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IODINE STATUS AND AVAILABILITY OF IODIZED SALT: A CROSS-COUNTRY ANALYSIS

SUE HORTON* AND ALEXANDER MILOFF**

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* Department of Economics, School of Business and Economics, Wilfrid Laurier University. Contact: shorton@wlu.ca

** Research Associate, The Iodine Network, 180 Elgin Street Suite 1000, Ottawa, Ontario.

Abstract

Background: Iodine deficiency has serious consequences, and the Universal Salt Iodization initiative has attempted to reduce the extent of deficiency.

Objective: We aim to see how far cross-country variations in urinary iodine in school-age children can be explained by environmental factors including salt iodization and soil iodine.

Methods: We use simple multivariate regression for two separate datasets, one for 30 developing countries, and one for 13 developed countries, using data on coverage of salt iodization and soil iodine levels.

Results: Median urinary iodine excretion is significantly and positively related to household consumption of iodized salt (elasticity is 0.73) for developing countries, but the soil coefficient is not significant, likely because the dummy variable is not well measured. For the developed countries, there is a positive and significant effect of salt penetration rates (elasticity of 0.83), and a positive and significant effect of soil iodine (elasticity of 0.77). There is also a suggestion that countries with more serious soil deficits, are more likely to iodize salt, such that univariate regressions of urinary iodine excretion on salt consumption or penetration rates underestimate the beneficial effects of iodized salt availability on iodine nutrition.

Conclusions: There are limitations to cross-section (ecologic) studies such as this, and the data are not perfect. Nevertheless, the results provide support for policies to iodize salt, given the widespread deficiency of iodine in diets worldwide.

Key words: salt iodization, iodine deficiency, urinary iodine excretion, soil iodine, regression analysis, cross-country analysis

Although considerable progress has been made in improving iodine status worldwide, particularly with the progress in the Universal Salt Iodization initiative, 1.8 – 2 bn individuals worldwide still have insufficient iodine intake [1,2]. Unlike the case for many other micronutrients, it is often in the industrialized countries (particularly those where iodization of salt is not required), where deficiencies exist.

In the past, goiter rates were used as a key indicator of iodine status and also used to link status with functional outcomes. However, when iodine nutritional status is changing, for example due to public intervention, goiter rates are no longer a good measure since they respond only with a lag, whereas urinary iodine responds immediately [3].

We use data from international databases to examine the relationship between median urinary iodine excretion (UIE) of school-age children with the availability of iodized salt for developing countries (household consumption of iodized salt, HCIS), using a dummy variable to control for soil iodine deficiency. We are able to construct a good database (where the UIE and HCIS data are for the same year) for 30 countries.

We also analyze results for a sample of industrialized countries for which soil iodine data are available, from a database collated by the British Geological Survey (described in [4]). We were able to obtain UIE data for schoolchildren matched within a five year period to salt penetration rates (proportion of table salt produced which is iodized) for 13 industrialized countries, for which soil iodine data were also available.

The next sections discuss in turn our data and methods, results, and conclusions.

Data and Methods

Several previous researchers have noted the positive correlation of UIE with HCIS for developing countries [5, 6, 7, 8]. Our work differs from the previous cross-country analyses of developing countries in that we constructed a consistent dataset for the developing world, retaining only UIE and HCIS data from the same year (in those cases it took more than one year to collect the UIE data, we retained observations only where one of the years overlapped with the year of the HCIS data collection). The WHO database ([9]; described in [10]) contains several hundred observations for different regions, different age groups and different iodine measures (mean, median, % below various cutoffs). Likewise, although the UNICEF database on HCIS [11] contains over 600 observations for developing countries for different years, there were only 30 countries for which matching data are available to form a consistent dataset (data were available for more than one matching year for a subset of 5 countries). It is methodologically preferred to use matching years; urinary iodine levels respond rapidly to adjustments of iodine in the diet and with the move towards Universal Salt Iodization, both UIE and HCIS have been changing in developing countries.

We use median UIE for schoolchildren. Iodine deficiency in children has been correlated with poorer performance on intelligence tests, and in some circumstances interventions have improved scores on cognitive tests [12]. Although "(T)he most serious adverse effect of iodine deficiency is damage to the fetus" ([1]: p3), there were too few data in the WHO database on UIE in pregnant women to use for this study.

Our work also differs from previous work in that we use a dummy variable for environmental iodine deficiency [13] which is in turn constructed from prevalence of goiter prior to program interventions [14]. This is a crude variable only, since some countries have regions of deficiency as well as regions of adequacy, and the larger the country, the more likely the heterogeneity across sub-regions. However, since policy on salt iodization is national in scope, there are reasons to conduct the analysis at national level. The developing country data are all listed in Appendix table 1.

The developing country data were analyzed by conducting population-weighted multivariate regressions, with UIE as the dependent variable, and three independent variables namely HCIS, an environmental deficiency dummy, and time. Time was included to capture effects such as improvements in quality monitoring in programs over time, as increased expertise was acquired internationally. Only one observation was included per country so as not to have an unbalanced data set: for those 5 countries where more than one observation was available, the most recent observation was the one which was used.

There are some limitations of the data. Countries do not necessarily have the same minimum cutoff level for salt iodization (the minimum required for USI is 15ppm, but some countries use 20ppm), and countries have also varied their level of salt iodization over time. In China for example, it is possible to track changes over time and see that in 1997 and 1999 as population coverage first approached the 90% goal, UIE levels overshot what was desired, and iodization levels were then adjusted downward to achieve the desired UIE level. We cannot control for this intra-program variability. The variable used (household consumption of iodized salt) does not necessarily measure whether salt is iodized to the mandated level, but rather that it is iodized. (Some countries report the more accurate titration data, others may simply report data obtained using the less accurate rapid test kits).

Another issue is presence of goitrogens in the diet. Thilly et al [15] noted in early work that populations could have similar levels of UIE inferring similar iodine intake, but different levels of observed goiter (regions with high reliance on cassava had higher goiter, which could be due to lower absorption). This implies some limitations in UIE as a measure of iodine utilization in the body, but again, this cannot readily be controlled for in the present analysis.

In addition to the developing country database, we also constructed a database for developed countries. The developed country database contained data on median UIE, salt penetration data (data on household consumption of iodized salt are not generally available for developed countries), and data on soil iodine from a database constructed by the British Geological Survey (median soil iodine data were used to correspond to median UIE). It was not possible to obtain a large enough sample with data on UIE and on salt penetration from the same year, so data were used within the same five-year period. Typically the salt penetration rates have not changed considerably in the industrialized countries covered, since policies have not changed over the particular period considered. There may be variations across countries as to whether salt used in the food industry is also iodized, but we do not have access to data on this. The developed country database is given in Appendix 2.

Soil iodine data are not a perfect guide to iodine uptake in agricultural products grown in a region, since this depends on many factors such as soil chemistry. Local water iodine levels are considered a better indicator, however there are very few of these data available. The soil database contains almost 2400 observations for 38 countries (although for 10 of these countries there are only 1 or 2 data points). Of the 28 countries with 3 or more data points, 8 are developing countries and were included in the previous database since they have household consumption of iodized salt rather than salt penetration data available, leaving data for 20 industrialized countries. For these, data on UIE and salt penetration could be matched with the soil data for 13 (only one observation was used for each country). It is possible that some kind of agricultural-production-weighted soil iodine database would be preferable, but this was beyond what could be constructed with the data available. Consumption also does not rely only on local food, and food from other regions (or other countries) will weaken the link between soil iodine and UIE.

Iodized table salt in developed countries is likely to have a less consistent effect on UIE. Even in the countries with mandatory fortification of table salt (Canada for example), the legislation does not necessarily apply to salt used in food processing. As incomes rise with development, households consume more and more processed and restaurant foods, and hence obtain less iodine from table salt, and this is compounded by health advisories advising households to curtail added salt. The US and Switzerland for example have recently observed declines in UIE, and Switzerland for example adjusted upwards the mandated amount of iodine in salt in 1998 to partially compensate.

For developed countries, there are frequently alternative sources of iodine in the diet. The use of iodofers in the dairy industry, and iodine supplements for cattle feed in the winter, have meant that milk has been a good source of iodine in several countries, although this was not originally the motivation. Coastal communities in many countries have high consumption of marine products, some of which (such as seaweed) have high iodine levels. A few countries (not included in the database, such as Thailand) practice iodization of products other than salt.

Results

The model estimated (using population-weighted least squares) was as follows:

UIE = b_0 + b_1 Salt Indicator + b_2 Soil Indicator + b_3 Time + error term

For developing countries, the salt indicator was HCIS and the soil indicator was a dummy variable deficient/not; for developed countries the salt indicator was salt penetration and the soil indicator was median soil iodine from the BGS database. The time variable was a linear trend starting in 1990 to allow for possible effects of USI in developing countries. It was not anticipated to have a particular effect in the developed countries.

For the developing countries, the results (table 1) show that UIE is related significantly to salt iodine as measured by HCIS, with an elasticity of 0.73 (this means that a 1% increase in HCIS is associated with a 0.75% increase in UIE). There is also a positive and significant time-trend, suggesting that UIE has been improving over time (likely due to improvements in policy implementation). The soil deficiency dummy coefficient is not significant, and has the “wrong” sign (UIE is higher in the countries with a dummy variable indicating soil deficiency).

For the industrialized countries, there is also a positive and significant effect of salt iodine as measured by salt penetration rates, with an elasticity of 0.83. There is also a positive and significant effect of soil iodine, with an elasticity of 0.77.

Discussion

These are cross-section results (an ecologic analysis), and as such are suggestive of the impact of national policy regarding salt iodization, although this is a different type of evidence as compared to randomized controlled interventions. For developing countries, our results confirm similar results from previous studies; the main improvement is that we use a consistent database with UIE and HCIS data for the same year. Our results for developed countries are new, and there have not been previous cross-country studies attempting to control for soil iodine.

One issue suggested by the data for the industrialized countries, is that policies are not implemented independently of environmental conditions. For the industrialized countries, the correlation between the salt coverage variable and the soil iodine variable is negative, albeit not significant given the small sample size. It is possible that governments are more impelled to act when there are visible consequences of dietary iodine deficiency. Thus, the fact that several cantons in Switzerland had widespread visible goiter may have made that country more likely to adopt widespread nationwide salt iodization than some of the neighbouring countries where the public health issue was less visible.

In such circumstances, the end result is that iodine deficiency is currently worse, not in those countries with the most deficient environments, but in those countries with milder deficiencies in their soil and water. Countries such as China and Switzerland (where there were overt cases of cretinism) currently have higher UIE status than for example Hungary prior to recent improvements in salt iodization, or Russia currently, despite the fact that median soil iodine in both China and Switzerland is lower than Hungary or Russia.

We cannot fully explore this hypothesis. Some countries with even higher soil iodine (UK and Ireland) attach an even lower priority to iodine deficiency as a public health issue, such that UIE surveillance data are not even available, although concerns have been raised about emerging problems (for example among pregnant women in Ireland in the summer [24]. Since the WHO now encourages all member countries to monitor the state of iodine nutrition every three years [25], it is possible that a more complete picture will emerge.

Given these determinants of policy, simple correlation (between UIE and salt penetration, or between UIE and HCIS) in fact underestimates the relationship between the two variables, and multivariate regression such as undertaken here using soil iodine is required.

We acknowledge the data limitations inherent in our analysis. However, the availability of comparable data internationally is improving, which will assist future research. Increased data on UIE for pregnant women (or greater knowledge as to how this correlates with data for school-age children) seems to be an urgent research priority.

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Table 1. Regression results, and variable means and standard deviations, for UIE

Variable	**Developing Countries**	**Industrialized Countries**	**Means & (SD's), developing**	**Means & (SD's), industrialized**
Salt iodine	1.787 (0.390)**	2.045 (0.513)**	67.107 (29.159)	54.000 (36.049)
Soil iodine	13.432 (18.378)	21.400 (8.881)*	0.333 (0.471)	4.796 (2.285)
Time	6.720 (1.996)**	-	11.6 (3.460)	-
Constant	-29.355 (32.237)	-34.886 (46.389)	-	-
Dependent variable	-	-	164.313 (67.749)	133.477 (74.437)
F statistic Adj. R^2 Degrees of freedom	20.78** 0.672 3,26	13.86** 0.682 2,10	-	-

Columns 2 and 3 are coefficients (standard errors in brackets); Columns 4 and 5 are means (standard deviations in brackets); * denotes significant at 5% level, ** at 1% level, one-tail test. Variables given to 3 decimal places.

Table 2. Simple correlation coefficients for variables

Developing Countries n=30

	UIE	HCIS
UIE		
HCIS	0.6331**	
Soil iodine (dummy)	0.0854	-0.0389

Industrialized Countries n=13

	UIE	Salt Penetration
UIE		
Salt penetration	0.4462	
Soil iodine	0.2559	-0.1694

Appendix 1: Developing country database

Country	HCIS %	Salt Date	UIE (ug/L)	Soil Deficiency Dummy (1=yes)
Afghanistan	28	2004	49	1
Armenia	97	2005	313	0
Bangladesh	55	1999	125.8	1
Bhutan	82	1996	230	1
Bosnia	62	2005	157.3	0
Belize	90	1995	184	0
Brazil	79	1996	140	1
Bulgaria	97.8	2003	198	0
Burundi	98	2005	70	0
Cape Verde	0.2	1996	52	0
China	90.2	2005	246.3	1
Gabon	36	2001	190	0
Gambia	9	1999	41.8	0
Guinea	67.9	2003	139.1	0
Haiti	3.1	2005	84	0
Indonesia	73.2	2003	229	1
Cote d'Ivoire	84.4	2004	202.7	0
Jordan	88.3	2000	154	0
Macedonia	94	2005	228.4	0
Myanmar	59.7	2003	205	0
Mongolia	74.9	2004	96.8	0
Philippines	56.4	2003	201	1
Romania	53	2002	83.5	0
South Africa	62.4	1998	177	1
Sri Lanka	90.1	2005	152.5	1
Turkmenistan	100	2004	170	0
Uzbekistan	56.6	2005	141.2	0
Yemen	39	1998	173	1
Zimbabwe	93.4	1999	245	0
Peru	93	1997	250	0

See text for data sources

Appendix 2: Developed country database

Country	**% Salt Penetration**	**Salt Date**	**UIE (ug/L)**	**UIE Date**	**Median Soil Iodine (ug/g)**
Armenia	97	2005	313	2005	3.6
Australia	10	2006	104	2004	2.4
Austria	95	1999	111	1994	2.58
Czech Rep.	90	1990s	107	1994	2.7
Germany	57	1989	148	1999	2.537
Hungary	27	1995	80	1995	2.382
Latvia	3	1990s	59	2000	3.82
Netherlands	40	1998	154	1994	10.33
New Zealand	83	2000	66	2002	1.5
Russia	20	2003	69	2003	2.6
Spain	27	1982	160	1982	4.35
Switzerland	94	1998	115	1999	1.97
USA	70	2000	249.2	2001	4.5

See text for data sources, except salt penetration sources as follows:

Armenia [11]; Australia [16]; Austria, Germany, Netherlands, Spain, Switzerland [17]; Czech Republic [18]; Hungary [19]; Latvia [20]; no date provided, but domestic salt remains uniodized; New Zealand [21]; Russia [22]; USA [23]