SUMMARY OF THE POTENTIAL COST-EFFECTIVENESS OF MICRONUTRIENT INTERVENTIONS

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Summary

SUMMARY

Micronutrients are substances that are needed only in minuscule amounts but that enable the body to produce enzymes, hormones and other substances essential for proper growth and development. The consequences of their absence can be severe. Iodine, vitamin A and iron are most important in global public health terms; their lack represents a major threat to the health and development of populations the world over, particularly for children and pregnant women in low-income countries.[1]

Mass fortification, in which micronutrients are put into staple foods, appears to be one of the most effective ways to quickly reduce such deficiencies. There are numerous case studies showing fortification apparently improving the nutritional status of a population. Giving What We Can has mainly focused its research on food fortification, but other promising interventions for combating micronutrient malnutrition also exist, though we have not yet looked into them.

It is difficult to quantify the benefits provided by micronutrient fortification, but several groups have tried. We have not yet critiqued their research methods, but present their results. It is suggested that the 'benefit-cost' ratio of food fortification is usually reported at 5 or higher, and in some cases over 20. The reported cost of saving a 'year of healthy life' ranges widely by location and trial, but in many cases falls between $20 and $100 per year of healthy life.

Nonetheless, the quality of evidence on micronutrients, fortification and health is patchy. While all of the claims above seem reasonable, there is reason to be cautious in interpreting the data available.

[1] http://www.who.int/nutrition/topics/micronutrients/en/ [Accessed 04/02/2013]

1 The Illness

1 THE ILLNESS

Iodine Deficiency

- Iodine deficiency is the world's most prevalent, yet easily preventable, cause of brain damage. Serious iodine deficiency during pregnancy can result in stillbirth, spontaneous abortion, and congenital abnormalities such as cretinism, a grave, irreversible form of mental retardation that affects people living in iodine-deficient areas of Africa and Asia. However, of far greater significance is iodine deficiency's less visible, yet pervasive, mental impairment that reduces intellectual capacity at home, in school and at work.[2]

Vitamin A Deficiency

- Vitamin A deficiency is the leading cause of preventable blindness in children and increases the risk of disease and death from severe infections. In pregnant women, vitamin A deficiency causes night blindness and may increase the risk of maternal mortality.[3]

Iron Deficiency

- Iron deficiency is the most common and widespread nutritional disorder in the world. 2 billion people — over 30% of the world's population — are anaemic, many due to iron deficiency, and in resource-poor areas this is frequently exacerbated by infectious diseases. Iron deficiency and anaemia reduce the work capacity of individuals and entire populations, bringing serious economic consequences and obstacles to national development.[4]

[2] http://www.who.int/nutrition/topics/idd/en/ [Accessed 04/02/2013]
[3] http://www.who.int/nutrition/topics/vad/en/ [Accessed 04/02/2013]
[4] http://www.who.int/nutrition/topics/ida/en/ [Accessed 04/02/2013]

2 The Issue of Micronutrients

2 THE ISSUE OF MICRONUTRIENTS

Micronutrient malnutrition (MNM) is a severe global health issue especially common in the developing world, which can lead to increased mortality and morbidity. The Copenhagen Consensus 2008 Challenge Paper on ‘Malnutrition and Hunger’ estimated that maternal and child undernutrition is the underlying cause of 11% of total global DALYs (Disability-Adjusted Life Years), and argued that combating MNM was a crucial step towards achieving Millennium Development Goals for primary education and child mortality.

The World Bank’s “Global Monitoring Report 2012: Food Prices, Nutrition, and the Millennium Development Goals” stated that undernutrition – including MNM – could potentially impact all 8 Millennium Development Goals.

It has also been suggested that micronutrient deficiencies can impact economic productivity, growth and development. For instance, researchers claimed that iron deficiency causes China to lose 3.6% of Gross National Product through reduced productivity[5]

Overall, the Copenhagen Consensus judged that combating malnutrition through micronutrient fortification was one of the highest-return investment opportunities in the world, with estimated cost- benefit ratios ranging from 7.8:1 – 39:1, dependent on the micronutrients used.

The three most important forms of MNM according to WHO’s ‘Role of Food Fortification’ report are iron, vitamin A and iodine deficiency. The WHO states that one in three of the world’s population suffer at least one of these deficiencies[6], with the majority of individuals affected residing in the developing regions. Table 2.1 (from the WHO report, 'The Role of Food Fortification in the Control of Micronutrient Malnutrition’) shows the prevalence of these three deficiencies:

[5] Ma, G., Jin, Y., Li, Y., Zhai, F., Kok, F. J., Jacobsen, E., & Yang, X. (2008). Iron and zinc deficiencies in China: what is a feasible and cost-effective strategy?. Public health nutrition, 11(06), 632-638.

[6] Horton, S., Alderman, H., & Rivera, J. A. (2008). The challenge of hunger and malnutrition. Copenhagen Consensus

Table 2-1 Annualized Costs, Annual Effects and Average Cost-Effectiveness of Iron Deficiency in Four Regions

INTERVENTION	AfrD	AmrB	EurA	SearD
Average Cost-effectiveness	______________	I $ per DALY Averted	_______________	
Iron supplementation				
50%	$30	$487	$15,328	$70
80%	$59	$561	$14,562	$102
95%	$66	$669	$14,359	$115
Iron fortification				
50%	$27	$214	$7,574	$43
80%	$21	$142	$5,589	$32
95%	$20	$134	$5,573	$35

This report did not include data concerning the prevalence of other important deficiencies, such as zinc; it seems the public health implications of other deficiencies are less well understood.

The health impact of micronutrient deficiency are estimated in WHO's "Global Burden of Disease" report: each year, iron-deficiency anaemia results in 25 million DALYs, vitamin A deficiency 18 million DALYs globally and iodine deficiency in 2.5 million DALYs. These figures may underestimate the overall health impact of MNM, because DALY figures usually do not embody small but widespread health effects or effects on cognitive abilities.

Even outside the 'big 3' deficiencies, many micronutrient deficiencies appear to have severe health consequences. Diagram 3.1, constructed using information from the WHO, gives a simplified overview of micronutrient deficiencies and their main health impacts.

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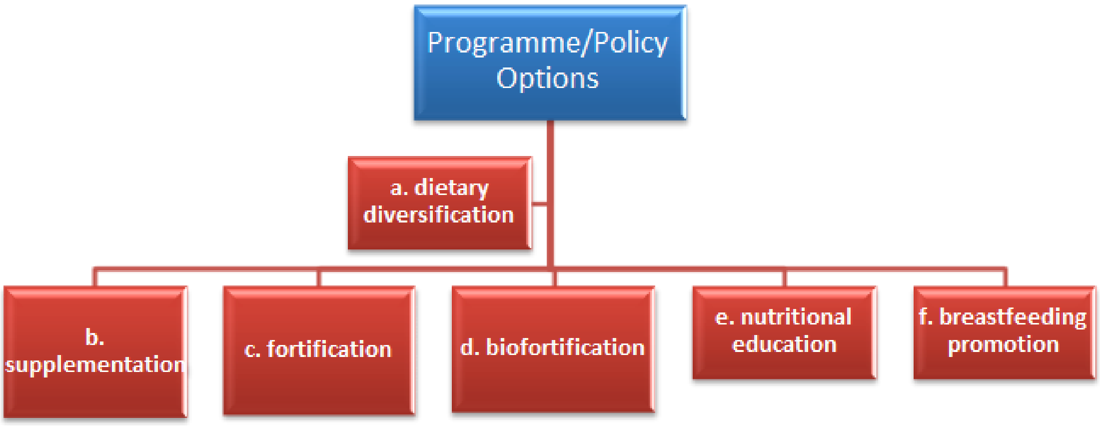
3 Alleviating Micronutrient Malnutrition

3 ALLEVIATING MICRONUTRIENT MALNUTRITION

Diagram 3-1 Alleviating MNM



Dietary diversification (option a. in Diagram 3.1) might be the 'ideal' option for addressing MNM– it entails individuals receiving a varied and healthy diet. However, it would take a long time and enormous cost to implement and reap the benefits of this option.

Options b. – d. are the programmes used, given scarce resources and time pressures. Other policy initiatives in developing countries include options e. and f.

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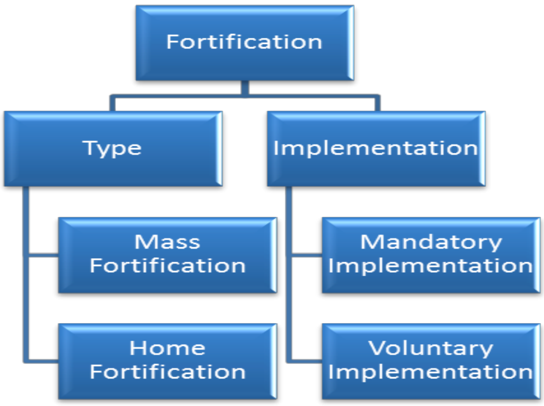
4 What is Fortification?

4 WHAT IS FORTIFICATION?

Fortification is the practice of deliberately increasing the proportion of micronutrients in food, to improve its nutritional quality and thus public health. Referring to Diagram 4.1, fortification can be:

- Mass fortification: Micronutrients are added to foods at the time of processing, in factories or local processing plants (e.g. mills).
- Home fortification: Micronutrients are added to foods at home before or after cooking (e.g. in the form of 'sprinkles').
- Mandatory: Fortification is required by law for minimally-processed staple foods. This is most cost-effective where a large proportion of the population is experiencing MNM.
- Voluntary: It is up to the manufacturer whether to fortify his/her products. This is more common when MNM is less severe, and for non-staple foods.
    - It is important to note here, that even when fortification is mandatory, coverage will not necessarily be 100% of the target population due to reasons such as a weak legal infrastructure, which is the case for many developing countries.

Diagram 4-1 Types & Implementation of Fortification



The most common food fortification policy is that of salt iodization[7]; the latest Global Unified Matrix database states that 55 out of 117 developing countries had legislation enacted for Universal Salt Iodization by 2005 (and additional countries have enacted such legislation since then). Sugar is fortified with vitamin A in most of Central and South America; it is estimated around 95% of households are reached in El Salvador and Guatemala[8] – Darnton-Hill & Nalubola (2002) stating that success of such programmes provided “the impetus for sugar fortification to be explored as an effective intervention strategy in other developing countries”.

[7] http://www.ffinetwork.org/ [Accessed 04/02/2013]
[8] Darnton-Hill, I., & Nalubola, R. (2002). Fortification strategies to meet micronutrient needs: successes and failures. Proceedings of the Nutrition Society, 61(02), 231-241.

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5 How Cost-effective is Food Fortification?

5 HOW COST-EFFECTIVE IS FOOD FORTIFICATION?

In principle, the main advantages of food fortification are as follows[9]

1. Fortification of widely distributed and widely consumed foods has the potential to improve the nutritional status of a large proportion of the population, including rich and poor.
2. Unlike dietary diversification, fortification requires no changes- notoriously difficult to achieve- in existing food consumption patterns.
3. In most countries, the delivery systems for fortified foods are already in place.
4. Several micronutrients can be added to foods simultaneously, without adding substantially to the cost.
5. Most costs can be borne by private bodies (e.g. manufacturers).

a. Does it Work at All?

The Flour Fortification Initiative claims that seventy-five countries worldwide require fortification of one or more types of wheat flour, among them developed, transitional and developing countries[10].

Empirical evidence from several studies suggests fortification can be an effective means of reducing MNM. For example, we have found evidence that:

- Multi-micronutrient fortification led to decreased morbidity from diarrhoea and respiratory diseases, and increased school attendance[11]
- Mandatory salt iodization eradicated goiter in some countries
- Fortification of salt with iron led to reduced anaemia among school children (dropping from
- 16.8% to 7.7% after a period of 10 months in the Indian state of Karnataka)
- Following the distribution of free milk fortified with Vitamin A and D and Iron, the prevalence of anaemia drop from 62.3% to 26.4% in Sao Paulo[12].
- A single or multi micronutrient fortification strategy in milk or cereals reduced risk of suffering anaemia by 50% in 6 month to 5 year olds, in a cross-country study

[9] Horton, S., Mannar, V., & Wesley, A. (2009). Food fortification with iron and iodine. Copenhagen Consensus Center Best Practice Paper. 2008.

[10] World Health Organization. (2006). Guidelines on food fortification with micronutrients. Geneva: World Health Organization.

[11] Best, C., Neufingerl, N., Del Rosso, J. M., Transler, C., van den Briel, T., & Osendarp, S. (2011). Can multi-–micronutrient food fortification improve the micronutrient status, growth, health, and cognition of schoolchildren? A systematic review. Nutrition Reviews, 69(4), 186-204.

[12] Eichler, K., Wieser, S., Rüthemann, I., & Brügger, U. (2012). Effects of micronutrient fortified milk and cereal food for infants and children: a systematic review. BMC public health, 12(1), 506.

However, some micronutrient fortification strategies have proved less effective and cost-effective. An example is the fortification of monosodium glutamate with Vitamin A in Indonesia, which was stopped due to political and technical issues (one of the technical issues was that, even though under laboratory testing the vitamin A remained white, once in the sun the product became discoloured which concerned producers and customers).[13]

And other potential disadvantages exist:

- Fortified foods may not be consumed by all members of the target population. Mass-manufactured fortified foods often don't reach the poorest rural members of the target population, for example, as these are more likely to produce their own food locally.
- There is insufficient evidence so far to rule out the concern that when several nutrients are added to food at once, biochemical reactions reduce their effectiveness. This concern has been raised in research articles[14], as well as by the WHO[15].
- Manufacturers' noncompliance with fortification regulation is a risk, especially in countries with weak legal infrastructure and/or high levels of corruption.
- Little thorough research has been done to estimate the overall health impact of mass fortification on a population. Most studies focus on small sample populations that consist of only infants, school children or breast feeding mothers[16].

b. When it Works, Is it Cost-effective?

Some evidence suggests fortification is one of the most cost-effective strategies to deal with MNM. The Copenhagen 2008 Malnutrition and Hunger Challenge Paper claims that zinc home fortification costs $12.20 per DALY averted, whilst zinc supplementation averts a DALY with each $63. The Copenhagen Consensus 2008 states that iron fortification and salt iodization are the second most cost-effective strategies to cope with micronutrient deficiencies. With Micronutrient supplements for children (vitamin A and zinc) coming first, and biofortification coming third.

[13] Berry, J., Mukherjee, P., & Shastry, G. K. (2012). Taken with a Grain of Salt? Micronutrient Fortification in South Asia. CESifo Economic Studies, 58(2), 422-44

[14] Christian, P., & Tielsch, J. M. (2012). Evidence for multiple micronutrient effects based on randomized controlled trials and meta-analyses in developing countries. The Journal of Nutrition, 142(1), 173S-177S.

[15] World Health Organization. (2006). Guidelines on food fortification with micronutrients. Geneva: World Health Organization.

[16] Bienz, D., Cori, H., & Hornig, D. (2003). Adequate dosing of micronutrients for different age groups in the life cycle. Food & Nutrition Bulletin, 24(Supplement 1), 7S-15S

Cost per Year of Life Gained

The WHO estimates the cost per year of lost life averted by Vitamin A fortification[17]. They take the current death rate for which vitamin A is responsible (deaths due to Vitamin A deficiency per 1000 people), and assume fortification would bring this down to 0. They combine this with information about the cost per 1000 people reached with fortification. Dividing years of lost life averted by cost, they produce an estimate of cost per year of life saved: $18.6. This cost-effectiveness is extremely high.

Benefit: Cost Ratios

The WHO estimates a cost:benefit ratio for iodine fortification of 1:26.5. This is based on the assumption that iodine's unit cost is $0.10, but they highlight that some experts put it as low as $0.01 in some areas of Sub-Saharan Africa (which would change the ratio to 1:265). The estimation assumes that iodine fortification will completely eradicate goitre in an area, which may not be accurate. The costs of iodine deficiency in this model derive from productivity losses of 10% when pregnant mothers have goitre, so are also dependent on the average wage of the country.

The WHO estimates the economic returns to iron fortification (as a result of increased productivity) as $8 for every $1 spent (1:8 cost:benefit ratio), based on fortification costing $0.12 per person, reducing deficiency in 24% of the population, and economically benefiting each person helped by $4 of wages. However, the last figure ($4) is from a model of the Venezuelan economy- we should expect productivity gains to differ by country.

Table 5.1, below, summarizes the Copenhagen 2008 Malnutrition and Hunger Challenge Paper's literature review of the cost-effectiveness of micronutrient fortification programmes. This paper uses benefit:cost ratios, by converting DALYs averted into economic 'equivalents' (see footnote 1).

Table 5-1 Summary of Micronutrient Fortification Benefit: Cost Ratios (CC 2008)

INTERVENTION	COST/PERSON/YEAR	BENEFIT: COST RATIO
Salt iodization	$0.05	30:1
Iron fortification	$0.10-12	7:8:1
Folate	$0.01	12:1 to 39:1

The more recent Copenhagen Consensus 2012 Challenge Paper on Hunger and Malnutrition published the following results (Table 5.2) from a further literature review on the benefit:cost ratio of micronutrient interventions.

[17] Allen, Benoist, Dary and Hurrell (2006). Guidelines on food fortification with micronutrients. Geneva: World Health Organization & Food and Agriculture Organisation.

Table 5-2 Summary of Micronutrient Fortification Benefit:Cost Ratios (CC2012)

MICRONUTRIENT	INTERVENTION	COST PER BENEFICIARY PER YEAR	BENEFIT: COST RATIO (RANGE OF ESTIMATES GIVEN)
Iodine	Salt Iodization	$0.05	15 – 520
Iodine and Iron	Doubly Fortified Salt	$0.25	2 – 5
Iron	Supplements, mothers and children 6-24 months	$0.96	23.8
	Supplements, pregnant mothers	$2.00	8.1 – 140
	Fortification, general	-	6.7 – 9.1
	Fortification of wheat flour	$1.17	9.1
	Home Fortification	$1.20	37
	Biofortification	<$0.01	11.6 – 19
Vitamin A		$0.29	4.3 – 250
Zinc		$1.26	2.85

CC12's estimate for the benefit:cost ratio of salt iodisation is promising, despite the very large range reported. This high benefit:cost ratio was derived from an average impact and cost across all individuals in the population, not just pregnant women or young children.

Cost:benefit ratios for iron fortification in general and of wheat flour in particular are lower than the proposed benefit:cost ratios of iron home fortification and iron biofortification (though the former may still be highly cost-effective).

DALYs/$1000

Sue Horton estimates the cost-effectiveness of mass fortification in terms of DALYs averted per $. Her results are depicted in Diagram 5.3[18]

"Note that the values assigned in the Copenhagen Consensus project areas follows: with a life expectancy of 60 years, a 3% discount rate, and a DALY value of $1000, a life saved (in infancy) is worth around $28,505; the same life saved is worth just $17,131 with a 6% discount rate. The same calculation at a DALY value of $5000 implicitly values a human life saved at birth at $142,525 with a 3% discount rate, and $85, 665 at a 6% discount rate" [Horton, Alderman & Rivera (2008) The challenge of hunger and malnutrition. Copenhagen Consensus.]

[18] *Horton, S. (2006). The economics of food fortification. The Journal of nutrition,136(4), 1068-107*

Diagram 5-3 Horton's Results: Cost-effectiveness of Fortification

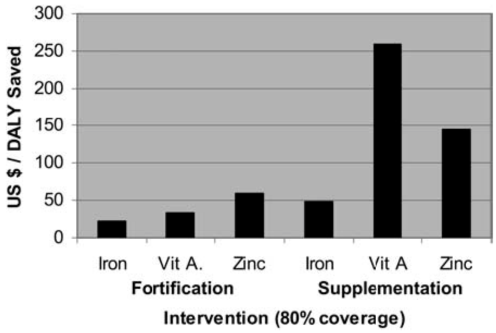

FIGURE 1 Cost per DALY saved, Africa E, micronutrient interventions.

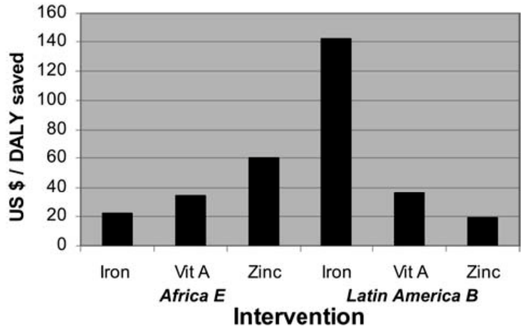

FIGURE 2 Comparison of cost effectiveness of fortification, two regions.

Horten estimates compare the cost-effectiveness of Iron, Vitamin A, and Zinc fortification and supplementation in sample population "Africa E". She estimates that fortification is many times more cost-effective than supplementation. Each form of fortification averts a DALY for less than $60, suggesting high cost-effectiveness. Figure 2 highlights her claim that the cost-effectiveness of fortification varies importantly by region. Table 5.4 summarises the cost-effectiveness ($s/DALY) estimates of several different articles, detailed below.

Table 5-4 Summary of Literature: Cost-effectiveness of Fortification

MICRONUTRIENT FORTIFICATION INTERVENTION	COST-EFFECTIVENESS (1$ per DALY averted*)	SOURCE
Iron fortification in AfrD	59**	(xv)
Iron fortification in SearD	102**	(xiii)
Iron fortification in AmrB	561**	(xiii)
Iron fortification in EurA	14,562**	(xiii)
Folic Acid fortification in Chile	89	(xvi)
Iron fortification in China	66	(xvii)
Zinc fortification in China	153	(xv)

*Costs are expressed in international dollars (I$), 1 I$ has the same purchasing power as 1 US$ has in the USA, costs in local currency units are converted to I$ by use of PPP.
** Assuming 80% coverage, AfrD ,Africa subregion with high rates of adult and child mortality; AmrB, South American subregion with low adult and child mortality; EurA, European subregion with low adult and very low child mortality; SearD, Southeast Asian subregion with high rates of adult and child mortality.

The literature used to compile Table 5.5 makes the following claims about the cost-effectiveness of fortification compared to supplementation:

- Baltussen et al (2004)[19]estimate that iron fortification is more cost-effective than iron supplementation. See Table 1.8 for this study's estimates of the cost-effectiveness of iron fortification and supplementation at different levels of coverage.
- Ma et al (2007)[20] also estimate that iron fortification is more cost-effective than iron supplementation (I$179 per DALY averted) or 'Dietary Diversification' (I$103 per DALY averted).
- Ma et al (2007) estimate that zinc fortification is more cost-effective than supplementation
- (I$399), but less cost-effective than dietary diversification (I$103 per DALY saved).

Table 5-5 **Cost-effectiveness of Iron Fortification and Supplementation at 50% and 95% Coverage Rates**

Annual costs, annual effects and average cost-effectiveness of iron deficiency control in 4 regions

INTERVENTION	AfrD	AmrB	EurA	SearD
Average Cost-effectiveness	---------------------	--------------------------	I$ per DALY Averted	--------------------------
Iron supplementation				
50%	$30	$487	$15,328	$70
80%	$59	$561	$14,562	$102
95%	$66	$669	$14,359	$115
Iron fortification				
50%	$27	$214	$7,574	$43
80%	$21	$142	$5,589	$32
95%	$20	$134	$5,573	$35

Fortification has thus been found to be cost-effective at <$100 per DALY averted in a significant range and proportion of contexts. However, the cost-effectiveness differs several-fold by region and study, meaning that it remains challenging to confidently judge the likely cost-effectiveness of any particular future project.

Some concerns we have about relying on the existing literature are:

- Much if it is written by a small number of researchers.
- Some prominent researchers are also advocates for investment in this area, and may be inclined to overstate the effectiveness of fortification.
- It is hard to aggregate many small effects on health because each is hard to precisely measure; often these are not captured in DALY estimates (leading to under-estimation of cost-effectiveness).

[19] Baltussen, R., Knai, C., & Sharan, M. (2004). Iron fortification and iron supplementation are cost- effective interventions to reduce iron deficiency in four subregions of the world. The Journal of nutrition, 134(10), 2678-2684.
[20] Ma, G., Jin, Y., Li, Y., Zhai, F., Kok, F. J., Jacobsen, E., & Yang, X. (2008). Iron and zinc deficiencies in China: what is a feasible and cost-effective strategy?. Public health nutrition, 11(06), 632-638.

- The effectiveness of fortification varies significantly according to pre-treatment levels of deficiency, making it hard to generalise across time and space.
- Findings of high cost-effectiveness could be due to error, or past 'low-hanging fruit' that have already been 'picked'. This means we shouldn't just take figures at face value and probably need to ‘regress them to the mean’, for reasons explained in more detail elsewhere on our website.

i Ma, G., Jin, Y., Li, Y., Zhai, F., Kok, F. J., Jacobsen, E., & Yang, X. (2008). Iron and zinc deficiencies in China: what is a feasible and cost-effective strategy?. Public health nutrition, 11(06), 632-638.

ii Horton, S., Alderman, H., & Rivera, J. A. (2008). The challenge of hunger and malnutrition. Copenhagen Consensus.

iii http://www.ffinetwork.org/ [Accessed 04/02/2013]

iv Darnton-Hill, I., & Nalubola, R. (2002). Fortification strategies to meet micronutrient needs: sucesses and failures. Proceedings of the Nutrition Society, 61(02), 231-241.

v Horton, S., Mannar, V., & Wesley, A. (2009). Food fortification with iron and iodine. Copenhagen Consensus Center Best Practice Paper. 2008.

vi World Health Organization. (2006). Guidelines on food fortification with micronutrients. Geneva: World Health Organization.

vii Best, C., Neufingerl, N., Del Rosso, J. M., Transler, C., van den Briel, T., & Osendarp, S. (2011). Can multi-°©−micronutrient food fortification improve the micronutrient status, growth, health, and cognition of schoolchildren? A systematic review. Nutrition Reviews, 69(4), 186-204.

viii Berry, J., Mukherjee, P., & Shastry, G. K. (2012). Taken with a Grain of Salt? Micronutrient Fortification in South Asia. CESifo Economic Studies, 58(2), 422-449.

ix Eichler, K., Wieser, S., Rüthemann, I., & Brügger, U. (2012). Effects of micronutrient fortified milk and cereal food for infants and children: a systematic review. BMC public health, 12(1), 506.

x Christian, P., & Tielsch, J. M. (2012). Evidence for multiple micronutrient effects based on randomized controlled trials and meta-analyses in developing countries. The Journal of Nutrition, 142(1), 173S-177S.

xi World Health Organization. (2006). Guidelines on food fortification with micronutrients. Geneva: World Health Organization.

xii Bienz, D., Cori, H., & Hornig, D. (2003). Adequate dosing of micronutrients for different age groups in the life cycle. Food & Nutrition Bulletin, 24(Supplement 1), 7S-15S

xiii Allen, Benoist, Dary and Hurrell (2006). Guidelines on food fortification with micronutrients. Geneva: World Health Organization & Food and Agriculture Organisation.

xiv Horton, S. (2006). The economics of food fortification. The Journal of nutrition,136(4), 1068-107

xv Baltussen, R., Knai, C., & Sharan, M. (2004). Iron fortification and iron supplementation are costeffective interventions to reduce iron deficiency in four subregions of the world. The Journal of nutrition, 134(10), 2678-2684.

xvi Llanos, A., Hertrampf, E., Cortes, F., Pardo, A., Grosse, S. D., & Uauy, R. (2007). Cost-effectiveness of a folic acid fortification program in Chile. Health Policy, 83(2), 295-303.

xvii Ma, G., Jin, Y., Li, Y., Zhai, F., Kok, F. J., Jacobsen, E., & Yang, X. (2008). Iron and zinc deficiencies in China: what is a feasible and cost-effective strategy?. Public health nutrition, 11(06), 632-638.