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Context

We want to investigate two potential concerns regarding external validity of the studies we use to generate an effect for rice fortification on anemia:

- *Difference in consumption of tea with meals between adults and children, comparing program and study settings.* If adults regularly consume tea with meals (including fortified rice), and children do not—we might expect that to be a key reason for studies finding a larger effect size than we'd expect for the population of interest.
- *Difference in prevalence of infectious disease between adults and children, comparing program and study settings.* Higher infectious disease burden could inhibit hemoglobin response to iron fortification, causing us to expect the effect of iron fortification on anemia to be higher for adults than children.

[Context](#)

[Summary](#)

[Population calculations/assumptions](#)

[Percentage of children vs. adults](#)

[Percentage of tea-drinkers in children vs. adults](#)

[Adjustment for tea consumption](#)

[Adjustment for inflammation exposure](#)

Summary

I calculate an [89% adjustment for tea consumption](#) and [99% adjustment for inflammation exposure](#). Together, **these adjustments decrease cost-effectiveness substantially (0.3 - 3x across states) to 11.8x in West Bengal, 10.6x in Meghalaya, and 7.4x in MP/Gujarat/Telangana..** Details on my process and rationale are below and calculations can be found in [this spreadsheet](#).

My biggest uncertainties are:

- **Rates of tea consumption with meals containing rice** – I am moderately confident about my estimate for any tea consumption in India, but I am highly uncertain about my 50% downward adjustment for tea not consumed with meals containing rice. However, I expect this to be an intractable question to answer and think 50% seems in the right ballpark. I also assume data for India overall applies equally to all states and to a study population in Bangladesh, though I believe in reality large differences could exist across these locations.
- **Assumption for inflammation in adults** – As a rough approximation, I rely on a study that provides an inflammation index for children 6-59 months and women

15-49 to estimate inflammation in children <15 and all adults ≥ 15 respectively. I've adjusted the inflammation exposure rankings for children but have not done so for adults.

- **Percent reduction in iron absorption caused by inflammation** – My assumption of 50% is purely speculative, and I expect a deeper review could shift our estimate by as much as 40 percentage points up or down.
- **Percent reduction in iron absorption caused by tea consumption** – My assumption of 50% is based on a shallow evidence review, and I expect a deeper review could shift our estimate by as much as 20 percentage points up or down.

Population calculations/assumptions

Percentage of children vs. adults

Per Cat, "Nutrition International plans to support 3 major SSNPs: (1) Public Distribution System (PDS), (2) Integrated Child Development Services (ICDS), and (3) PM Poshan (Mid-Day Meal) programs."

My understanding is that:

- Rice distributed through the PDS (Channel #1) is through ration/fair price shops uncooked and then cooked at home.¹ My assumption is that this channel would therefore target a demographic equivalent to the average SSNP beneficiary household, which I'd roughly guess is not that dissimilar from the average Indian household ([NFHS-5](#) shows ~27% of households composed of children <15). Since rice delivered via PDS is cooked at home, it could be eaten with tea.
- Rice distributed through the ICDS is not at schools but is delivered pre-cooked as part of a meal (it's possible some of these meals are taken home and consumed with other foods/beverages, including tea, but I don't consider this explicitly).² The target population includes both children <6 and pregnant and lactating mothers.³ My rough scan of a few ICDS sources suggests that tea would not be provided through this channel.⁴

¹ ". The operational responsibility including allocation within State, identification of eligible families, issue of Ration Cards and supervision of the functioning of Fair Price Shops (FPSs) etc., rest with the State Governments. Under the PDS, presently the commodities namely wheat, rice, sugar and kerosene are being allocated to the States/UTs for distribution. Some States/UTs also distribute additional items of mass consumption through the PDS outlets such as pulses, edible oils, iodized salt, spices, etc." [PDS website](#)

² "Under the revised Nutritional and Feeding norms which have been made effective from February 2009, State Governments/UTs have been requested to provide 300 days of supplementary food to the beneficiaries in a year which would entail giving more than one meal to the children from 3-6 years who visit AWCs. This includes morning snacks in the form of milk/banana/egg/seasonal fruits/micro-nutrient fortified food followed by a hot cooked meal (HCM). For children below 3 years of age, pregnant and lactating mothers, Take Home Rations (THRs) in the form of pre-mixes/ready-to-eat food are provided. Besides, for severely underweight children in the age group of 6 months to 6 years, additional food items in the form of micronutrient fortified food and/or energy dense food as THR is provided." [ICDS Scheme website](#)

³ "The delivery of services to the beneficiaries is as follows: Supplementary Nutrition: Children below 6 years, Pregnant & Lactating Mothers (P&LM)" [ICDS Scheme website](#)

⁴ No mention of tea is made in the operational guidelines for supplementary feeding through ICDS [here](#) and [here](#)

- Rice distributed through [POSHAN/Midday Meal Scheme \(MMS\)](#) is explicitly a school meal program and targets children <15 (primary and upper primary school children). Meals delivered via POSHAN/MMS do not appear to include tea (see food entitlements through this program [here](#)).

Data available from the Indian government shows ~91% of rice is allocated to PDS, ~3% to ICDS, and ~6% to POSHAN.⁵ I assume fortified rice allocations are proportional to total rice allocations, which appears to be roughly corroborated by the government's goals for rice fortification.⁶ Assuming the PDS population distribution is equivalent to the national distribution (73% over 15, 27% under 15—see [above](#)) and that ICDS beneficiaries roughly break down into 50% under 15 and 50% over 15 (this is made up but decided not to dig into it because it has little effect on the bottom line), I [roughly calculate that ~32% of program beneficiaries are <15](#).

Percentage of tea-drinkers in children vs. adults

Based on a 2018 report from the Tea Board of India, I begin with an assumption that ~85% of adults (≥ 15 years) are regular tea-drinkers, and 0% of children <15 are tea-drinkers.⁷

⁵ The best data I was able to source on rice allocation comes from the Indian government's Department of Food and Public Distribution monthly ["Food Grain Bulletin"](#). I use the most recent bulletin ([February 2023](#)) and refer to the amounts referred to as "allocations" for Year "2022-23". I double checked that the percentages below are roughly similar to the past few years.

- Total 2022-23 rice allocation across PDS, ICDS, and POSHAN (in lakh tons): **383.85** =
349.14+11.66+23.05
 - PDS: 349.14 (91%)
 - ICDS: 11.66 (3%)
 - POSHAN: 23.05 (6%)

⁶

- "Phase I:- 35 LMT of Fortified rice to be distributed till March 2022 in ICDS+ PM POSHAN schemes. Phase II:- 175 LMT of Fortified rice to be distributed till March 2023 in ICDS+ PM POSHAN +291 Aspirational & High Burden districts. Phase III:- 375 LMT of Fortified rice to be distributed till March 2024 in entire TPDS and OWSs." [Press Information Bureau of India, December 2021 Press Release](#)
 - $35/375 = \sim 10\%$
- "He added that about 105 LMT of Fortified Rice was lifted by Phase II targeted 27 States/UTs for PDS distribution. In addition, about 29 LMT was lifted by the States/UTs under ICDS and PM POSHAN in Phase II, making a total of about 134 LMT fortified rice lifted in the FY 2022-23."
 - $29/134 = \sim 20\%$

⁷ "The penetration of tea in the kids segment below 12 years of age which on an average comprise of ~25% of the overall population is almost negligible. In the next layer we estimate the penetration of tea in the households. Close to 88% of the total households (based on the samples in the survey) in India have reported consumption of tea. Within the potential tea drinkers within a household, the penetration of tea is around 96%. Overall around 64% of the total population in India is the tea drinking population." [Tea Board of India, Executive Summary of Study on Domestic Consumption of Tea in India](#)

- My understanding is the way this paper generates the 64% statistic is by multiplying 75% (% of population "eligible" to consume tea, assuming 0% of individuals <12 drink tea) x 88% (percentage of HHs reporting tea consumption) x 96% (within a HH that drinks tea, the percent of "eligible" HH members that drink tea).
- I believe this should mean that $64/75 = \sim 85\%$ is the percentage of individuals ≥ 12 that regularly consume tea, and 0% is the percentage of individuals <12 that regularly consume tea.
- I make a simplifying assumption that these percentages hold true for the respective age brackets of adults (≥ 15 years) and children <15.

Based on some limited evidence and general intuition that at least some children likely consume tea, I adjust my best guess of the percentage of children <15 that are regular tea-drinkers upwards to 10%.⁸ Lastly, I account for the fact that not all tea consumed will be regularly consumed with meals containing fortified rice, very roughly assuming that 50% of tea is consumed with or near meals (both for children and adults).⁹ This last assumption is the most uncertain because I was able to find the least information on this input (but deprioritized because I expect it to be a relatively intractable question to answer).

Including this 50% adjustment, I [arrive at a final estimate of 42.5% of individuals > 15 and 5% of children <15](#) regularly consume tea with or near meals containing rice.

Adjustment for tea consumption

Incorporating data on % of fortified rice delivered through each of the three SSNP channels, **I roughly calculate that [~30% of program beneficiaries would consume tea with fortified rice](#).**

A very rough scan of the [studies in SG's meta-analysis](#) suggests that only in one of the studies was rice delivered to the study population uncooked ([Ara 2019](#)) and that rice was delivered pre-cooked via school meal programs in all other studies.¹⁰ I assume tea was not

The 88% statistic reported on HH tea consumption seems to be corroborated by a 2011-12 household consumption expenditure survey conducted in India. Table T12 (p. 29) in [the report](#) shows 86.1% of rural households and 83.8% of urban households consumed tea at home within a week.

⁸ I rely on very limited data points but think the below sources suggest a higher percentage of children <15 consume tea. 10% is my rough guess:

- [Fledderjohann et al. 2015](#), a study of the beverage consumption patterns of children in India using NFHS-3 (2005) data, found that ~8% of all children 6-59 months consumed tea in the last 24 hrs: "Less than 4 % of children who received no water had both fresh milk and breast milk in the last 24 h. 2.55 % received tea or coffee only, while just under 5 % received a combination of either tea/coffee and fresh milk (2.44 %) or tea/coffee and breast milk (2.37 %)."
- [The Hindu Business Line. 2018 article](#) suggests low consumption of tea among children, including adolescents, but also that the tea industry is actively trying to grow this market: "Nearly 30 per cent of the population, including schoolchildren, do not drink tea, the association says. It is this segment that the industry hopes to tap... 'We are working on a strategy to promote tea primarily among teenagers. We have done it with youths, colleges and now, we want to do it through schools,' said ITA Chairman Azam Monem... There are about 350 million people, primarily children, who do not drink tea, he said."

⁹ I found very limited detailed information on tea consumption patterns in India but think on average, a reasonable approximation is that on average ~50% of tea is consumed with or near meals (assuming rice is generally not consumed during breakfast).

- "Over 80% of the people consume tea either before breakfast or with breakfast, which is also one of the reasons behind the high in-home consumption of tea. A certain proportion also considers tea as "any time of the day" drink. This segment is sizeable in the Eastern parts of the country." [Tea Board of India, Executive Summary of Study on Domestic Consumption of Tea in India](#)
- "A health and fitness app HealthifyMe has released some interesting chai drinking patterns in India, after studying almost 12 million logs of 1.5 million customers....The study goes on to reveal that for Indians, tea is an essential part of their evening snack on 65 per cent more days than breakfast." [Times of India. 2019 article](#)

10

- [Angeles-Agdeppa 2008](#): "This study was conducted from July to December 2004 in San Joaquin Elementary School... A standard two-week cycle menu was developed, consisting of meat, vegetables such as potatoes, sweet potatoes, green papaya, and bananas (saba). Each child received 40 g meat,

included with any of the pre-cooked school meals. I also assume the same percentage of tea consumption in the study population of [Ara 2019](#) that I do for the Indian adult population [above](#) (42.5%). Although [Ara 2019](#) was conducted in Bangladesh, I roughly assume tea consumption patterns are similar in the two settings based on geographic proximity, though I remain highly uncertain about this. Using relative weights of studies in SG's meta-analysis, **I roughly calculate that [9% of the study population consumed tea with fortified rice](#).**

I assume tea consumption inhibits iron absorption by 50%. This is my very rough guess based on [SG's report on effectiveness of rice fortification](#), which references a study in India that reported a lower bound effect size of ~50%.¹¹ I did not look further into this, as I expect it to be at least several hours of work to develop a better estimate and expect the percentage point change to be on the order of ~20 (either up or down). **Including expected % of program and study population consuming tea with fortified rice and my best guess for the effect of tea consumption on iron absorption, I calculate an [89% adjustment](#) to external validity to account for differences in tea consumption.**

Adjustment for inflammation exposure

An inflammation exposure index is reported in [Petry et al. 2016](#) for children of pre-school age (6-59 months) and women of reproductive age (15-49 years). For simplicity, I assumed the ranking provided for pre-school age children is equivalent to the ranking for children <15 and the ranking for women of reproductive age is equivalent to the ranking for all

20 g vegetables, and 40 g sauce. Weighed cooked rice (160 g) and dish (100 g) were packed in color-coded lunch boxes with partitions."

- [Radhika 2011](#): "The MDM consisted of cooked rice equivalent to ;125 g rice (dry weight) per child per meal along with regular side dishes provided under the government-implemented MDM program on all school working days, excluding Sundays and school holidays... The main ingredients used on a daily basis were tomatoes, onions, peanuts, red chilies, salt, and peanut oil. The rice and side dishes were cooked in wide-mouthed aluminum vessels covered with a lid, and firewood was used for fuel. A boiled egg was provided once per week."
- [Thankachan 2012](#): "The lunch meals were provided 6 d/wk for 6 mo except for school holidays... The 3 types of rice (high iron: 12.5 mg Fe/100 g, low iron: 6.5 mg Fe/ 100 g, and control, ;100 g raw rice/meal) were used to prepare lunch meals daily in the kitchen of the Division of Nutrition at St. John's Research Institute. A rotating menu of 5 traditional recipes was used: lemon rice, tamarind rice, vegetable rice, curd rice, and tomato rice."
- [Hardinsyah 2016](#): "The research team was provide the cookware to cook for fortified rice in accordance with the boarding school kitchen manager order (boiler, stove, furnace and baskets of rice-3 pieces with different colors)."
- [Perignon 2016](#) ©: "A total of 20 primary schools were selected to constitute four intervention groups (including placebo) and a control group. Sixteen schools (intervention groups and placebo) were selected from the primary schools participating in the World Food Programme (WFP) school meal program. This program provides children with a daily breakfast consisting of rice, beans, canned fish, iodine-fortified salt, and vegetable oil enriched with vitamins A and D."
- [Ara 2019](#): "Under the VGD programme, a monthly ration of 31.25 kg wheat or 30 kg rice over two years were distributed to rural ultra-poor women to ensure food security in their households [15]."

¹¹ "The consumption of 1 or 2 cups of tea decreased iron absorption in the control subjects by 49% (P < 0.05) or 66% (P < 0.01), respectively, and in the [iron deficiency anemia] group by 59% or 67% (P < 0.001 for both), respectively." [Thankachan et al. 2008](#), abstract.

adults ≥ 15 . Ratings in [Petry et al. 2016](#) were provided as scores out of a maximum possible number of points, 9 for pre-school aged children, and 15 for women of reproductive age.¹² I divide rankings by maximum possible points in order to account for this.

I begin by pulling the inflammation exposure index ratings for India and calculate the overall exposure index in the program population by multiplying the ratings for pre-school age children by the expected percentage of beneficiaries who are children <15 and the ratings for women 15-49 years by the percentage of beneficiaries who are adults ≥ 15 (see calculations [here](#)). I then pull inflammation exposure index ratings for the countries and age groups for each of the studies included in SG's meta-analysis [here](#), and multiply the ratings by study weights (see calculations [here](#)).

I then adjust for the expectation that infectious disease burden (and therefore inflammation) in children <5 is likely higher than for all children <5 . [Petry et al. 2016](#) considers prevalence of malaria, schistosomiasis, and enteric disease in its inflammation exposure scores for children 6-59 months.¹³ I pulled GBD data on infectious disease burden for malaria, schistosomiasis, and enteric disease for children <5 and 5-14. I sum YLD rates from each of the three diseases for both age groups and divide the <5 summed figure by the 5-14 summed figure to develop an adjustment factor for inflammation exposure scores in [Petry et al. 2016](#). See calculations for different locations [here](#).

I very roughly assume inflammation inhibits iron absorption by 50%, meaning that a population with half as much inflammation exposure would receive 1.5x the benefits of fortification. This is a purely speculative, made-up number, though seems roughly in the right ballpark. I believe developing a better estimate will be at least several hours of work and potentially intractable. **Including expected inflammation exposure in program and study population and my best guess for the effect of inflammation on iron absorption, I calculate a [99% adjustment](#) to external validity to account for differences in inflammation between program and study population.**

¹² See the Inflammation-exposure index ratings in [Table S1](#) of the supplementary materials for Petry et al. 2016.

¹³ "For children, the inflammation-exposure score was based on (a) prevalence of presumed and confirmed malaria cases [18,19]; (b) schistosomiasis prevalence [20]; and (c) an overall hygiene score based on the proportion of population using improved drinking water source and the proportion of the population using improved sanitation facilities (evenly weighted) as a proxy for the risk of enteric inflammation [21]. For women, the different factors used to estimate country-specific inflammation-exposure were (a) prevalence of presumed and confirmed malaria cases [18,19]; (b) HIV prevalence in adults [22]; (c) obesity prevalence in female adults [23]; (d) schistosomiasis prevalence [20]; and (e) an overall hygiene score based on the proportion of population using improved drinking water source and the proportion of the population using improved sanitation facilities (evenly weighted) as a proxy for the risk of enteric inflammation [21]." [Petry et al. 2016](#)