Agriculture and Child Under-Nutrition in India: A State Level Analysis

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Abstract

The literature review on agriculture-child nutrition linkage indicates that the evidence base is weak and inconclusive (Kadiyala et al., 2013). This paper explores the possible linkages between agricultural prosperity with rural child nutrition at the macro level, controlling for sanitation and safe drinking water, using panel data fixed effects and random effects models. The four alternate indicators of agricultural prosperity viz., agricultural growth, worker productivity, land productivity and food grain production per capita used alternatively enable us to conclude that negative influence of agricultural prosperity on child undernutrition exists, though the influence of various aspects of prosperity on underweight and stunting differ. Other aspects of agriculture considered, such as female agricultural wages help to reinforce the negative influence of agricultural prosperity on underweight in children and the land operational inequality dampens the impact of agricultural prosperity as it increases the incidence of stunting. Water and sanitation help reduce child undernutrition albeit differently on stunting and underweight. The same set of variables seems to influence stunting and underweight differently. Their trajectories seem to differ. The present study enables us to conclude that Indian agricultural growth through higher food grain production and through higher land productivity, when percolates through, labour productivity and higher wages, can reduce child undernutrition in rural India. However, public policy has to promote social provisioning of sanitation and health and make sure that agricultural growth is consistent. Public policy should ensure that growth translates into higher labour productivity and higher wages.

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INTRODUCTION

The basic rationale for exploring agriculture-nutrition linkage in developing countries is the existence of high level of undernutrition among rural population and a high level of their dependence on agriculture for livelihood. Agriculture nutrition links and concern for the vulnerable people occupied centre stage after the price rise in food commodities internationally beginning 2007. This has a relevance to agricultural transformation process in the developing countries. Declining share of agriculture in the GDP, without a commensurate decline in the population dependent on agriculture leads to per worker productivity gaps between agriculture and non-agriculture (Timmer *et al.*, 2008). Major reason for this prolonged period before the sector-level productivity convergence is the relative neglect of agriculture. There were no investments in research and infrastructure. Agricultural productivity stagnated. Climate change problems and shift of land to non-food crops and bio-fuels made things worse (Timmer *et al.,* 2008). India is no different in this respect. The share of agricultural GDP in the overall GDP declined from about 30 percent in 1990-91 to about 14.5 percent in 2010-11 (GOI, 2012). The share of agriculture in the total workforce is still as high as 54.6 percent as per the 2011 census. Farm size declined from 2.28 hectares in 1970-71 to 1.16 hectares in 2009-10 (GOI, 2010). Further, there was a deceleration in food grain production in the country. The growth rate of wheat production decelerated from about 4.52 percent in the decade ending 2000 to 1.39 percent in the decade ending in 2010. The rate of growth of rice production decelerated from 2.09 percent to 1.34 percent over the same period. Barring maize, used as animal-feed, there was deceleration in the production of all coarse cereals. In contrast, the production of oilseeds and cotton and horticulture crops accelerated. Thus, there was a visible shift of production and area towards non-food grain crops. Further, the agricultural enterprise shifted towards milk, poultry and fish production. The share of livestock in the value of total agricultural output increased

by 5 percent, that of horticultural crops by 4 percent, fisheries by 2 percent and fibres by 1 percent over the same period. Investment represented by gross capital formation as a percentage of agricultural GDP declined initially but picked up marginally after 2005. It marginally fell from 12.8 percent in 1990-91 to about 12.4 percent in 2004-05. Lower public sector investment in infrastructure over this period is apparent. (GOI, 2012). Vaidyanathan (2010) argued that the patterns of growth observed in India, reflect changing agrarian structures, changing rural labour markets; uneven spread of technology and its sub-optimal performance; government policies that are not conducive to efficient use of resources and inputs; and serious deficiencies in the functioning of institutions.

Commensurate with a possible low worker productivity in agriculture compared to non agriculture, rural poverty remained high at about 41.8 percent in 2004-05 compared to about 25.7 percent in urban areas as per the Tendulkar methodology (Planning Commission, 2013). The child undernutrition rates also remained high during this period. India reported about 50.7 percent of stunted children and 45.6 percent of underweight children in rural areas (National Family Health Survey, 2005-06). Fairly, high rates of growth of Indian economy during 2002-07 at about 7.6 percent per annum and that of agriculture at about 2.4 percent per annum (GOI, 2012) associated with high rates of child undernutrition as mentioned above are considered as being inconsistent. Doubts arise about the ability of growth especially that of agriculture in India to substantially reduce poverty and child undernutrition (Headey *et al.*, 2011), despite the evidence the world over that agricultural growth reduces poverty (DFID, 2004) and child undernutrition.

The agriculture nutrition linkages are not straightforward. The relationship between agriculture and human nutrition is more complex than production and consumption link (World Bank, 2007). Child nutrition improvements seem to have a range of prerequisites such as food-

security, (calorie protein and nutrient adequacy), nutrition enhancing interventions in agriculture, health, hygiene, water supply, education, of women in particular (FAO, 2013). Poverty reduction no doubt is essential for translating the agricultural prosperity into child nutrition along with other enabling aspects.

United Nations International Children's Emergency Fund (UNICEF, 1990) first provided the conceptual framework to link agriculture to nutrition in terms of three pathways, through food, quality and care of feeding. The World Bank further elaborated these pathways into five (World Bank, 2007). The pathways that link agriculture to nutrition were set in the backdrop of agricultural transformation taking place in the developing nations. Essential pathways identified are subsistence-oriented agricultural production for own consumption, income-oriented agricultural production for sale in markets, reduction in real food prices, women as agents instrumental to household health outcomes and agriculture sector's contribution to national income. These pathways are not mutually exclusive. The evidence on linkages between agriculture and nutrition in India was examined across seven pathways under the project 'Tackling the Agriculture and Nutrition Disconnect in India (TANDI)' and found to be weak (Gillespie *et al.*, 2011). Another review paper identified six pathways in the Indian context (Kadiyala, 2013) and found the evidence from existing literature as inconclusive of a strong linkage but suggestive of influencing diets, incomes and food prices in general. Both the literature reviews are comprehensive and point to the evidence gaps that exist in the Indian context.

This paper has the limited objective of looking at the linkages between child undernutrition and four chosen indicators of agricultural prosperity. Agricultural growth, labour productivity, land productivity and food grain production per capita have been used alternatively as explanatory variable for the proportion of underweight children and proportion of stunted children at the state level. Access to toilets and

piped water supply (considered to be safe) and aspects of agriculture viz., female agricultural wages, land operational inequality and crop diversification index at the state level have also been included in all the equations. Thus, four sets of variables (with only agricultural prosperity variable being different between the sets) have been regressed on proportion of stunted or underweight children below the age of three at the state level. The time points used in the panel data estimation correspond to NFHS rounds of 1998-99 and 2005-06.

The paper has four sections. The second section discusses the correlates of child undernutrition and agricultural prosperity and possible linkages of nutrition to agriculture. The third section gives descriptive statistics of the state data, methodology of analysis and the results. The fourth section interprets results and concludes the study.

Correlates of Nutrition and Links to Agriculture

There are different ways of capturing nutrition. Undernourishment or calorie deficiency is a measure of inadequate dietary energy supply. It is not a health outcome. Undernutrition refers to the physical state and uses anthropometric indices to measure the level (WHO, 2010). Child under-nutrition of children below the age of three is a better indicator of nutrition status as it has long-term consequences for health, learning potential (*and earning potential*) as adults (Victoria *et al.,* 2008). Undernourishment and undernutrition can coexist and undernourishment or food deprivation may lead to undernutrition. In India, under-nutrition rates, as indicated by the proportion of stunted children and underweight children, are considerably higher than the prevalence of undernourishment, as indicated by inadequacy of dietary energy supply (FAO, 2013). The trajectories of different measures of child undernutrition viz., stunting (height for age) and underweight (weight for age) need not necessarily be the same, though there is a strong correlation between them. While stunting is irreversible beyond a point, underweight is reversible with better food. Height-for-age measures

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linear growth retardation, primarily reflecting chronic long-term under-nutrition. Weight-for-age reflects both chronic and acute malnutrition. (NFHS, 2005-06).

The other well-known causes of stunting and underweight in children in addition to food deprivation are poor sanitation and poor water supply both of which lead to repeated pathogenic germ infections resulting in stunting (Humphrey, 2009; Checkley *et al.,* 2008) Poor health status of a child due to food deprivation can make the child more vulnerable to diarrhoea (UNICEF, 2009). Past literature on the subject highlights the significance of better sanitation, safe drinking water and electricity on lower incidence of child malnutrition (Spear Dean 2013; Bhagowalia *et al.,* 2012; Mishra *et al.,* 2000)

In the literature on child undernutrition, childcare in general receives more attention. Aspects such as feeding practices, nutrition knowledge, immunization, awareness about sanitation and child health contribute to a lowering of the percentage of underweight and stunted children. Care aspect of children relates to mothers and other care-givers. This brings into focus the women's ability to provide both care and act freely and also possess resources to perform her role effectively. Economic resources at the disposal of women, their freedom and level of education seem to be associated with underweight and stunting of children (Mishra, 2000; NFHS, 1998-99; Maitra, 2004).

Nutrition Agriculture Linkage: This is apparent through food linkage. Food deprivation or calorie inadequacy due to drought or non-affordability of adequate food due to poverty results in child undernutrition. Smith and Haddad (2000), estimated that underweight caused by calorie deprivation and other socio-economic indicators and concluded that 26 percent of the improvement in child underweight was due to increased calorie availability between 1970 and 1995. Other studies relate child mortality to drought and food deprivation and rainfall

shocks (Rose, 1999). Staple food availability seems to have an important link to child underweight and child mortality.

Another apparent link of child nutrition to agriculture is via women's work in agriculture. Studies show both positive and negative impacts. Nair *et al*. (2012) find that birth weight of children with mothers earning wages through the MGNREGA is better while exclusive breastfeeding and its timeliness did affect the infant feeding practices. Bhalotra *et al.* (2010) on the other hand show that economic recession and income volatility increases female labour force participation with detrimental effects on health care seeking and child survival. Rao (2005) in a conceptual paper argues that even access to land in distress situations only increases the work burden of women rather than empowering them through income effect.

Correlates of Agricultural Prosperity and Links to Child Nutrition

Agricultural Growth: Generally, agricultural growth is considered as an indicator of agricultural prosperity. Higher growth leads to consistent land and labour productivity improvements, poverty reduction and better health. In the literature review on agricultural growth and poverty reduction (DFID, 2004), the argument has been that, growth in agricultural sector is beneficial to the poor, especially in Asia. Agricultural productivity growth in the past forty years has been mentioned as the single most significant factor in reducing poverty. Improvement in gross domestic product per capita from agriculture was seen to have brought about more than proportional improvement in the incomes of the lowest quintile (DFID, 2004). Every 1 per cent growth in per capita agricultural GDP was found to have led to 1.61 per cent growth in the incomes of the poorest 20 per cent of the population. This was greater than the impact of the increases in the manufacturing or service sectors (Gallup *et al*. (1997). A more recent cross-country study indicates that agriculture is significantly more effective than non-agriculture in reducing poverty among the poorest of the poor (as reflected in the $1-day squared

poverty gap). It is also up to 3.2 times better at reducing $1-day headcount poverty in low-income and resource-rich countries, where societies are not fundamentally unequal (Christiaensen *et al.,* 2010). A negative relationship between poverty index and agricultural labour productivity index has been confirmed for many developing countries including India (de Janvry and Sadoulet, 2009). Hence, agricultural growth can be considered as one of indicators of agricultural prosperity for poverty reduction and nutrition improvements.

Evidence on India is mixed. Some studies show that agricultural growth in India reduced poverty in both rural and urban areas, while economic growth in urban areas did little to reduce rural poverty (Datt and Ravallion, 1997). Gaurav Nayyar (2005) in a panel data study for 15 major states between 1983 and 2000, found that agricultural growth represented by per worker agricultural state domestic product at constant prices has a significant negative association with the level of poverty. However, the authors note that it does not provide a complete explanation. Public expenditure on anti-poverty schemes has a significant impact on rural poverty as does greater gender equality and increased democratic decentralization.

Production of Staple Foods: While production of staples need not necessarily lead to agricultural prosperity, they are more important for calorie adequacy and poverty reduction. As has been demonstrated in 1970s-1980s, agricultural growth and green revolution were driven by staple cereals in south Asia. Growth in agriculture can lead to prosperity, but when driven by food production, it may become more sustainable means of poverty reduction. Regions with abundance of staple production such as rice and wheat, are also irrigated regions, and absorb more labour than the other crops and tend to be prosperous as cultivation is intensive.

Land Productivity and Labour Productivity: The historic evidence indicates that a dynamic agriculture that is growing fast, raises labour productivity (output per worker) in the rural economy, pulls up wages, and gradually eliminates the worst dimensions of absolute poverty (Timmer *et al.*, 2008). Decomposition of output per worker yields two components: output per unit of land and land per unit of labour: Output/Worker = Output/Land × Land/Worker (Gollin *et al.*, 2014). If the land labour ratio is unchanged, then, land productivity entirely results in worker productivity pushing up wages. If the land labour ratio worsens, the worker productivity turns low, based on the relative changes in the three ratios. Further, as explained by Timmer (1998), land productivity improves with technology as it happened in most of south Asia during the green revolution. Agricultural worker productivity as well as land productivity and wages could be indicators of agricultural prosperity.

The success stories also point to the deliberate public policy initiatives taken by governments, to monitor employment shift out of agriculture as in China or enhance agricultural growth manifold as in Brazil (Timmer *et al.,* 2008) to boost agricultural worker productivity. In the Indian context, agricultural worker-productivity enhancement link to poverty elimination and child nutrition improvements need caveats. If the rural population consists of a large dependent population or a large percentage of the population happen to be marginal workers, worker productivity improvement cannot eliminate rural poverty. In India, the proportion of marginal male workers increased by 5 percent between the census years of 2001 to 2011. About 17.7 percent of the male workers and 40.4 percent of the female workers were marginal workers working for less than six months in a year as per Census 2011. Rural India accounts for about 69 percent of all female marginal workers amounting to about 40 million.

Agricultural Wages: If agricultural land productivity and worker productivity translates into higher wages then all those who get labour

income benefit, even if they are marginal workers. Hence, agricultural wage is a mechanism through which agricultural prosperity gets translated into benefit for labour. In the agriculturally prosperous areas, needing more human labour such as rice growing areas and cotton growing areas, agricultural wages are high during peak seasons, though the work may not be available throughout the year. Generally, when men's wages are high the female wages will also be high albeit lower than the men's wages. Thus, female wage is a better indicator of the mechanism that translates agricultural prosperity into better nutrition for women and children. Benefits of agricultural wages are likely to be more, as there are more agricultural labourers (30 percent of total workers in 2011, compared to 26 percent of total workers in 2001).

Land Operational Inequality: Further an unequal distribution of operated land in agriculture seems to reduce overall agricultural land productivity. One standard deviation reduction in land operational inequality seems to bring about an increase of 8.5 percent in land productivity (Vollrath, 2007). Some of the earlier studies also note inequality as a factor that impedes poverty reduction. Land inequality and the initial level of inequality determine whether agricultural growth can reduce poverty (DFID, 2004). This also points to the fact that land inequality may have an adverse impact on labour productivity in agriculture. Worsening land labour ratios as well as high inequality in land operational distribution prevents the percolation of benefits to lower strata. Land operational distribution varies across the states. Hence, there are reasons to believe that the same productivity growth distributes benefits differently across the states.

Crop Diversification: Crop diversification is normally high in less irrigated areas as a mechanism of reducing the risk of crop failure. Monoculture is the norm in high irrigated areas. Similarly, small farms have higher diversification than big ones. However, when agricultural transformation takes place all farms diversify into high value crops and

benefit. Thus diversification into milk production, cotton, oilseeds maize etc, may help farmers to realize more value for output. However, the crops that use less labour, such as horticultural crops may increase unemployment in rural areas[1]. In such cases, labour intensive monoculture in irrigated areas are beneficial to the farm labour than diversified agriculture into horticultural crops in relatively dry areas. In other words, the benefits of agricultural growth and prosperity do not percolate to the poor automatically. Crop pattern makes a difference. Use of manual human energy for farm operations as a percentage of total energy requirements of farm operations in agriculture declined from 10.64 percent in 1970-71 to 5.39 percent in 2004-5 and further to 5.12 percent in 2009-10 (GoI, 2012). Mechanization reduced labour absorption in agriculture. Hence, diversification into more labour intensive agricultural enterprises benefits poverty reduction, whereas less labour using diversification could perpetuate poverty.

Agriculture and Child Nutrition Link
The evidence of agriculture-nutrition linkage in the Indian context is limited. The authors of a recent study conclude that both overall agricultural growth and food-grain production growth are not a necessary condition for nutritional improvement in India. However, the study finds agricultural GDP per worker and non-agricultural GDP per worker to have a negative significant association with stunting but not with underweight at the state level (Headey *et al.*, 2011). Household level study based on Indian Human Development Survey (IHDS) data for 2004-05 show that agricultural income did not have any positive impact on poverty reduction or reduction in underweight and stunting, but non-agricultural income was associated in rural areas with better nutritional outcomes (Bhagowalia *et al.,* 2012). Some studies found consumption out of own production as being beneficial while others do not find them beneficial.

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[1] For example as per cost of cultivation data in 2005-06, the human labour requirement of paddy crop in Andhra Pradesh is 871 person hours compared to just 7.48 hours for Onion crop.

An Indian study shows that households who sell their produce in the market rather than those who predominantly consume from the market had lower underweight rates among children (Galab, 2011). The overall evidence of the linkage of agriculture to reduction of child under-nutrition in the case of India appears to be mixed and rather weak.

This study attempts to look at the association of underweight and stunting with four alternative indicators of agricultural prosperity including agricultural growth five years prior to the year in which the underweight and stunting are recorded, along with sanitation, water supply, land inequality, female agricultural wages and diversification of crops.

DATA AND METHODOLOGY

In order to attain the proposed objective, data has been sourced from different databases across states of India. Child under-nutrition data in India is from the two National Family health survey data sets pertaining to the periods 1998-1999 and 2005-2006 (NFHS -2, 1998-99 and NFHS-3, 2005-06). This database provides information on water and sanitation but not on agriculture or consumption or employment/wages. Agriculture related data are from the agricultural census and the ministry of agriculture. The Central Statistical Organization data on net state domestic product at factor cost for agriculture and data on employment in agriculture with principal status as well as subsidiary status are the other sources.

Net state domestic product for agriculture and allied activities at constant prices are used to compute annual compound rate of agricultural growth for two-five year periods ending in 1999 and in 2006. Per capita food grain production for the states is calculated as the ratio of triennium average food grain production ending in 1999 and 2006 and the estimates of projected population for 1999 and 2006. This same

population data is also used for calculating the per capita net state domestic product for agriculture. Land operational inequality at the state level has been calculated from the land distribution tables given in the Agricultural census for 2000-01 and 2005-06. Diversification index has been calculated for the relevant years from the cropping pattern details available with the Ministry of Agriculture.[2] Land productivity per hectare of net sown area has been calculated by dividing the net state domestic product from agriculture with net sown area in the relevant year.

The estimates of the number of agricultural workers in the relevant years have been obtained by applying the National Sample Survey (NSS) proportion of agricultural workers. The proportion of these workers to the rural population as reported in the NSS of the 50th round (1999-2000) and 55th round (2004-05) is applied to the estimated rural population in 1999 and 2006. The Rural Labour Enquiry Report of earnings and wages of rural households 2010, compiled from the national sample surveys of 1999-2000 and 2004-05 is the source of data for female wages state-wise. We find that when male wage is high, female wage is also high but it is less than the male wage. In case of Jammu and Kashmir since female wage is not available we have taken the male wage.

Variance-inflation factor tests confirm that multi-co-linearity is not a problem for the variables selected as explanatory factors. Typically long time series studies are better suited to test the impact of agricultural growth on underweight and stunting at the macro level. In the absence of such time series data for all the variables, at present we have to be content with observed association of undernutrition with agricultural

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[2] ADI = $1 \div [\Sigma (a_i / \Sigma a_{i)}^2]$ is the formula used for calculation. ADI= Area Diversification Index, ai $_=$ Area under ith crop group, Σ ai $_=$ total cropped area. Larger area under any single crop makes Index to fall. Higher diversification means more number of crops in smaller percentage of the total cropped area.

growth and other agricultural aspects in a cross section of states over two time points, viz., 1998-99 and 2005-06.

Estimates based on panel data fixed effects and random effects models are used to analyse the links between child undernutrition and agriculture. Hausaman tests confirmed fixed effects model for stunting equations, and two underweight equations. However, the model fit was better for stunting with fixed effects. Random effects indicated a better fit for under weight (Appendix I). The different variables capturing agricultural prosperity are agricultural growth, worker productivity, land productivity and food grain production per capita. Four different model variants, which differ in only one of these agricultural prosperity variables have been estimated for stunting as well as underweight.

Summary Statistics and Basic Associations Between the Variables

Table 3.1 shows that stunting and underweight rates are nearly similar but the latter measure of under-nutrition has higher standard deviation across the states than the former. Access to toilets and piped water supply also show a larger variation across the states. Variation seems to be high in growth rates as well as food grain production compared to other variables.

Association of proportion of moderately stunted children below the age of three with proportion of moderately underweight children of the same age, at the state level, at a point of time, appears to be positively associated as indicated in the scatter plot (Figure 3.1). However, the linear association is not very strong with several points scattered far above and below the fitted line. Further, the strength and nature of association of the different explanatory variables considered in this study (as mentioned above) differ between stunting and underweight rates as can be observed in the scatter plots (Appendix II).

Table 3.1: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
underwt_rural	52	40.31	11.60	19.4	63.1
stunting_rural	52	39.68	9.42	18.1	57.3
nsdpperagworker	49	5198.61	3076.28	1519	15117
aggr5yr	50	3.53	3.93	-6.48	15.72
landopginiratio	51	50.16	7.70	30.92	75.24
agfewage_rural	52	50.17	24.42	22.31	114.5
divindex	52	269.21	110.87	143.22	534.07
water_rural	52	58.35	27.94	3.9	99.3
toilets_rural	52	42.22	30.50	5.1	97.7
fgpercap	52	1.61	1.42	0.09	9.34

Notes:

underwt_rural	:	Percent of underweight children
stunting_rural	:	Percent of stunted children
nsdpperagworker	:	Per Worker Net State Domestic product from agriculture
aggr5yr	:	Five year agricultural growth
landopginiratio	:	Gini ratios for inequality of land
agfewage_rural	:	Agricultural wage rate of females
divindex	:	Crop Diversification Index
water_rural	:	Percent of rural households having access to piped water
toilets_rural	:	Percent of rural household having toilets
nsdp_sownarea	:	Per hectare Net State Domestic product from agriculture
fgpercap	:	Per Capita Production of food grain (tons.)

Source: District level Health Survey-2, RBI, Agricultural Census, Ministry of Agriculture.

Figure 3.1: Association between Stunting and Underweight in Children below the Age of Three
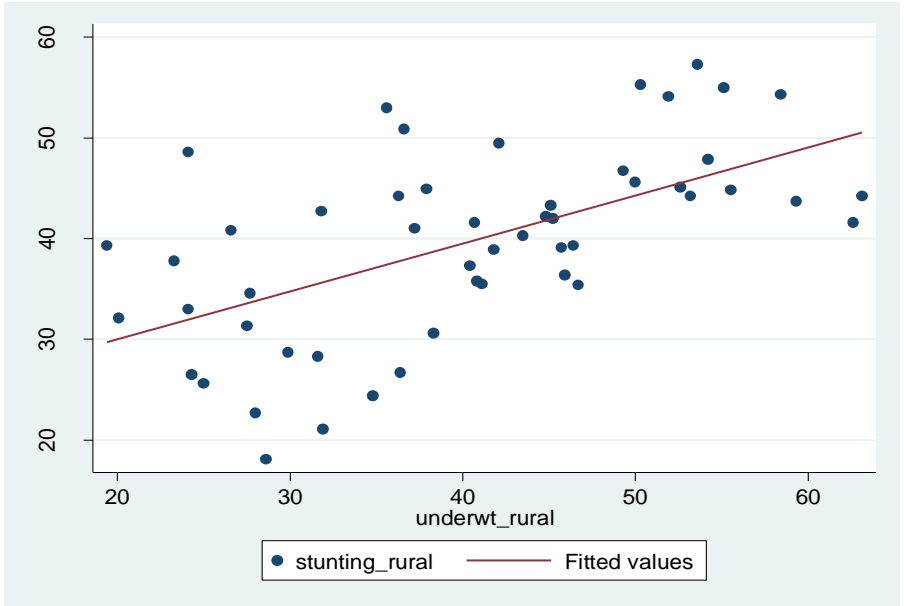
Hence, we discuss stunting and underweight separately though we use the same set of explanatory variables. When we regress each of the explanatory variables separately on stunting rates and underweight rates, the explanatory capacity differs. The R-square value varies from a low of 0.00 for agricultural growth in the past five years with underweight to a high of 0.593 for access to toilets with underweight. (Appendix I: Table AI.1 and AI.2) Three of the four chosen agricultural prosperity indicators except agricultural growth show significant relationship with stunting. One of the four prosperity indicators, viz., worker productivity turns out to be significant for underweight. Female agricultural wage has significant explanatory power with underweight but not with stunting. Access to toilets and piped water supply show high negative linear association with stunting rates but only access to toilets

shows negative association with underweight rates. While the land gini-ratio shows significant negative association with stunting, diversification Index has insignificant coefficient for both stunting and under weight. The independent variables together have a better explanatory power than individual variables and hence included in the models (see Appendix I: Tables AI.1 and AI.2). These linear associations are useful for preliminary analysis while a multiple regression model is more relevant to understand the nature of relationship of the different explanatory variables and undernutrition rates after controlling for others. The next section discusses the results of the multiple regression models with fixed effects and random effects for stunting and underweight respectively.

RESULTS AND INTERPRETATION

While no single aspect of agriculture can explain the variations in stunting and underweight effectively, a combination of agricultural aspects some of which make the benefits to reach the rural poor and the others that hinder the benefits from reaching the rural poor appear to explain the variations in stunting and underweight better in rural India. Since the trajectories of stunting and underweight appear to be different, the results discuss the agriculture- child nutrition linkages separately for stunting and underweight. Another important aspect to bear in mind is that the results of a rural study differ from a study that combines urban and rural areas. As agricultural transformation takes place, the benefits of trade, processing and intensive animal production such as dairy and poultry may shift to those living in semi urban areas as opposed to those remaining in rural areas. Value added activities increase worker productivity but may not be available to rural people.

Linkage of Agriculture to Stunting in Rural India
The fixed effects models with chosen variables show significant negative association of agricultural growth, worker productivity as well as land productivity with proportion of stunted children in the rural areas.

Stunting rates do not show any significant relationship with food grains per capita. Thus, agricultural prosperity in terms of growth and productivity appears to improve nutrition and reduce the proportion of stunted children. The models fit well (Tables 4.1 to 4.4).

Among the other agricultural aspects in all the four equations land operational inequity shows significant positive influence of increasing the proportion of stunted children as expected. This could be an indirect indication of inequality preventing the benefits of agricultural prosperity reaching the lower strata in the rural areas to reduce poverty and child undernutrition. Female agricultural wage turns out to be insignificant in all the equations but improves explanatory capacity of the model.

Table 4.1: Association of Child Stunting with Agricultural Worker Productivity and Other Agriculture Variables, Access to Water and Sanitation Variables (Fixed Effects Model)

Variable	Coefficient	P -value
Ag. NSDP per Agricultural Worker	-0.005*	0.053
Land operational inequality (gini ratio)	1.959**	0.011
Female Wage in Agriculture (rural)	-0.196	0.262
Diversification Index	0.125*	0.06
Population with access to safe water (rural percent)	-0.099**	0.04
Population with access t toilets (rural percent)	0.166	0.549
Constant	-59.356*	0.058
Number of observations = 48		
R-sq: within = 0.6792	F(6,25) = 13.46	
between = 0.0064	Prob > F = 0.0026	
overall = 0.0180		

Note: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Table 4.2: Association of Child Stunting with Agricultural Growth and Other Agricultural Variables, Access to Water and Sanitation Variables (Fixed Effects Model)

Variable	Coefficient	P-value
Agricultural Growth rate (5 years)	-0.802**	0.034
Land operational Inequality (Gini ratio)	1.369***	0.004
Ag. Female Wage (Rural)	0.021	0.866
Diversification Index	0.142**	0.013
Population with access to safe Water (Rural percent)	-0.118***	0.006
Population with access to toilets (Rural percent)	-0.109	0.56
Constant	-56.190	0.005
Number of observations = 49	F(6,25) = 15.83 Prob > F = 0.0010	
R-sq: within = 0.6971		
between = 0.0331		
overall = 0.0028		

Note: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Table 4.3: Association of Child Stunting with Land Productivity and Other Agricultural Variables, Access to Water and Sanitation Variables (Fixed Effects Model)

Variable	Coefficient	P- value
Ag. NSDP per hectare of net area sown	-0.09*	0.096
Land operational Gini Ratio	1.61***	0.009
Female Wage in Agriculture (Rural)	-0.07	0.600
Diversification Index	0.13 *	0.097
Population with access to safe water (Rural percent)	-0.10**	0.031
Population with access to Toilets (Rural percent)	0.03	0.894
Constant	-53.45*	0.085
Number of observations = 48	F(6,25) = 12.73	
R-sq: within = 0.6818		
between = 0.0091		
overall = 0.0000		

Note: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Table 4.4: Association of Stunted Children with Food Grain Production per Capita and Other Agriculture Variables (Fixed Effects Model)

Variable	Coefficient	P-value
Per capita Food grain production	1.65	0.252
Land operational inequality (Gini ratio)	1.31***	0.007
Female wage in Agriculture (Rural)	-0.17	0.408
Diversification Index	0.13	0.102
Population with access to safe water (Rural percent)	-0.10**	0.029
Population with access to toilets (Rural percent)	0.01	0.981
Constant	-49.58**	0.022
Number of observations = 51		
R-sq: within = 0.6528	F(6,26) = 25.74	
between = 0.0234	Prob > F = 0.0019	
overall = 0.0009		

Note: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Diversification index shows significant adverse relationship with stunting in all the equations except in combination with food grains per capita where it turns insignificant. While diversification may add to the prosperity, if high value crops are grown, its ability to reduce poverty and stunting depends upon the nature of diversification. Typically, as diversification is more, in rain-fed areas compared to monocultures of wheat, rice sugarcane etc., in the irrigated areas, it may not add to the land productivity or worker productivity. Diversification in this case could be just capturing the rural poverty and child undernutrition of the dry-land agriculture. On the other hand, if diversification into horticultural crops reduces the labour input and also typically more on big farms, the land productivity associated with diversification bypasses the rural poor and accrues benefits to those in trade and processing than labour involved in crop and animal production.

As expected piped water supply shows significant negative influence on stunting but access to toilet facility turns insignificant in all

the models. While household access to toilets is an important factor in reducing stunting, its impact probably being captured in other prosperity parameters. On the other hand, piped water supply seems to reduce stunting in rural areas as expected, the coefficient turns negative and significant. One could argue in general that stunting rates are reduced with agricultural prosperity represented by either agricultural GDP growth or worker productivity or land productivity improvements, provided the prosperity spreads. Social provisioning of sanitation and piped water supply contribute to the reduction in stunting rates. The state fixed effects appear to be significant judging from the high within state variation being, explained rather than the in-between variation.

In addition, the fact that agricultural aspects alone can explain more than half the variation in stunting, without sanitation being included[3] points to the fact that agriculture does have a link to child nutrition in its own right. On the whole we may conclude that agricultural prosperity could reduces rural stunting rates, provided, the pattern of growth enables the prosperity to percolate to the poor.

Linkage of Agriculture to Underweight in Children

As has been mentioned earlier, random effects model appears appropriate for underweight judging from the fit of the model. Underweight shows significant negative association with worker productivity in agriculture and food grain production per capita. Land productivity and agricultural growth were insignificant. Land inequality has positive significant relationship with underweight as expected, only in combination with food grain production per capita. On the other hand, female agricultural wage has a negative significant association with underweight in all the models showing a strong income effect of women's work participation in reducing underweight in children. Crop

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[3] The fixed effects model estimated without the sanitation variable has no change in the significance of the remaining variables and the r square value remains high pointing to the robustness of the relationship of agricultural aspects with stunting.

diversification index turns insignificant. This may also mean that in the areas of food grain abundance and high female agricultural wages, underweight children proportion would be low. Only access to toilets has significant negative relationship with underweight as expected in all the models. In contrast to stunting models, the piped water supply turns insignificant. Model fit appears satisfactory, showing that agricultural prosperity via worker productivity and food grain production and women's access to wages as being more important for reduction in underweight (Tables 4.5 to 4.8).

Table 4.5: Association of Underweight Children with Agricultural Worker Productivity and Other Agricultural Variables and Water Sanitation Variables (Random Effects Model)

Variable	Coefficient	P-value
Agricultural NSDP per Ag worker	-0.001***	0.01
Land operational inequality (Gini ratio)	-0.077	0.653
Female Agricultural Wage (Rural)	-0.143**	0.015
Diversification Index	-0.001	0.942
Population with access to safe water (Rural percent)	0.001	0.957
Population with access to Toilets (Rural percent)	-0.202***	0.001
Constant	63.144***	0
Number of obs = 48	Prob > chi2 = 0.00	
R-sq: within = 0.0149		
between = 0.7359		
overall = 0.6647		

Note: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Table 4.6: Association of Underweight Children with Agricultural Growth and Other Agricultural Variables and Water Sanitation Variables (Random Effects Model)

Variable	Coef.	P- value
Agricultural growth rate (5 years)	0.430	0.105
Land operational inequality (Giniratio)	-0.190	0.228
Female agricultural wage (Rural)	-0.186***	0.005
Diversification Index	-0.005	0.639
Population with access to safe Water (Rural percent)	-0.007	0.782
Population with access to Toilets (Rural percent)	-0.208***	0.000
Constant	68.050***	0.000
Number of observations = 49		
R-sq: within = 0.0061	Prob > chi2 = 0.00	
between = 0.7409		
overall = 0.6739		

Note: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Table 4.7: Association of Underweight Children with Agricultural Land Productivity and Other Agricultural Variables and Water Sanitation Variables (Random Effects Model)

Variable	Coefficient	P- value
Ag. NSDP per hectare of net sown area	0.006	0.707
Land operational inequality (Gini Ratio)	-0.180	0.198
Agricultural female Wage (Rural)	-0.168***	0.002
Diversification Index	-0.003	0.814
Population with access to safe Water (Rural percent)	-0.005	0.855
Population with access to Toilets (Rural percent)	-0.214***	0.000
Constant	66.267***	0.000
Number of observations = 48		
R-sq: within = 0.0157	Prob > chi2 = 0.00	
between = 0.7120		
overall = 0.6393		

Note: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Table 4.8: Association of Underweight Children with Food Grain Production per Capita and Other Agricultural Variables and Water and Sanitation Variables (Random Effects Model)

Variable	Coefficient	P -value
Food grain production per capita	-1.49965 ***	0.004
Land operational inequality (Gini ratio)	-0.20516 *	0.091
Female agricultural wage (Rural)	-0.1037*	0.071
Diversification Index	-0.00799	0.444
Population with access to safe Water (Rural percent)	-0.02914	0.251
Population with access to toilets (Rural percent)	-0.25236***	0.000
Constant	72.70361	0.000
Number of obs = 51	Prob > chi2 = 0.00	
R-sq: within = 0.0157		
between = 0.7120		
overall = 0.6393		

Note: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

CONCLUSIONS

Overall, we may conclude that growth in the net state domestic product from agriculture represented by growth rate of five years preceding the recording of child nutrition has association with stunting and not with underweight. The reason for lack of association with underweight is not clear, but growth per se could be a poor proxy for prosperity. Deceleration of agricultural growth in recent years could be one of the reasons. All the same, agriculture could influence positive child nutrition outcomes based on the pattern of growth and percolation of benefits via land productivity and worker productivity to the poor. Land inequality dampens the positive influence of agricultural prosperity. Crop diversification has no influence on child undernourishment.

Food grain production abundance in the state is important for rural underweight but not for stunting. Probably because underweight is amenable to reversal, where as stunting once caused by food deprivation

for longer term remains irreversible. Diversification of agricultural crops has no impact on child nutrition. Probably diversification of agricultural enterprise across crops, livestock, poultry and fisheries could have captured the diversification impacts better. Alternately, diversification away from food grains probably does not benefit rural people.

The other very important aspect of agriculture is the income effect of high female agricultural wages. Agricultural wages are generally high in agriculturally prosperous areas. Female agricultural wages capture general prosperity effect as well as women's empowerment effect. In the agricultural context, female work participation was found in some studies to be associated with adverse impact on childcare. While this study cannot throw any light on the mechanisms of translating female agricultural work to better nutrition outcomes, there seem to be some positive income effect on child nutrition. Probably as agriculture gets prosperous with high wages, women's income access leads to positive nutrition outcomes for children.

The agriculture-child-nutrition linkages do exist at the macro level in the Indian context, though agricultural growth per se would not help, especially if the levels are low. On the top of it, the dampening effects of land inequality and pattern of growth that does not lead to high levels of worker productivity and wages cannot help child undernutrition. This only emphasizes the need for public policy interventions to promote growth and spread the benefits of agriculture to all those engaged in it. More research is needed to understand the public policy initiatives that exist and needed to be promoted for agricultural prosperity to influence better child nutrition outcomes.

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Appendix I

CHOICE BETWEEN FIXED EFFECT AND RANDOM EFFECT MODEL

The choice of model between Random Effect and Fixed Effect is essentially been done using two criteria — Hausman Test and the chi sq. /F statistics test. For all the four models of stunting, Hausman test indicated the use of fixed effects model (at 10 percent level of significance). Hence fixed effect model was estimated for stunting.

Although Hausman test concluded fixed effects for two models of underweight, (Models with Worker productivity and Land Productivity) and random effects for one model with food grain production per capita, it was inconclusive for one of the models with agricultural growth. However the fixed effects gave a poor fit compared to random effects model for all the four equation with underweight as a dependent variable. Moreover, the model fit was better with random effects as indicated by Chi sq (i.e Prob> Chi Sq.) for under-weight at less than 5 Percent (less than 0.05) Hence, random effect model was estimated for under-weight.

<div align="center">

**Table AI.1: Association of Stunting with
Individual Explanatory variables**

</div>

Stunting (FE Model)	Coef.	p val	R Square		
Prosperity variables			within	between	overall
NSDP per Ag. worker	-0.004*	0.091	0.107	0.209	0.165
Ag. Growth (5years)	-0.602	0.230	0.050	0.025	0.003
NSDP/ Net sown area	-0.096*	0.069	0.169	0.060	0.083
Food grain prod/capita	2.40***	0.001	0.233	0.034	0.085
Other aspects					
Land Gini ratio	1.534**	0.020	0.209	0.039	0.016
Ag female wage -rural	-0.174	0.493	0.029	0.118	0.085
Diversification Index	0.098	0.375	0.035	0.049	0.025
Access to safe water-R	-0.1***	0.000	0.396	0.009	0.138
Access to toilets -rural	-0.40**	0.015	0.166	0.225	0.172

Source: Based on NFHS-2, NFHS-3 and RBI, Ministry of agriculture, Agricultural census and NSS 61st round.

<div align="center">

**Table AI.2: Association of Underweight with
Individual Explanatory variables**

</div>

underwt (RE Model)	Coef.	p val	R Square		
Prosperity variables			within	between	overall
NSDP per Ag Worker	-0.001***	0.000	0.005	0.173	0.170
Ag Growth (5 years)	-0.068	0.798	0.013	0.014	0.000
NSDP / net sown area	-0.024	0.223	0.026	0.034	0.055
Food grain Prod./capita	0.221	0.646	0.006	0.000	0.000
Other aspects					
Land Gini ratio	0.115	0.687	0.003	0.007	0.004
Ag. Female wages (rural)	-0.262***	0.000	0.011	0.469	0.424
Diversification Index	0.003	0.854	0.000	0.000	0.006
Access to safe Water (rural)	-0.031	0.186	0.049	0.068	0.033
Access to Toilets (rural)	-0.265***	0.000	0.012	0.628	0.596

Source: Based on NFHS , RBI. Ministry of Agriculture, Agricultural census and NSS 61st Round.

Appendix II

ASSOCIATION OF STUNTING AND UNDER-WEIGHT WITH AGRICULTURAL PROSPERITY

Figure AII.1: Association of Child Underweight with Female Wages
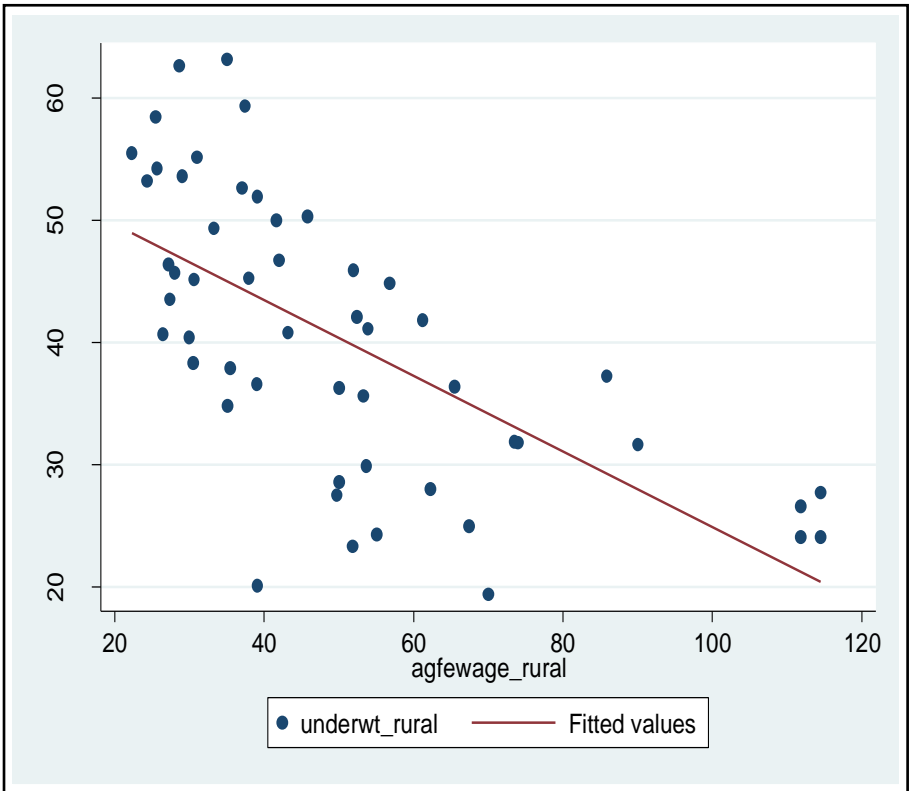
Source: Based on NFHS-2, NFHS-3 and Rural labour enquiry Report.

Figuer AII.2: Association of Stunting with Female Agricultural Wages
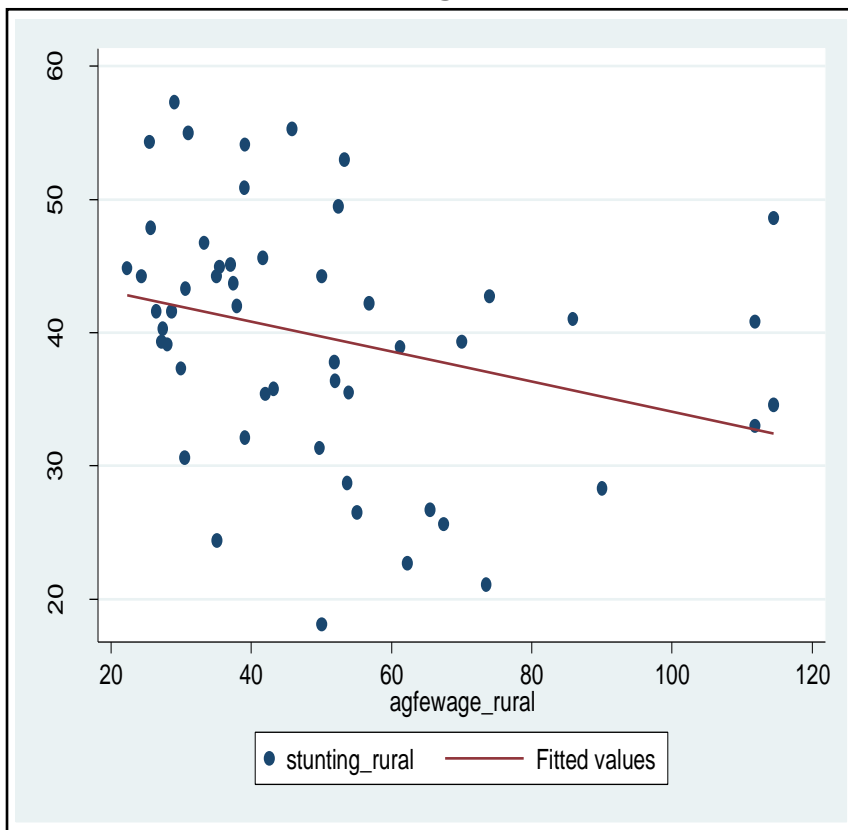
Source: Based on NFHS-2, NFHS-3 and Rural labour enquiry Report.

Figure AII.3: Association of Stunting with Agricultural NSDP per Worker
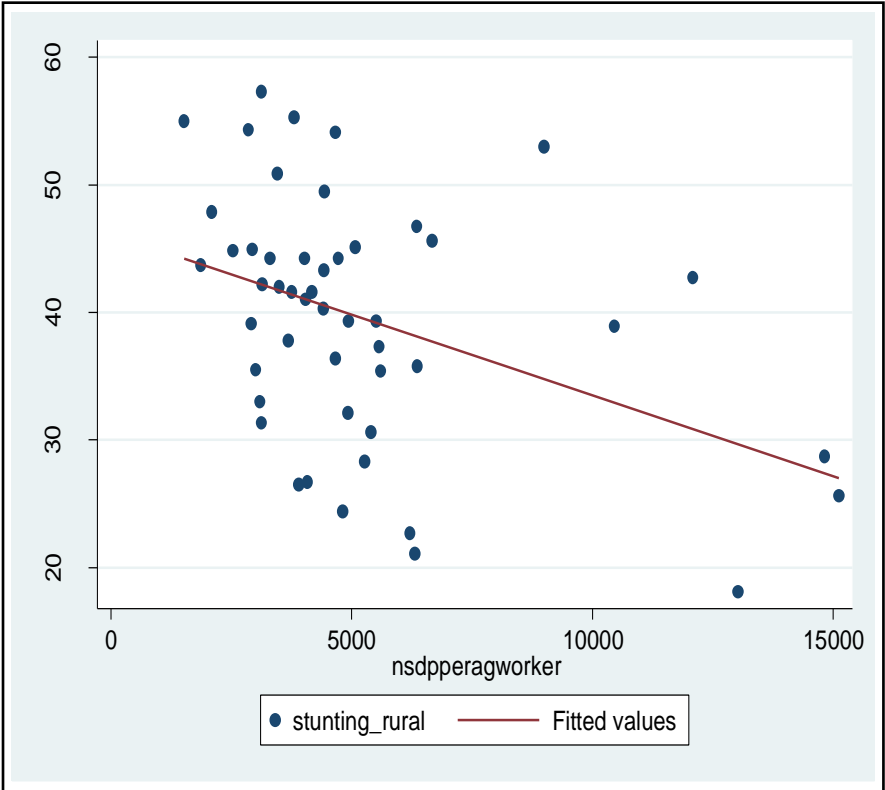
Source: Based on NFHS-2, NFHS-3 and RBI data on state domestic product.

Figure AII.4: Association of Underweight with Net state Domestic Product per Worker
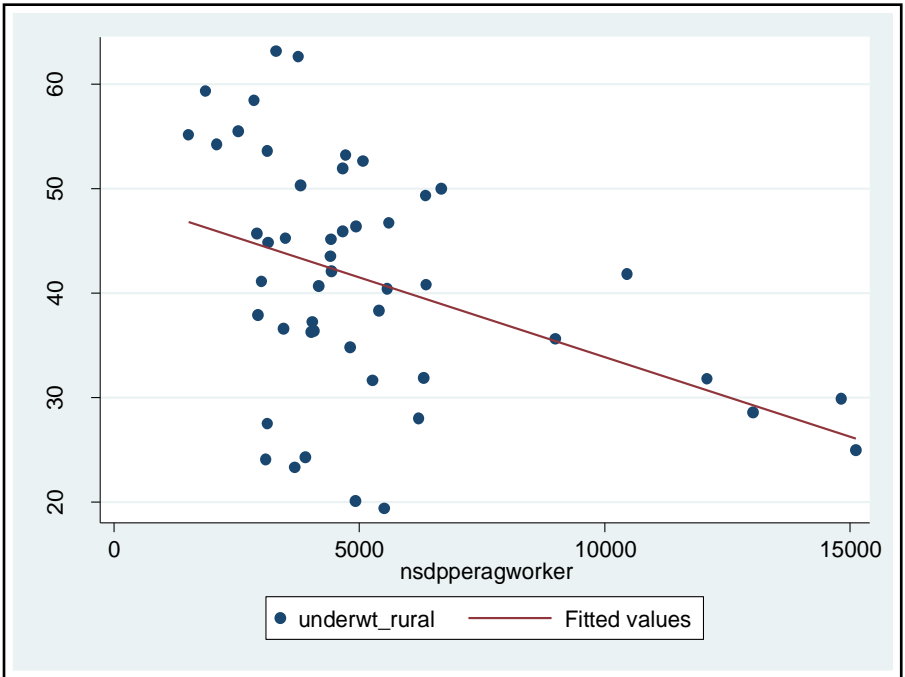
Source: Based on NFHS-2, NFHS-3 and RBI data on state domestic product.

Figure AII.5: Association of Stunting with Agricultural Land Productivity
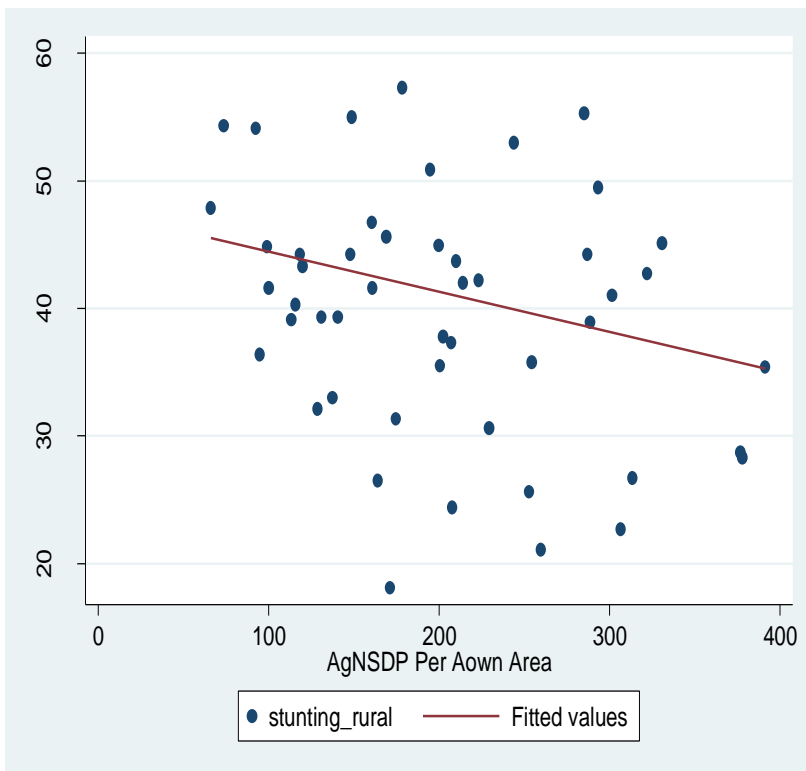
Figure AII.6: Association of Underweight with Agricultural Land Productivity
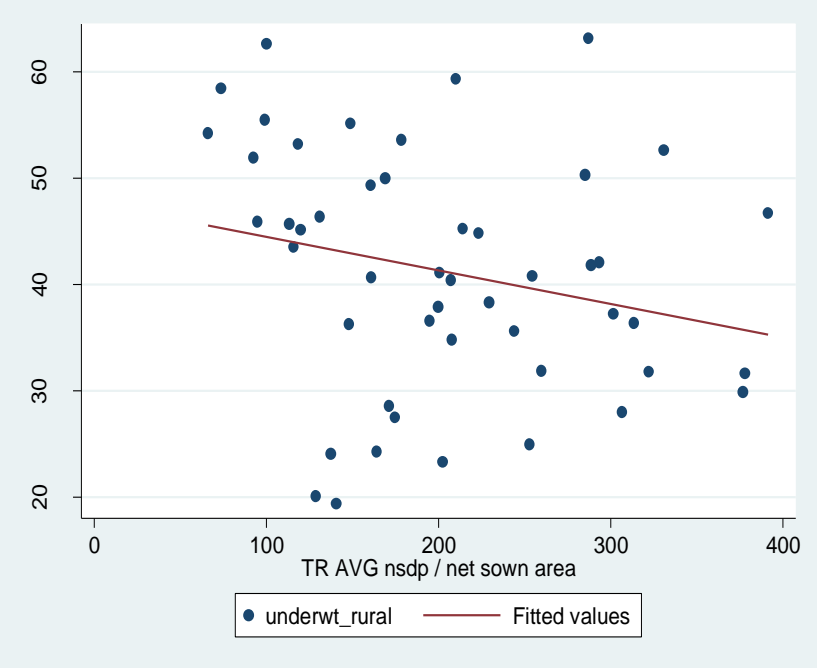
Figure AII.7: Association of Underweight with Sanitation
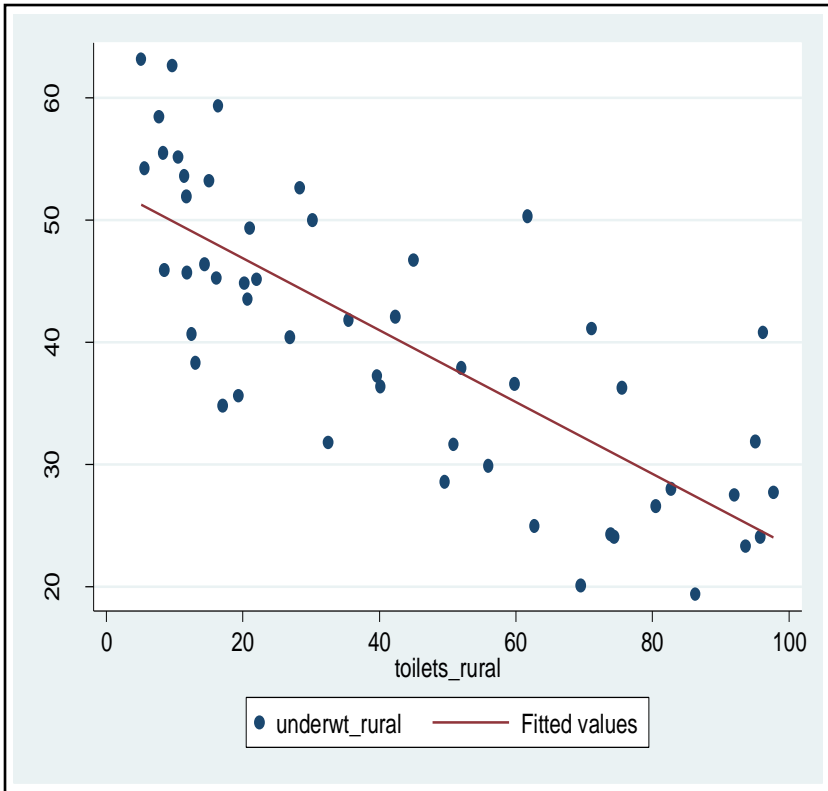
Figure AII.8: Association of Stunting with Sanitation
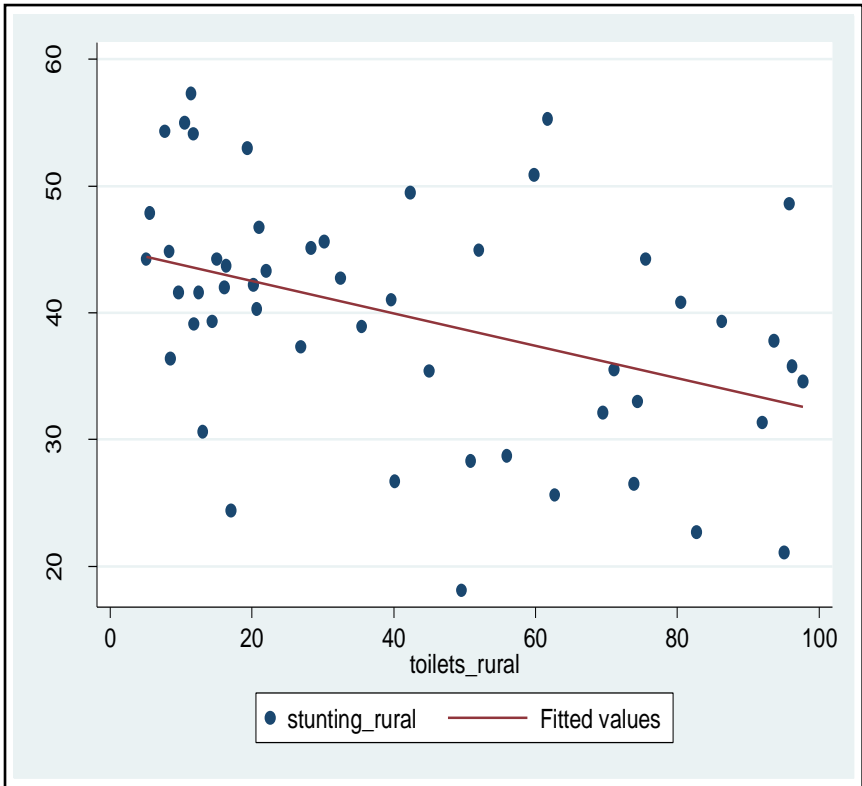
Figure AII.9: Association of Underweight with Availability of Piped Water
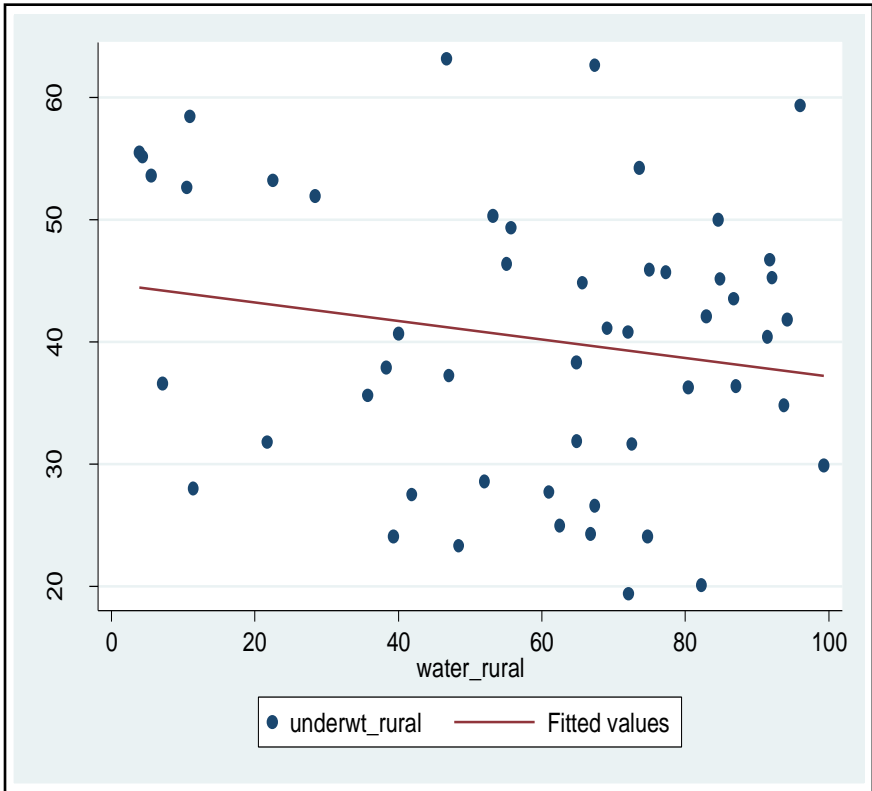
Figure AII.10: Association of Underweight with Availability of Piped Water
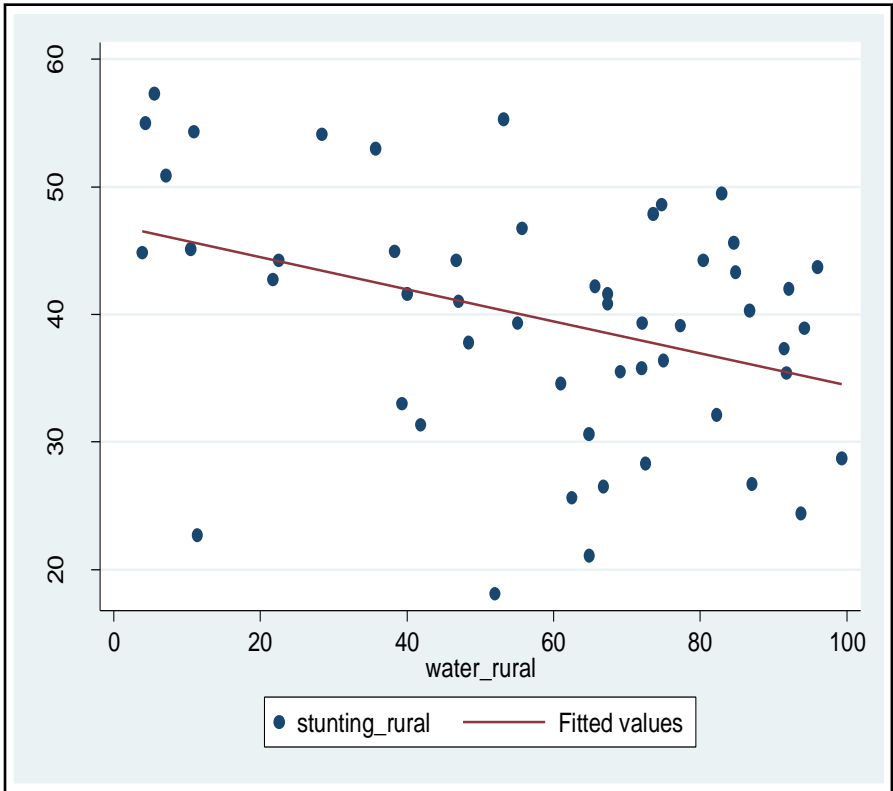
Source: Based NFHS -2 and 3.

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