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Effect of Food Subsidies on Micronutrient Consumption

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Abstract

In this article, we study the effect of an exogenous increase in wheat and rice price subsidy to poor families resulting from a targeted food price subsidy program in India called the Targeted Public Distribution System (TPDS) on micronutrient intake in low-income families. Descriptive results show that wheat and rice have one of the lowest micronutrient density scores, suggesting that these are poor suppliers of micronutrients. Empirical analysis suggests that the increase in subsidy amount of Rs. 15-18 resulting from the TPDS expansion lowered calcium intake by 12-14 percent and had negligible to small (often negative) effects on the consumption of most micronutrients.

Keywords: Food subsidies; Micronutrients; Consumption; Poverty.

JEL Classification: I38, I10, I32

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Introduction

Scientific studies document widespread prevalence of micronutrient deficiency among young children and women in India (Swaminathan, Edward, Kurpad 2013). Data from the National Nutrition Monitoring Bureau show that two thirds of women and children across age groups suffer from iron deficiency. Over 70% of pre-school children consume less than half the Recommended Dietary Allowances for vitamin A, iron, folic acid and riboflavin (Sesikeran, 2012). Several of these deficiencies can have devastating effects on immune systems and health and some may even influence their long-term health and productivity (Swaminathan, Edward, Kurpad 2013). The Indian government has a large nation-wide program - the Public Distribution System - that gives food price subsidies to reduce nutritional deficiencies. But there is no research on the effect of these subsidies on micronutrient consumption, resulting in a knowledge gap around whether these deficiencies could be eliminated simply through general nutritional programs or whether special targeted programs are needed. In this paper, we bridge this gap by studying the effect of food subsidies on micronutrient consumption. [1]

Extant research shows that food subsidies in India have influenced the consumption pattern of the households in favor of the subsidized food items, but have modest to negligible effects on consumption of major nutrients, namely, calorie, protein and fat (Kaushal and Muchomba, 2015; Kochar, 2005). Our objective is to examine if these changing consumption patterns have influenced micronutrient deficiencies in low-income families.

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[1] Jensen and Miller (2011) studied the effect of food price subsidy in two provinces in China on micronutrient intake. Their study is based on a short-term experiment and they found that food price subsidy had no effect on the consumption pattern and micronutrient intake of families that received the subsidy. Arguably, households may not change their consumption pattern in response to what they know is a short term experiment and they may be more likely to change their consumption patterns in response to a policy change which they may consider to be long term.

The primary challenge in this research emanates from the fact that families with low-incomes, the target of food subsidies, also have a higher incidence of nutritional deficiency. Thus, a simple correlation analysis between food subsidy receipt and nutrition is likely to yield biased results. To establish a causal link between food subsidy and nutrition, we require a change in subsidy that is unrelated to the economic circumstances of low-income families. In this study we exploit an exogenous increase in food subsidy resulting from the Targeted Public Distribution System (TPDS), introduced in 1997, to provide subsidized wheat and rice to the poor. Under the TPDS, the government issued ration cards, called BPL cards, to households with incomes below the official poverty threshold. Families could use the BPL cards to purchase at approximately two thirds of the market price 10 kg of rice or wheat per month - an amount that was raised to 35 kg in 2002.[2] We use the probability of BPL card ownership as an instrumental variable to predict the food price subsidy of households and study how the increase in predicted food price subsidy after the TPDS expansion affected per capita consumption of various micronutrients.

Our primary objective is to study the effect of the increase in income resulting from the subsidy program on micronutrient consumption. In supplementary analysis, however, we also study the effect of the price subsidy per se. Our empirical approach is similar to Kaushal and Muchomba (2015). We take advantage of divergent consumption patterns across districts to stratify the sample covered by our study into two groups: districts where wheat and rice are the staple food and districts where coarse grains are the staple food. In districts where wheat and rice are the staple food (66 districts), the average monthly household consumption of wheat and rice in the pre-TPDS period is 35 kg, the PDS purchase limit, or higher. In these districts, TPDS will

[2] The government provides rice and wheat at about 50% of the government's cost of procurement, which is somewhat higher than the market price. In our data, the price subsidy is on average 36% of the market price.

have a purely income effect on households receiving the subsidy. In 15 districts, however, the average consumption of wheat and rice in the pre-TPDS period is 20 kg or less. These are districts where coarse grains are the staple food, but the price subsidy is provided for wheat and rice. The marginal price of wheat and rice for most households receiving the subsidy in these districts would be the subsidized price.

Kaushal and Muchomba (2015) find that in high-wheat and rice consuming districts, the price subsidy (% price discount) increased by 16 to 19 percentage points and the subsidy amount was by about 5% of the per capita total food expenditure in the pre-TPDS expansion period. In moderate wheat and rice consuming districts, the price discount increased by 17 to 21 percentage points and subsidy amount was about 3% of the per capita expenditure in the pre-expansion period. In our primary analysis, we study the effect of the increase in total subsidy amount (income) and in the supplementary analysis, we study the effect of price subsidy on micronutrient consumption.

Our empirical analysis is based on three cross sections of the National Sample Survey for 1993-1994 (50th round), 1999-2000 (55th round) and 2004-2005 (61st round) that allow us to control for long-term trends in nutrition and estimate the effect of food price subsidy and total subsidy amount on micronutrient consumption. The implementation of the PDS varies across states: in some the PDS system works well, in others it is saddled with poor targeting and corruption, and in some the implementation has been improving. Our objective is not to evaluate the PDS, but to study the effect of food subsidies. Therefore, we focus on states often described as PDS "functioning or reviving" states, with relatively high take up and cover a post-expansion period when BPL cards had been issued and the TPDS was fully implemented. Further, our study excludes states that already had a targeted PDS prior to 1999.

Theoretical Issues

Kaushal and Muchomba (2015) construct a simple theoretical model and illustrate that in households with high wheat and rice consumption (>35kg per month), the TPDS will have a purely income effect. By lowering the price of subsidized food items, wheat and rice subsidies will release funds that families can use, depending on their tastes, for buying: (i) higher quantities of subsidized food items, (ii) higher quantities of non-subsidized food, and (iii) non-food items. Increase in income may also lower consumption of coarse grains that are cheaper, but generally considered inferior (taste-wise) substitutes for wheat and rice. Overall, it is unclear if TPDS would raise or lower nutrition; indeed, income increase resulting from the subsidy may have a negligible or even negative effect on nutrition if substitution from cheap grains to expensive food or non-food items is large. How TPDS will affect micronutrients consumption depends on whether consumption patterns change in favor of items that have higher quantities of micronutrients or not.

Kaushal and Muchomba's theoretical model also suggests that in states where the staple food is coarse grains and the average monthly household consumption of wheat and rice is relatively low (say 20 kg or less), wheat and rice price subsidy will largely have a substitution effect. The subsidy will lower the relative price of wheat and rice (compared to coarse grains) raising their consumption and lowering the consumption of coarse grains. Households may also increase consumption of other expensive food items or non-food items. Here too, the effect of price subsidy on nutrition and micronutrient-intake is ambiguous.

Targeted Public Distribution System

India's Public Distribution System provides subsidized wheat, rice, sugar and kerosene via a network of approximately half-million fair price shops across the nation. In 1997, to address criticism relating to high operational costs, poor-targeting, and corruption, the government replaced the universal PDS program with a Targeted PDS that restricted sale of subsidized food grains to families with incomes below the 1993-1994 poverty threshold fixed by the Federal government (henceforth referred to as BPL households). Full-implementation of TPDS, however, could not begin in most states till 2000 due to delays in identification of BPL households and distribution of BPL ration cards (Umali-Deininger, Sur, and Deininger 2005).

The initial monthly allocation under TPDS was a modest 10 kg per household, at roughly half the price at which the government could procure the grains. It was increased to 20 kg in April 2000 and to 35 kg in April 2002. In December 2000, a third tier called the Antyodaya Anna Yojana (AAY) was added to give a higher subsidy to the poorest of the poor. Three types of cards were issued under the new system: AAY cards to the poorest of the poor, BPL cards to the other poor with incomes below the poverty line, and APL cards to the non-poor. In the initial period of the TPDS, APL families could buy food grains from ration shops at market prices; since April 2002, a modest subsidy, contingent on availability after meeting the needs of BPL families, is provided to certain purchases by APL card holders as well (Ministry of Consumer Affairs, Food and Public Distribution 2013).

Public and private evaluations of the PDS document large-scale diversion and poor targeting. State and private evaluations of the TPDS have been mixed. A detailed evaluation by the government shows that the TPDS remains afflicted with large-scale diversion of grains in many states (Planning Commission 2005).[3] Umali-Deininger et al. (2005) and Khera (2011),

[3] A detailed evaluation of the program showed that nationally only about 57% of the poor households were covered by it and only about 42% of the subsidized grains issued by the central pool reached the poor: about a third of the budgetary subsidy was siphoned off the supply chain and 21% reached the non-poor households (APL) (Planning Commission, 2005).

however, find increased grain allocation and off-take in most states after the TPDS expansion.[4] Khera (2011) documents that there are seven large states where the PDS has been functioning well, and in another five states it has ‘revived’ since TPDS implementation. The focus of our study is six “well-functioning or reviving” states that have implemented the TPDS system, namely: Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Maharashtra, Uttaranchal, and Chhattisgarh. States that had dual pricing prior to TPDS, namely Orissa, and four major southern states- Andhra Pradesh, Tamil Nadu, Kerala and Karnataka (all well-functioning states) are excluded from the analysis.[5] Further, we do not include Uttar Pradesh, classified a “reviving’ state by Khera, because in 2004-2005, the post policy period covered by our study, the per capita PDS off-take in the state was modest (less than 500 grams per month).

Data

The study is primarily based on data from three rounds of the National Sample Surveys – Consumer Expenditure (NSS): the 50th round conducted in 1993-1994, the 55th round conducted in 1999-2000, and the 61st round conducted during 2004-2005. These are nationally representative surveys covering between 120,000 to 125,000 households in each round. The last two rounds were conducted about two years before and two years after the expansion of the TPDS, therefore, are appropriate to study its effect on nutrition. In recent decades, there has been a steady decline in calorie intake across income quintiles in India (Deaton and Drèze 2009, 42-65). These trends are likely to confound our estimates of the effect of the TPDS on nutrition. We

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[4] Swaminathan and Misra (2001) found that shifting from universal to targeted coverage increased errors of exclusion (excluding poor people) but lowered the errors of inclusion in Maharashtra. But they used 1995-2000 data, thus their study did not cover the post TPDS expansion period.

[5] These states either opted to not follow the dual pricing scheme of the federal government (e.g. Tamil Nadu adopted a universal PDS with the AAY covering the entire population) or had a targeted program prior to 1997 (e.g Andhra Pradesh, Orissa, Karnataka), or are states where TPDS reduced subsidized food grain allocation (e.g. Kerala).

combine the 1993-1994 NSS data with the two later rounds and include district specific trends to control for the long-term trends in nutrition.

The NSS collects detailed data on household food consumption over the past 30 days. Specifically, for the purpose of this analysis, the surveys provide information on the quantities of wheat and rice purchased and the value of their purchases from ration shops as well as in the open market. We stratify districts in our sample states into three groups based on their average household wheat and rice consumption in the pre-TPDS period: high-wheat/rice consuming districts (with the combined wheat and rice consumption of 35 kg per month or higher), moderate wheat/rice consuming districts (average combined rice and wheat consumption of 20 kg per month or less); and the rest (average monthly wheat and rice consumption per household between 20kg and 35 kg). The focus of our study is the first two groups. To minimize measurement error in estimating district-level consumption of wheat and rice and other district-level parameters, we drop from the analysis districts with fewer than 80 observations (households) in any year. Further, the 1993-1994 NSS does not provide district identifiers for urban areas.[6] Therefore, all analysis is restricted to rural areas. Overall, our study covers households in 66 rural districts where average monthly household consumption is 35 kg or higher and households in 15 rural districts where the average monthly household consumption is 20 kg or less.[7]

We supplement NSS data with a dataset of micronutrient content of 700 Indian food items obtained from the National Institute of Nutrition (NIN) (Gopalan, Rama Sastri, and

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[6] We are grateful to Anjini Kochar for providing us with documentation on district identifiers for rural households in the 1993-1994 NSS data.

[7] There are only 11 districts (2,285 households) in our sample with an average monthly consumption of 20-35kg. Theoretically, the effect of TPDS on these districts could be either purely an income effect or both an income and a substitution effect. This sample is not included in the analysis we present.

Balasubramanian, 1996). We merge the micronutrient information into NSS data by matching the food item names. For 11 food items in the NSS data that we are unable to match with the NIN data, we use micronutrient information from the United States Department of Agriculture's Food Composition Databases (United States Department of Agriculture 2016). The focus of our study is16 minerals and vitamins: magnesium, sodium, potassium, copper, manganese, zinc, calcium, phosphorus, iron, carotene, thiamin, riboflavin, niacin, folic acid, vitamin c, and choline. As shown in Table 1, these micronutrients are essential for healthy body function and consuming inadequate amounts is linked to health problems. An exception is sodium for which there is limited evidence of health problems due to its deficiency and strong evidence that excess sodium causes high blood pressure and other health problems (Institute of Medicine 2006). In fact, because sodium is commonly available in processed foods in western diets, there are efforts to limit sodium intake in western countries. We calculate each household's intake of these 16 micronutrients from data on food consumption by multiplying the amount of each food item consumed with its per unit nutrient content. To allow comparison with recommended dietary intakes, we convert micronutrient intake to daily per capita amounts. Consumption data does not account for food wastage, food given to non-household members, and micronutrients destroyed while cooking and therefore our results refer more directly to nutrient availability in the household rather than intake.

Our primary set of outcomes is the per capita daily amount of each micronutrient. We log-transform the outcomes in our regression analyses to estimate percentage changes. We assign 1 *mg* of micronutrient to cases where the intake of a particular micronutrient is 0 *mg*.

To ensure that the analysis is not driven by extreme values, households reporting per capita monthly consumption of more than 30 kilograms of any specific cereal (e.g. wheat, rice, bajara, maize etc.) are dropped from the analysis. Further, households reporting a per capita daily calorie[8] consumption of more than 10,000 and a per capita daily protein consumption of more than 300 grams are dropped from the analysis. Overall, as a result of these exclusions, 160 households (less than 1% of the overall sample) are dropped from our sample. We also exclude, from the combined sample, 819 households (2.6% of the sample) that report purchasing PDS wheat and rice at prices greater than their districts' average open market price. Additionally, two districts (with a combined sample of 287 observations) are excluded because a third of their samples reported purchasing PDS wheat and rice at prices that exceeded the districts' mean open market price. In our analysis of micronutrient intake, we exclude households that have log per capita intake of micronutrients that is more than 3.5 times the median absolute distance from the sample median.

The NSS has detailed data on individual household members, including their age, educational attainment, sex, marital status, current employment status, and relationship with the household head, and household characteristics namely: household size, caste, religion, occupation of household head, land ownership, amount of land irrigated, detailed data on ownership of durables, urban-rural residence, district of residence, state or union territory of residence, and expenditures on semi-durable goods, durable goods, services and other non-food items. Appendix 1 provides descriptive data on household characteristics. We compute district-level monthly per capita expenditure, open market price of rice, and open market price of wheat by averaging the respective household values in each district. These variables are controlled in some regressions. Following Kochar (2005) and Deaton (1997), we compute district-level open market prices of wheat and rice from the NSS household data by dividing the value with the

[8] A calorie in this paper refers to one kilocalorie (kcal), also called a large calorie (Cal).

quantity of each item (wheat or rice) purchased from the open market. All expenditures are adjusted for inflation using the Agricultural Laborers Consumer Price Index.

Because the new ration cards were issued after the implementation of TPDS, the NSS surveys covering 1993-1994 and 1999-2000 do not have information about a household's TPDS status. The 2004-2005 NSS provides data on type of ration card that a household owns: AAY (extremely poor), BPL (poor), APL (non-poor) and no card. We use the 2004-2005 data on card ownership to predict the probability of BPL/AAY card ownership using a rich set of household characteristics that are exogenous to the Targeted Public Distribution System. Only 2.4% of the households had an AAY card in our 2004-2005 sample. To minimize prediction error, we combine the AAY and BPL categories. We use a logit model to predict the probability of BPL/AAY card ownership:

$$(1) \qquad \ln\left[\frac{\Pr(BPL\_card_{ij}=1)}{\Pr(BPL\_card_{ij}=0)}\right]=X_i\beta+\zeta_j$$

In equation (1) the probability that household *i* in district *j* has a BPL/AAY card (binary variable – for convenience, henceforth we call this variable *BPL card*) is defined as a function of household characteristics, X_i, namely the household head's age (a set of dummy variables indicating age categories: 0-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, and 70 or older), education (categorical variables indicating illiterate; literate with less than primary education; primary education; more than primary but less than secondary; and secondary or higher education), sex, marital status, and occupation, education of other household members (all illiterate; at least one, but not all, literate; all literate), household caste (categorical variables indicating scheduled caste, scheduled tribe, and other castes) and religion (categorical variables indicating Hinduism, Islam, Christianity, Sikhism, Jainism, Buddhism, Zoroastrianism, and other religions), land ownership, household size (categorical variables indicating 1, 2, 3-5, 6-8, and 9 or more household members), whether land is irrigated, ownership of durables, namely radio, TV, bicycles, electric fan, sewing machine, fridge, motor cycle, or car; and ζ_j, district of residence fixed effects. The coefficients from this regression are used to predict the probability of BPL ration card ownership of households in all years. Prediction statistics for the logit model indicate medium to high accuracy in our predictions.

Estimation Strategy

We begin our analyses by comparing the micronutrient content of the subsidized foods (wheat and rice) with non-subsidized foods. The case for public subsidies for wheat and rice will be strengthened if these foods are more nutritious than other foods. We group all food items listed in the NSS survey questionnaire into: wheat and rice; coarse cereals; pulses and pulse products; fruits and vegetables; milk and milk products; eggs, fish, and meat; sugar and sugar substitutes; and all other foods. For each food group, we calculate the average amount of micronutrients in 100g of the foods that comprise the food group. In addition, we compute two summary measures of the nutritional richness of the foods. First, we compute the adequacy ratio (Drewnowski and Fulgoni 2008), which is the proportion of recommended dietary allowance (RDA) in100g of a given food item, averaged over the micronutrients we study. For each food group we compute:

$$(2)\quad AdequacyRatio = \frac{1}{F}\sum_{f=1}^{F}\left(\frac{1}{M}\sum_{m=1}^{M}\frac{AmountOfMicronutrientPer100g_{mf}}{RDA_m}\right),$$

where *f* is the indicator of food items in the food group and *m* is the indicator of micronutrients. Our calculations use the RDAs for a female aged 19-30. We also compute the nutritional density score (Drewnowski and Fulgoni 2008) by dividing the adequacy ratio by the number of calories in 100g of the food item.

Next, we examine the impact of food price subsidy on micronutrient intake. Our strategy is similar to Kaushal and Muchomba (2015) and involves, first, estimating the effect of TPDS on food price subsidy, and then, estimating the effect of increase in subsidy on account of TPDS on micronutrient consumption. Equations (3) and (4) describe the first stage of our analysis. The per capita food price subsidy amount (S_{ijt}) that household *i* in district *j* receives in year *t*, is computed as the difference in the open market price (P^m_{fjt}) of the food grains (wheat, rice) minus the PDS price reported by the household (P^s_{fijt}) multiplied by the quantity purchased from the PDS (q_{fijt}). The total household subsidy amount is divided by N (household size) to arrive at the per capita subsidy amount:

(3) $$S_{ijt} = \frac{1}{N_{ijt}} \sum_f q_{fijt} (P^m_{fjt} - P^s_{fijt})$$
$$f = wheat, rice$$

Equation (4) describes the model used to study the effect of TPDS on the food grains subsidy amount received by BPL households:

(4) $$S_{ijt} = X_{it}\beta + \beta_c (\Pr Card_i * Post_t) + \delta_0 * \Pr Card_i + \delta_1 * D_{jt} + \pi_j + \pi_t + u_{ijt} ,$$

The per capita food price subsidy amount (S_{ijt}) is defined as a function of household characteristics (X_{it}), as described above. π_j and π_t are district and year fixed effects. D_{jt} denotes district-level time-varying factors namely mean district level monthly per capita expenditure, and district-specific trends. In our final specification, we replace district-level trends with interactions of the district dummy variables with $Post_t$. $\Pr Card_i$ is the predicted probability that the household has a BPL card. The variable $Post_t$ is equal to 1 if the observation is taken from the post-2002 period, after the TPDS expansion. The coefficient, β_c, estimates the effect of the TPDS on the average food price subsidy as the probability of BPL card ownership increases from 0 to 1.

The identifying assumption in equation (4) is that in the absence of TPDS, the change in food price subsidy in the pre- to post-policy period of households with a low probability of having a BPL card would be the same as that of households with a high probability of having a BPL card. This is a restrictive assumption. In general families with a low probability of owning a BPL card are likely to be richer than families with a high probability of owning a BPL card and the effect of economic factors on these two groups of families is likely to be very different. To allow a more reasonable comparison, we estimate equation (4) restricting samples to households with a monthly real per capita expenditure below the median.[9] An equation similar to (4) is applied to study one other outcome: % price discount defined as price discount divided by the market price of the subsidized food items.

Our next objective is to study the effect of subsidy amount and % price subsidy on micronutrient intake in the poor households. Equation (5) describes the empirical model:

(5) $N_{ijt} = X_{it}\phi + \varphi * Subsidy_{ijt} + \varphi_0 \Pr Card_i + \phi_0 * D_{jt} + \eta_j + \eta_t + e_{ijt}$,

N_{ijt} , the log per capita micronutrient in-take of household i in district j in year t, is defined as a function of household characteristics (X_{it}), per capita food grains subsidy amount ($Subsidy_{ijt}$), the predicted probability that the household has a BPL or AAY card ($\Pr Card_i$), time-varying

[9] The median monthly per capita expenditure for our sample of states is Rs 485.55 at 2004-2005 prices, which is equal to $1.04 per day at the ppp exchange rate of $1=Rs 15.54.

district level variables that may influence nutrition (D_{jt}), and district (η_j) and year (η_t) fixed effects.

$Subsidy_{ijt}$ is likely to be endogenous to household nutrition (N_{ijt}). We use an instrumental variables methodology to address this issue. Specifically, we use the predicted probability of BPL card ownership interacted with $Post_t$ to instrument for $Subsidy_{ijt}$. The first stage regression for this methodology is described in equation (4). In the second stage, the predicted $\hat{Subsidy}_{ijt}$ from equation (4) replaces $Subsidy_{ijt}$ in equation (5). Note that the first stage estimate includes all the covariates that are in the second stage, so the identification of the coefficient φ in the second stage depends entirely on the exclusion of interaction term ($\Pr Card_i * Post_t$) from the second stage regression. In the empirical analysis, we use the IVREGRESS command of Stata to compute the first and second stage estimates in a single step. Standard errors correct for errors in the first stage prediction and cluster on district of residence (Murphy and Topel 1985; Hardin 2002; Hardin, Schmiediche, and Carroll 2003). An equation similar to (5), with one modification, is applied to estimate the effect of price discount on nutrition: the subsidy amount is replaced by % price discount. The sample for this analysis is districts with combined monthly household wheat and rice consumption of less than 20kg.

Results: Micronutrient Content of Foods

Table 2 compares the nutritional richness of the subsidized and non-subsidized foods. The top two panels present the average amount of micronutrients in 100g of various food groups, and Panel 3 summarizes the data on all micronutrients in a food item in a single statistic. Rice and wheat have lower amounts of micronutrients than the two other major sources of energy in the Indian diet—coarse cereals and pulses. The exceptions are manganese (pulses have less), niacin (coarse cereals have less), and vitamin C (rice, wheat and coarse cereals have none), and choline (rice, wheat and coarse cereals have none). It is therefore no surprise that rice and wheat have a lower adequacy ratio than both coarse cereals and pulses. The results in Table 2 also show that pulses followed by coarse cereals are the most micronutrient rich food groups with 100g of pulses providing on average 28.5% of the daily recommended amounts of micronutrient and coarse cereals providing on average 25.5% of RDA.

The goal of the nutritional density score is to differentiate between nutrient-dense foods and foods that have high calorie content but little or no other nutrients. One calorie of a food with a nutritional density score of one will provide on average 100% of recommended daily amounts of micronutrients. Table 2 shows that white and rice have one of the lowest nutritional density scores. On the whole, these results indicate that if the goal of food price subsidies is to improve nutrition, other major sources of energy in the Indian diet are more nutritious substitutes.

Results: Descriptive

Table 3 presents the average daily per capita micronutrient intake in the pre- to post-PDS expansion periods in rural households with less than the median per capita monthly expenditure – the sample of our analysis. For comparison, we also present RDAs for a female aged 19-30 as a summary measure of per capita micronutrient adequacy in households. There are several points to note: one, in the pre-TPDS period, there is deficiency of sodium, potassium, calcium, iron (in households in high rice/wheat consuming districts), and of all vitamins except thiamin and niacin. For four micronutrients—sodium, carotene, folic acid, and choline—the deficiency is severe with estimated average per capita intakes less than 25% of the RDAs. Two, micronutrient intakes decline over time except for carotene, which registers a modest improvement, and folic acid intake, which improves in households in moderate rice/wheat consuming districts. Overall, the micronutrient deficiencies deepen over time and niacin intake, which was adequate in the pre-TPDS period, falls below the RDA after TPDS expansion. These declines mirror declines in Indian households' caloric intake that have been documented in previous research (Deaton and Dreze 2009). Overall, Table 3 corroborates the literature highlighting micronutrient deficiency in Indian diets and suggests that expansion of TPDS was not associated with alleviation of these deficiencies.

Next we systematically examine whether the decline in nutrient intake is, at least in part, an unintended consequence of the TPDS expansion. Our approach follows that of Kaushal and Muchomba (2015). Briefly, we first examine the effect of the exogenous increase in income resulting from the food price subsidy on micronutrient intake of poor households in high wheat/rice consuming districts and then study the effect of the wheat and rice price discount on poor households in moderate wheat/rice consuming districts.

Results: Effect of TPDS on Food Price Subsidy

Table 4 presents estimated coefficients from equation (4). The sample for our analysis is low-income rural households with per capita monthly expenditure below the median and we present results using four different models. Model 1 includes controls for a rich set of individual characteristics, and district and year fixed effects. Model 2 includes an additional control of household monthly per capita expenditure,[10] model 3 further adds two more controls: mean district per capita expenditure and district-specific trends, and model 4 replaces district specific trends with interactions of district dummy variables and an indicator that the observation is from

[10] We also estimated models 2-4 without the control for monthly per capita expenditure. The results were similar to those reported in Table 4 from models inclusive of this control.

the post-TPDS expansion period. We have reported results from all the four models to document that our results are robust to controlling for a rich set of time-varying variables that may be correlated with TPDS implementation and that our results are not driven by these controls.

Estimates in panel 1, based on the sample of households in high wheat and rice consuming districts, suggest that an increase in the predicted probability of BPL card ownership (from 0 to 1) resulting from TPDS expansion raised the food price discount on subsidized grains by 16 to 19 percentage points and increased the subsidy amount by Rs 15 to Rs 18 per capita. This effect is about five percent of the per capita average household expenditure in the pre-TPDS expansion period.

Estimates in panel 2 are for households in districts where coarse grains are the staple food. In these districts, the average wheat + rice consumed by households is 16 kg, which is less than half the maximum quantity that can be purchased at subsidized price under the TPDS. Therefore, the marginal price that most households in these districts would face is the subsidized price. Estimates suggest that an increase in the predicted probability of BPL card ownership (from 0 to 1) increased the price discount of subsidized grains by 17-21 percentage points after the TPDS expansion and increased the overall subsidy amount by Rs 11 to Rs 14. Our analyses thus suggest that TPDS increased the food price subsidy of households with a BPL card by economically significant amounts.

Results: Effect of Food Price Subsidy on Nutrition

Table 5 has the estimates of the effect of food subsidy amount on micronutrient intake. We fit three separate models for each of the 16 micronutrients. Model 1 one controls for household characteristics and a full set of district fixed effects. Model 2 adds a control for the average district per capita expenditure and district-specific linear trends. Model 3 includes district-post-TPDS interactions. In all analyses we instrument subsidy amount with the predicted probability of BPL card ownership interacted with a dummy variable representing households observed after TPDS expansion. The F-statistics of the excluded instrument are much larger than the critical F-ratio of 10 used to assess whether instruments are weak (Staiger and Stock 1997; Cameron and Trivedi 2005).

The results in Model 1 suggest that an increase in subsidy amount had small and statistically insignificant effects on micronutrient intake. In Models 2 and 3 we include time-varying controls to purge our results of secular changes in nutrient intake that are due to factors outside of TPDS expansion such as changes in tastes. Results from Model 2 suggest that a one Rupee increase in subsidy reduced calcium intake by 1.2 percent and carotene intake by 2.3 percent. In Model 3, the estimated effect for Carotene turns statistically insignificant but the effect on calcium intake remains significant. Model 3 results also suggest that an increase in subsidy increased sodium, manganese and folic acid intake, and reduced iron intake although the effects are modest—0.4 to 0.6 percent change per rupee increase in subsidy amount. In short, results in Table 5 suggest that the increase in subsidy amount of Rs 15-18 resulting from TPDS expansion reduced calcium intake by 12 to 14 percent and had neglible to small, often negative, effects on the consumption of most micronutrients.

Next, we investigate the effect of the wheat and rice price discount on micronutrient intake. The sample of analysis is households in districts where coarse grains are the staple food. Specifically, these are districts where monthly wheat and rice consumption was less than 20 kg per household in the pre-TPDS period, much less than 35 kg, the maximum allowed under TPDS. Table 6 presents the results. Estimates in Models 1 and 2 suggest that a one percentage point increase in the wheat and rice price discount reduced vitamin C and choline intake by between one and 1.5 percent. However, these effects disappear in Model 3. One the other hand, Model 3 results suggest that a percentage point increase in price discount increased niacin consumption. However, the effect is modest and represents an increase, resulting from TPDS expansion, of 10 to 12 percent in niacin consumption.

Conclusion and Discussion

In this paper, we study the effect of an exogenous increase in wheat and rice price subsidy to poor families resulting from the Targeted Public Distribution System (TPDS) on micronutrient intake in low-income families. Descriptive results show that wheat and rice have one of the lowest micronutrient density scores. Regression analysis suggests that the increase in subsidy amount of Rs. 15-18 resulting from the TPDS expansion lowered calcium intake by 12-14 percent and had negligible to small (often negative) effects on the consumption of most micronutrients. We find similar, but statistically insignificant, effects of the price subsidy on micronutrient consumption. In previous research, we found that income increase resulting from the food price subsidy changed consumption patterns in favour of the subsidized food – wheat and rice (Kaushal and Muchomba, 2015). In light of those findings, our current research shows that increased wheat and rice consumption resulting from the food price subsidy program has lowered consumption of food items that are richer in micronutrients. This is an unintended effect of selectively subsidizing certain food items and has lowered micronutrient intake among a population that suffers from high levels of micronutrient deficiency.

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Table 1. Micronutrients, their functions, and health problems due to inadequate intake

Micronutrient	Function	Deficiency health problems
Minerals		
Magnesium	For bone health and involved in over 300 enzyme processes	Muscle cramps, seizures, fatigue, etc
Sodium	Regulates body fluid volume	Insufficient evidence
Potassium	Required for cell function and neurotransmission	High blood pressure, kidney stones, cardiovascular disease, muscle weakness, etc
Copper	Component of several enzymes	Anemia and osteoporosis. Deficiency is rare because copper is common.
Manganese	Involved in the formation of bone, as well as enzymes involved in amino acid, cholesterol, and carbohydrate metabolism	Some evidence of skin inflammation and low cholesterol level
Zinc	Component of multiple enzymes and proteins; involved in regulating the production of gene products	Diverse and inconsistent including: growth retardation, delayed sexual maturation, hair loss, diarrhea, etc
Calcium	Essential role in blood clotting, muscle contraction, nerve transmission, and bone and tooth formation	Low bone mass and osteoporosis
Phosphorus	Component of bones and teeth. Maintenance of pH, storage and transfer of energy and nucleotide production	Anemia, muscle weakness, bone pain, rickets, etc. Deficiency is rare because phosphorus is ubiquitous
Iron	Component of hemoglobin and numerous enzymes	Anemia
Vitamins		
Carotene	A form of Vitamin A. Required for normal vision, gene expression, reproduction, embryonic development and immune function.	Vision loss and decreased immunity
Thiamin	Also known as Vitamin B_1. Involved in the metabolism of carbohydrates and certain proteins	Beriberi, weight loss, muscle weakness, mental changes (e.g. memory loss)
Riboflavin	Also known as Vitamin B_2. Involved in many biological reactions	Sore throat, dandruff, anemia, etc
Niacin	Also known as Vitamin B_3.Involved in many biological reactions and required for energy metabolism	Pellagra (i.e., rash, vomiting, constipation/diarrhea, depression, memory loss, etc)
Folic acid	Also known as Vitamin B_9. Involved in the metabolism of nucleic and amino acids	Anemia, birth defects
Vitamin C	Involved in numerous biological reactions	Scurvy
Choline	A form of Vitamin B_4. Building block for compounds involved in neurotransmission and structure of cell membranes	Some evidence of liver damage

Source: Compiled using information from Institute of Medicine (2006)

Table 2. Average micronutrient content and micronutrient adequacy of various food groups

	Rice and wheat	Coarse cereals	Pulses	Milk and milk products	Fruits and vegetables	Sugar and its substitutes	Eggs, fish, meat	All others
Panel 1:Minerals per 100g								
Magnesium, mg	95	146	135	6	49	44	0	55.3
Sodium, mg	3.1	11.3	29.2	34.5	15.0	13.7	8.6	890.3
Potassium, mg	105	283	686	111	103	204	34	44
Copper, mg	0.24	0.60	1.05	0.04	0.31	0.20	0.01	0.34
Manganese, mg	1.17	1.99	0.90	0.01	0.64	1.40	0.00	0.78
Zinc, mg	1.67	2.45	2.44	0.40	0.69	0.79	0.00	0.66
Calcium, mg	23	105	118	308	52	107	156	66
Phosphorus, mg	225	287	347	213	84	72	215	88
Iron, mg	2.10	4.58	5.83	1.02	2.01	3.82	1.13	4.57
Panel 2:Vitamins per 100g								
Carotene, µg	10	78	116	736	254	2	64	461
Thiamin, mg	0.23	0.39	0.42	0.10	0.10	0.03	0.10	0.11
Riboflavin, mg	0.12	0.17	0.17	0.32	0.08	0.04	0.09	0.05
Niacin, mg	2.70	2.08	2.19	0.55	0.95	0.55	1.43	1.24
Folic acid, µg	17	26	81	15	10	6	13	2
Vitamin C, mg	0.0	0.0	1.1	7.4	25.6	0.3	1.1	3.5
Choline, mg	0.0	0.0	95.6	6.1	30.4	12.4	27.0	17.7
Panel 3: Adequacy								
Mineral adequacy ratio, per 100g	0.212	0.376	0.389	0.091	0.140	0.190	0.060	0.236
Vitamin adequacy ratio, per 100g	0.077	0.100	0.152	0.092	0.098	0.020	0.054	0.054
Mineral & vitamin adequacy ratio, per 100g	0.153	0.255	0.285	0.091	0.121	0.116	0.057	0.156
Energy, Calories per 100g	344	345	333	413	123	348	118	264
Mineral density score, per 100 Calories	0.062	0.109	0.117	0.022	0.114	0.055	0.051	0.089
Vitamin density score, per 100 Calories	0.022	0.029	0.046	0.022	0.080	0.006	0.045	0.020
Mineral & vitamin density score, per 100 Calories	0.045	0.074	0.086	0.022	0.099	0.033	0.049	0.059
Number of food items	3	4	14	8	56	6	7	47

Note: Analysis is based on the 145 different food items listed in NSS 61st round questionnaire. Wheat and rice = wheat, atta (flour), and rice. Coarse cereals are jowar (sorghum), bajra (pearl millet), maize, and ragi (finger millet). Pulses are arhar/tur (pigeon pea), whole and split gram, moong, masur (red lentil), urd (black gram), peas, soyabean, khesari (grass pea), besan (gram flour), and other pulses and gram products. Nutrient content obtained from the Indian Council of Medical Research. Nutrient adequacy ratios and nutrient density scores are unweighted means of the percentage of the recommended daily allowance (RDA) of each nutrient that the food group provides. RDAs for females aged 19-30 are used.

Table 3. Average daily per capita micronutrient intake in households before and after the expansion of the targeted public distribution system

	Moderate rice/wheat-consuming districts		High rice/wheat-consuming districts		Recommended dietary allowance (female aged 19-30)
	Pre-TPDS expansion	Post-TPDS expansion	Pre-TPDS expansion	Post-TPDS expansion	
Minerals					
Magnesium, mg	679.9	597.9	558.8	494.5	310
Sodium, mg	98.8	75.6	89.4	75.2	1500
Potassium, mg	1,271.7	1,200.1	1,239.2	1,098.2	4700
Copper, mg	2.8	2.4	2.0	1.7	0.9
Manganese, mg	5.5	5.2	6.3	5.8	1.8
Zinc, mg	9.2	8.6	9.3	8.2	8
Calcium, mg	366.5	301.4	396.6	323.4	1000
Phosphorus, mg	1,274.0	1,210.9	1,346.6	1,198.3	700
Iron, mg	22.1	19.3	17.3	14.7	18
Vitamins					
Carotene, μg	1,204.2	1,390.3	1,093.8	1,367.3	8400
Thiamin, mg	1.8	1.6	1.5	1.3	1.1
Riboflavin, mg	0.9	0.8	0.8	0.7	1.1
Niacin, mg	14.9	13.7	14.5	13.0	14
Folic acid, μg	156.9	158.5	145.8	140.7	666.7
Vitamin C, mg	39.0	34.3	43.4	38.5	75
Choline, mg	84.9	79.5	113.4	101.2	425
Adequacy					
Adequacy ratio	1.082	1.001	1.009	0.892	1

Note: The sample of analysis is rural households with less than the median monthly per capita expenditure. Adequacy ratio is the average proportion of recommended dietary allowance of micronutrients that is consumed.

Table 4. Estimates of the Effect of Targeted Public Distribution on Food Price Subsidy and Subsidy Amount

	% Price Discount				Subsidy Amount (in Rupees)			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Panel 1: High Rice/Wheat Consuming Districts								
Predicted probability of BPL card ownership*Post TPDS	15.99***	15.97***	16.84***	19.23***	14.80***	14.78***	16.09***	18.17***
	(1.90)	(1.90)	(1.96)	(1.98)	(1.83)	(1.84)	(1.71)	(1.60)
Mean of the dependent variable before TPDS	2.60	2.60	2.60	2.60	1.85	1.85	1.85	1.85
Mean of the dependent variable after TPDS	8.17	8.17	8.17	8.17	7.33	7.33	7.33	7.33
N	12,989	12,989	12,989	12,989	12,989	12,989	12,989	12,989
Panel 2: Moderate Rice/Wheat Consuming Districts								
Predicted probability of BPL card ownership*Post TPDS	20.38***	20.51***	17.67***	17.47***	13.99***	14.02***	10.85***	11.42***
	(4.02)	(4.03)	(3.39)	(4.50)	(1.96)	(1.97)	(1.87)	(2.25)
Mean of the dependent variable before TPDS	9.86	9.86	9.86	9.86	2.32	2.32	2.32	2.32
Mean of the dependent variable after TPDS	14.09	14.09	14.09	14.09	6.95	6.95	6.95	6.95
N	3,732	3,732	3,732	3,732	3,732	3,732	3,732	3,732
Model controls for:								
Household monthly per capita expenditure	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Mean district monthly per capita expenditure, District specific trend	No	No	Yes	No	No	No	Yes	No
Mean district monthly per capita expenditure, district- Post TPDS interactions	No	No	No	Yes	No	No	No	Yes

Note: Each figure in the top row of each panel is based on a separate regression that controls for household head's age, education, gender, marital status, and occupation, education of other household members, household caste and religion, land ownership, household size, whether land is irrigated, ownership of durables, predicted probability of BPL card ownership, year and district fixed effects, in addition to the factors listed in the Table. The sample of analysis is rural households with less than the median monthly per capita expenditure. Further, the sample of analysis in panel 1 is restricted to districts where the average monthly household consumption of wheat and rice is 35kg or higher in the pre-TPDS period; the sample of analysis in panel 2 is restricted to districts where the average monthly household consumption of wheat and rice is less than 20 kg in the pre-TPDS period. Standard errors are clustered around the district of residence. Post-TPDS is equal to 1 if the observation is from 2004-2005. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5. Instrumental Variable Estimates of the Effect of Subsidy Amount on Per Capita Daily Micronutrient Intake in High rice/wheat Consuming Districts (average monthly wheat+rice consumption≥35 kg/household)

Minerals				Vitamins			
Dependent variable	Model 1	Model 2	Model 3	Dependent variable	Model 1	Model 2	Model 3
Log(Magnesium)	0.001	-0.002	-0.000	Log(Carotene)	-0.020	-0.023**	-0.003
	(0.003)	(0.004)	(0.003)		(0.012)	(0.011)	(0.007)
Log(Sodium)	-0.006	-0.003	0.006*	Log(Thiamin)	0.003	-0.001	0.000
	(0.005)	(0.005)	(0.003)		(0.006)	(0.004)	(0.002)
Log(Potassium)	0.003	-0.000	0.003	Log(Riboflavin)	-0.000	-0.004	-0.001
	(0.005)	(0.005)	(0.003)		(0.003)	(0.003)	(0.002)
Log(Copper)	0.002	-0.002	0.001	Log(Niacin)	0.004	-0.000	0.001
	(0.005)	(0.004)	(0.002)		(0.004)	(0.004)	(0.002)
Log(Manganese)	0.006	0.003	0.005*	Log(Folic acid)	0.005	-0.002	0.004*
	(0.006)	(0.005)	(0.003)		(0.005)	(0.004)	(0.003)
Log(Zinc)	0.000	-0.002	0.001	Log(Vitamin C)	-0.002	-0.002	0.000
	(0.003)	(0.003)	(0.002)		(0.006)	(0.006)	(0.004)
Log(Calcium)	-0.009	-0.012***	-0.008**	Log(Choline)	0.004	0.003	0.005
	(0.008)	(0.004)	(0.003)		(0.005)	(0.005)	(0.004)
Log(Phosphorus)	0.001	-0.004	-0.002				
	(0.004)	(0.004)	(0.003)				
Log(Iron)	0.001	-0.005	-0.004*				
	(0.006)	(0.004)	(0.002)				
District per capita expenditure	No	Yes	Yes		No	Yes	Yes
District specific trend	No	Yes	No		No	Yes	No

District*Post-TPDS interactions	No	No	Yes		No	No	Yes
N	12,811	12,811	12,811		12,811	12,811	12,811

Note: Figures in each cell are based on a separate regression that controls for household head's age, education, gender, marital status, and occupation, education of other household members, household caste and religion, land ownership, household size, household total expenditure, whether land irrigated, ownership of durables, the predicted probability of BPL card ownership, year and district fixed effects in addition to controls listed. The reported figures are the coefficients on predicted subsidy coefficient. Standard errors clustered on district of residence, and corrected for two-stage estimation, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 6. Estimates of the Effect of Food Price Subsidy (% price discount) on Per Capita Daily Calorie Intake from Specific Food Items in Moderate rice/wheat consuming districts (average monthly wheat+rice consumption≤20 kg/Household)

Minerals				Vitamins			
Dependent variable	Model 1	Model 2	Model 3	Dependent variable	Model 1	Model 2	Model 3
Log(Magnesium)	-0.001	0.005	0.007	Log(Carotene)	-0.000	0.001	0.011
	(0.005)	(0.005)	(0.005)		(0.010)	(0.008)	(0.011)
Log(Sodium)	-0.005	0.001	0.010	Log(Thiamin)	-0.001	0.003	0.001
	(0.004)	(0.004)	(0.007)		(0.003)	(0.004)	(0.003)
Log(Potassium)	-0.002	0.006	0.010	Log(Riboflavin)	-0.001	0.001	0.002
	(0.004)	(0.005)	(0.007)		(0.004)	(0.004)	(0.005)
Log(Copper)	-0.004	0.001	0.001	Log(Niacin)	0.002	0.006	0.006**
	(0.003)	(0.005)	(0.006)		(0.003)	(0.004)	(0.003)
Log(Manganese)	0.005	0.009	0.008	Log(Folic acid)	-0.001	0.002	0.004
	(0.004)	(0.005)	(0.006)		(0.006)	(0.007)	(0.007)
Log(Zinc)	-0.001	0.002	0.002	Log(Vitamin C)	-0.010**	-0.010	0.005
	(0.003)	(0.004)	(0.004)		(0.004)	(0.006)	(0.005)
Log(Calcium)	-0.003	0.002	0.004	Log(Choline)	-0.015**	-0.013*	-0.002
	(0.004)	(0.005)	(0.005)		(0.006)	(0.007)	(0.005)
Log(Phosphorus)	-0.003	0.003	0.006				
	(0.004)	(0.005)	(0.006)				
Log(Iron)	-0.000	0.003	0.002				
	(0.004)	(0.005)	(0.005)				
District per capita expenditure	No	Yes	Yes		No	Yes	Yes
District specific trend	No	Yes	No		No	Yes	No

District*Post-TPDS interactions	No	No	Yes	No	No	Yes
N	3,716	3,716	3,716	3,716	3,716	3,716

Note: The sample of analysis is rural households with less than the median monthly per capita expenditure. The reported figures are the coefficients on % price discount. See notes to Table 5 for model description. Standard errors clustered on district of residence, and corrected for two-stage estimation, are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Appendix 1. Descriptive statistics of households in pre-TPDS period (1993-94 and 1999-00)

	Moderate wheat/rice consuming districts		High wheat/rice consuming districts	
	Mean	Standard deviation	Mean	Standard deviation
Household head:				
Never married	0.012	0.108	0.015	0.120
Married	0.912	0.284	0.872	0.334
Widowed	0.067	0.251	0.107	0.309
Divorced/separated	0.009	0.094	0.006	0.080
Female	0.059	0.236	0.076	0.265
Age	43.9	13.61	44.2	13.64
Illiterate	0.515	0.500	0.596	0.491
Literate with less than primary education	0.151	0.359	0.159	0.366
Primary education	0.145	0.352	0.121	0.326
More than primary but less than secondary	0.104	0.305	0.070	0.256
Secondary or higher education	0.085	0.279	0.054	0.226
Self-employed in non-agriculture	0.056	0.231	0.070	0.255
Agricultural labor	0.510	0.500	0.342	0.474
Casual/other labor	0.050	0.218	0.071	0.257
Self-employed in agriculture	0.240	0.427	0.459	0.498
Other occupation	0.041	0.198	0.048	0.213
Missing occupation	0.102	0.303	0.011	0.104
Household size	5.5	2.4	5.7	2.7
All illiterate	0.320	0.467	0.376	0.484
One or more but not all illiterate	0.529	0.499	0.532	0.499
All literate	0.151	0.358	0.092	0.289
Scheduled tribe	0.216	0.411	0.258	0.437
Scheduled caste	0.186	0.389	0.204	0.403
Non-scheduled caste/tribe	0.598	0.490	0.539	0.499
Owns land	0.931	0.254	0.959	0.197
Land Possessed (Ha)	1.7	3.1	1.5	2.6
Land is irrigated	0.177	0.382	0.264	0.441
Owns radio	0.161	0.368	0.231	0.421
Owns TV	0.085	0.279	0.092	0.289
Owns bicycle	0.168	0.374	0.354	0.478
Owns electric fan	0.138	0.345	0.167	0.373
Owns sewing machine	0.019	0.138	0.085	0.280
Owns fridge	0.002	0.040	0.003	0.053
Owns motorcycle	0.012	0.108	0.011	0.105
Owns car	0.002	0.040	0.002	0.040
N	3,732		12,989	

Note: N corresponds to the sample for all three NSS rounds.