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Introducing Biofortified Rice and Wheat through the Public Distribution System: An Empirical Analysis of Its Implications in Bihar and Odisha

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ABSTRACT

The paper examines the potential of India's Public Distribution System for introducing biofortified crops to address the challenges of micronutrient deficiencies in Bihar and Odisha, two of the country's most poverty-stricken states. The analysis indicate that the replacement by bio-fortified varieties had the potential to increase the intake of zinc and iron by nearly 33 per cent.

Keywords: Public distribution system, Biofortification, Paddy, Wheat, Bihar, Odisha

JEL: I18, P36, Q13, Q16

I

INTRODUCTION

Since the beginning of the 20th century, India has made many concerted efforts to deal with the chronic problem of malnutrition. Among these, the Public Distribution System (PDS) stands out as one of the most prominent mechanisms to combat malnutrition, hunger, and poverty in the country. The PDS, now known as the Targeted Public Distribution System (TPDS), traces its origins in the pre-Independence era, during the time of the Second World War.

The PDS was expanded in the 1960s when the country began facing food shortages and was unable to import food grains due to insufficient foreign exchange reserves. In 1965, creation of the Food Corporation of India (FCI) and the Agricultural Prices Commission (now called the Commission for Agricultural Costs and Prices) further strengthened the position of the PDS in ensuring food security in the country. In 1997, the PDS was revamped and took on its current format, the TPDS; it specifically targeted the poor—those falling below the poverty line (BPL)—to receive food grains and fuel at highly subsidised prices. Food grains are procured from farmers at a minimum support price (MSP) and stored in 'godowns' (warehouses) and modern silos; they are

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then moved to distribution agencies and, finally, delivered to the poor at subsidised prices through a nationwide network of more than 550,000 fair price shops (FPSs).

The implementation of the TPDS is the collective responsibility of the central and state governments. The central government, through the Food Corporation of India, handles procurement, storage, transportation, and the bulk allocation of food grains to state governments; state governments are responsible for the allocation of food grains within the state, the identification of beneficiaries, the issuing of ration cards to beneficiary families, and the supervision of FPSs. The TPDS presently includes the commodities most essential for BPL households, typically including rice, wheat, sugar, and kerosene. Some states also opt to distribute other commodities of mass consumption such as edible oils, pulses, and salt.

In 2015/2016, almost seven decades after India's Independence, despite the efforts of successive governments to alleviate poverty and malnutrition, 23 per cent of women (27 per cent in rural areas) and 20.2 percent of men (23 per cent in rural areas) were found to be malnourished (India, Ministry of Health and Family Welfare, n.d.). The status of child health and nutrition is even more unsettling. In 2015/2016, 38 per cent of children under five were stunted (low height-for-age) and 36 per cent were underweight (low weight-for-age) (ibid). These figures are a cause for worry. Economic growth and development can be inclusive only when the underlying population is well-fed, well nourished and healthy.

Health portfolios often concentrate entirely on the communicable and non-communicable diseases, especially in the context of developing countries like India; nutritional well-being has been neglected in this discourse. Nutritional security assumes significant importance in the Indian context. A large part of the country's population suffers from micronutrient deficiencies, often referred to as the "hidden hunger" because there may not be visible signs of the deficiencies. Even in the case of visible diseases such as blindness and night blindness, people are often unable to make the connection between these outcomes and micronutrient deficiencies. In 2016, however, micronutrient deficiencies accounted for nearly 0.5 per cent of the total deaths in India (The Lancet, 2017).

Biofortified crops, which are bred to contain higher quantities of nutrients, can be one part of the answer to the problem of rampant nutritional insecurity among India's poorer populations. Consumption of biofortified food grains can help fulfil the nutritional requirements of the large part of the population that is unable to access foods that are naturally rich in micronutrients or other important nutritional interventions because of lack of availability or affordability. The introduction of biofortified foods, especially biofortified staples, is an integral component of food-based approaches to improved food and nutritional security, in addition to dietary diversification, supplementation, and commercial fortification.

India is already a leader in the field of biofortification. Iron-rich pearl millet has been introduced successfully in other parts of India, and iron has now been recommended as a mandatory trait for breeding of pearl millet. Important clinical trial

data was generated in India about the nutritional and functional benefits of iron pearl millet, including the reversal of iron deficiency and improved cognitive and physical performance. Millets, overall, are nutrient rich, and making them available through the PDS can help address the problem of micronutrient deficiency. The inclusion of millets among grains supplied by the PDS was recently recommended by a high-level committee that was chaired by NITI Aayog and attended by officials from the Ministry of Food and Agriculture and members of the Indian Council of Medical Research (ICMR). The Indian Council of Agricultural Research (ICAR) has released, and continues to develop, biofortified varieties of staples such as rice, wheat, maize, millet, and even a few types of vegetables, fruits, and oilseeds. To sustainably eradicate malnutrition, these commodities are being biofortified with vitamins, minerals, proteins, and other trace elements that are required for a healthy human mind and body.

In this paper, we explore the scope for introducing biofortified iron- and zinc-rich rice and wheat into the diets of people in Bihar and Odisha to improve the micronutrient (iron and zinc) intake and nutritional outcomes. We look at what role the PDS programme can play in dealing with iron, and zinc deficiencies in these states.

The rest of the paper is organised as follows. Section II describes the data used for analysis; Section III describes the potential contribution of the PDS in the promotion of biofortified wheat and rice; in Section IV, we discuss the patterns and trends of the PDS; Section V uses econometric analysis to explore the determinants of a household's decision to access the PDS for food grains; and Section VI offers conclusions that are based on the results and analyses presented in the paper.

II

DATA

This study is based on both primary and secondary data, along with qualitative data from interactions with various stakeholders. The primary data used for this study is drawn from a survey conducted by International Food Policy Research Institute (IFPRI) in 2015/2016 in the states of Bihar and Odisha, after the 2013 enactment of the National Food Security Act (NFSA). The NFSA aims to strengthen the country's efforts at ensuring food and nutritional security for its population. The Act provides for coverage of up to 75 per cent of the rural population and up to 50 per cent of the urban population for receiving subsidised food grains under TPDS, thus covering about two-thirds of the population.[1]

The sample for analysis consists of 962 rural households from five districts in Bihar (Patna, Darbhanga, Banka, Munger, and West Champaran) and 338 rural households from the Kalahandi and Kandhamal districts of Odisha. The survey collected detailed data - stratified by caste, gender, class, and location - on the various household characteristics and consumption patterns; it also collected information on the type of ration card owned by the household (Below Poverty Line [BPL], Above Poverty Line [APL], Antyodaya Anna Yojana [AAY], on households' engagements

with the PDS, and information on rice and wheat purchases from the PDS and on the open market.

The average household in Bihar has six members and in Odisha has four. Household size has a direct implication on the demand for food grains and, consequently, also for the uptake of the PDS, other things remaining constant. In Bihar, 55.4 per cent of the sample households belong to Other Backward Classes (OBCs), 19.9 per cent belong to Scheduled Castes (SCs), 12.2 per cent belong to Scheduled Tribes (STs), and the remaining 12.6 per cent of households belong to the General Caste (GC) category.

In addition to primary survey data for the states of Bihar and Odisha that analyses the trends and patterns of consumption of rice and wheat from different sources, we also use unit-level data on household consumption expenditure from the 50th (NSSO, 1994), 61st (NSSO, 2005), and 68th (NSSO, 2012) rounds of the National Sample Survey Office (NSSO). To arrive at policy relevant conclusions, the study combines these two sources of data to validate the propositions and analyse the variables of interest. We also examine the factors that affect a household's decision to purchase rice or wheat from FPSs in Bihar and Odisha. To do this, we estimate a probit regression model using data on household consumption expenditure from the 68th round (NSSO, 2012). We use a PDS beneficiary (dichotomous outcome variable) as an independent variable; this takes the value of 1 if, in 2011/2012, a household purchased rice and/or wheat from the PDS, and 0 if they purchased neither rice nor wheat from the PDS. Various demographic and socio-economic characteristics of the household are chosen as explanatory variables and are tested as determinants of whether they influence households' access to PDS in Bihar and Odisha.

III

POTENTIAL CONTRIBUTION OF THE PDS IN THE PROMOTION OF BIOFORTIFIED WHEAT AND RICE

The functioning of the PDS varies widely across states, but in most states, it has improved markedly and consistently. For a long time, the idea of doing away with the PDS in favour of alternatives such as food stamps, food credit, food coupons, and direct cash transfers has been floating around in policy circles; however, several evaluations of its functioning and outreach in different states have consolidated the importance of the PDS as a means of income support and social protection in rural India (Drèze and Khera, 2013). It is generally deemed that a more sensible way forward would be to improve the PDS to better serve its purpose (Khera, 2011). Kumar and Ayyappan (2014) observe that the contribution of the PDS in reducing poverty and improving food security has been increasing over time; they conclude that the PDS is the most important instrument for ensuring food security in India. Drèze and Khera (2015) find clear evidence that leakages from the PDS have decreased in recent years, especially in states such as Bihar which have undertaken bold PDS reforms. All this evidence has bolstered the view that, rather than abolishing the PDS, it must be retained and made

more efficient. In Odisha, household- and community-level factors such as greater awareness and better education have had a positive influence on improvements in food and nutritional security in the state (Kumar *et al.*, 2017).

With the Government's 2013 launch of the NFSA, efforts at reforming the PDS and improving its governance picked up steam in many states. Bihar and Odisha were two of the states that began enthusiastically to reform the PDS, though their recovery has gone largely unnoticed and has not been adequately studied or captured in the research and policy arena; lately, however, evidence of their revival has started to surface.

IV

PATTERNS AND TRENDS OF PDS OUTREACH IN BIHAR AND ODISHA

We utilise data from the survey conducted in Bihar and Odisha to assess the 2015/2016 consumption levels of staples (rice, wheat, and pulses) and to examine the amounts of PDS rice and wheat consumed. From this we can derive a fair idea of the importance of the PDS in the consumption patterns of the rural population of these states; this, in turn, is useful in discerning the extent to which biofortified rice and wheat can help improve iron and zinc intake among the target population and thus ameliorate the deficiency of those micronutrients.

Table 1 presents the patterns and trends in the consumption of rice in Bihar and Odisha, and the contribution of PDS rice to the amounts consumed. In 2015/2016, the members of an average rural household in Bihar consumed about 0.27 kg/person/day of rice, of which the PDS supplied 31.05 per cent. Though the estimates from our survey are not strictly comparable with the estimates from the surveys conducted by the National Sample Survey Office (NSSO), we use the NSSO estimates to observe the broad trends in consumption patterns and the amounts contributed by the PDS.

TABLE 1. AVERAGE PER CAPITA CONSUMPTION OF RICE (KG/DAY) IN BIHAR AND ODISHA, AND CONTRIBUTION OF THE PUBLIC DISTRIBUTION SYSTEM (PDS) TO RICE CONSUMPTION IN THOSE STATES, 1993/1994 TO 2015/2016

	Average consumption of rice (kg/person/day)						Contribution of PDS to rice consumption (per cent)					
	R		U		All		R		U		All	
	B	O	B	O	B	O	B	O	B	O	B	O
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1993/1994*	0.24	0.51	0.21	0.38	0.24	0.49	0.13	0.79	0.17	0.40	0.14	0.76
2004/2005*	0.24	0.44	0.21	0.37	0.24	0.43	0.51	6.74	0.58	2.82	0.52	6.29
2011/2012*	0.21	0.42	0.19	0.31	0.21	0.41	20.63	29.64	10.39	14.43	19.64	27.89
2015/2016^	0.27	0.41	–	–	–	–	31.05	20.17	–	–	–	–

Source: Authors' calculations based on National Sample Survey Office (NSSO) and International Food Policy Research Institute (IFPRI) survey data.

Note: R = rural; U = urban; All = both rural and urban; B = Bihar; O = Odisha; * = NSSO data; ^ = IFPRI survey data; kg/day = kilogram/day.

The estimates for the years 1993/1994, 2004/2005, and 2011/2012 have been calculated based on the data on household consumption and expenditure that is found

in the 50th, 61st, and 68th rounds of the NSSO, respectively. It is interesting to note that while the annual per capita consumption of rice among rural households in Bihar has been largely stable, among rural households in Odisha it declined steadily from 0.51 kg/person/day in 1993/1994 to 0.44 kg/person/day in 2004/2005 to 0.42 kg/person/day in 2011/2012, and ultimately to 0.41 kg/person/day in 2015/2016. According to our data, in Bihar the contribution of the PDS to rice consumption increased to 31.05 per cent in 2015/2016, while in Odisha the PDS share fell to 20.17 per cent.

Table 2 presents the consumption pattern and trends for wheat in Bihar and Odisha, and the contribution of the PDS to wheat consumption in the two states. In 1993-94, daily per capita consumption of wheat was 0.22 kg in Bihar and 0.02 kg in Odisha. The contribution of PDS to wheat consumption in both the states were negligible during 1993-94. The share of PDS in wheat consumption kept increasing since then. Among rural households in Bihar, the contribution of the PDS to total wheat consumption went up significantly, increasing from 17.23 per cent in 2011/2012 to 28.48 per cent in 2015/2016. Odisha is a primarily rice-consuming state, with only 23.1 per cent in 2011/2012 of the sample in that state reporting the consumption of wheat in rural areas. When the entire sample from that Odisha is considered, the contribution of the PDS to wheat consumption in 2015/2016 stands at a meagre 10.76 per cent. This seems logical, as those who consume wheat in Odisha are unlikely to be growing it themselves; they either buy it in the open market or utilise their entitlement under the PDS.

TABLE 2. AVERAGE PER CAPITA CONSUMPTION (KG/DAY) OF WHEAT IN BIHAR AND ODISHA, AND THE CONTRIBUTION OF THE PUBLIC DISTRIBUTION SYSTEM (PDS) TO WHEAT CONSUMPTION IN THOSE STATES, 1993/1994 TO 2015/2016

	Average consumption of wheat (kg/person/day)						Contribution of PDS to wheat consumption (percent)					
	R		U		All		R		U		All	
	B	O	B	O	B	O	B	O	B	O	B	O
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1993/1994*	0.22	0.01	0.22	0.07	0.22	0.02	0.46	7.99	0.67	20.64	0.48	13.59
2004/2005*	0.18	0.02	0.20	0.07	0.18	0.02	1.07	0.47	1.32	0.81	1.10	0.60
2011/2012*	0.19	0.02	0.19	0.07	0.19	0.03	17.23	23.11	7.20	15.26	16.14	20.53
2015/2016^	0.24	0.02	-	-	-	-	28.48	10.76	–	–	–	–

Source: Authors' calculations based on National Sample Survey Office (NSSO) and International Food Policy Research Institute (IFPRI) survey data.

Note: R = rural; U = urban; All = both rural and urban; B = Bihar; O = Odisha; * = NSSO data; ^ = IFPRI survey data; kg/day = kilogram/day.

4.1 *Contribution of Rice and Wheat to the Intake of Iron and Zinc in Bihar and Odisha*

We use iron intake levels from the household consumption expenditure data of the NSSO to estimate the contribution of rice and wheat to the total intake of iron among rural populations in Bihar and Odisha. The National Institute of Nutrition (NIN), which is part of the Indian Council of Medical Research (ICMR), has published the Indian Food Composition Tables in 2017. These tables provide the nutritional components for over 500 food items, including their content of minerals and trace elements; they were

used to convert rice and wheat consumption into iron and zinc intake (ICMR 2017). The iron content of parboiled, milled rice (Oryza sativa) is given to be 0.72 ± 0.20 mg per 100-gram edible portion; that of whole wheat (Triticum aestivum) is 3.97 ± 0.78 mg per 100-gram edible portion. Whereas, zinc concentration for brown rice is 2.14 ± 1.14 mg per 100-gram edible portion and for whole wheat is 3.04 ± 0.3 mg per 100-gram edible portion (Rashid *et al.*, 2019).

Table 3 presents the average level of iron and zinc intake in Bihar and Odisha between 1993/1994 and 2015/2016, and the contribution of rice and wheat to this intake. Among rural households in Bihar in 2015/2016, rice accounted for 12.5 per cent of the total iron intake, whereas wheat contributed a much larger share (61.8 per cent). Over the past three decades, there has been a steady increase in the contribution of wheat and rice to overall iron intake. In 2015/2016 in rural Bihar, cereals accounted for 74.2 per cent of iron intake. In rural Odisha it is the reverse; there, rice makes a much larger contribution to iron intake (29.6 per cent) than does wheat, which is understandable given the rice-centric diets of the population of that state. In Odisha, unlike in Bihar, the contribution of wheat and rice to overall iron intake has also

TABLE 3. CONTRIBUTION OF RICE AND WHEAT TO IRON INTAKE IN BIHAR AND ODISHA, 1993–1994 TO 2015–2016

	Bihar											
	Iron (Fe) intake (mg/person/day)			Contribution of rice to Fe intake (per cent)			Contribution of wheat to Fe intake (per cent)			Contribution of cereals to Fe intake (per cent)		
Year	R	U	All	R	U	All	R	U	All	R	U	All
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1993/1994*	18.9	18.2	18.8	8.8	8.2	8.8	57.0	58.3	57.2	69.6	66.8	69.3
2004/2005*	16.9	18.5	17.0	9.9	7.8	9.7	52.7	52.9	52.7	65.1	61.2	64.7
2011/2012*	15.7	15.8	15.7	9.3	8.3	9.2	58.5	59.8	58.6	68.6	68.4	68.6
2015/2016^	15.7*	–	–	12.5	–	–	61.8	–	–	74.2	–	–
Gap** (Actuals – Recommended) for 2011/2012 (Surplus+/Deficit–)	-4.3	-4.2	-4.3	–	–	–	–	–	–	–	–	–
	Odisha											
	Iron (Fe) intake (mg/person/day)			Contribution of rice to Fe intake (per cent)			Contribution of wheat to Fe intake (per cent)			Contribution of cereals to Fe intake (per cent)		
Year	R	U	All	R	U	All	R	U	All	R	U	All
1993/1994*	10.2	13.1	10.6	34.9	20.0	32.5	6.0	25.4	9.1	45.0	46.0	45.1
2004/2005*	10.0	13.2	10.4	31.2	19.6	29.2	8.7	25.2	11.5	41.9	45.0	42.5
2011/2012*	9.9	12.3	10.2	29.8	17.7	27.6	12.9	28.8	15.7	43.7	46.8	44.2
2015/2016^	9.9*	–	–	29.6	–	–	10.1	–	–	39.8	–	–
Gap** (Actuals – Recommended) for 2011/2012 (Surplus+/Deficit–)	-10.1	-7.7	-9.8									

Source: Authors' calculations based on National Sample Survey Office (NSSO) and International Food Policy Research Institute (IFPRI) survey data.

Note: R = rural; U = urban; All = both rural and urban; ** = recommended intake of iron is 20 mg/day/person. * = NSS data; ^ = IFPRI survey data.

declined somewhat. The intake of iron in Bihar and Odisha is below the recommended level of about 20mg/day. In Bihar, the intake is about 16mg/day and in Odisha it is about 10mg/day.

The study has relied on NSS data to estimate total zinc intake and the contribution of rice, wheat, and cereals to this total over the 1993/1994 to 2011/2012 period (Table 4). Zinc intake among rural and urban households has declined steadily since 1993/1994, though Bihar fares much better than Odisha despite this decline. In both states, wheat, and more generally cereals, have increasingly contributed to the overall zinc intake. Among rural households in Bihar, cereals account for a whopping 72.2 per cent of total zinc intake; in Odisha, the contribution of cereals to zinc intake has witnessed a sharper rise than it has in Bihar, though the total share remains much less (30.7 per cent in 2011/2012). In Bihar, the contribution of cereals to zinc intake is largely comparable between rural and urban households; in Odisha, however, cereals contribute a larger share of the zinc intake of members of urban households (52.3 per cent) than their rural counterpart (30.7 per cent). Even so, compared to the recommended intake values for zinc, intake in Bihar and Odisha remains quite low.

TABLE 4. CONTRIBUTION OF RICE AND WHEAT TO ZINC INTAKE IN BIHAR AND ODISHA, 1993–1994 TO 2011–2012

	Bihar								
	Zinc (Zn) intake (mg/person/day)			Contribution of wheat to Zn intake (per cent)			Contribution of cereals to Zn intake (per cent)		
Year	R	U	All	R	U	All	R	U	All
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1993/1994*	10.0	10.1	10.0	48.6	47.3	48.4	55.9	48.1	55.1
2004/2005*	7.0	8.4	7.2	56.7	52.2	56.2	63.5	53.0	62.3
2011/2012*	5.9	6.0	5.9	70.0	71.3	70.1	72.2	71.6	72.2
Gap** (Actuals – Recommended) for 2011/2012 (Surplus+/Deficit–)	-3.1	-3.0	-3.1						
	Odisha								
	Zinc (Zn) intake (mg/person/day)			Contribution of wheat to Zn intake (per cent)			Contribution of cereals to Zn intake (per cent)		
Year	R	U	All	R	U	All	R	U	All
1993–1994*	4.3	7.6	4.8	6.4	19.8	9.1	12.0	20.4	13.7
2004–2005*	3.3	5.4	3.6	11.6	27.6	14.9	15.3	28.1	17.9
2011–2012*	2.0	3.1	2.2	27.9	51.8	32.9	30.7	52.3	35.2
Gap** (Actuals – Recommended) for 2011/2012 (Surplus+/Deficit–)	-7.0	-5.9	-6.8						

Source: Authors' calculations based on National Sample Survey Office (NSSO) data.

Note: R = rural; U = urban; All = both rural and urban; ** = recommended intake of zinc is 9 mg/day/person; * = NSS data.

4.2 *Contribution of the PDS in Bihar and Odisha to Iron and Zinc Intake through Rice, Wheat, and Cereals*

To assess the contribution that the PDS can make to improving iron and zinc intake from rice and wheat among rural households in Bihar and Odisha, we examine the contribution of the PDS in Bihar and Odisha to iron and zinc intake through rice and wheat for the period 1993/1994 to 2011/2012 (Table 5). In Bihar, the contribution of the PDS to iron intake from rice is the less than its contribution to zinc intake from wheat. In Odisha, by contrast, we have observed that the contribution of the PDS to iron intake from rice is higher than its contribution to zinc intake from wheat.

TABLE 5. CONTRIBUTION OF THE PUBLIC DISTRIBUTION SYSTEM (PDS) TO IRON AND ZINC INTAKE FROM RICE AND WHEAT IN BIHAR AND ODISHA, 1993/1994 TO 2011/2012

	Contribution of PDS to iron (Fe) intake from rice (per cent)						Contribution of PDS to Fe or zinc (Zn) intake from wheat (per cent)					
	R		U		All		R		U		All	
Year	B	O	B	O	B	O	B	O	B	O	B	O
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1993/1994*	0.01	0.28	0.01	0.08	0.01	0.26	0.26	0.50	0.37	4.65	0.26	1.24
2004/2005*	0.05	2.12	0.05	0.55	0.05	1.84	0.60	0.05	0.68	0.21	0.60	0.08
2011/2012*	1.92	8.85	0.87	2.57	1.80	7.74	11.05	4.71	4.72	6.17	10.43	4.99

*Sou*rce: Authors' calculations based on National Sample Survey Office (NSSO) data.

Note: R = rural; U = urban; All = both rural and urban; B = Bihar; O = Odisha; * = National Sample Survey data.

4.3 *Potential of Biofortified (Iron- and Zinc-Rich) Varieties of Rice and Wheat for Improving Intake of Iron and Zinc in Bihar and Odisha*

What incremental gains in zinc and iron intake can be had from the consumption of biofortified rice and wheat? This section examines the potential increase by considering two scenarios: (1) the gains in zinc and iron intake that can be achieved through replacing all the rice and wheat being consumed in Bihar and Odisha with biofortified varieties; and (2) the potential gain in intake of iron and zinc that can be achieved if only PDS rice and wheat is replaced with biofortified varieties.

Using the 2011/2012 annual per capita consumption levels of rice and wheat, combined with the kg/person/year share of the PDS in this consumption, we first examine the impact of replacing popular varieties of rice with the biofortified zinc-rich rice developed by ICAR (DRR Dhan 45). While the zinc content in ordinary varieties of rice is 14 ppm (or mg per litre), in DRR Dhan 45 it is 22.6 ppm. Table 6 shows the increase in zinc intake from consumption of this variety of rice when all rice consumed is DRR Dhan 45 and when only PDS rice is replaced with this zinc-rich variety. The per capita zinc intake in Bihar can increase from 2.88 mg/day to 4.64 mg/day and in Odisha from 5.68 mg/day to 9.16 mg/day.

TABLE 6. POTENTIAL INCREASE IN ZINC INTAKE FROM REPLACEMENT OF POPULAR VARIETIES OF RICE BY A BIOFORTIFIED ZINC-RICH VARIETY OF RICE IN BIHAR AND ODISHA

	Average zinc intake from ordinary popular variety of rice consumed (mg/person/day)						Estimated zinc intake from DRR Dhan 45 (zinc-rich rice variety) (mg/person/day)					
	R		U		All		R		U		All	
	B	O	B	O	B	O	B	O	B	O	B	O
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Zn from rice consumption	2.92	5.87	2.65	4.37	2.88	5.68	4.71	9.47	4.27	7.06	4.64	9.16
Contribution by PDS	0.60	1.74	0.28	0.63	0.56	1.58	0.97	2.81	0.45	1.02	0.91	2.56

Source: Figures are authors' calculations, based on Indian Council of Agricultural Research (ICAR) estimates of the zinc content of ordinary popular varieties of rice and of DRR Dhan 45, and on the date from the National Sample Survey (NSS) 68th Round.

Note: R = rural; U = urban; All = both rural and urban; B = Bihar; O = Odisha.

Table 7 shows the increase in levels of both iron and zinc intake from replacing the ordinary variety of wheat with a biofortified zinc- and iron-rich variety (WB 02) in Bihar and Odisha. The ordinary, popular varieties of wheat have an average of 32 ppm of zinc and 30 ppm of iron, while WB 02, developed by ICAR, is estimated to have 42 ppm of zinc and 40 ppm of iron. Accordingly, in Bihar, replacement of the ordinary variety of wheat with the biofortified variety is likely to increase zinc intake from 6.05 mg/person/day to 7.94 mg/person/day (31.3 per cent) and iron intake from 5.67 mg/persona/day to 7.56 mg/person/day (33.3 per cent).. Similarly, in Odisha, the replacement of biofortified variety is likely to increase zinc intake from 1.05

TABLE 7. POTENTIAL INCREASE IN ZINC AND IRON INTAKE FROM REPLACEMENT OF POPULAR VARIETIES OF WHEAT WITH A BIOFORTIFIED ZINC- AND IRON-RICH VARIETY OF WHEAT IN BIHAR AND ODISHA

	R		U		All	
	B	O	B	O	B	O
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Zinc (Zn) intake from ordinary popular variety of wheat consumed in Bihar and Odisha (mg/person/day)						
Zn from wheat consumption	5.96	0.79	6.22	2.28	6.05	1.05
Contribution by Public Distribution System (PDS)	1.02	0.18	0.45	0.35	0.97	0.22
Estimated zinc intake from WB 02 (Zn- and iron [Fe]-rich wheat variety) in Bihar and Odisha (mg/person/day)						
Zn from wheat consumption	7.82	1.04	8.17	2.99	7.94	1.38
Contribution by PDS	1.35	0.24	0.59	0.46	1.28	0.29
Iron intake from ordinary popular variety of wheat consumed in Bihar and Odisha (mg/person/day)						
Fe from wheat consumption	5.59	0.74	5.84	2.14	5.67	0.99
Contribution by PDS	0.96	0.17	0.42	0.33	0.91	0.21
Estimated iron intake from WB 02 (Zn- and Fe-rich wheat variety) in Bihar and Odisha (mg/person/day)						
Fe from wheat consumption	7.45	0.99	7.78	2.85	7.56	1.32
Contribution by PDS	1.28	0.23	0.56	0.44	1.22	0.27

Source: Figures are authors' calculations, based on Indian Council of Agricultural Research (ICAR) estimates of the zinc and iron content of ordinary popular varieties of wheat and WB 02, and on data from the National Sample Survey (NSS) 68th Round.

Note: R = rural; U = urban; All = both rural and urban; B = Bihar; O = Odisha.

mg/person/day to 1.38 mg/person/day (31.4 per cent) and iron intake from 0.99 mg/person/day to 1.32 mg/person/day (33.3 per cent).

V

DETERMINANTS OF ACCESSING THE PDS IN BIHAR AND ODISHA

Table 8 shows the trend in the share of households accessing the PDS for rice and/or wheat in both Bihar and Odisha from 1993/1994 to 2011/2012. The reach of the PDS has increased substantially over time, particularly among rural households in both states. In rural Bihar, the share of rural households accessing the PDS for rice increased from a negligible 0.14 per cent in 1993/1994 to 44.5 per cent in 2011/2012; In rural Odisha, during this period, showed an increase from 3.7 per cent to 54.9 per cent. In 1993/1994, only 0.5 per cent of rural households in Bihar were accessing PDS wheat; by 2011/2012, this figure had increased to 44.2 per cent. Despite the low consumption of wheat in Odisha, by 2011/2012, 11.2 per cent rural households were accessing PDS wheat, increased from 1.29 per cent in 1993/1994. While access to PDS staples has gone up noticeably in the urban sector as well (except in the case of wheat among urban households in Odisha), the increase is more pronounced in the rural sector.

TABLE 8. HOUSEHOLDS ACCESSING THE PUBLIC DISTRIBUTION SYSTEM (PDS) FOR RICE AND/OR WHEAT IN BIHAR AND ODISHA, 1993/1994 TO 2011/2012

	Households accessing PDS for rice (per cent)						Households accessing PDS for wheat (per cent)					
	R		U		All		R		U		All	
Year	B	O	B	O	B	O	B	O	B	O	B	O
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1993/1994	0.14	3.72	0.11	0.45	0.13	3.27	0.50	1.29	1.02	16.39	0.56	3.36
2004/2005	1.00	21.54	0.70	5.83	0.97	19.27	1.74	0.20	1.56	0.97	1.72	2.94
2011/2012	44.52	54.92	19.01	17.66	41.73	48.70	44.18	11.20	19.18	12.86	41.44	11.48

Source: Authors' calculations based on National Sample Survey Office (NSSO) data.
Note: R = rural; U = urban; All = both rural and urban; B = Bihar; O = Odisha; * = NSS data.

While access to the PDS clearly has increased over the past three decades (Table 8), it is important to identify what factors drive a household's decision to access the PDS for wheat or rice. We use a probit model to empirically assess what factors count in households' decisions regarding participation in the PDS. We fit the model using the consumption expenditure survey data from the 68th Round of the NSSO (2011/2012), with PDS participation (for rice and/or wheat) as the dependent variable and several demographic and socio-economic characteristics of households as determinants. Our sample for the econometric estimation consists of 8,608 households; of these, 3,666 households are PDS beneficiaries for rice and or wheat, and the remaining 4,942 households do not access the PDS for either rice or wheat. Our dependent variable (PDS beneficiary) is a dichotomous outcome variable; it takes the value of 0 if, in 2011/2012, the household reported purchasing neither rice nor wheat from the PDS and takes a value of 1 if in that period the household purchased rice and/or wheat from the

PDS. District-level variations have been controlled for using district fixed effects by factoring district dummies. For better interpretation, we have provided marginal effects obtained from the probit model. In Table 9, we provide three models/estimates: Model

TABLE 9. PROBIT REGRESSION RESULTS OF PARTICIPATION OF HOUSEHOLDS IN THE PUBLIC DISTRIBUTION SYSTEM (PDS) IN BIHAR AND ODISHA (MARGINAL EFFECTS)

Dependent variable (PDS beneficiary = 1; otherwise, 0) (1)	Model 1 dy/dx (2)	Model 2 dy/dx (3)	Model 3 dy/dx (4)
Age of household head (years)	0.017***	0.013***	0.020***
	(0.003)	(0.005)	(0.003)
Age squared	-0.000***	-0.000**	-0.000***
	(0.000)	(0.000)	(0.000)
Female-headed households	0.008	0.087**	-0.024
	(0.023)	(0.042)	(0.026)
Household size	-0.007**	-0.003	-0.010**
	(0.003)	(0.005)	(0.004)
Education (Base: illiterate)			
Up to primary	-0.066***	-0.068***	-0.058***
	(0.017)	(0.025)	(0.022)
Middle and secondary	-0.121***	-0.102***	-0.129***
	(0.018)	(0.026)	(0.022)
Higher secondary and above	-0.254***	-0.250***	-0.265***
	(0.018)	(0.028)	(0.023)
Monthly per capital expenditures quintiles (Base: very poor)			
Poor	-0.171***	-0.198***	-0.154***
	(0.015)	(0.022)	(0.019)
Middle	-0.283***	-0.291***	-0.277***
	(0.016)	(0.023)	(0.019)
Rich	-0.308***	-0.285***	-0.313***
	(0.016)	(0.025)	(0.020)
Very rich	-0.349***	-0.345***	-0.350***
	(0.017)	(0.020)	(0.022)
Land category (Base: marginal)			
Small (1 to 2 hectares)	-0.071***	-0.110***	
	(0.022)	(0.026)	
Medium (2 to 4 hectares)	-0.136***	-0.175***	
	(0.027)	(0.031)	
Large (more than 4 hectares)	-0.217***	-0.313***	
	(0.046)	(0.032)	
Social category (Base: Other Backward Class)			
Scheduled Caste/Scheduled Tribe	0.089***	0.129***	0.066***
	(0.019)	(0.028)	(0.022)
General Category	-0.058***	-0.044	-0.065***
	(0.018)	(0.029)	(0.021)
Households from rural sector	0.059**	0.050*	0.049**
	(0.025)	(0.028)	(0.025)
Farming households	-0.004		
	(0.028)		
Rural farm households belonging to farming category	-0.022		
	(0.030)		
District fixed effect	Yes	Yes	Yes
Observations	8,529	3,315	5,214

Source: Authors' calculations based on National Sample Survey Office (NSSO) data.

Note: Robust standard errors in parentheses; *, **, and *** indicate statistical significance at the $p < 0.1$, $p < 0.05$, and $p < 0.01$ levels; clustering at village level.

1 includes a rural and urban sample from Bihar and Odisha; Model 2 is a rural farm sample from Bihar and Odisha; and Model 3 is a rural non-farm sample from Bihar and Odisha. In all models, the probability of households accessing the PDS for rice and/or wheat is significantly higher if they belong to a Scheduled Tribe (ST) or Scheduled Caste (SC) than if they belong to the Other Backward Class (OBC). Households belonging to the General Category (GC), however, are less likely to purchase rice or wheat from the PDS for Model 1 and Model 3; but for Model 2—that is, the sample from farming households—the coefficient of GC households is not significant. This result reaffirms the inclusive character that the PDS is supposed to have for all households, including non-farm households.

A common trend that can be read from the estimation is that as a household becomes better off, they are less likely to purchase rice or wheat from the PDS. This is supported intuitively as well: the better off a household, the weaker its incentive to purchase subsidised grains from a fair price shop. This is reflected in the negative and significant coefficients obtained for the second, third, fourth, and fifth group of the household's monthly per capita expenditure (MPCE); it is also shown to some extent in the level of education of the household head for all three estimates/models. Large farmers, similarly, have less incentive to purchase rations from the PDS in the case of the sample as a whole and of the farming sample household. Interestingly, the older the household head, the more likely is the household to access PDS rice and/or wheat; this is possibly because the elderly rely more on government support schemes and programmes. As household size increases, non-farming households (Model 3) are less inclined to purchase PDS grains; we found the same coefficient sign for Model 1 (rural and urban combined) households. However, farm households headed by females, however, prefer to access the PDS (Model 2). Lastly, rural households in general have a greater incentive to purchase grains from the PDS.

VI

CONCLUSION

In Bihar and Odisha, the PDS is an important source of staples, including rice and wheat, especially for households in the rural sector. The high incidence of poverty and malnutrition in both states justifies and necessitates efforts to resuscitate the PDS to ensure that targeted beneficiaries can benefit from it and improve their nutritional outcomes. The PDS in Bihar and Odisha has started showing signs of recovery because of substantial supply-side reforms taken up by these states which have focused on the coverage, leakages, and governance. Demand-side revival is also gradually picking up momentum, due to a heightened awareness of entitlements and improved functioning and governance of the PDS; as a result, the PDS has begun to make deep inroads, particularly among rural households. In both Bihar and Odisha, where micronutrient deficiency is significant, the contribution of the PDS to rice and wheat consumption has increased among rural households. This is encouraging, as it broadens the scope in

those states for introducing iron- and zinc-rich varieties of rice and wheat through the PDS. Given the importance of micronutrients to the growth and development of healthy human minds and bodies, it is crucial to eradicate micronutrient deficiency among the poor. In collaboration with other institutions, ICAR has been developing a sustainable mechanism for alleviating nutritional insecurity through iron- and zinc-rich varieties of staples. The HarvestPlus, working in partnership with international and Indian experts, has also produced biofortified varieties of several crops including rice and wheat.

Using econometric estimation to model the factors at play in the probability of a household's purchase of rice and/or wheat from the PDS in Bihar and Odisha, we find that the poor, illiterate, and less well-off participate to a greater degree in the PDS. This finding is intuitive in that the poor are far more price-sensitive and thus more likely to take advantage of subsidies on grains and other staples. The finding also indicates that the targeting capability of the PDS has improved in these states and that leakages have been reduced.

In Bihar and Odisha, the PDS plays a significant role in rice and wheat consumption. There is scope for using it to introduce biofortified varieties of rice and wheat and to encourage the eligible non-beneficiaries to use PDS staples to increase their consumption and improve their nutrition. Given the high incidence of poverty and malnutrition in these states, all efforts must be made to accelerate improvements in the functioning, governance, and outreach of the PDS in Bihar and Odisha. There should be an urgent focus on the use of the PDS in those states for the delivery of high nutrition, biofortified varieties of rice and wheat to targeted beneficiaries to alleviate malnutrition and micronutrient deficiency.

NOTE

1) https://dfpd.gov.in/nfsa.htm.

REFERENCES

Drèze, J. and R. Khera (2013), "Rural Poverty and the Public Distribution System", *Economic & Political Weekly*, pp.55–60.

Drèze, J. and R. Khera (2015), "Understanding Leakages in the Public Distribution System.", *Economic and Political Weekly*, Vol.50, No.7, 14 Februarypp.39–42.

India, Ministry of Health and Family Welfare.(n.d.) *National Family Health Survey, India: Key Findings from NFHS–4.* Mumbai, India: International Institute for Population Sciences, Ministry of Health and Family Welfare. http://rchiips.org/nfhs/factsheet_NFHS-4.shtml.

Indian Council of Medical Research (ICMR) (2017), Indian Food Composition Tables, *National Institute of Nutrition. Department of Health Research*. Ministry of Health & Family Welfare. Government on India.

Khera, R. (2011), "Revival of the Public Distribution System: Evidence and Explanations." *Economic & Political Weekly* 46 (44,45): 36–50.

Kumar, A. and S. Ayyappan (2014), "Food Security and Public Distribution System in India", *Agricultural Research,* Vol.3, No.3, pp.271–77.

Kumar, A.; S. Parappurathu, S.C. Babu and P.K. Joshi (2017), "Can Better Governance Improve Food Security? An Assessment of the Public Food Distribution System in Odisha, India", *Food Security,* Vol.9, No.6, pp.1433–445.

National Sample Survey Office (NSSO) (1994), "NSS 50th Round: Consumer Expenditure Survey (July 1993 to June 1994)", Ministry of Statistics and Programme Implementation (MOSPI), Government of India.

National Sample Survey Office (NSSO) (2005), "NSS 61st Round: Consumer Expenditure Survey (July 2004 to June 2005)", Ministry of Statistics and Programme Implementation (MOSPI), Government of India.

National Sample Survey Office (NSSO) (2012), "NSS 68th Round: Consumer Expenditure Survey (July 2011 to June 2012)", Ministry of Statistics and Programme Implementation (MOSPI), Government of India.

Rashid, A.; H. Ram, C.Q. Zou, B. Rerkasem, A.P. Duarte, S. Simunji, A. Yazici, S. Guo, M. Rizwan, R.S. Bal, Z. Wang, S.S. Malik, N. Phattarakul, R.S. de Freitas, O. Lungu, **V.L.,** N.P. Barros and I. Cakma (2019), "Effect of Zinc-Biofortified Seeds on Grain Yield of Wheat, Rice, and Common Bean Grown in Six Countries", *Journal of Plant Nutrition and Soil Science*, Vol.182, No.5, pp.791–804. doi: 10.1002/jpln.201800577.

The Lancet (2017), "India State-Level Disease Burden Initiative Collaborators. Nations Within a Nation: Variations in Epidemiological Transition Across the States of India, 1990–2016 in the Global Burden of Disease Study", *The Lancet* No.390, pp.2437–60.