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Nutrition, Iron Deficiency Anemia, and the Demand for Iron-Fortified Salt

Evidence from an Experiment in Rural Bihar

Abhijit Banerjee, Sharon Barnhardt, and Esther Duflo

10.1 Introduction

According to the World Health Organization (WHO) Global Database on Anemia, 24.8 percent of the world's population is anemic (de Benoist et al. 2008). Iron deficiency, along with other nutritional deficiencies, disease (malaria) and infections (parasites), is one of the leading causes of anemia. The consequences of iron deficiency anemia (IDA) depend on age. For children, IDA is associated with slower physical and cognitive development (Lozoff 2007) with potentially long-lasting effects (Lozoff et al. 2006). For working age adults, IDA may lower productivity, as feeling weak is the most common symptom of the disorder (Haas and Brownlie 2001). Severe anemia during pregnancy can lead to low birth weight and child mortality (Stoltzfus 2001). For older adults who have passed their most physically productive years, high rates of anemia are generally observed, and lower hemoglobin levels are associated with cognitive decline (Peters et al. 2008) and lower physical performance (Penninx et al. 2004).

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Reduced productivity caused by IDA and its potential impact on earnings have become an area of focus for health research in developing countries, where large sections of the population provide physical labor in agriculture, construction, and manufacturing. To address iron deficiency anemia, health policies normally focus on providing mineral supplements or fortifying foods. Surprisingly, few evaluations have looked at the impact of treating IDA in any form on actual output. While Basta et al. (1979) found a large effect of iron supplementation on sugar tree tappers in Indonesia (though their study suffered from attrition), Li et al. (1994) and Edgerton et al. (1979) found a much smaller effect on productivity. Thomas et al. (2003) found a large effect of an iron supplementation program on the labor supply and earnings of males who were anemic at baseline, but only for those who were self-employed.

Providing supplements to a large population, particularly pregnant women, is a standard policy in many countries.[1] However, it faces two problems. The first is that it relies on public health infrastructure and local providers, whom the government struggles to monitor (Banerjee, Deaton, and Duflo 2004; Chaudhury et al. 2006). The second is that individuals often do not comply with the protocol, perhaps because potential gains are not easily measurable while potential side effects (such as constipation) are evident (Allen et al. 2006). In our study area, which is covered by a supplementation policy aimed at pregnant women, we found 60 percent of pregnant females to be anemic using the standard 12 g/dL cutoff.

The second approach to prevent widespread anemia is to add iron to foods that are a regular part of the local diet. Fortification is a compelling solution in locations where households regularly purchase packaged foods that can be fortified centrally during mass production. For example, in the United States, all enriched grain products are fortified with folic acid to help prevent neural tube defects in newborns, toothpaste is fortified with fluoride to prevent cavities, salt is fortified with iodine to prevent goiter, and milk is fortified with vitamin D to prevent rickets. Several states in India now have iron fortification subsidies for flour, which is then purchased on the open market.

These channels do not effectively reach low-income populations in remote locations, however, because such populations do not buy as much processed grain. Village-level fortification, which we examined in a prior study (Banerjee, Duflo, and Glennerster 2011) had a very low rate of take-up, which suggests that this is not a sustainable alternative. The study found no impact on anemia after one year, as most households stopped fortifying after six

1. Under the National Rural Health Mission in India, large iron supplements are to be provided to pregnant women and adolescent girls, at a cost of INR 105 per 1,000 tablets. This is less than USD 2 for enough supplements for ten women. When cases of severe anemia (a pregnant woman with a hemoglobin level of less than 8 g/dL) are identified they may be addressed with intravenous iron sucrose.

months. This suggests that the need for continued household effort, in particular taking the grain to a mill that is equipped for fortification (and monitoring that the miller actually fortifies the food), is a barrier to long-term take-up.

This project will study the feasibility and the impact of an alternative approach, which is to fortify salt with iron. There are currently two accepted formulas for double-fortified salt (DFS) in India, one produced by the National Institute of Nutrition (Hyderabad) and the other by the Micronutrient Initiative. There is evidence from clinical trials in several countries (including India) that iron-fortified salt has the potential to improve hemoglobin status and reduce anemia among young adults and lactating women (Nadiger et al. 1980; Sivakumar et al. 2001) and children (Nair et al. 1998; Brahmam et al. 2000; Andersson et al. 2008).

These studies, however, involve very small samples in carefully controlled environments, often ensuring consumption by adding the salt to food consumed by the participants, or distributing it at home for free. Thus, there have so far been no large-scale studies of the effect of making DFS available, potentially at a discounted rate, on usage and eventual health, let alone productivity. DFS is a promising technology, for at least three reasons. First, it can be fortified centrally and stored for up to one year due to technology that slows iron and iodine degradation (Ranganathan and Sesikeran 2008). Second, all local diets include salt, whereas some regions eat more rice than flour-based rotis. Third, even in remote villages, households purchase salt throughout the year rather than produce it.

Unless we directly study take-up and impact, however, one cannot assume that DFS will be part of the answer to the anemia problem among the poorest. Furthermore, to the extent a government is willing to subsidize the fight against anemia, it can do so by subsidizing DFS; but without evidence on the willingness to pay for DFS at various prices, how should the subsidy level be set? It may take more than a nudge to shift consumption to DFS, since the benefits may not be obvious. Perhaps the price of DFS needs to be below high-quality iodized salt to change consumer behavior.

Our broader project fills this gap by implementing a large-scale randomized controlled trial in 400 villages in Bihar, including 200 where DFS produced by Tata Chemicals will be made available at a price subsidized by the UK Department for International Development. In this chapter, we report findings from the baseline survey that strongly suggest potential returns to intervention to fight anemia. We find 53 percent of women age 15–49 have hemoglobin levels under 12 g/dL and 21 percent of men have a hemoglobin level under 13, the rough cutoffs for anemia. A large majority of households (94 percent) purchase iodized salt, which makes an intervention with DFS potentially promising.

This chapter also presents the results of a small-scale experiment to assess willingness to pay for double-fortified salt using randomly assigned discount

vouchers. We find that the take-up of DFS falls quickly with price. At a price point of 45 percent of the retail price of DFS sold in major Indian metros, the take-up of DFS is 30 percent in private stores.[2] We also assess the impact on purchase behavior of three separate information campaigns: a basic campaign limited to written promotional materials, the basic campaign plus a street play, or all of the above plus a door-to-door public health campaign conducted by incentivized volunteers referred to as ASHAs (accredited social health workers). We find no differential impact of information campaign type among households who were given vouchers to purchase DFS.

10.2 Setting and Background on Double-Fortified Salt

10.2.1 Setting for Baseline Survey and Pricing Experiment

Our pricing experiment and baseline survey for the larger impact assessment were conducted in the state of Bihar. With a population of 104 million (Registrar General of India 2011), a state Human Development Indicator that puts it in 21st place out of 23 ranked states (Planning Commission and IAMR 2011), and an underweight prevalence rate of 56.1 percent for children under age five (Menon, Deolalikar, and Bhaskar 2009), Bihar is large, poor, and undernourished. Anemia rates are also high in the state, as 68 percent of ever-married women fifteen to forty-nine years old and 88 percent of children under age three are anemic according to official sources (International Institute for Population Sciences 2007). Our study takes place in Bhojpur, a district with approximately forty-four doctors for a population of 2.2 million (District Health Society Bhojpur 2011). From our survey, we estimate there are 912 girls for every 1,000 boys under the age of five in the district.

10.2.2 DFS Formulation and Evidence from Studies in Controlled Conditions

The DFS used in the pricing experiments reported here (and for the larger project of which this is part) is manufactured by Tata Chemicals, Ltd., a leading private manufacturer of salt, based in Mumbai. Tata Chemicals uses the National Institute of Nutrition formulation for DFS, which is fortified with 1 mg of iron and 30 to 40 μg of iodine per gram of salt. When consumed regularly at 10 g/day (roughly the consumption of an adult), this formulation is estimated to provide 10 mg of iron and 150 μg of iodine (Ranganathan and Sesikeran 2008), or 56–125 percent of the RDA of iron and 100 percent of the RDA of iodine. This formulation has been endorsed by a committee set up by the Indian Council for Medical Research (ICMR). The maximum

2. A rate of 20 to 30 percent of households purchasing DFS was estimated as the requirement to observe an average increase in hemoglobin of 0.7 g/dL, which is meaningful.

retail prices in major urban markets where DFS was introduced under the brand name "Tata Plus" is INR 20 per kg.[3]

10.3 Baseline Survey

10.3.1 Data Collection

The survey was conducted across the fourteen blocks (subdistrict administrative units) of Bhojpur District between May 2011 and March 2012. We excluded villages with fewer than fifty households from the District Rural Development Agency (DRDA) household and village listing for Bhojpur, stratified by block, and randomly selected twenty-eight or twenty-nine villages from each block to include in the study. In total, 400 villages were included. We then randomly selected fifteen households per village to participate in our surveys, which are managed by research associates from the South Asia office of the Abdul Latif Jameel Poverty Action Lab (J-PAL).

Our baseline survey collected information on both households and individual household members. The household module collected information on the economic status of the household: consumption, savings, assets, and so forth. The background modules collected data on time use, food consumption, education, and pregnancy. The health modules collected anthropometric measurements, hemoglobin counts, objective measures of physical fitness, and subjective measures of illness and general health. Finally, the cognition modules involved several tests assessing respondents' memory, attention, and mental awareness. In total, 39,606 individuals in 5,970 households have complete objective health survey data and are reported here.

10.3.2 Education, Income Generation, Assets, and Consumption

Table 10.1 presents a snapshot of the households interviewed for the baseline. There are slightly more women in the sample (20,330 females versus 19,276 males), reportedly due to seasonal migration of adult males for income generation. Households are also young, with nearly 40 percent of the sample under the age of fifteen years. In this area, there is a fairly high percentage of families belonging to Scheduled Castes (19 percent) and other Backward castes (14 percent), but almost no Scheduled Tribes.

Literacy rates, based on reading a paragraph presented by the surveyor, are under 50 percent for women, and much lower for women over age fifty (as may be predicted by historical rates of schooling). Approximately 88 percent of girls under the age of fifteen are presently enrolled in school. Literacy rates are much higher for males in our sample, with 85 percent of males age fifteen to forty-nine and 73 percent of males age fifty and older

3. At the time of editing this chapter for publication, the exchange rate was approximately INR 61 per USD.

Table 10.1 Demographics of baseline survey sample

Households (number)	5,970
Scheduled caste (proportion of heads)	0.19
Scheduled tribe (proportion of heads)	0.004
Other backward caste (proportion of heads)	0.14
General category (proportion of heads)	0.67

	Age 0–4	Age 5–14	Age 15–49	Age 50+	Total
Females					
Number	2,462	5,003	9,387	3,478	20,330
Can read paragraph easily or with difficulties (proportion)	—	0.47	0.49	0.17	
Enrolled in school (proportion)	—	.88	.13	—	
Number who are working	—	—	3,651	1,703	
Primary income generating activity is agricultural fieldwork (proportion)	—	—	0.26	0.23	
Primary income generating activity is animal husbandry	—	—	0.60	0.68	
Primary income generating activity is textiles & handicrafts	—	—	0.04	0.01	
Primary income generating activity is shop, business, etc.	—	—	0.03	0.04	
Primary income generating activity is other	—	—	0.08	0.05	
Males					
Number	2,557	5,468	7,658	3,593	19,276
Can read paragraph easily or with difficulties (proportion)	—	0.55	0.85	0.73	
Enrolled in school (proportion)	—	0.91	0.24	—	
Number who are working	—	—	5,826	2,796	
Primary income generating activity is agricultural fieldwork (proportion)	—	—	0.30	0.35	
Primary income generating activity is animal husbandry	—	—	0.37	0.48	
Primary income generating activity is mining, construction, physical work	—	—	0.11	0.05	
Primary income generating activity is shop, business, etc.	—	—	0.13	0.07	
Primary income generating activity is other	—	—	0.09	0.04	

Notes: A dash indicates question not asked for this age group.

Table 10.2 Household assets and consumption (baseline survey)

Bicycle (proportion owning)	0.63
Motorcycle or scooter	0.14
Kerosene stove	0.34
Mobile phone	0.77
CD/DVD player or radio	0.25
Television	0.23
Number rooms in house (excluding bathroom)	4.1
Number cows	0.7
Number buffaloes	0.9
Number goats	1.7
Number chickens	0.5
Number pigs	0.03
Total animals	2.7
Monthly per capita consumption (INR)	1,694
Household dietary diversity score (out of 12)	6.8
Last salt purchased was iodized (proportion yes)	0.94

Notes: Household dietary diversity score (HDDS) is the number of food types out of twelve consumed on the previous day. It is a composite measure of food access and socioeconomic status. $N = 5{,}970$ households.

able to read the short paragraph easily or with some difficulties. For boys age five to fourteen school enrollment is 91 percent.

Most women in our sample do not earn an income. Those who do are principally engaged in animal husbandry or agricultural fieldwork. For men, the most common income-generating activities are also animal husbandry and agricultural fieldwork, followed by work in shops or in the mining sector.

To approximate relative wealth levels, we asked households a series of questions about the assets they own (table 10.2). More than half of households own a bicycle (63 percent) and 14 percent own a motorcycle or a scooter. Mobile phones can be found in 77 percent of households. Only one-third have a kerosene stove, 25 percent own a radio, and 23 percent have a television.

Houses have approximately four rooms on average (including the kitchen), with a household size of six to seven persons. The average household owns about three animals, the most popular being goats and buffaloes.

We measure consumption with a series of questions about the amount consumed of various categories over the previous thirty days (food broken down into nine types, paan/tobacco/alcohol, fuels, personal and house care, entertainment and media, gambling, travel, phones, other) over the previous year (clothing, shoes, schooling, festivals and ceremonies, health care, and eight types of durable goods). These figures were then converted into an estimated monthly expenditure divided by the number of household members. Monthly per capita consumption is high at just over INR 1,694 (table 10.2), reflecting the value of articles produced as well as purchased in the market.

This is higher than monthly per capita expenditure of INR 1,054 in rural areas in 2009 to 2010 estimated by the National Sample Survey Office (2011).

We also asked individuals which types of foods anyone in the household consumed the day before the survey and counted the number of food groups eaten out of the 12 used to estimate dietary diversity.[4] Unsurprisingly, less than 2 percent of households consumed meat the previous day, about 4 percent consumed eggs, and only about 6 percent consumed fish.[5]

Dietary diversity is a useful proxy for a diet associated with caloric and protein sufficiency, better birth weight, improved child anthropometric status, and higher hemoglobin (Swindale and Bilinsky 2006). As our measurement combines answers for foods consumed by anyone in the household about which the respondent knows, it may be an overestimation of diversity for individual members. Nonetheless, the average household consumed 6.8 out of 12 food groups the previous day. This result is in line with Bhagowalia, Headey, and Kadiyala (2012), who find dietary diversity at the household level to be around 7 in India. Comparatively, Swindale and Bilinsky (2006) recommend setting dietary diversity targets in such a sample using the score for the highest income tercile or the highest diversity tercile in the population. For our sample, the dietary diversity score for the highest diversity tercile is approximately 8.5.

Finally, we also asked about the type of salt that the household normally consumes. In this sample, 94 percent of households reported buying iodized salt the last time they purchased salt.

10.3.3 Health of Children

We turn next to the results of extensive health and physical measurements in our baseline survey. Our full sample of children age fourteen and younger includes 7,465 girls and 8,025 boys. Rates of anemia in young girls and boys are high, at around 50 percent for "any" anemia (see appendix table 10A.1 for thresholds) and around 25 percent for moderate or severe anemia in the age group of six months to under five years (see table 10.3). The gender gap in anemia rates is evident in older children, with 40 percent of girls age five to fourteen years testing as having any anemia (22 percent are moderately or severely anemic) and 29 percent of boys measured as having any anemia (15 percent are moderately or severely anemic).

The vast majority of children eat at least three meals a day. For children there is no standard of thinness related to body mass index (BMI), but in our villages the average BMI among children is around 14.6 to 15.1. According

4. We excluded responses for people who had attended a festival or other special event the previous day.

5. The third National Family Health Survey (NFHS-3) found 7 percent of adults in India eat chicken, meat, or fish daily (Arnold et al. 2009). In Bihar, 18.3 percent of women eat animal protein at least once per week and 20.5 percent eat eggs at least weekly (IIPS and Macro International 2008).

Table 10.3 Individual nutrition and health—children (baseline survey)

	Girls		Boys	
Age (yrs)	0–4	5–14	0–4	5–14
Number	2,462	5,003	2,557	5,468
Hemoglobin (g/dL)	10.70	11.78	10.81	12.18
Anemic (proportion yes)	0.54	0.40	0.49	0.29
Moderately or severely anemic (proportion yes)	0.27	0.22	0.23	0.15
Eats less than 3 meals daily	0.01	0.02	0.02	0.03
BMI	14.63	15.05	15.07	14.86
Mid-upper-arm circumference (cm)	14.07	18.02	14.30	17.50
Mid-upper-arm circumference indicates undernourished (proportion yes)	0.08	—	0.04	—
Completed Queens College Step Test (proportion)	—	0.54	—	0.74
Completed all 3 balance tests (proportion)	—	0.89	—	0.92
Seconds taken to walk 4 meters	—	3.18	—	2.82
Seconds taken to stand up & sit 5 times	—	8.89	—	7.95
Reported health is good or very good (proportion)	0.89	0.94	0.87	0.95
Number illnesses over last 30 days (out of 10 asked)	2.12	1.79	2.26	1.80
Had any illness "all the time" over the last 30 days (proportion)	0.05	0.04	0.06	0.03
Missed school in last 30 days due to illness or excessive fatigue (proportion)	—	0.40	—	0.40
Missed work in last 30 days due to illness or excessive fatigue (proportion)	—	0.26	—	0.24
Depression index (6–18, higher more depressed)	—	7.27	—	7.21

Notes: Hemoglobin and anemia are only for children above the age of six months. For hemoglobin, $N = 1{,}803$ girls and 1,907 boys age six months to five years old. There is no established MUAC cutoff for people age five to nineteen. Physical tests were administered to individuals age ten and older. For physical tests, $N = 1{,}785$ girls and 1,851 boys. Balance, walk, and sit/stand only tested if QCST could not be attempted. Disease symptoms asked about were blood loss, bad sight, night blindness, tuberculosis, malaria, pain in joints, worms, bloody stool/urine. The Adapted CES-D Depression Index in this sample has a mean of 8.6 with a standard deviation of 2.73. The median is 8. A dash indicates test not done for the age group.

to mid-upper-arm circumference (MUAC) benchmarks, about 8 percent of young girls and 4 percent of young boys in our sample are undernourished.

We also conducted four objective tests of physical fitness among children age ten and older. The Queens College Step Test (QCST) is a variation of the Harvard Step Test, which has been previously used with Indian populations to create a physical fitness index (Chatterjee et al. 2004, 2005). The QCST is performed using a 16.25-inch-high step. All respondents are asked to follow the same protocol, which required them to step on and off the step to the beat of an electric metronome. All male respondents were asked to follow a ninety-six beats per minute rhythm, while women and children (ten to fourteen years), were asked to follow eighty-eight beats per minute, in accordance to the guidelines established by Chatterjee et al. (2004).

Of the 2,051 girls who attempted the QCST, 54 percent were able to complete it. Of the 2,263 boys who attempted it, 74 percent finished. If a respondent fell out of sync with the beat of the QCST for more than fifteen seconds, he or she was asked to stop and perform the other basic fitness tests.

Second, for the balance tests, respondents were asked to stand in three positions for at least ten seconds (feet side by side, semitandem, full tandem). For those who could not finish or would not attempt the QCST, 89 percent of girls finished all three balance tests and 94 percent of boys finished all three. For the walk test, individuals were asked to walk a distance of four meters in a fast walking pace twice. On average, girls covered this distance in 3.2 seconds and boys covered it in 2.8 seconds. For the fourth test, subjects were asked to sit on and stand up from a stool five consecutive times. Girls did this in 8.9 seconds on average and boys finished in 8.0 seconds.

In addition to objective measures, we also covered subjective health. The surveyors began by asking the respondents to rank their overall health on a scale from 1 ("very good") to 4 ("very bad"). For very young children, a parent was asked the question about the child's health. Self-reported health is good or very good for the vast majority of all ages of children.

Next, respondents were asked to indicate the number of occurrences of short-term sicknesses in the last thirty days as well as more severe disease symptoms in the last six months from two respective lists. Very few children (3 percent to 6 percent) report chronic illness over the past thirty days, though about 40 percent of girls and boys have missed school due to illness or excessive fatigue in the same time period. About one quarter of the older children have also missed work for the same reasons. The most common sicknesses reported for children, adults, and the elderly are cold, fever, fatigue, and diarrhea.

Last, the survey also measured perceived mental health. Respondents were asked to indicate how frequently each mental state from the following list is experienced: (a) I felt sad; (b) I felt like crying; (c) I felt scared; (d) I felt lonely, like I did not have any friends; (e) I felt like people I know were not friendly or did not even want to be with me; and (f) I did not feel like

eating or was not hungry. For each mental state the respondent indicates how intensely/often she felt that way in the last week: (a) not at all, (b) a little, or (c) a lot.

Our depression index is formed by summing the intensity values (1–3) for all six feelings. Someone who does not feel any of these negative states over the previous week will, therefore, score a 6. This test is modeled after the CES-D depression index (Radloff 1977).[6] Children scored very low on this index and with no difference between girls (7.3) and boys (7.2), indicating on average they felt one of the negative states a little during the previous week.

10.3.4 Health of Adults

In order to assess the health of adults and older adults, we used a similar set of objective tests and self-reports. They are reported in table 10.4 In this sample, the average woman is anemic, with hemoglobin under 12 g/dL. Among adult women, 52 percent are anemic by all definitions, and 25 percent are moderately or severely anemic. These percentages increase with age: 68 percent of women age seventy and older are anemic by any definition, 39 percent moderately or severely. The situation is only relatively better for adult males for whom the rate of any anemia is 22 percent for the fifteen to forty-nine age group. The gender gap in any anemia goes away in this sample, as the proportion of anemic men increases to 55 percent for men in their sixties and to 67 percent for men over the age of seventy. However, men do have lower rates of moderate and severe anemia in all age groups. Figure 10.1 illustrates the relationship between hemoglobin and age in our sample.

Many adult females and adult males eat fewer than three meals per day, but this is particularly high among men in their sixties (43 percent) and seventies (49 percent). Over 85 percent of women across all age groups never eat meals outside. For adult males under fifty this proportion is only 58 percent, but it rises to 82 percent for men in their seventies. Nonetheless, the percentage of meals taken outside is extremely low for all adults at 6 percent or less, indicating that iron-fortified salt will reach this group if it is in food cooked and consumed at home.

In terms of weight for height, the average adult is within the healthy range for BMI. However, a fairly high proportion of adults have a BMI that would be classified as moderate or severe thinness. This is true for 12 percent of women between the ages of twenty and forty-nine, and increases to 29 percent for women in their seventies. Approximately 10 percent of men age twenty to forty-nine are moderately or severely thin, and this increases to 22 percent among men in their seventies. Figure 10.2 shows the relationship between BMI and age is strong and is not mediated by a measure of wealth. The thinner lines indicate individuals whose household

6. The number of feelings and coding of answers of this survey differs from the standard ten-item CES-D index.

Table 10.4 **Individual nutrition and health—adults (baseline survey)**

	Female				Male			
Age (yrs)	15–49	50–59	60–69	70+	15–49	50–59	60–69	70+
Number	9,387	1,424	1,241	813	7,657	1,123	1,408	1,062
Hemoglobin (g/dL)	11.7	11.7	11.5	11.2	14.0	13.3	12.6	11.9
Anemic (proportion yes)	0.52	0.55	0.59	0.68	0.22	0.39	0.55	0.67
Moderately or severely anemic (proportion yes)	0.25	0.25	0.30	0.39	0.03	0.09	0.16	0.28
Eats less than 3 meals daily	0.19	0.35	0.38	0.39	0.20	0.36	0.43	0.49
Never eats meals outside home (proportion yes)	0.87	0.89	0.87	0.90	0.58	0.64	0.70	0.82
Share of meals taken outside	0.01	0.01	0.01	0.01	0.06	0.04	0.03	0.02
BMI (kg/m^2)	20.34	20.75	20.52	19.39	20.01	20.73	20.04	19.48
BMI indicates moderate or severe thinness (over age 20)	0.12	0.17	0.21	0.29	0.10	0.11	0.17	0.22
Mid-upper-arm circumference (cm)	24.65	24.98	24.39	23.19	25.65	26.18	25.25	24.16
Mid-upper-arm circumference indicates undernourished (proportion yes)	0.17	0.19	0.25	0.41	0.10	0.12	0.22	0.35
Completed Queens College Step Test	0.25	—	—	—	0.73	—	—	—
Completed all 3 balance tests (proportion)	0.88	0.81	0.71	0.53	0.90	0.88	0.82	0.65
Seconds taken to walk 4 meters	3.98	4.03	4.45	5.68	3.26	3.48	3.50	4.30
Seconds taken to stand up & sit 5 times	11.44	12.75	13.66	15.49	10.36	10.86	11.77	13.68
Number of ADL that can be done (out of 6)	3.40	2.57	2.01	1.14	3.95	3.69	3.22	2.20

Self-reported health is good or very good (proportion)	0.79	0.65	0.6	0.56	0.90	0.82	0.75	0.67
Number illnesses over last 30 days (out of 10 asked)	2.95	3.47	3.57	3.75	2.08	2.45	2.62	2.91
Had any illness "all the time" over the last 30 days	0.19	0.30	0.38	0.46	0.10	0.17	0.27	0.41
Missed school in last 30 days due to illness or excessive fatigue	0.31	—	—	—	0.24	—	—	—
Missed work in last 30 days due to illness or excessive fatigue	0.26	0.32	0.33	0.29	0.28	0.31	0.31	0.28
Depression index (6–18, higher more depressed)	9.15	10.09	10.29	10.53	8.11	8.51	8.78	8.98

Notes: Anemia thresholds are adjusted for pregnancy and smoking. Thinness thresholds adjusted for pregnancy. MUAC cutoff for undernourishment for adults is 20. This is a conservative estimate. The QCST was administered to individuals between the ages of ten and forty-nine. Activities of daily living (ADL) asked about were standing up, filling a bucket, walking 0.5 kilometers, walking 5 kilometers, carrying 5 kilograms, and sowing rice for one day. "Can Do" ADL includes "can easily do" and "can do with some difficulty." Disease symptoms asked about were blood loss, bad sight, night blindness, tuberculosis, malaria, pain in joints, worms, bloody stool/urine. A dash indicates question not asked or test not done for the age group.

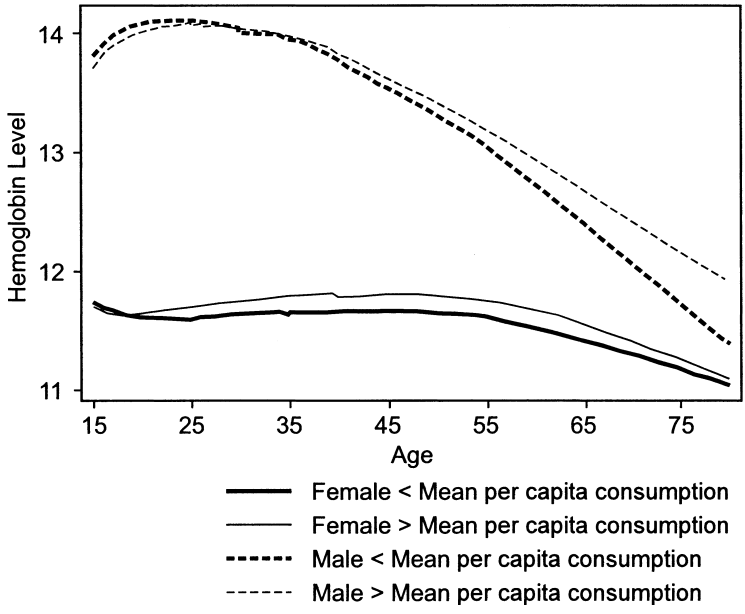

Fig. 10.1 Lowess graph of hemoglobin level by sex and consumption

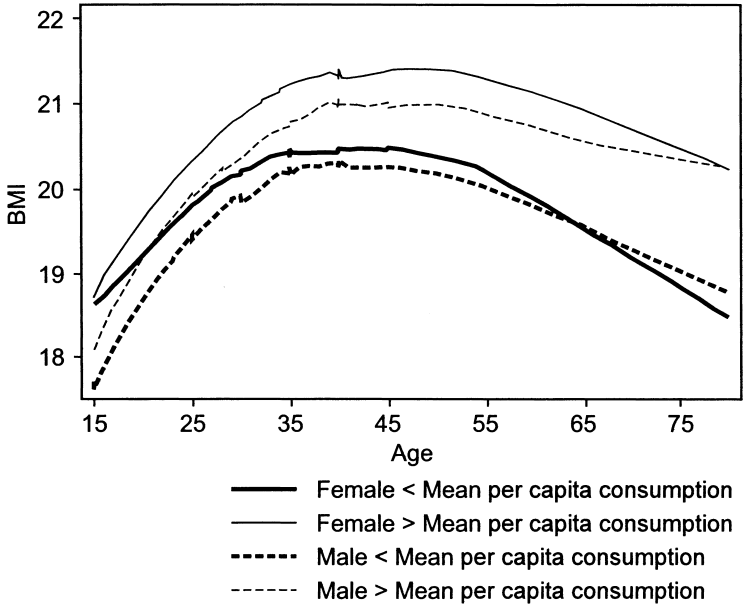

Fig. 10.2 Lowess graph of body mass index by sex and consumption

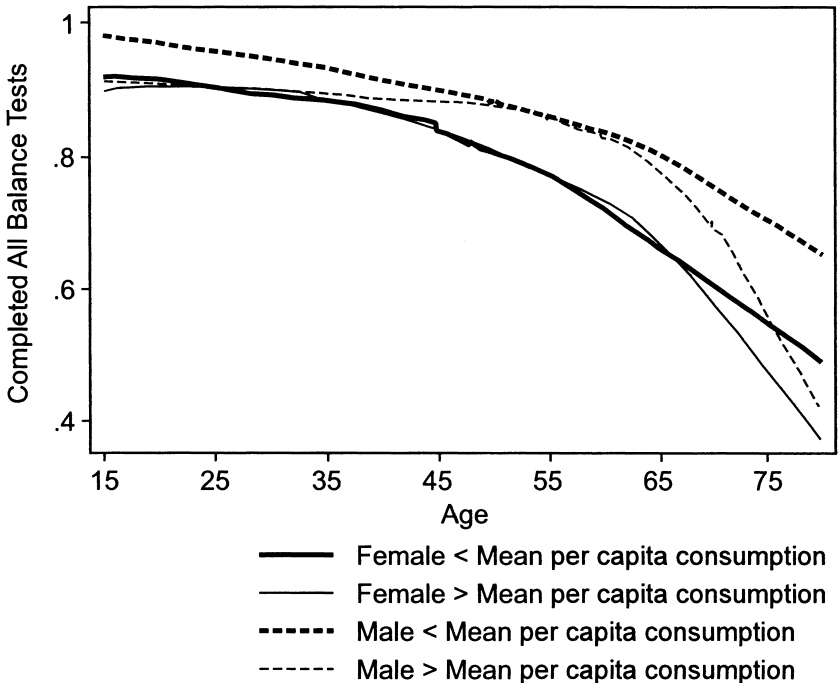

Fig. 10.3 Lowess graph of balance tests by sex and consumption

consumption per person places them in the upper half of the consumption distribution.

Undernourishment among adults is corroborated using a conservative benchmark of a 20 cm MUAC for adults. By this measure, approximately 14 percent of adults under the age of fifty are undernourished. The MUAC is roughly stable until individuals reach their seventies.

For adults, the Queen's College Step Test was limited to people under age fifty; 25 percent of women and 73 percent of men who attempted the test could complete it. Most women under age fifty could, however, complete the three balance tests, as could men of the same age. For both sexes, balance declines as the decades pass. Figure 10.3 highlights the decline, which is greater for women.

Time taken to walk four meters starts at about 4 seconds for adult women and 3.3 seconds for adult men. Both sexes are slower at older ages, but the difference is greater for women. The average man over age seventy covers the distance in the same amount of time as a woman in her sixties. Next, table 10.4 shows us that the time taken to stand up and sit down five times is quite a bit longer for adults than for children. It takes adult women over eleven seconds and adult men need over ten seconds to complete the task. Men are

faster than women on this test at all ages, but particularly when comparing women and men in their seventies.

A more direct way to capture physical health through self-reported information is to ask respondents about their ability to perform activities involving different degrees of physical stress. In the survey, adult and elderly respondents were asked to report the level of difficulty they experience during the following seven common activities of daily living (ADL): stand up from sitting on the floor, fill a bucket with water, use a hand pump, walk 0.5 km, walk 5 km, carry 5 kg weight, and sow rice for one day.

For each activity, the respondent indicated whether he or she can do it easily, can do it with some difficulty, finds it very difficult to do, or cannot perform the activity. We report the number of activities that can be done easily or with some difficulty as "can be done." The average working-age woman can complete 3.4 of these activities and the average male can complete 4.0. Older people can do fewer tasks; women in their seventies can only compete one task, while men in their seventies can complete two on average.

Next, we look at reports of subjective health. Nearly 80 percent of working-age women and 90 percent of working-age men report that their health is good or very good. With each decade of age, reports of good health are lower. But, remarkably, 56 percent of women and 67 percent of men in their seventies report that their health is good or very good. This, of course, could be the result of sicker people dropping out of the population.

As in other surveys, we find high rates of self-reported diseases (an "ocean of diseases"). The average number of illnesses reported over the past thirty days is higher for adults of all ages than for children. This potentially reflects the relative difficulty parents had remembering children's illnesses versus their own. Prime-age adult women report 2.95 symptoms of disease over the last thirty days, and 19 percent say they had an illness "all the time" over the last thirty days. This jumps to 3.47 diseases for women in their fifties, 30 percent of who feel ill "all the time," and keeps increasing with age. The same pattern is present for men, though at all ages they report fewer illnesses than women. As in many other studies, we find higher self-reported status among men and women, and self-reported health status declines with age. Remarkably, 26 percent of prime-age women, and 28 percent of prime-age men report having missed some days of work due to illness or excessive fatigue over the last thirty days, which suggests that poor health status may in fact have an impact on productivity.

Finally, we report the results for adults on the depression index in table 10.4 Women under fifty score an average of 9.2 on the test while men score 8.1. This is slightly higher than for children (scoring just over 7). The score is higher with greater age; women in their seventies score 10.5, and men in the same age group score 9.0 on average.

10.3.5 Cognitive Health

An interesting feature of this survey is the combination of the rich demographic and economic data (and the experiment) with a detailed cognitive assessment for both children and adults. The test instruments are based on internationally or locally validated measures, and are described in detail in the appendix. Cognitive health was measured by four age groupings: 0 to 30 months, 5 to 14 years, 15 to 49 years, and 50 years and older.

For infants, the Lucknow Development Screen measures psychomotor skills by asking parents if the infant can complete age-appropriate activities, such as recognizing his or her mother, turning his or her head toward a sound, and walking with help or alone (Bhave, Bhargava, and Kumar 2010). Children in our population score below the expected range of the test: table 10.5 shows approximately 47 percent of infants (both boys and girls) can accomplish all of their age-appropriate tasks. This is also slightly less than the clinical sample in Lucknow used to validate the test for India (142 children age six to twenty-four months), where 49.3 percent of children could complete all age-appropriate tasks. This suggests low levels of cognitive development among infants.

For children between the ages of five and fourteen, we used two tests. The Digit Span Test from the PGI Memory Scale (Pershad and Wig 1988) asks the child to repeat four sequences of numbers, three to eight numbers in length forward and two to eight long backward. The maximum number of digits in a row a child can repeat, forward and backward separately, are the child's scores. Table 10.5 shows children in our sample scored on average from 2.1 to 4.2 on the forward test and from 0.3 to 2.5 on the backward span, depending on age and sex.[7]

The block-tapping test from the National Institute of Mental Health and Neurosciences (Rao, Subbakrishna, and Gopukumar 2004) firsts asks children to tap the top of four matchboxes in the same order they just saw a surveyor tap. The child is next asked to repeat the tap in reverse order. Each correct answer on five forward and five reverse tapping tests earns the child one point. The maximum possible is ten points. Well-nourished children in a Bangalore school were measured at 5.6 taps for ages five to seven, and 7.6 taps for ages eight to ten (Kar et al. 2008).

Our youngest respondents score under these means. The average scores increase with age and are higher for boys than for girls. At the age of five to seven years the gender gap is 0.7 points, with girls earning a total of 3.9 points on average and boys earning 4.6. In the eight- to ten-year group, girls earned 7.8 points and boys 9.5 points. For the oldest children, age eleven to

7. In a sample of Italian children age four to ten years, the mean (backward and forward) digit span is approximately 4.5 for both boys and girls (Orsini et al. 1987).

Table 10.5 Cognitive capacity (baseline survey)

A. Infants 0–30 months

	Female	Male
Lucknow Development Screen (proportion completed all)	0.47	0.47
Number	952	1,083

B. Children

	Female			Male		
Age (yrs)	5–7	8–10	11–14	5–7	8–10	11–14
Forward digit span (maximum out of 8)	2.08	3.35	3.92	2.30	3.60	4.23
Backward digit span (maximum out of 8)	0.34	1.15	1.87	0.48	1.62	2.49
NIMHANS Visuospatial Working Memory (out of 10)	1.97	3.79	4.48	2.29	4.57	5.74
Number	1,342	1,454	1,623	1,560	1,648	1685

C. Adults 15–49 yrs old

	Female	Male
Number	8,087	6,365
Forward digit span (maximum out of 8)	3.34	4.17

Backward digit span (maximum out of 8)	1.16	2.27
Word recall (out of 10)	6.29	7.04
Sentence reproduction (out of 12)	7.89	8.66
Word pairs (out of 20)	8.46	11.99
Verbal cognition (out of 42)	22.69	27.71

D. 50 yrs old and older

	Female			Male		
Age	50–59	60–69	70+	50–59	60–69	70+
Number	1,290	1,102	666	1,017	1,284	942
Overall cognition (out of 36)	20.63	19.04	16.86	25.35	24.13	22.29

Notes: The Lucknow Development Screen shows the percentage of infants that can do all age-appropriate actions. Age-appropriate actions can be done by 97 percent of children at a given age. There are no validated cognitive tests for thirty months to fifty-nine months. Elderly cognition is the sum of eleven individual tests.

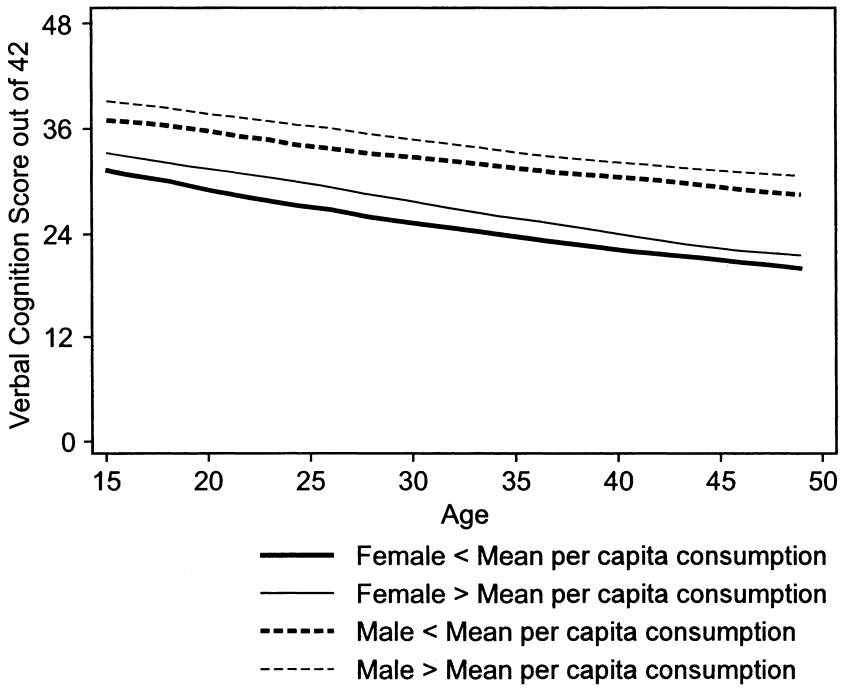

Fig. 10.4 Lowess graph of adult verbal cognition by sex and consumption

fourteen, the gap is widest, with girls earning 10.1 points and boys earning 12.7 on average. Overall, boys performed better than girls by approximately 1.5 points (significant at 99 percent).

For adults (age fifteen to forty-nine), we again used subtests from the PGI Memory Scale. The first test is similar to the children's Digit Span Test with three- to eight-digit forward spans and two- to eight-digit backward spans used. In normative data from Italy, the range for adults age twenty to fifty on the forward span is 6.47 to 6.12 and on the backward span is 5.07 to 4.68 (Monaco et al. 2013). Table 10.5 shows our sample is around two to three digits lower than these on both spans.

The second test asks the individual to listen to a sequence of words read out slowly and then repeat it back after one minute; out of ten possible points, the range of PGI norms for twenty- to fifty-year-olds is 7.6 to 8.3. The third test requires the subject to listen to sentences of increasing length and repeat back phrases from the sentences and can earn the individual twelve points; the range of PGI norms is 7.2 to 7.8. The final test asks the individual to listen to a sequence of word pairs and then to complete the pair when the first word is repeated. The final test is worth twenty points, and the range of PGI norms is 13.8 to 16.6 for the relevant age

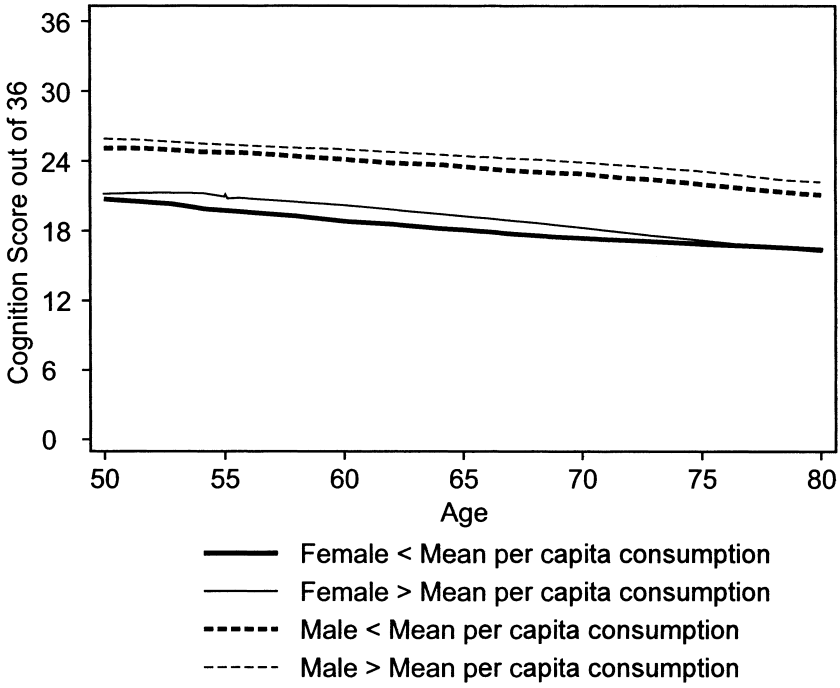

Fig. 10.5 Lowess graph of older adult cognition by sex and consumption

group (Pershad and Wig 1988). This makes the possible total for the final three verbal tests forty-two. The average woman scores twenty-two on this battery of tests, while the average male scores twenty-seven, suggesting the gender gap observed among children persists into adulthood. Figure 10.4 shows that scores are lower for older adults, even in the group under age fifty.

Finally, we measure cognition among adults age fifty and older using the Hindi Mental State Examination (Ganguli et al. 1995), which is based on the Mini-Mental State Examination (MMSE) and validated in India populations. This exam contains eleven different sections involving orientation to time and location, repetition and recall, registration and recognition of objects, figure drawing, and addition (of sevens serially). The maximum score on this battery is 36. In the validation of the test in Ballabargh, a rural setting outside Delhi, with a population over fifty-five years old (mean age 70.7), Ganguli et al. find that the scores varied from 21 among those with no education to 27 among those with some education. Overall, women in our survey age fifty and older score 19.2 points and men score 24. Figure 10.5 shows the decline in women's and men's scores as they age. Table 10.5 shows that women's average scores decline from 20.6 for fifty- to

fifty-nine-year-olds to 19 for sixty- to sixty-nine-year-olds and 16.9 for those age seventy and older. Men in their fifties score 25.4 points, men in their sixties score 24.1 points, and men age seventy and older score 22.3 points.

10.3.6 Associations between Anemia and Health Characteristics

Without attempting to make any causal inference (since the causality is likely to run both ways), in table 10.6 we present the associations between anemia and other characteristics separately for each sex. At the household level, there is a significant association between the percentage of the household that is moderately or severely anemic and measures of wealth. Households with more anemic members have slightly lower monthly per capita expenditure and own slightly fewer assets (panel A). Anemia is also more prevalent in households that have a lower level of nutritional variety. This correlation persists (and remains significant) even after controlling for assets (which is strongly significant) and for per capita consumption. This suggests that the prevalence of anemia may be related to quality, rather than quantity, of nutrition.

We also observe many significant associations between individual hemoglobin and other personal characteristics controlling for age, smoking status, and pregnancy in regressions with standard errors clustered at the village level. Hemoglobin is lower for males who never eat meals outside (most adult males are in this category) and is higher among those who eat fewer than three meals daily (most individuals do eat three meals daily—see table 10.4). Interestingly, among females, anemia is not correlated with the number of meals missed.

We also observe a strong pattern of associations between hemoglobin and measures of physical fitness. Higher hemoglobin is associated with higher BMI, higher completion rates for the Queens College Step Test and the balance tests, faster time in walking four meters, faster times standing up and sitting down (for males only), and a higher number of activities of daily living that can be done.

Table 10.4 also shows that higher hemoglobin is associated with better self-reported health, fewer number of illnesses reported, and having an illness "all the time" in the past thirty days. There is, however, no relationship between hemoglobin and the depression index (which was fairly uniformly low among males and females). Table 10.7 shows the relationship between anemia and self-reported health is consistent across all age groups except infants when controlling for BMI, age, sex, consumption, and asset ownership. For respondents over age fifty, anemia is also associated with objective measures of health such as longer times taken to stand and sit five times and being able to do fewer activities of daily living.

We also look at the relationship between anemia status (mild, moderate, and severe) and other measured characteristics. We note that BMI as discussed

Table 10.6 Associations between hemoglobin and personal characteristics (baseline survey)

A. Household level

Association between variable and anemia	Coefficient	SE	N
Monthly per capita consumption (INR 000s)	–0.005***	0.002	5,478
Number assets reported owned (0 to 8)	–0.018***	0.002	5,880
Household dietary diversity score (0 to 12)	–0.013***	0.002	5,200

B. Individual level

	Female			Male		
Association between variable and hemoglobin level	coefficient	SE	N	coefficient	SE	N
Never eats meals outside home (% yes)	–0.02	(0.05)	9,282	–0.22***	(0.04)	9,555
Eats less than 3 meals daily	0.01	(0.04)	15,651	0.25***	(0.05)	16,527
BMI	0.03***	(0.00)	15,282	0.17***	(0.01)	16,170
Completed Queens College Step Test	0.20***	(0.05)	5,072	0.38***	(0.04)	7,598
Completed all 3 balance tests (%)	0.15**	(0.05)	5,984	0.47***	(0.09)	4,102
Time taken to walk 4 meters (seconds)	–0.07***	(0.02)	6,545	–0.11***	(0.03)	4,379
Time taken to sit & stand up 5 times (seconds)	–0.01	(0.01)	6,379	–0.04***	(0.01)	4,287
Number of ADL that can be done (out of 6)	0.05**	(0.02)	9,136	0.18***	(0.02)	9,518
Self-reported health is good or very good (%)	0.19***	(0.03)	15,551	0.60***	(0.06)	16,377
Number illnesses over last 30 days (out of 10 asked)	–0.04***	(0.01)	15,585	–0.13***	(0.01)	16,420
Had any illness “all the time” over the last 30 days	–0.17***	(0.04)	15,590	–0.52***	(0.06)	16,411
Depression index (6–18, higher more depressed)	–0.01	(0.01)	11,387	–0.01	(0.01)	11,846
Lucknow Development Screen—infants	0.35**	(0.11)	699	0.10	0.12	806
Forward digit span—children 5+	0.08***	(0.01)	4,377	0.05***	0.01	4,868
Forward digit span—adults	0.03*	(0.01)	6,076	0.12***	0.02	6,254
HMSE—adults 50+	0.04***	(0.01)	2,963	0.12***	0.02	3,138

Notes: Anemia is defined as percentage of people in the household being moderately or severely anemic. Sixty percent of households have > 0 moderately or severely anemic members. Coefficients reported are from regressions where the outcome variable is hemoglobin level (g/dL) and controls include age, smoker, pregnant. Standard errors clustered by village.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 10.7 Anemia and physical health

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Self-reported health is good or very good				Time to walk 4 m	Time to stand & sit 5 times	Number ADLs can do
Age (yrs)	Under 5	5 to > 15	15 to < 50	50+	50+	50+	50+
Has moderate or severe anemia	0.01	–0.02**	–0.04***	–0.04***	0.07	0.28**	–0.13***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.06)	(0.13)	(0.04)
Age in years	0.04***	0.00**	–0.01***	–0.00***	0.06***	0.13***	–0.05***
	(0.01)	(0.00)	0.00	(0.00)	(0.00)	(0.01)	(0.00)
Female	0.03***	–0.01	–0.10***	–0.14***	0.97***	1.85***	–0.81***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)	(0.11)	(0.03)
Monthly consumption pp (INR 000s)	–0.01	0	0	0	0	0.01	0
	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.03)	(0.01)
Number assets owned	0.01**	0.00*	0.01***	0.01***	0	–0.01	0.02**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.03)	(0.01)
BMI	0.01***	0.00*	0	0	0	0.04***	–0.03***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)
Constant	0.67***	0.90***	1.01***	1.06***	–0.31	3.22***	8.46***
	(0.04)	(0.02)	(0.02)	(0.06)	(0.23)	(0.51)	(0.15)
Observations	3,561	9,304	14,227	6,111	5,996	5,843	6,066
R-squared	0.022	0.004	0.044	0.035	0.158	0.105	0.204

Notes: Includes controls for percent others in household anemic; household is Scheduled Caste, Scheduled Tribe, or Other Backward Class; and missing consumption or missing assets, which were set to mean levels. Robust standard errors in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

earlier is in the healthy range on average. Anemia rates seem high in relation to this relatively acceptable physical status. Table 10.8 shows that, unsurprisingly, correlates of anemia include asset ownership, consumption per capita, own BMI, age, and education. Perhaps more interestingly, controlling for everything else, household dietary diversity is correlated with anemia. Along with the fact that this is not a *very* poor population and BMI is acceptable, this suggests that anemia may be due to micronutrient deficiency despite consumption of sufficient calories.

Finally, there are also strong associations between hemoglobin and cognition for all age groups. Higher hemoglobin is associated with slightly higher LDS scores for female infants (the sign is the same, but not significant, for male infants). Higher hemoglobin is also associated with higher cognition for children age five and older and adults of all ages. Though the effect is significant for adults under age fifty, the size is small (0.005 for female and 0.01 for male adults). Table 10.9 shows that lagging infant development and worse memory are also associated with anemia (mild, moderate, and severe) in infants and children, controlling for consumption. These relationships are robust to household fixed effects for children above age five, though they become smaller. Table 10.10 shows a similar pattern for adults and older adults. Anemia is significantly associated with worse memory and cognition after controlling for BMI, age, sex, diet, consumption, and assets—though the association is not robust to household fixed effects.

In summary, the baseline survey paints a picture similar to other surveys of rural populations in India. Anemia is ubiquitous, particularly among women, as are various symptoms of poor health, frequent self-reported diseases, and poor performance on physical fitness tests. What is striking, however, is that this is a population that is neither particularly poor by the standard of rural India (the average per capita consumption is INR 56 per day), and the overall level of nutrition seems to be satisfactory, judging from average BMI (though a substantial fraction of people do not eat three meals a day). There is no proof that anemia is associated with poor nutrition, but it is strongly correlated with dietary diversity among both men and women. There is thus some indication from the baseline that anemia is related to micronutrient availability. In turn, anemia is associated with poor health outcomes and poor cognition outcomes among people of all ages and both genders. Moreover, all households surveyed buy salt, and they frequently buy iodized salt. This suggests that the introduction of salt that is fortified with iodine may be a promising way to fight anemia.

In the second part of this chapter, we report the results of a randomized controlled trial we conducted to determine what the take-up of double-fortified salt would be at various prices, and whether the way information is shared with the villagers would affect this take-up.

Table 10.8 Anemia and household dietary diversity

Dependent variable: Anemic (any)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sex	All	All	Female	Male	All	Female	Male
Household dietary diversity score (/100)	–1.57***	–0.52**	–0.18	–0.89***	–0.47**	–0.17	–0.83***
	(0.18)	(0.21)	(0.29)	(0.29)	(0.21)	(0.30)	(0.29)
Age		0.00***	0.00***	0.00***	0.00***	0.00***	0.01***
		0.00	0.00	0.00	0.00	0.00	0.00
BMI					–0.01***	0	–0.02***
					(0.00)	(0.00)	(0.00)
Female		0.17***			0.18***		
		(0.01)			(0.01)		
Monthly consumption per person (INR 000s)		0	0	0	0	0	0
		(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)
Food as percentage of monthly expenditure		0.03	0.06*	0	0.03	0.05	0.02
		(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)
Number assets reported own		–0.02***	–0.02***	–0.02***	–0.02***	–0.02***	–0.02***
		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Household is SC, ST, or OBC		–0.01**	–0.02**	–0.01	–0.01**	–0.02**	0
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Constant	0.53***	0.34***	0.48***	0.37***	0.45***	0.48***	0.64***
	(0.01)	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)
Observations	34,221	28,540	14,825	13,715	27,949	14,521	13,428
R-squared	0.002	0.061	0.022	0.047	0.063	0.02	0.064

Notes: Columns (2) through (7) include controls for missing assets, missing consumption, and caste, which were set to means.
Robust standard errors in parentheses.
***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Table 10.9 Anemia and cognition—children

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	LDS		Forward digit span		Backward digit span	
Age	0 to 30 months		5 to < 15 yrs		5 to < 15 yrs	
Any anemia (mild, moderate, or severe)	–0.07**	–0.02	–0.16***	–0.09*	–0.14***	–0.09*
	(0.03)	(0.27)	(0.04)	(0.06)	(0.03)	(0.05)
BMI	0.01**	–0.01	–0.01	–0.03**	0.01	–0.02*
	(0.00)	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)
Age	0	0.06	0.28***	0.29***	0.26***	0.26***
	(0.03)	(0.18)	(0.01)	(0.01)	(0.01)	(0.01)
Female	0.01	–0.05	–0.23***	–0.27***	–0.42***	–0.48***
	(0.03)	(0.22)	(0.03)	(0.05)	(0.03)	(0.04)
Household dietary diversity score (/100)	0.61		4.10***		6.88***	
	(0.95)		(1.35)		(1.16)	
Monthly consumption per person (INR 000s)	0		0.02		0	
	(0.02)		(0.02)		(0.02)	
Number of assets	0.03***		0.11***		0.15***	
	(0.01)		(0.01)		(0.01)	
Household is SC, ST, or OBC	0.02		0.10**		0.16***	
	(0.03)		(0.04)		(0.04)	
Constant	0.20**	0.49	–0.64***	0.48**	–2.67***	–1.05***
	(0.10)	(0.65)	(0.15)	(0.20)	(0.12)	(0.18)
Household fixed effects	No	Yes	No	Yes	No	Yes
Observations	1,340	1,340	9,170	9,170	9,180	9,180
R-squared	0.04	0.92	0.25	0.64	0.31	0.68

Notes: Includes control for currently in school, number animals own, missing school enrollment, missing assets, animals, caste, and HDDS. Robust standard errors in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

Table 10.10 Anemia and cognition—adults

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Forward digit span		Backward digit span		HMSE score	
Age (yrs)	15 to < 50		15 to < 50		50+	
Any anemia (mild, moderate, or severe)	–0.06**	–0.05	–0.09***	–0.05	–0.67***	–0.21
	(0.03)	(0.05)	(0.03)	(0.04)	(0.14)	(0.33)
BMI	0.03***	0.02***	0.03***	0.01**	0.11***	0.07
	(0.00)	(0.01)	(0.00)	(0.01)	(0.02)	(0.05)
Age	–0.03***	–0.03***	–0.04***	–0.04***	–0.12***	–0.16***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.02)
Female	–0.80***	–0.84***	–1.06***	–1.12***	–5.01***	–5.36***
	(0.03)	(0.04)	(0.03)	(0.03)	(0.11)	(0.25)
Household dietary diversity score (/100)	4.48***		4.52***		29.98***	
	(1.05)		(1.12)		(4.71)	
Monthly consumption pp (INR 000s)	0.02*		0.01		0.10**	
	(0.01)		(0.01)		(0.04)	
Number of assets	0.15***		0.21***		0.39***	
	(0.01)		(0.01)		(0.04)	
Household is SC, ST, or OBC	0.21***		0.28***		0.63***	
	(0.04)		(0.04)		(0.15)	
Constant	3.38***	4.75***	1.45***	3.29***	25.91***	33.40***
	(0.10)	(0.11)	(0.10)	(0.11)	(0.69)	(1.88)
Household fixed effects	No	Yes	No	Yes	No	Yes
Observations	14,109	14,109	14,097	14,097	5,838	5,838
R-squared	0.16	0.56	0.26	0.62	0.30	0.79

Notes: Also includes control for number animals own, missing assets, animals, caste, and HDDS. Robust standard errors in parentheses.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

10.4 Pricing Experiment

10.4.1 Design of Experiment

Double-fortified salt had not been marketed in rural Bihar before this trial. Our pricing experiment, which was conducted in October and November 2011, was designed to assess household willingness to pay for DFS as a first stage in our larger research agenda. As the benefits of iron fortification may not be obvious—even to users—the subsidy to encourage adoption may need to be large enough to make it competitive with iodized salt. Working in one district of Bihar (Bhojpur), we randomly selected forty-three villages in Behea block (an administrative area smaller than the district) and in cooperation with Tata Chemicals we stocked Tata Salt Plus in small private stores (known as kirana shops) and Public Distribution System (PDS) shops. Within these forty-three villages, we randomized assignment of information treatments at the village level and pricing/outlet assignment at the household level. Each village was randomly assigned to receive one of three information campaigns:

1. a basic campaign consisting solely of printed materials displayed at the participating stores;
2. the full Tata campaign, which included street plays and group activities similar to those Tata conducts in other markets, in addition to the basic campaign; or
3. household visits by the government's ASHA health workers, in addition to the basic campaign and the full Tata campaign.

After the campaign was conducted, our team distributed vouchers for DFS purchase to ninety-nine households in each village and conducted a short survey asking about previous salt usage, socioeconomic status, and knowledge of DFS. The net price after discount was INR 12, 11, 10, 9, or 8 per kilogram. Within each of the villages, anyone was free to purchase one-kilogram packets of DFS at the kirana store for INR 17, the price in 2011 without any subsidy. Coupons either showed consumers the full price at local kirana shops and offered them a subsidized price at the government Price Distribution System (PDS) shop, or were valid at the same price (full or various levels of subsidy) at both the PDS shop and the selected kirana(s), in order to assess purchase habits and take-up in both distribution channels. In all, there were eleven types of vouchers (see table 10.11) distributed; all were valid for four weeks.

Our data collection activities included both household survey and administrative data. When the first vouchers were handed out, households were asked to complete a short survey including simple questions about use of PDS and kirana stores and the wealth of the household. The location of these households were also recorded with a handheld GPS device. In addi-

Table 10.11 Pricing experiment vouchers

	Voucher type	PDS price	Kirana price
Lower price only at PDS shops; MRP at kirana	1	8	
	2	9	
	3	10	17
	4	11	
	5	12	
Same price at kirana and PDS shops	6	8	8
	7	9	9
	8	10	10
	9	11	11
	10	12	12
No discount	11	17	17

tion, data were collected on DFS sales and voucher use from the PDS and kiranas, and DFS consumption and satisfaction, as well as possible resale, by households.

Table 10A.2 presents the results of checks of the household-level randomization. Each household characteristic listed was the dependent variable in an ordinary least squares (OLS) regression with ten binary variables indicating voucher type as independent variables along with a covariate for the village. We present the test statistics for the joint test of significance for all of the voucher-type independent variables. This allows us to detect a correlation, if any, between the voucher type assigned to the household and its characteristics. The hypothesis of joint significance can be rejected for all but one of the characteristics: voucher types predict the number of buffaloes a household owns. They cannot, however, predict other measures of economic well-being, such as ownership of land, asset ownership, better construction materials, number of goats owned, or total number of animals owned.

Table 10A.3 presents the results of checks of the village-level randomization of the information campaigns. Again, each row presents the results from a separate regression in which the dependent variable is a household characteristic and the independent dichotomous variables indicate the type of information campaign. Standard errors are clustered at the village level. The fifteen villages that were given the Tata campaign have slightly fewer (–0.22) children per household, are less often constructed of bricks (rather than mud), and own 0.33 fewer animals than households in the fourteen villages that received only the basic information campaign. While 97 percent of households report that they ever buy goods from the PDS, this share is 98 percent for households in the fourteen villages that got all three information campaigns. Since the survey where people were

asked about anemia was conducted after the information campaigns, the 5 percentage point increase in ever hearing about anemia in the Basic + Tata + ASHA group likely reflects the success of ASHAs in delivering the health message.

10.4.2 Results of Pricing Experiment

Overall, 4,179 vouchers were distributed, of which 1,237, or 30 percent, were redeemed. Total sales of DFS were 1,808; voucher sales thus comprised 68 percent of total sales. There were 571 purchases of DFS without vouchers (32 percent of total sales). Take-up for those given full-price vouchers was approximately 8 percent.

Table 10.12 presents the results of the pricing experiment. Columns (1) through (5) estimate purchases in both types of stores combined when the amount of the discount offered was from INR 5 to INR 9. At every discount level, total take-up is higher when the discount is available at both outlets than when it is only available at PDS. Offering a discount in the PDS increased total household purchases more than offering it in the private shops (17 pp vs. 14 pp). Each rupee discounted from the price in the PDS increased household purchases by approximate 2.2 pp, while each rupee discount in the private shops increased sales by 2.0 pp. This result is robust to the inclusion of the information campaign in the regressions (column [5]). Column (3) suggests that the impact of the discount is linear over the discount amounts we tested.

The final two columns measure take-up by store type— PDS (column [6]) or kirana (column [7]). These models show that discounting sales simultaneously in both store types increased sales more in private shops than in the PDS shops. When looking at the subset of vouchers that offered the same discount in both PDS and private shops, we can see in figure 10.6 that vouchers are more than twice as likely to be used in the private shops.

Comparing figure 10.6 and figure 10.7 also allows us to see purchase responses at the intensive margin. For example, when a discounted price of INR 8 is available at both types of stores, total take-up is 45 percent; when the same discount is available at only PDS, total take-up falls to 29 percent. At any discount level, the shift from kirana to PDS is incomplete when the discount is constrained to the PDS. Although people are sensitive to price and shift to PDS when the discount is constrained, not all do so. Many households simply do not purchase DFS at all. This is reminiscent of the results from our earlier study (Banerjee et al. 2011), where households were not willing to switch millers permanently to take advantage of the opportunity to fortify grain. Sales appear to be quite sensitive to price, particularly when it falls from INR 10—the price at which regular iodized salt is often sold—to INR 9. When DFS is priced

Table 10.12 Impact of price and information campaign on take-up (price experiment)

Variables	(1) Purchased anywhere	(2) Purchased anywhere	(3) Purchased anywhere	(4) Purchased anywhere	(5) Purchased anywhere	(6) Purchased at PDS	(7) Purchased at kirana
Discount given at PDS (any)	0.166***						
	(0.03)						
Discount given at kirana (any)	0.136***						
	(0.02)						
PDS discount amount (INR 5 to 9)		0.022***	0.031**		0.022***	0.022***	–0.001
		(0.00)	(0.01)		(0.00)	(0.00)	(0.00)
Kirana discount amount (INR 5 to 9)		0.020***	0.017		0.020***	–0.014***	0.034***
		(0.00)	(0.01)		(0.00)	(0.00)	(0.00)
PDS discount amount squared			–0.001				
			(0.00)				
Kirana discount amount squared			0				
			(0.00)				
Info campaign: Basic + Tata				–0.002	–0.002	–0.011	0.009
				(0.05)	(0.05)	(0.05)	(0.02)
Info campaign: Basic + Tata & ASHA				0.021	0.02	0.02	0.001
				(0.06)	(0.06)	(0.05)	(0.03)
Sales at full price (mean)	0.084					0.047	0.037
	[0.28]					[0.21]	[0.19]
Observations	4,179	4,179	4,179	4,179	4,179	4,179	4,179
R-squared	0.042	0.05	0.05	0.001	0.05	0.029	0.126

Notes: Table reports results from OLS regressions, in which purchase is the outcome variable. Robust standard errors in parentheses, clustered at the village level. Standard deviations of means in square brackets. Omitted information campaign category is Basic Campaign.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

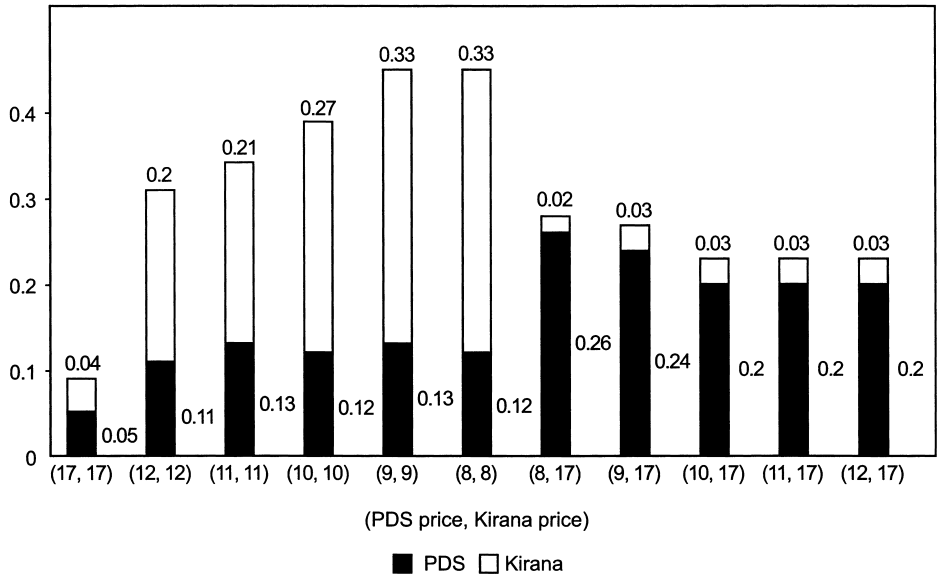

Fig. 10.6 All vouchers: Total take-up by voucher and store type

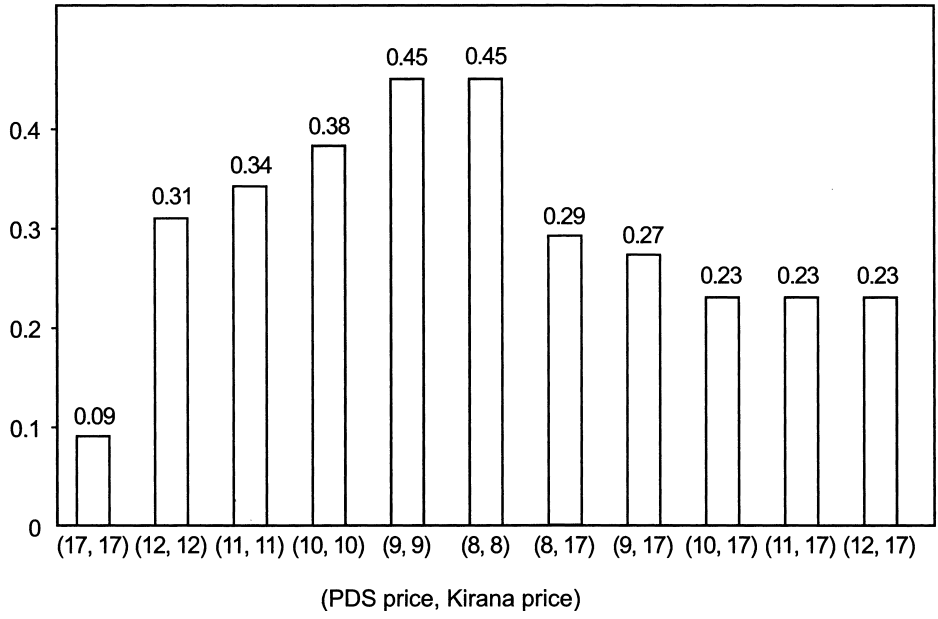

Fig. 10.7 All vouchers: Total take-up by voucher type

just below the price of regular iodized salt, it is probably seen as a cheaper way to buy iodized salt.

10.4.3 Results of the Information Campaign Experiment

The last variable row in table 10.12 shows the impact on take-up of adding a more involved information campaign (led by Tata) and a door-to-door campaign by ASHA workers. There seems to be no effect whatsoever. The estimates are not very precise due to the low sample size at the village level, but the point estimates indicate fairly low impact. We also tested whether information affects price elasticity (results not reported) but found no evidence for this. Additional evidence we collected strengthens these findings. For example, in the ASHA group, only 1 percent of households had heard of DFS through an ASHA. In our first survey, shortly after the information campaigns, 21 percent of the households had heard about Tata salt. They were more likely to have heard about it through a play in the villages where a play was performed, but it seems that information that the product actually existed was not a constraint, at least among surveyed households. Among people who had heard about the salt in the first survey, 35 percent knew it was "healthy,'' 31 percent knew that it contains iron, and 25 percent knew that it contains iodine. However, only 6 percent reported that it helps fight anemia, and 4 percent that it may help fight common diseases. By the end of the experiment, 68 percent of households knew about DFS, though most still did not know what it stood for or how it differed from regular salt. By and large, it seems that households appear less interested in the specific features of Tata Salt Plus than in the fact that it gives them access to a brand name product at a price that they consider affordable.

10.5 Conclusion

The baseline survey indicated that anemia is prevalent, and may be both caused by and a cause of poverty: households with low expenditure per capita and with low diversity in their diet are more likely to have an anemic member. Anemic individuals are weaker, sicker, and perform worse on cognitive tests than nonanemic individuals. Finding a way to solve this issue on a large scale is important for policy, and would also give us an opportunity for the first time to reliably measure the impact of a plausible instrument to fight IDA on health and economic outcomes.

Double-fortified salt, if priced sufficiently low, seems to have some promise. At a discount of 55 percent, it appears that take-up of DFS was reasonably high, even though households did not quite understand why Tata Plus was more desirable than any other type of salt.

A caveat is that there may have been a Hawthorne effect, since the very

fact of distributing a voucher (even for the full price) may have made households aware of the product and may have given them a motive to try it out. Moreover, the sensitivity to a reduction in price through a voucher may be larger than that of a low price offered in the shop if households feel that they have gotten a bargain. In the full-scale experiment, salt was made available at INR 9 per kg, the price that was likely to maximize take-up according to the price experiment. An information campaign similar to the basic campaign was run in every village by a group subcontracted by Tata. We are monitoring take-up, and so far (on a relative small sample) the take-up is only about 10 percent on average, much lower than in the price experiment. This may come from teething problems at the beginning of the program (it took awhile to supply all the shops, and to renew their stocks when they ran low), as well as from poor implementation of the information campaign at this large scale. Tata also reported to us that a take-up of 10 percent is standard for a new product (although this one is discounted).

Appendix

Description of Cognitive Tests

The cognition modules used in the baseline survey drew from a series of tests validated on Indian populations to assess respondents' cognitive ability and awareness. Four different batteries of tests were used to assess these characteristics among respondents of different age groups: infants (1–30 months), children (5–14 years), adults (15–49 years) and elderly (50 years and older). All cognition tests were conducted in isolation with the respondent, or in an isolated area overseen by a guardian, in order to maximize concentration. These tests were also conducted in the local language, Bhojpuri, to facilitate a clear understanding of the exercise.

Infants (1–30 months)

The infant cognition module is entirely based on the Lucknow Development Screen (LDS), a screening tool validated to assess the psychomotor skills of infants. The LDS was adapted from the Bayley Scales for an Indian population in Lucknow, Uttar Pradesh, by Professors Bhave, Bhargava, and Kumar from the CSM Medical University (Bhave, Bhargava, and Kumar 2010). In this test, the mother of the child is asked about the infant's ability to perform a set of tasks (from the infant's capacity to thrust his or her arms and legs forward in play while lying to the infant's ability to walk up stairs and down stairs with help), with the number of tasks asked about depending

Table 10A.1 Thresholds for determining "any" anemia

Age or gender group	Hemoglobin threshold (g/dL)	Smokers (g/dL)
Children (0–4 yrs)	11.0	—
Children (5–11 yrs)	11.5	—
Children (12–14 yrs)	12.0	12.3
Pregnant females	11.0	11.3
Nonpregnant females (15 yrs & older)	12.0	12.3
Adult males	13.0	13.3

Notes: Mild anemia refers to hemoglobin between 10 and 11 g/dL for young children and between 11 and 12 g/dL for everyone else. Moderate anemia is defined as hemoglobin between 7 and 10 g/dL for young children and between 8 and 11 g/dL for older children and adults. Severe anemia is 7 g/dL and below for children and 8 g/dL and below for older children and adults. All of these benchmarks are adjusted for smoking and pregnancy (as reflected in the table) when determining if an individual's hemoglobin measurement reflects mild, moderate, or severe anemia. A dash indicates threshold not available for this age group.

Table 10A.2 Household-level balance checks by voucher type assigned

Dependent variable	*N*	Test: Voucher dummies are jointly significant	
Number adults in household	4,178	2.51	*F*-stat
		(0.12)	*p*-value
Number children in household	4,178	0.86	
		(0.57)	
Children enrolled in school (%)	4,178	0.84	
		(0.59)	
Household has a below poverty line card (any type)	4,178	0.75	
		(0.68)	
Ever shops at public distribution system shop	4,179	0.54	
		(0.86)	
Household owns other land	4,151	1.02	
		(0.42)	
Number assets owned (out of 8 asked about)	4,178	0.73	
		(0.70)	
House construction includes bricks (not only mud)	4,178	0.76	
		(0.67)	
Number buffaloes owned	4,155	3.41	
		(0.00)	
Number goats owned	4,135	1.29	
		(0.23)	
Total number animals owned	4,179	1.41	
		(0.17)	
Ever heard of anemia	4,178	0.21	
		(1.00)	

Notes: Table reports *F*-statistics and *p*-values for a test of joint significance of voucher-type dummies after OLS regressions in which the voucher assignment is used to predict the characteristic on the left. The regressions also include a covariate for the village, as voucher assignment was done within the village. Households were asked if they owned these assets: TV, motorcycle, music player, gas/kerosene stove, mobile phone, bicycle, chair, cots/beds. Total animals includes cows, buffalos, goats, chickens, and pigs.

Table 10A.3 Village-level balance checks by information campaign

	Basic campaign (mean)	Basic + Tata (diff. from basic)	Basic + Tata + ASHA (diff. from basic)	Test: Basic = (B + T) + (B + T + A)
Villages in sample	14	15	14	
Households in sample	1356	1455	1368	
Average village population	1945	–441	–53	0.32
(administrative data)	[1349]	(465)	(537)	(0.58)
Number adults in household	4.77	–0.25	–0.09	1.69
	[3.06]	(0.16)	(0.16)	(0.20)
Number children in household	3.5	–0.22*	–0.16	3.99
	[2.66]	(0.13)	(0.10)	(0.05)
Children enrolled in school	0.62	–0.01	0.00	0.01
(%)	[0.39]	(0.03)	(0.02)	(0.94)
Household has a below poverty	0.56	0.06	0.06	2.35
line card (any type)	[0.50]	(0.05)	(0.05)	(0.13)
Ever shops at public	0.97	0.01	0.01*	3.56
distribution system shop	[0.16]	(0.01)	(0.01)	(0.07)
Household owns other land	0.61	–0.04	–0.07	1.13
	[0.49]	(0.07)	(0.06)	(0.29)
Number assets owned (out of	3.59	–0.31	0.01	1.14
8 asked about)	[2.10]	(0.19)	(0.15)	(0.29)
House construction includes	0.77	–0.08**	–0.02	2.51
bricks (not only mud)	[0.42]	(0.04)	(0.04)	(0.12)
Number animals owned	2	–0.33**	–0.12	3.19
	[4.69]	(0.14)	(0.15)	(0.08)
Ever heard of anemia	0.09	0.02	0.05**	3.75
	[0.28]	(0.02)	(0.02)	(0.06)

Notes: Differences shown are the coefficient on "Basic + Tata" or "Basic + Tata + ASHA" from separate OLS regressions using household-level data and standard errors clustered at the village level. Final column shows *F*-statistic and *p*-value for test of joint significance following the regression. Households were asked if they owned these assets: TV, motorcycle, music player, gas/kerosene stove, mobile phone, bicycle, chair, cots/beds. Total animals includes cows, buffalos, goats, chickens, and pigs.

Standard deviation of mean in square brackets and standard error of difference in parentheses in difference columns.

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

on the age of the child. Therefore, this test requires having accurate information on the age of the infant (in months).

The LDS used for the baseline followed the 97 percent screen; that is, it only inquired about tasks that can be expected to be performed by 97 percent of infants of the infant's age group. All the tasks in the LDS and the age up to which this task is applicable for the 97 percent screening are listed later. The metric from this test is the percentage of children who can perform all of their 97 percent screen tasks. (See table 10A.4.)

Table 10A.4 Lucknow Development Screen

Task	Screening age (in months)
Arms and legs thrust in play	1
Lateral head movement	1
Follows moving person	1
Social smile	3
Holds head steady	4
Recognizes mother	4
Laughs aloud	5
Reaches for dangling ring	5
Turns head to sound	6
Turns supine to prone	8
Sits alone steadily	8
Retains two things in two hands	9
Raises self to sitting	10
Playful response to mirror image	10
Says *da-da*, *ma-ma*	10
Waves *ta-ta*	11
Picks up small things	11
Stands by leaning on furniture	11
Inhibits on command	13
Walks with help	13
Stands alone	16
Speaks two words with meaning	18
Stands up	18
Walks alone	18
Gestures for wants	19
Speaks sentences of two words	25
Walks up and down stairs with help	25

Children (5–14 years)

The child cognition module is based on tests taken from two different batteries. First, it uses the digit span tests from the PGI Memory Scale (PGIMS), a memory scale developed for the Indian population by Professors Dwarka Pershad and N. N. Wig from the Post Graduate Institute of Medical Education and Research, Chandigarh. The digit span test involves a respondent repeating a sequence of numbers articulated by the surveyor. The reverse sequence questions expect the respondent to repeat the numbers articulated in reverse order. The forward sequence begins with a sequence of three numbers and goes up to a sequence of eight numbers. The reverse sequence begins with a sequence of two numbers and proceeds up to a sequence of eight. Two scores are awarded for the maximum number of digits that can be recalled.

The second test in this module is the taken from the visuospatial working memory span task (block-tapping test) from the NIMHANS child neuro-

Table 10A.5 **Adult verbal cognition subtests and scoring**

Test	Maximum points
Word recall	10
Sentence reproduction	12
Word pairs	20
Total points	42

psychology tests. This battery of tests was developed by Professors Kar, Rao, Chandramouli, and Thennarau from the National Institute of Mental Health and Neurosciences (NIMHANS) in Bangalore. The box-tapping test involves the surveyor tapping a set of four matchboxes in a particular order that the respondent is expected to replicate. In the reverse tapping test, the respondent is expected to tap the boxes in the reverse order. There are five tests in each direction and a point is awarded for each correct sequence, making ten the total number of possible points.

Adults (15–49 years)

The adult cognition module was based on four subtests taken from the PGIMS module. The first subtest is the digit span test, which is identical to the one used for the child cognition module. The second is a word recall test, which involves two sets of five words each. Each set of words is recited slowly, and the respondent is asked to remember as many words as possible after a one-minute interval. Each correctly remembered word is given one point. The third is a sentence recall test, where three sentences of increasing length are used. Each phrase correctly recalled from a sentence scores one point. Unlike the word test, there is no interval for recalling the sentence. The last subtest involves the use of related and unrelated word pairs. The respondent is verbally told a list of word pairs at the start of the test. The respondent is then expected to recall the pair of each word recited thereafter. Each correctly recalled pair scores a point. These tests and their maximum scores are listed in table 10A.5.

Older Adults (50 years and older)

The older adult cognition module is based entirely on the Hindi Mental State Examination (HMSE), a version of the Mini-Mental State Examination that has been modified for Indian populations. The HMSE was developed by Professors Ganguli and Ratcliffe from the University of Pittsburgh, in collaboration with the Centre of Ageing Research in New Delhi, India. The HMSE is made up of several different subtests. All the subtests check for basic cognitive awareness and alertness. The scoring for these sections is shown in table 10A.6.

Table 10A.6 Older adult cognition subtests and scoring

Question type	Maximum score
Orientation to time	5
Orientation to location	5
Registration of three objects	3
Days of the week (in reverse order)	5
Recall	3
Ability to recognize objects	2
Sentence repetition	1
Following command	1
Three-step command	3
Figure drawing	3
Attention and calculation (serial sevens)	5
Total score	36

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Comment Amitabh Chandra

This chapter forces us to think about a number of issues that are central to economics and public health, and is far more general than the specific question that is answered in the chapter. More generally, I think of the chapter

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