



Straub, N., Grunert, P., Northstone, K., & Emmett, P. (2019).  
Economic impact of breast-feeding-associated improvements of  
childhood cognitive development, based on data from the ALSPAC.  
*British Journal of Nutrition*, 122(s1), S16-S21.  
<https://doi.org/10.1017/S0007114515001233>

Publisher's PDF, also known as Version of record

License (if available):  
CC BY

Link to published version (if available):  
[10.1017/S0007114515001233](https://doi.org/10.1017/S0007114515001233)

[Link to publication record in Explore Bristol Research](#)  
PDF-document

This is the final published version of the article (version of record). It first appeared online via Cambridge University Press at <https://www.cambridge.org/core/journals/british-journal-of-nutrition/article/economic-impact-of-breastfeeding-associated-improvements-of-childhood-cognitive-development-based-on-data-from-the-alspac/28B08119F7691429030CFBF09A5F6A6B> . Please refer to any applicable terms of use of the publisher.

## University of Bristol - Explore Bristol Research

### General rights

This document is made available in accordance with publisher policies. Please cite only the published version using the reference above. Full terms of use are available:  
<http://www.bristol.ac.uk/red/research-policy/pure/user-guides/ebr-terms/>



## Economic impact of breast-feeding-associated improvements of childhood cognitive development, based on data from the ALSPAC

Niels Straub<sup>1\*</sup>, Philipp Grunert<sup>1</sup>, Kate Northstone<sup>2</sup> and Pauline Emmett<sup>2</sup>

<sup>1</sup>*Institute for Market Research, Strategy and Planning, Munich D-80639, Germany*

<sup>2</sup>*University of Bristol, School of Social and Community Medicine, Oakfield House, Oakfield Grove, Bristol, BS8 2BN, UK*

(Submitted 11 August 2014 – Final revision received 16 March 2015 – Accepted 19 March 2015 – First published online 22 January 2016)

### Abstract

The aim of this study was to assess the economic benefits of improved cognitive development related to being breast-fed. Breast-feeding rates were assessed in the Avon Longitudinal Study of Parents and Children. Educational attainment was assessed at age 16 years with higher attainment defined as gaining five General Certificate of Secondary Education (GCSE) passes at a high grade. The economic benefit of being breast-fed was calculated in a decision model using a child's educational attainment and the corresponding expected value of average income in later life. There was a positive association between being breast-fed and achieving higher educational attainment, which remained significant, after adjustment for possible confounders: being breast-fed <6 months yielded an OR of 1.30 (95% CI 1.13, 1.51) and for ≥6 months yielded an OR of 1.72 (95% CI 1.46, 2.05), compared with never breast-fed children. On the basis of UK income statistics, the present value of lifetime gross income was calculated to be £67 500 higher for children achieving 5 high-grade GCSE passes compared with not achieving this. Therefore, the economic benefit of being breast-fed <6 months would be £4208 and that for ≥6 months would be £8799/child. The model shows that the increased educational attainment associated with being breast-fed has a positive economic benefit for society, even from small improvements in breast-feeding rates. Within a total UK birth cohort of 800 000/year an increase by 1% in breast-feeding rates would be worth >£33.6 million over the working life of the cohort. Therefore, breast-feeding promotion is likely to be highly cost-effective and policymakers should take this into consideration.

**Key words:** Breast-feeding; Cognitive development; Health economic model; ALSPAC

It is well established that infant nutrition can have a programming effect on human health in later life<sup>(1)</sup>. In particular, the beneficial effects of being breast-fed on the child's later health status have been known for some time. Organisations like WHO, UNICEF and many national health agencies recommend exclusive breast-feeding as the best type of infant nutrition for the first 4–6 months of life. Besides the improvements relating to blood cholesterol, blood pressure and obesity risk in later life<sup>(2–5)</sup>, one of the most widely known effects of being breast-fed is improved cognitive development<sup>(6)</sup>. Several observational studies and one randomised trial<sup>(7)</sup> have shown a strong association of breast-feeding with full-scale IQ, with breast-fed children scoring up to five points higher on average; the results have been consistently confirmed in several meta-analyses<sup>(8–10)</sup>. There is still some controversy as to whether these beneficial effects result from the properties of breast-feeding itself, or whether there are other social or genetic factors between mother and child that contribute to increased intellectual development.

It has been suggested that the supply of long-chain PUFA (LCPUFA), particularly DHA and arachidonic (AA) acids, in breast milk is responsible for optimum fetal neurodevelopment. The effect of these LCPUFA has been tested in trials with supplemented formula in comparison with standard infant formula and showed mixed results<sup>(11,12)</sup>.

Theory and research show that infant nutrition plays a major role in cognitive development in early childhood and that this effect continues at school age and has an impact on academic performance and productivity in later life<sup>(13–16)</sup>. Therefore, early nutrition is likely to have both social and economic importance over the life course. Many programmes have been implemented to improve education systems and learning conditions in schools, but little effort has been made to improve the nutritional status of infants and preschool children despite the consistent associations that have been demonstrated between early nutrition and cognitive development. It has been shown that early childhood nutrition programmes can help to improve

**Disclaimer:** This paper was published as part of a supplement to British Journal of Nutrition, publication of which was supported partially by UNILEVER, NUTRIMENTHE EU Project and an unrestricted educational grant from the University of Granada. The papers included in this supplement were invited by the Guest Editor and have undergone the standard journal formal review process. They may be cited.

**Abbreviations:** ALSPAC, Avon Longitudinal Study of Parents and Children; GCSE, General Certificate of Secondary Education; KS, Key Stage.

\* **Corresponding author:** N. Straub, fax +49-89-9789 1045, email [straub@imsp.de](mailto:straub@imsp.de)

child health status, and later educational performance at school, and therefore gain a positive cost–benefit factor<sup>(17–19)</sup>. Data from the most recent publication of the Organisation for Economic Co-Operation and Development (OECD)<sup>(20)</sup> on the distribution of income and educational attainment in industrialised countries show a clear association between school attainment and later income. The higher the educational attainment, the higher the percentage of people with earnings above the median. Below the upper secondary education attainment level, the percentage of people earning less than the median income is >70% and almost every fourth person receives less than half of the median income.

To assess the economic impact of infant nutrition-related improvements in cognitive development and child's later school performance, health economic model calculations showed a great potential benefit for society<sup>(21)</sup>. In this study we have used data from the Avon Longitudinal Study of Parents and Children (ALSPAC) to assess the effect of infant nutrition on the educational attainment of the cohort at age 16 years and to estimate the possible later economic impact of infant nutrition as predicted by a modified economic model calculation.

## Methods

### Study population

ALSPAC is an ongoing population-based study designed to investigate the effects of environmental, genetic and other influences on the health and development of children<sup>(22)</sup>. Eligible participants were pregnant women resident in the former Avon health authority in South West England who were expected to deliver between April 1991 and December 1992. A cohort of 14 541 pregnant women were recruited, resulting in 13 988 children (alive at 12 months). Self-completion questionnaires were administered to the mothers during pregnancy and at various ages of the child. Infant feeding was assessed by parental-completion postal questionnaires when the child was 6 and 15 months of age, which covered the use of infant formula and duration of breast-feeding as well as the age at which other drinks and solids were introduced. The questionnaire answers were verified in a sub-sample of the infants (*n* 1000) whose parents recorded everything they consumed in a 24-h period at 4 months of age. Copies of the questionnaires are available at the ALSPAC website <http://www.bristol.ac.uk/alspac/researchers/resources-available/data-details/questionnaires>. Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committees. The study website contains details of all the data that are available through a fully searchable data dictionary: <http://www.bris.ac.uk/alspac/researchers/data-access/data-dictionary/>

### Outcome variable: school attainment

In the UK, all children are assessed for their attainment of the set criteria at each age or Key Stage (KS) of education. KS scores obtained from the relevant education authorities in the National Pupil Database (NPD) were matched to the ALSPAC child

cohort. We used the KS4 results, administered as General Certificate of Secondary Education (GCSE) when children are 15–16 years of age, to assess school attainment. GCSE are available in more than forty academic and nine 'applied' subjects. GCSE are graded A\*–G and U (unclassified): In the ALSPAC cohort GCSE scores were available for 10 107 children. As a threshold for the classification of attainment, we applied the commonly used benchmark of achieving five or more GCSE at grades A\*–C, including maths and English.

### Statistical methods

School attainment, as the binary outcome variable, and the type of infant feeding used (breast milk or formula) are both influenced by a number of socio-economic, demographic and lifestyle factors. Possible confounders or mediators relating to the mother that were considered included maternal age, maternal education, maternal smoking and maternal life events and those relating to the child included whether the child was a single or multiple birth, sex and ethnicity, birth weight and the number of siblings at birth (see Table 1). The majority of these factors differed strongly between the two educational attainment groups and were controlled for in the analysis to attempt to remove confounding bias.

To assess the effect of breast-feeding on the outcome variable, the association was tested by calculating the OR of two groups of breast-fed children (up to 6 months, and 6 months or more of breast-feeding duration) compared with never breast-fed children.

### Model design

The economic decision model was developed, using the special decision analysis software TreeAge Pro 2012 (TreeAge Software Inc.), to calculate the economic impact in terms of later lifetime income. The Model analyses the expected economic outcome related to the choice of infant feeding method, comparing upper and lower educational attainment and their resulting average income in later life (micro-economic approach). Because of data availability the model had to be limited to the two measured school attainment levels (achieving five GCSE at grade A\*–C compared with not achieving this) without stratification for sex- or age-specific data.

The model's structural design is shown in Fig. 1. It consists of a decision tree with an assumed effective nutritional intervention at the beginning and the subsequent strategy paths to the two different educational attainment levels and the corresponding yearly income, allocated with the associated probabilities. The duration of this complete process is divided into equal intervals, so-called cycles, reflecting 1 year. The time component is built into the model, as every path has its economic outcome for the different years. The model reflects the human lifecycle, where a person passes a decision path with a certain probability and gets a specific economic outcome for each year of life. In the present model, a person after having failed or achieved the relevant attainment level can go on with further secondary/tertiary education or start working. After finishing the education phase in the years of

**Table 1.** Distribution of potential confounding/mediating factors between children not achieving and those achieving five or more General Certificates of Secondary Education (GCSE) at grade C or above (Numbers and percentages)

	<5 GCSE*, Grade C or above (49.7 %)		At least 5 GCSE*, Grade C or above (50.3 %)	
	<i>n</i>	%	<i>n</i>	%
<b>Sex</b>				
Male (50.5 %)	3383	55.6	2797	45.5
Female (49.5 %)	2698	44.4	3354	54.5
$\chi^2 = 126.3$ ( $P < 0.0001$ )				
<b>Maternal age</b>				
<20 (9.4 %)	736	12.1	418	6.8
20–29 (56.1 %)	3709	61.0	3152	51.2
30+ (34.5 %)	1636	26.9	2581	42.0
$\chi^2 = 344.2$ ( $P < 0.0001$ )				
<b>Maternal education</b>				
Low (31.6 %)	2232	45.7	1037	18.9
Medium (36.0 %)	1758	36.0	1969	36.0
High (32.5 %)	893	18.3	2468	45.1
$\chi^2 = 1156.9$ ( $P < 0.0001$ )				
<b>Housing</b>				
Owner/occupied (76.5 %)	3265	64.7	4779	87.4
Council/housing association (16.8 %)	1385	27.5	386	7.1
Rented/other (6.7 %)	394	7.8	306	5.6
$\chi^2 = 843.6$ ( $P < 0.0001$ )				
<b>Maternal life events</b>				
None (31.5 %)	909	30.4	1366	32.4
1 (30.9 %)	909	30.4	1321	31.3
2 (20.0 %)	604	20.2	836	19.8
3+ (17.6 %)	572	19.1	699	16.6
$\chi^2 = 9.28$ ( $P = 0.026$ )				
<b>Birth weight</b>				
<2500 g (11.1 %)	716	11.8	647	10.5
≥2500 g (88.9 %)	5365	88.2	5504	89.5
$\chi^2 = 4.87$ ( $P = 0.027$ )				
<b>Gestation</b>				
<37 weeks (6.2 %)	390	6.8	328	5.6
37+ weeks (93.8 %)	5375	93.2	5523	94.4
$\chi^2 = 6.73$ ( $P = 0.009$ )				
<b>Maternal smoking</b>				
None (74.9 %)	3537	66.9	4678	82.4
Some (25.1 %)	1753	33.1	1001	17.6
$\chi^2 = 350.5$ ( $P < 0.0001$ )				
<b>Parity</b>				
0 (44.1 %)	2075	40.1	2674	47.7
1 (35.5 %)	1820	35.1	2010	35.9
2+ (20.4 %)	1284	24.8	917	16.4
$\chi^2 = 129.9$ ( $P < 0.0001$ )				

\* GCSE are graded A\* (highest value) to G (lowest value).

working life following, a corresponding economic outcome is received every year. From the point of view of society the economic benefit is contributed in the form of individual net income and social benefits (income tax and social security contributions).

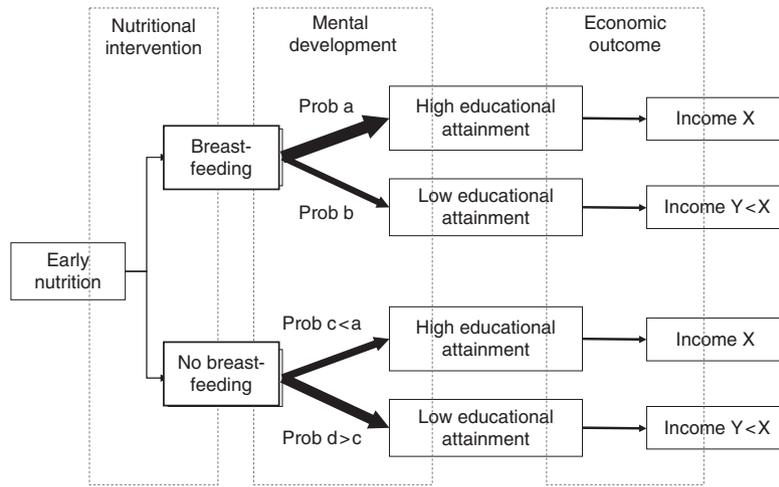
As a result of the analysis, the expected average income values for the different model paths are calculated, and, given the implicit assumptions, a clear monetary statement on the potential economic benefit of a nutritional intervention and its assumed effect on educational achievements can be made.

#### Assessment of economical costs and benefits

The model was designed for the economic analysis from the societal point of view to compare the resulting economic

benefits with possible public intervention costs – for example, for promoting breast-feeding as the most favourable nutrition strategy.

The most important cost factor for the economic analysis is the expenditure on educating a person that has to be included in the model calculations. As we are analysing the impact of different educational attainment levels at age 16 years, the costs for education up to this stage are supposed to be the same, whether or not the high attainment level is achieved. Therefore, the difference in educational costs is only assessed after completion of KS4 (with GCSE), and the costs for the different types of continuing education (sixth form, college and university) have to be taken into account as well as the fact that students with higher educational attainment at age 16 years tend to have more years of continuing education. The yearly



**Fig. 1.** Structure of the decision model. The figure shows the simplified structure of the decision tree, starting on the left with the decision between the two infant feeding alternatives breast-feeding (top branch) and bottle feeding (bottom branch). The arrows in each branch represent the associated mental development status with its specific probabilities and the subsequent later economic outcome.

expenditure for the different educational institutions per student and the average years of education for the different attainment levels were taken from the OECD statistical database on education<sup>(20)</sup> and implemented in the developed model, according to the corresponding model stages.

On the economic outcome side of the model, higher educational attainment is associated with an increased chance of a better-paid job, hence a higher income from working life<sup>(23,24)</sup>. The economic impact of improved educational skills will not be realised until the students move into the labour force. Because of their average longer duration of continuing education, students with higher attainment levels start later in the working process. Therefore, the age-specific income data had to be implemented into the different model paths. As we are analysing the economic effect from the societal point of view, not only does the individual's net income need to be assessed but also the employee's income tax payments and social security contributions have to be taken into account. These three factors are combined into the gross income, which reflects the societal economical benefit generated by the employee's working productivity (micro-economic approach of economic growth).

Finally, because economic costs and benefits accumulate at varying times into the future, it is important to recognise that more immediate benefits are both more valuable and more certain than those far in the future. In order to incorporate this, the entire future costs and benefits in the model are converted into a discounted present value. In our model we used the commonly accepted rate of 5%/annum for discounting the future income<sup>(25)</sup>. Hence, this calculation of present discount values allows a relevant comparison for the different paths in the model.

## Results

### Association of breast-feeding with school attainment

The association between breast-feeding and school attainment at KS4 was assessed (Table 2). Unadjusted analysis showed an almost 2-fold higher chance of a child achieving five GCSE at a

high grade if breast-fed for up to 6 months and a 3.5-fold higher chance if breast-fed for 6 months or more compared with never being breast-fed. After adjustment for the confounders listed in Table 1, the effect size was attenuated but there was still evidence of a beneficial effect of breast-feeding: an OR of 1.30 (95% CI 1.13, 1.50) for <6 months and an OR of 1.72 (95% CI 1.46, 2.05) for ≥6 months of breast-feeding. We also tested the possible additional effect of maternal intake of *n*-3 long-chain fatty acids in pregnancy, but the effect sizes were unchanged by adjustment for maternal fish consumption as an indicator for intake of these fatty acids (Table 2).

### Calculation of individual lifetime income

The model and its imputed data on the economic outcome for the different educational attainment levels were used to calculate the stratified individual lifetime income, expressed as amount of Great Britain Pound at its present value for the year 2012. The calculated income in later working life is based on the current nominal income data for the UK. This individual gross income consists of net income, income tax payments and individual social security contributions, with time-dependent varying income data with each model cycle. The income is calculated until the age of 65 years and subsequent pension payments are disregarded, as they have to be generated by the productive working population at that time.

Using the data from the UK labour force survey and income statistics<sup>(23)</sup> for our model calculation, the current value of lifetime income for children achieving the attainment threshold of five GCSE at grades A\*–C was calculated to be £67 535 higher than for children not obtaining these grades (Table 3). The difference between the calculated lifetime incomes of the two educational attainment groups represents the net benefit for the society from improved educational attainment.

Table 4 shows the expected benefit of being breast-fed to the lifetime income of ALSPAC children. In the present model the expected lifetime income was calculated to be on average £4208 higher for children who were breast-fed for up to

**Table 2.** Associations between breast-feeding duration and having five or more General Certificates of Secondary Education (GCSE) grades at grade C or above, including maths and English (Odds ratios and confidence intervals)

	Unadjusted ( <i>n</i> 10 107)		Adjusted for typical confounders* ( <i>n</i> 6223)		Additional adjustment for maternal fish intake ( <i>n</i> 6075)	
	OR	95 % CI	OR	95 % CI	OR	95 % CI
Child breast-fed						
Never (26.2 %)	1.00		1.00		1.00	
<6 months (45.0 %)	1.92	1.74, 2.13	1.30	1.13, 1.50	1.30	1.13, 1.51
6+ months (28.8 %)	3.48	3.10, 3.90	1.72	1.46, 2.05	1.71	1.45, 2.01
<i>P</i>	<0.0001		<0.0001		<0.0001	

\* Adjusted for sex, maternal age, maternal education, housing, maternal life events, birth weight, gestation, maternal smoking and parity

**Table 3.** Lifetime income calculation

Educational attainment	Expected average lifetime income discounted to present value (£)
5 or more GCSE at grade A*–C	516 433
<5 GCSE at grade A*–C	448 898
Difference	67 535

GCSE, General Certificates of Secondary Education.

**Table 4.** Income effect of breast-feeding (95 % confidence intervals)

	95 % CI	
Expected lifetime income per child (never breast-fed)	£473 255	
Adjusted OR 1.30 for breast-feeding <6 months		
Expected lifetime income per child	£477 463	475 193, 479 962
Benefit per child	£4208	1938, 6708
Adjusted OR 1.71 for breast-feeding 6+ months		
Expected lifetime income per child	£482 054	479 274, 484 782
Benefit per child	£8799	6019, 11 528

6 months compared with never breast-fed children. For those breast-fed for 6 months or more the average expected lifetime income is increased by £8799.

## Discussion

Although there is still a debate about which components of breast-feeding can be claimed to be responsible for improving child cognitive development, the analysis of ALSPAC data showed a positive effect of being breast-fed on educational attainment at the age of 15/16 years, which remained after adjustment for socio-economic confounders. Such results confirm the long-term programming effect of early nutrition. This combined with the well-established association between educational achievements and later individual and societal economic benefits suggests that being breast-fed has a net-positive economic benefit; we have quantified this at current UK monetary values. The present model calculation shows that the economic benefit of improving childhood cognitive skills by breast-feeding (<6 months) was an increase in

expected lifetime income of £4200 (approximately €5000) per child. Breast-feeding for 6 months or more was more than double at £8800 (approximately €10 000). This relatively small benefit per child could have a great economic impact for society even with only a small increase in the breast-feeding rate among mothers. In the ALSPAC cohort with approximately 10 000 children, with 26 % of them being never breast-fed, a reduction of non-breast-feeding by only 1 % would generate a total economic benefit of >£400 000 (approximately €500 000). Transferring this to a total UK birth cohort of approximately 800 000 children/year, the 1 % increase in the breast-feeding rate would generate a gain of >£33 million (€40 million) over the working lifetime of the cohort.

There are some limitations in the present model calculations, which warrant discussion. The present analysis was developed to reduce the various complex relationships and correlations that occur in reality to a well-structured model that considers only a few relevant economic effects. The design of the decision model is highly simplified and should therefore be examined critically. One of the model's main simplifications is the differentiation between only two levels of educational attainment. In reality there is much greater variation in educational attainment within a population, but this is a recognised dichotomy in the UK (e.g. for entry into further education courses). At the time of this study, KS4 was the latest available educational outcome and therefore this model simplification was inevitable. It is important to emphasise that this limitation is likely to underestimate the real economic impact. With a more detailed range of educational outcomes (such as further and higher education), the economic benefits of achieving a higher attainment resulting in increased expected income would tend to be higher than in the present model with only one threshold.

Furthermore, we have not considered sex-related differences in educational achievements; this maybe important for the expected lifetime income as there may be fewer average working years of females because of maternal child care. These effects had to be disregarded because of the limited availability of relevant data. Other effects of increased educational attainment not considered in this model are the decreased risk of unemployment and the increase in public spending needed for increased education infrastructure. Like every other economic model, the present analysis cannot represent the reality in detail, but it attempts to reflect the main effects and their resulting consequences.

On the basis of these findings, any publicly financed breast-feeding promotion activity that achieved an increase in breast-feeding rates would be highly cost-effective and should be supported. Furthermore, it is important to point out that any additional positive health benefit of improved early nutrition due to breast-feeding is likely to bring additional economic benefit for the individual and society<sup>(26)</sup>. Hence, the current analysis of the economic impact from breast-feeding of improved mental development will be an underestimate of the real benefit that can be gained.

### Acknowledgements

The authors are extremely grateful to all the families who took part in ALSPAC, the midwives for their help in recruiting them, and the whole ALSPAC team, which includes interviewers, computer and laboratory technicians, clerical workers, research scientists, volunteers, managers, receptionists and nurses.

The studies reported herein have been carried out with partial financial support from the Commission of the European Community, specific to its 7th Framework Programme (FP7/2008–2013) under grant agreement no. 212652 'The Effect of Diet on the Mental Performance of Children (NUTRIMENTHE)'. This manuscript does not necessarily reflect the views of the Commission and in no way anticipates the future policy in this area. The UK Medical Research Council and the Wellcome Trust (grant ref: 092731) and the University of Bristol provide core support for ALSPAC.

This publication is the work of the authors, and P. E. serves as guarantor for the contents of this paper. N. S.: conception and design of the analysis and first and final draft of the manuscript; P. G.: performance of statistical analyses of economic data; K. N.: performance of statistical analyses of the ALSPAC data and reviewed the manuscript; P. E.: initiated the analysis, critically reviewed and revised the manuscript.

There are no conflicts of interest.

### References

- Koletzko B, Decsi T, Molnar D *et al.*, (editors) (2009) *Early Nutrition Programming and Health Outcomes in Later Life: Obesity and Beyond*. New York: Springer. *Adv Exp Med Biol*; 646, 1–196.
- Owen C, Martin R, Whincup P, *et al.* (2005) Effect of infant feeding on the risk of obesity across the life course: a quantitative review of published evidence. *Pediatrics* **115**, 1367–1377.
- Martin R, Gunnell D & Davey Smith G (2005) Breastfeeding in infancy and blood pressure in later life: systematic review and meta-analysis. *Am J Epidemiol* **161**, 15–26.
- Arenz S, Ruckerl R, Koletzko B, *et al.* (2004) Breast-feeding and childhood obesity – a systematic review. *Int J Obes Relat Metab Disord* **28**, 1247–1256.
- Dewey KG (1998) Growth characteristics of breast-fed compared to formula-fed infants. *Biol Neonate* **74**, 94–105.
- Hodkinson P, Tappin D & Wright C (2008) Breast feeding. *BMJ* **336**, 881–887.
- Kramer MS, Aboud F, Mironova E, *et al.* (2008) Breastfeeding and child cognitive development: new evidence from a large randomized trial. *Arch Gen Psychiatry* **65**, 578–584.
- Anderson JW, Johnstone BM & Remley DT (1999) Breast-feeding and cognitive development: a meta-analysis. *Am J Clin Nutr* **70**, 525–535.
- Der G, Batty D & Deary IJ (2006) Effect of breast feeding on intelligence in children: prospective study, sibling pairs analysis, and meta-analysis. *BMJ* **333**, 945.
- Horta BL, Bahl R, Martines JC, *et al.* (2007) *Evidence on the Long-term Effects of Breastfeeding: Systematic Reviews and Meta-Analyses*. Geneva: WHO.
- Hibbeln JR, Davis JM, Steer C, *et al.* (2007) Maternal seafood consumption in pregnancy and neurodevelopmental outcomes in childhood (ALSPAC study): an observational cohort study. *Lancet* **369**, 578–585.
- Beyerlein A, Hadders-Algra M, Kennedy K, *et al.* (2010) Infant formula supplementation with long-chain polyunsaturated fatty acids has no effect on Bayley developmental scores at 18 months of age – IPD meta-analysis of 4 large clinical trials. *J Pediatr Gastroenterol Nutr* **50**, 79–84.
- Feinstein L (2003) Inequality in the early cognitive development of children in the 1970 cohort. *Economica* **70**, 73–97.
- Lanting CI, Fidler V, Huisman M, *et al.* (1994) Neurological differences between 9-year-old children fed breast-milk or formula-milk as babies. *Lancet* **344**, 1319–1322.
- Richards M, Hardy R & Wadsworth M. (2002) Long-term effects of breastfeeding in a national birth cohort: educational attainment and midlife cognitive function. *Public Health Nutr* **5**, 631–635.
- Horwood L & Fergusson D (1998) Breastfeeding and later cognitive and academic outcomes. *Pediatrics* **101**, E9.
- Feinstein L, Sabates R, Sorhaindo A, *et al.* (2008) Dietary patterns related to attainment in school: the importance of early eating patterns. *J Epidemiol Community Health* **62**, 734–739.
- Behrman JR (1996) The impact of health and nutrition on education. *World Bank Econ Rev* **11**, 23–37.
- Currie J & Thomas D (1999) *Early Test Scores, Socioeconomic Status and Future Outcomes. Working Paper*. Cambridge: National Bureau of Economic Research; No. 6943.
- OECD (2012) *Education at a Glance 2012: OECD Indicators*. OECD Publishing, Paris. DOI: <http://dx.doi.org/10.1787/eag-2012-en> (accessed March 2013).
- Anjos T, Altmäe S, Emmett P, *et al.* (2013) Nutrition and neurodevelopment in children: focus on NUTRIMENTHE project. *Eur J Nutr* **52**, 1825–1842.
- Boyd A, Golding J, Macleod J, *et al.* (2013) Cohort profile: the 'Children of the 90s'—the index offspring of the Avon Longitudinal Study of Parents and Children. *Int J Epidemiol*. **42**, 111–127.
- United Kingdom Office for National Statistics (2012) Labour market statistics. [www.ons.gov.uk/ons/rel/lmac/earnings-by-qualification-in-the-uk/2011/supporting-spread-sheet.xls](http://www.ons.gov.uk/ons/rel/lmac/earnings-by-qualification-in-the-uk/2011/supporting-spread-sheet.xls) (accessed September 2013).
- Gebel M & Pfeiffer F (2010) Educational expansion and its heterogeneous returns for wage workers. *Schmollers Jahrbuch* **130**, 19–42.
- Corso PS & Haddix AC (2003) Time effects. In AC Haddix, SM Teutsch and PA Corso, editors. *Prevention Effectiveness: A Guide to Decision Analysis and Economic Evaluation*, 2nd ed. London: Oxford University Press.
- Renfrew MJ, Pokhrel S, Quigley M, *et al.* (2012) *Preventing disease and saving resources: the potential contribution of increasing breastfeeding rates in the UK*. UNICEF; <http://bura.brunel.ac.uk/handle/2438/10266> (accessed March 2015).