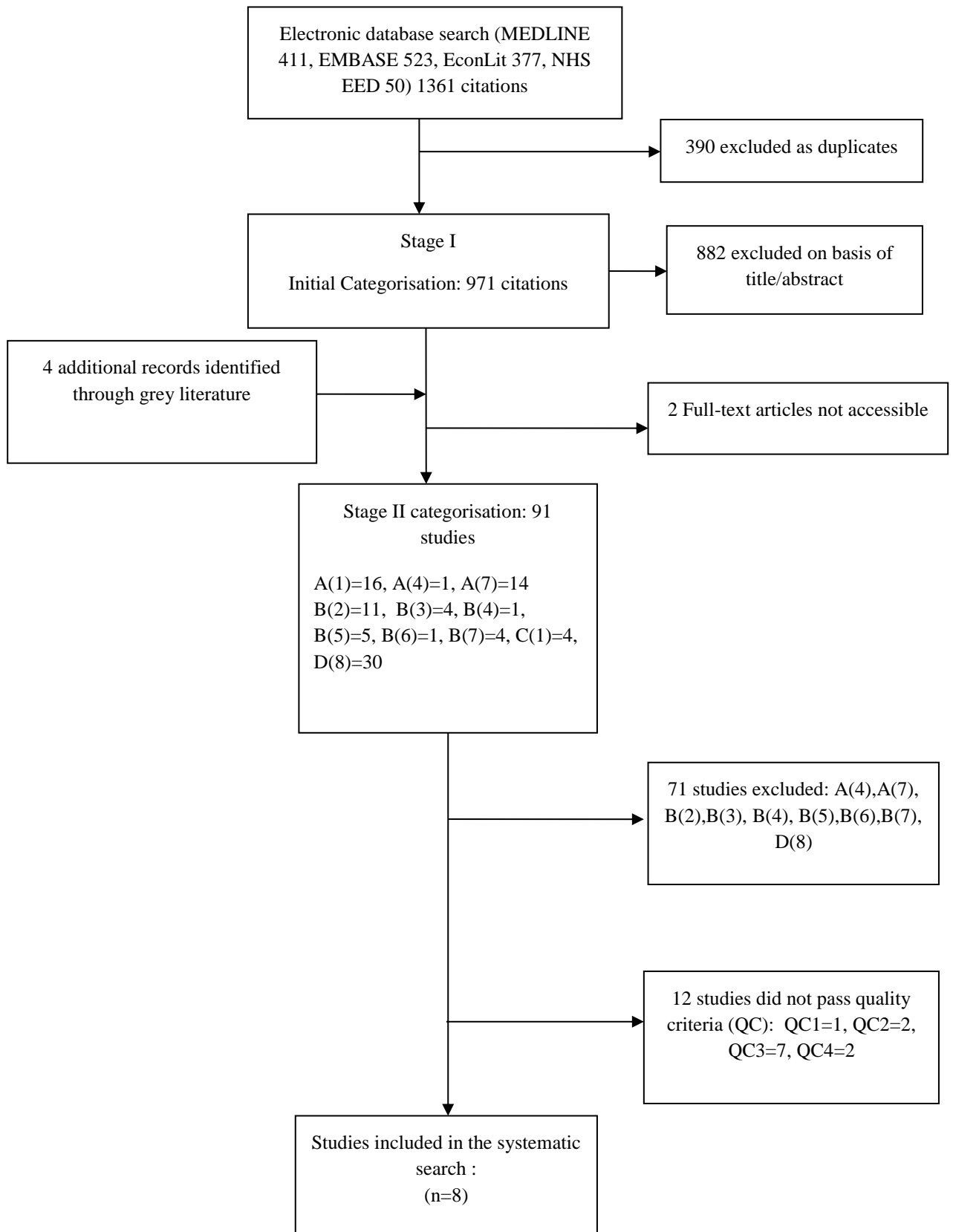
Other studies which make use of a monetary value of an IQ point, such as environmental cost benefit analyses of health hazards, typically use an updated version of a monetary value of an IQ point calculation from one paper. Grosse and colleagues[21] based their value on Schwartz's estimate for IQ's total impact on earnings and aimed to make it applicable to a two year old cohort. Simply updating their figure to the current year is not sufficient unless the cohort is of the same age. For example, their IQ monetary value would not be suitable for the iodine supplementation model as the cohort have yet to be born and the future benefits should be discounted more as they reach working age later than a two year old cohort. If a study is considering the costs of cognitive damage to society that affects a broad population base, a weighted average approach of the PVLE calculations across ages would be more appropriate than a cohort, albeit requiring more extensive workings.

The ideal monetary value of the IQ point for the iodine supplementation from an earnings premium would be taken from a UK study with a representative cohort, panel data containing earnings over the years, variables controlling for non-cognitive skills and a valid IQ test with the conventional normal distribution. Likewise, a desirable willingness to pay figure would be a UK population representative sample with participants informed of the societal lifetime implications of an additional IQ point. Future research is welcomed towards improving the estimate in the systematic search for different country contexts.

References

1.	Centre for Reviews and Dissemination, University of York. Systematic Reviews: CRD's Guidance for Undertaking Reviews in Health Care. York: Centre for Reviews and Dissemination, University of York, 2009. Available from: http://www.york.ac.uk/inst/crd/pdf/Systematic_Reviews.pdf.
2.	Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med. 2009;151(4):264-9.
3.	Roberts T, Henderson J, Mugford M, Bricker L, Neilson J, Garcia J. Antenatal ultrasound screening for fetal abnormalities: a systematic review of studies of cost and cost effectiveness. BJOG. 2002;109(1):44-56
4.	Lutter RW. Valuing children's health: A reassessment of the benefits of lower lead levels. AEI-Brookings Joint Center Working Paper No. 00-02. 2000.
5.	de Wolff P, van Slijpe ARD. The Relation Between Income, Intelligence, Education and Social Background. Europ Econ Rev. 1973;4(3):235-64.
6.	Zax JS, Rees DI. IQ, Academic Performance, Environment, and Earnings. Rev Econ Stat. 2002;84(4):600-16.
7.	Mueller G, Plug E. Estimating the Effect of Personality on Male and Female Earnings. Ind Lab Relat Rev. 2006;60(1):3-22.
8.	Zagorsky JL. Do you have to be smart to be rich? The impact of IQ on wealth, income and financial distress. Intelligence. 2007;35(5):489-501.
9.	Fletcher J. Friends or Family? Revisiting the Effects of High School Popularity on Adult Earnings. 2013. National Bureau of Economic ResearchWorking Papers: 19232
10.	Schwartz J. Societal benefits of reducing lead exposure. Environ Res. 1994;66(1):105-24.
11.	Salkever DS. Updated estimates of earnings benefits from reduced exposure of children to environmental lead. Environ Res. 1995;70(1):1-6.
12.	Heckman JJ, Stixrud J, Urzua S. The effects of cognitive and noncognitive abilities on labor market outcomes and social behavior. National Bureau of Economic Research, 2006.
13.	Gayer T, Hahn RW. Designing Environmental Policy: Lessons from the Regulation of Mercury Emissions. J Regul Econ. 2006;30(3):291-315.
14.	Grosse SD. How much is an IQ point worth? Implications for regulatory impact analyses. AERE Newsl. 2007;27(2):17-21.
15.	Salkever DS. Assessing the IQ-earnings link in environmental lead impacts on children: Have hazard effects been overstated? Environ Res. 2014;131:219-30.
16.	OECD. OECD.StatExtracts (database) 2014 [23rd October 2014]. Available from: http://stats.oecd.org/Index.aspx?DataSetCode=SNA_Table4#.
17.	Office of National Statistics. Labour Market Statistics, March 2014. 2014. Available from: http://www.ons.gov.uk/ons/dcp171778_354442.pdf.
18.	NICE. Guide to the methods of technology appraisal. London: National Institute for Health and Clinical Excellence, 2013.
19.	Office of National Statistics. United Kingdom National Life Tables: 1980-82 to 2011-2013. 2014. Available from: http://www.ons.gov.uk/ons/rel/lifetables/national-life-tables/2011-2013/stb-uk-2011-2013.html.
20.	Bring J. How to standardize regression coefficients. Am Stat.1994;48(3):209-13.
21.	Grosse SD, Matte TD, Schwartz J, Jackson RJ. Economic gains resulting from the reduction in children's exposure to lead in the United States. Environ Health Perspect. 2002;110(6):563-9.

Appendix 1 Figure 1: Prisma Diagram of the Monetary Value of an IQ point Systematic Search

Electronic database search (MEDLINE 411, EMBASE 523, EconLit 377, NHS EED 50) 1361 citations

390 excluded as duplicates

Stage I

Initial Categorisation: 971 citations

882 excluded on basis of title/abstract

4 additional records identified through grey literature

2 Full-text articles not accessible

Stage II categorisation: 91 studies

A(1)=16, A(4)=1, A(7)=14
B(2)=11, B(3)=4, B(4)=1,
B(5)=5, B(6)=1, B(7)=4, C(1)=4,
D(8)=30

71 studies excluded: A(4),A(7), B(2),B(3), B(4), B(5),B(6),B(7), D(8)

12 studies did not pass quality criteria (QC): QC1=1, QC2=2, QC3=7, QC4=2

Studies included in the systematic search :
(n=8)

Appendix 1: Table 1 – Summary of Characteristics of included IQ papers

Lead Author (Year)	Type of study	Population	Dataset	Intelligence measure	Dependent variable	Result	Key Covariates
Fletcher[9] (2013)	Econometric Analysis	Men and Women in the USA	National Longitudinal Study of Adolescent Health (Add Health)	Peabody Picture Vocabulary Test (PPVT)	Log of annual earnings	IQ has no effect on earnings	Academic achievement, age, race, popularity, years of education, and personality
Lutter[4] (2000)	Revealed Preference	Parents deciding on chelation therapy for their children in the USA	Agee and Crocker (1996) data	N/A	N/A	A willingness to pay of between $1,100 and $1,900 per IQ point gained for child	N/A
Mueller[7] (2006)	Econometric Analysis	Men and Women in Wisconsin, USA	Wisconsin Longitudinal Study of Social and Psychological Factors in Aspiration and Attainment (WLS)	Henmon-Nelson Test of Mental Ability	Log hourly wages	An increase of 0·69% and 0·48% in earnings per additional IQ point for men and women respectively	Personality traits
Salkever[11] (1995)	Cost Benefit Analysis	Men and Women in the USA	National Longitudinal Survey of Youth 1979 (NLSY79)	Armed Forces Qualifications Test (AFQT)	Log of annual earnings	An increase of 2·09% for men and 3·63% for women in earnings per additional IQ point	N/A
Schwartz[10] (1994)	Cost Benefit Analysis	Men and Women in the USA	National Longitudinal Survey of Youth 1979 (NLSY79)	Armed Forces Qualifications Test (AFQT)	Log of annual earnings	An increase of 1·76% in earnings per additional IQ point	N/A
de Wolff[5] (1973)	Econometric Analysis	Men and Women in Sweden	Malmö Longitudinal Study	Swedish Military IQ test	Log of annual earnings	An increase of 0·4% of earnings per additional IQ point	Social Class, Educational Performance, and Civil Status.
Zax[6] (2002)	Econometric Analysis	Men in Wisconsin, USA	Wisconsin Longitudinal Study of Social and Psychological Factors in Aspiration and Attainment (WLS)	Henmon-Nelson Test of Mental Ability	Log of earnings when subjects aged 35 and log of earnings when subjects aged 53	An increase of 0·75% for 35 year olds and 1·40% for 53 year olds in earnings per additional IQ point	None
Zagorsky[8] (2007)	Econometric Analysis	Men and Women in USA	National Longitudinal Survey of Youth 1979 (NLSY79)	Armed Forces Qualifications Test (AFQT)	Annual household income	An increase of $202 to $616 in annual household income per additional IQ point	Age, race, net worth, non-cognitive ability and education

Appendix 2: List of Sensitivity Analysis scenarios for the iodine supplementation model

This appendix describes the sensitivity analysis scenarios employed to assess the stability of base case results. We performed a total 21 univariate sensitivity analyses where we changed one variable at a time across the two different perspectives to evaluate its impact on the model.

1. Sensitivity Analysis related to IQ gain

As the IQ gain for the children whose mothers would have been iodine deficient without supplementation is likely to vary, we carried out three separate sensitivity analysis scenarios. This was also done to relax the assumption of perfect adherence to iodine supplementation.

(i) We reduced the IQ point gain for the children of severely iodine deficient expectant mothers in the iodine supplementation strategy to be the same IQ gain experienced by the children of mildly/moderately iodine deficient mothers;

(ii) We reduced the IQ gain from iodine supplementation to a single IQ point for children of iodine deficient mothers; and

(iii) We assumed no IQ gain for children of mildly / moderately iodine deficient mothers.

2. Sensitivity Analysis related to Iodine Supplementation

The uncertainty around the prevalence of iodine deficiency in pregnant women and the cost of supplementation was arbitrarily tested by:

(iv) halving the prevalence of iodine deficient pregnant women.

(v) doubling the baseline early pregnancy loss.

(vi) doubling the cost of iodine tablets

(vii) doubling the discount rate. Increasing the discount rate reduces the value of benefits and costs that accrue in the future.

(viii) removing the assumption of thyroid dysfunction being caused by supplementation. This was done as there is no evidence of thyroid dysfunction caused by iodine supplementation in pregnant women.[1]

(ix) halving the health cost savings from IQ gains for Analysis 1 (Health Service perspective) only.

Changes in Analysis 2 (societal perspective) only:

In terms of the monetary value of an IQ point, a lower estimate was investigated by:

(x) halving the earnings benefit per IQ point gain.

(xi) modifying an assumption to allow for no real wage growth. Real wage growth in the UK in the 2000's increased by 1·2% on average annually but this trend has reversed and since the first three months of 2010, real wage growth has fallen by 2·2% per annum.[2]

(xii) substituting an updated willingness to pay figure identified in the systematic search (see Appendix 1). This was done to allay any concerns about using earnings as a basis for the value of an IQ point.

(xiii) excluding public sector costs savings.

References

1. European Commission. Opinion of the Scientific Committee on Food on the tolerable upper intake level of iodine. Bruxelles: European Commission. 2002.

2. Office of National Statistics. An Examination of Falling Real Wages 2010 - 2013. 2014. Available from: http://www.ons.gov.uk/ons/rel/elmr/an-examination-of-falling-real-wages/2010-to-2013/art-an-examination-of-falling-real-wages.html.

Appendix 3: Reduction in children in the lower IQ categories

The benefits in increasing IQ in the model come largely from the health and education savings arising from fewer children in the lower IQ categories. Below are the steps we took to calculate how many fewer children would be in the lower IQ categories as result of the iodine supplementation strategy.

We assume IQ follows the conventional normal distribution with a mean of 100 and the standard deviation of 15. To calculate the proportion of a child in an IQ category, we use Z scores.

The Z score of being in the IQ category of 70 and below: $\frac{(70-100)}{15} = -2.00$

A Z score of -2.00 corresponds to a probability of 2·28%

The Z score of being in the IQ category of 81 and below: $\frac{(81-100)}{15} = -1·2\dot{6}$

A Z score of -1·2$\dot{6}$ corresponds to a probability of 10·26%

The Z score of being in the IQ category of 92 and below: $\frac{(92-100)}{15} = -0·5\dot{3}$

A Z score of -0·5$\dot{3}$ corresponds to a probability of 29·69%

An increase of IQ as a result of iodine supplementation for the mildly/moderately iodine deficient expectant women is assumed to be 2·2 IQ points. This raises the mean IQ from 100 to 102·2.

The Z score of being in the IQ category of 70 and below: $\frac{(70-102·2)}{15} = -2·15$

A Z score of -2·15 corresponds to a probability of 1·59%

The Z score of being in the IQ category of 81 and below: $\frac{(81-102·2)}{15} = -1·41$

A Z score of -1·41 corresponds to a probability of 7·88%

The Z score of being in the IQ category of 92 and below: $\frac{(92-102·2)}{15} = -0·68$

A Z score of -0·68 corresponds to a probability of 24·83%

The reduction of children in the lower IQ categories as a result of iodine supplementation for the mildly/moderately iodine deficient expectant women are as follows:

The probability of being in the IQ category of 70 and below is reduced by 0·69% (2·28%-1·59%).

The probability of being in the IQ category of 81 and below is reduced by 2·38% (10·26%-7·88%).

The probability of being in the IQ category of 92 and below is reduced by 4·86% (29·69%-24·83%).

The probability of being in the 71to 81 IQ category is the probability of being in the IQ category of 81 and below minus the probability of being in the IQ category of 70 and below. The reduced probability of being in the 71to 81 IQ category is 1·69% (2·38%-0·69%).

The probability of being in the 82 to 92 IQ category is the probability of being in the IQ category of 92 and below minus the probability of being in the IQ category of 81 and below. The reduced probability of being in the 82 to 92 IQ category is 2·48% (4·86%-2·38%).

These calculations were also done in the model for the severely iodine deficient IQ gain of 3·0 and the IQ loss of 7 from hypothyroidism induced by iodine supplementation.