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Nutrition and Learning Outcomes: Evidence from Indian States

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Nutrition and Learning Outcomes: Evidence from Indian States.

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Abstract

This study examines the relationship between nutrition and children's learning outcomes through the lens of the nutrition-based efficiency-wage hypothesis extending its underlying capacity mechanism from physical productivity to learning and cognitive capacity. The analysis exploits three distinct policy interventions in India : alcohol prohibition in Bihar, the introduction of millet-based meals under the Mid-Day Meal (MDM) programme in Haryana and the provision of eggs in MDM in economically disadvantaged districts of Karnataka. Using district-level aggregates constructed from the Annual Status of Education Report (ASER), the study employs a difference-in-differences (DID) framework to compare treated and control groups before and after each intervention. Pre-intervention placebo tests provide evidence consistent with the absence of differential trends while synthetic difference-in-differences (SDID) using unit and time weights provides a complementary assessment of the baseline estimates. The findings indicate improvements in school participation, retention and selected learning outcomes following nutrition-related policy changes. In Bihar, changes in household resource allocation following prohibition are consistent with a potential nutrition-mediated pathway while the Haryana and Karnataka interventions suggest that strengthening the nutritional content of school meals may support educational participation. The research highlights the importance of integrating nutrition-sensitive interventions with conventional education policies as part of broader strategies for human-capital formation particularly in nutritionally disadvantaged settings.

Keywords : *Nutrition; Learning Outcomes; School Participation; Mid-Day Meals (MDM); difference-in-differences (DID); synthetic difference-in-differences (SDID).*

JEL Classification: I15 , I21, I25, I38, O15.

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1 Introduction

Cognitive skills play a pivotal role in enhancing individual earnings, influencing the distribution of income and are conducive to broader economic development (Hanushek and Woessmann, 2008). One of the key factors influencing the endowment of such skills is the availability of quality schooling institutions imparting crucial lessons to the younger demographic. The investment in structural transformation of the learning environment in low-income and economically disadvantaged countries is thus an imminent necessity for closing the economic gap between developing and advanced countries.

Time spent in school becomes an important determinant of the skill endowment of the populace. To further explore the association between instructional time and learning process the literature primarily considers two dimensions - the duration of a school day and the length of the school year. There are studies documenting a positive effect of additional time on student achievement, so much so that the differences along these dimensions are an understudied aspect of educational inequality thereby stressing the need to substantially increase the instructional time (Kraft and Novicoff, 2024).

Utilising data on approximately 9,00,000 students from 80 countries over the time period (1995 - 2007) and employing a specific assessment framework called Trends in International Mathematics and Science Study (TIMSS) Assessments[1], it has been established that duration of the school day positively affects the learning outcomes of the students though with diminishing returns. The effects are particularly pronounced among students from socio-economically disadvantaged backgrounds (Wu, 2020).

Evidence from the United States similarly points to the importance of instructional time. Using a sharp regression discontinuity design in Florida that exploits an administrative eligibility rule generating variations in school day duration, a study demonstrates that additional literacy instruction improved student's reading achievement (Figlio et al., 2018). In the same light a study exploiting variation in West German short school years introduced in 1966-67 that exposed some students to significantly lesser school time than others finds that shorter school years increased primary grade repetition subsequently

[1] The Trends in International Mathematics and Science Study (TIMSS) is an international assessment that measures students' achievement in mathematics and science at regular intervals across participating education systems. It also collects contextual information on students, teachers, schools and curricula enabling comparisons of learning outcomes across countries and over time.

reducing the number of students attending higher grades (Pischke, 2007).

Further evidence comes from research examining the causal impact of mathematics instructional time on student achievement. Using TIMSS 2011 data, the study exploites within-student differences in instructional time across mathematical topics and states that an additional hour of weekly instruction in a particular topic raises students' test scores in that topic by 4.3 % of a standard deviation. The estimated effect remains consistent across students from different genders and social backgrounds and is evident across all 42 countries examined (Briole, 2026).

The principal factor affecting the school participation is the health and nutritional status of the cohorts. There have been plethora of studies elaborating the crucial link between nutrition and the ability to attend schools which in turn affects the learning outcomes and skill acquisition at a young age. This eventually shape earning capabilities and economic outcomes at the later stages in life. Drawing on a sample of Filipino children over time, a study identifies that better nourished children owing to their higher productivity perform significantly better in school thus providing credence to the link between nutrition and learning outcomes (Glewwe et al., 2001).

Another study from Guatemala detailing the influence of pre-school and school experiences on adult cognitive skills reveals that height for age at 6 years as a proxy for health status of children significantly increased the non-verbal component of cognitive skills along with affecting school attainment which then had a significant effect on verbal cognitive skills. The findings stress on the importance of early life health investments thereby reinforcing the importance of childhood nutrition consistent with the broader literature associated with the Flynn effect[2] (Behrman et al., 2014).

The evidence from two developing countries - Ethiopia and Peru using Young Lives study dataset documents that stunting at a younger age is negatively related with memory and inhibitory controls measured years later in adulthood, predicting reductions to the tune of 12.6 % and 5.8 % of standard deviation in working memory and inhibitory control respectively (Sánchez et al., 2024). Research exploiting the effect of civil wars and droughts on the preschool nutritional status in rural Zimbabwe indicates that improved

[2] The Flynn effect refers to the observed rise in average scores on intelligence tests across successive generations over substantial periods. The phenomenon has been documented in several countries although its magnitude and persistence vary across populations, age groups and cognitive domains.

nutritional status as measured by height for age was associated with increased school attainment thereby substantiating the impact of early age malnutrition on human capital formation (Alderman et al., 2003).

In rural Guatemala an intervention to provide nutritious supplements to children led to significant increase in grades completed for women with further improvement in comprehension and cognitive abilities of both men and women even after the ending of program a quarter century later. Thus improvement in nutritional status of children can have long term beneficial consequences (Maluccio et al., 2009). Corroborating this study, an interesting paper with data on cohort studies from Brazil, Guatemala, India, Philippines and South Africa states that instances of maternal and child malnutrition were related with adult outcomes like schooling and economic productivity. The implication being that damage suffered in early life has long term consequences adversely affecting future generations as well. Thus an adequate attention to childhood nutrition can bring about important educational and economic benefits (Victora et al., 2008).

A study deploying the data on early childhood stunting and the poverty rate as the indicators of poor development indicates that these indicators are related with poor cognitive and educational performance in children residing mostly in south Asia and sub-saharan Africa. These disadvantaged children will eventually have lower incomes and poor economic status with high fertility eventually leading to transmission of poverty across generations (Grantham-McGregor et al., 2007). Using the timing of cognitive tests that Swedish males were required to undertake at approximately age 18 as part of preparation for military service, a study induces random variation to address potential confounders in the timing of the tests. The findings indicate that an extra 10 days of schooling raised scores on crystallized intelligence tests by 1 % of SD (Carlsson et al., 2015).

The theoretical underpinnings of the linkage between nutrition and productivity has been established by the nutrition based efficiency wage hypothesis which has laid down the foundation to understand how improved nutritional intake can translate into greater productivity in low-income settings (Leibenstein, 1957). The underlying idea is that when workers are living close to subsistence then wages influence nutritional intake and their capacity to work. The relationship can be represented through a capacity curve where productive capacity rises with consumption particularly at low levels of nutrition

before exhibiting diminishing returns at higher levels. Thus inadequate consumption may generate a low-nutrition–low-productivity equilibrium while higher wages can improve nutritional status and productive capacity (Figure 1).

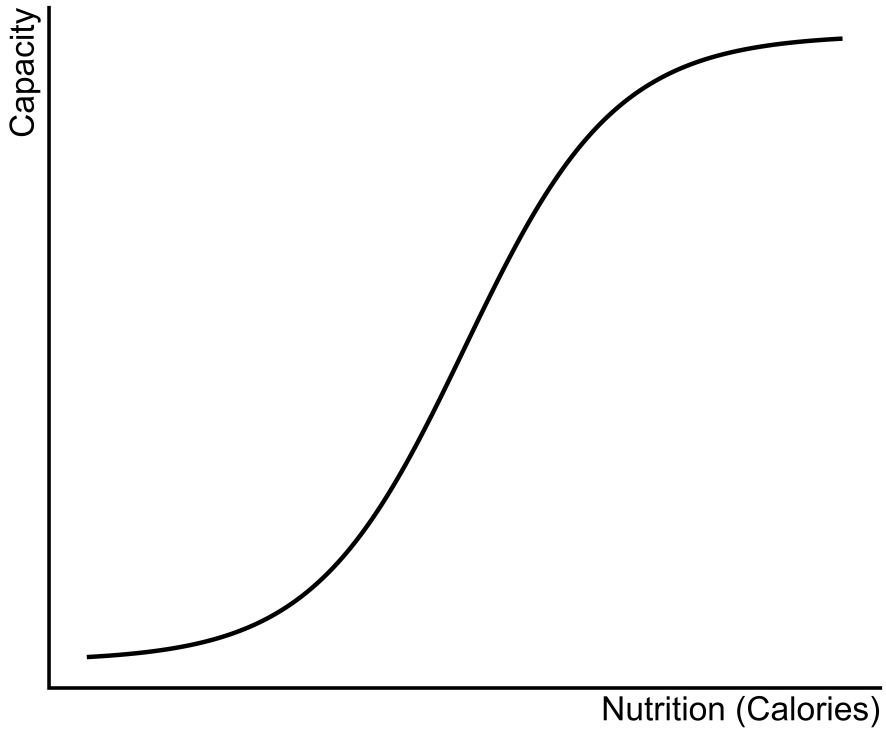


Figure 1: Capacity Curve.

The nutrition- productivity framework has been further developed over time with extension to explain persistent poverty, nutritional deprivation and labour-market outcomes. (Bliss and Stern, 1978; Dasgupta and Ray, 1986). For instance, in a study by incorporating body size heterogeneity, the hypothesis has been extended to study the impact of body size on productivity, demonstrating that findings are in line with nutrition based efficiency wage model as it was observed that taller workers earned higher wages and were less likely to be out of work in developing countries (Dalgaard and Strulik, 2011).

In a study conducted with household level data from Sierra Leone to empirically test the hypothesis it has been stated that caloric intake significantly enhances labour productivity thus supporting the nutrition - productivity linkage. The effect on productivity falls as the calorie intake rises but stays positive at moderately high levels of intake (Strauss, 1986).

The nutrition-based efficiency-wage framework can be extended from physical pro-

ductive capacity to cognitive and learning capacity. Adequate nutrition may raise the capacity to attend, concentrate and process instruction thereby increasing the productivity of time spent in school. In this sense nutrition can be viewed as an input into learning capacity and human-capital formation. This is further elaborated with the aid of capacity curves which are now defined in the space of learning capacity and nutrition (calories). The following figures depict the effect of improved nutrition on learning capacity with Figure 2 incorporating the effect along the capacity curve due to an increase in nutritional intake in terms of calories consumed. It is evident that a movement along the curve from pt A to pt B due to better nutrition enhances the capacity of the individuals. Similarly in Figure 3, a qualitative improvement in nutrient consumption wisely by a shift from low quality to better quality nutritious food stuffs while keeping overall calories fixed leads to an upward shift in the capacity curve and the movement which can be traced from pt A on the former curve to pt B on the new curve again reflects an improvement in the capacity.

In order to decipher the adverse effects of hunger on the effort and cognitive performance of students a study analyses that extension of Mid-Day Meal[3] (MDM) from primary to middle grades enhanced the cognitive performance of students to the tune of 13-16 %. The findings suggest that short term interventions in school meals provision can have longer term beneficial effects on learning outcomes in developing countries. (Afridi et al., 2019a). Similarly research exploring the beneficial effects of better transfer design documents that shifting from packaged foods to cooked meals in Municipal schools in Delhi in 2003 with no accompanied change in the meal's budget, led to a 3 percentage point increase in school attendance with the effect being stronger for schools serving diverse food menus (Afridi et al., 2019b).

[3] The Mid-Day Meal Scheme is a school-based nutrition programme in India that provides meals to children enrolled in government and government-aided schools. Besides addressing nutritional needs, the aim is to encourage school participation and support learning by reducing classroom hunger.

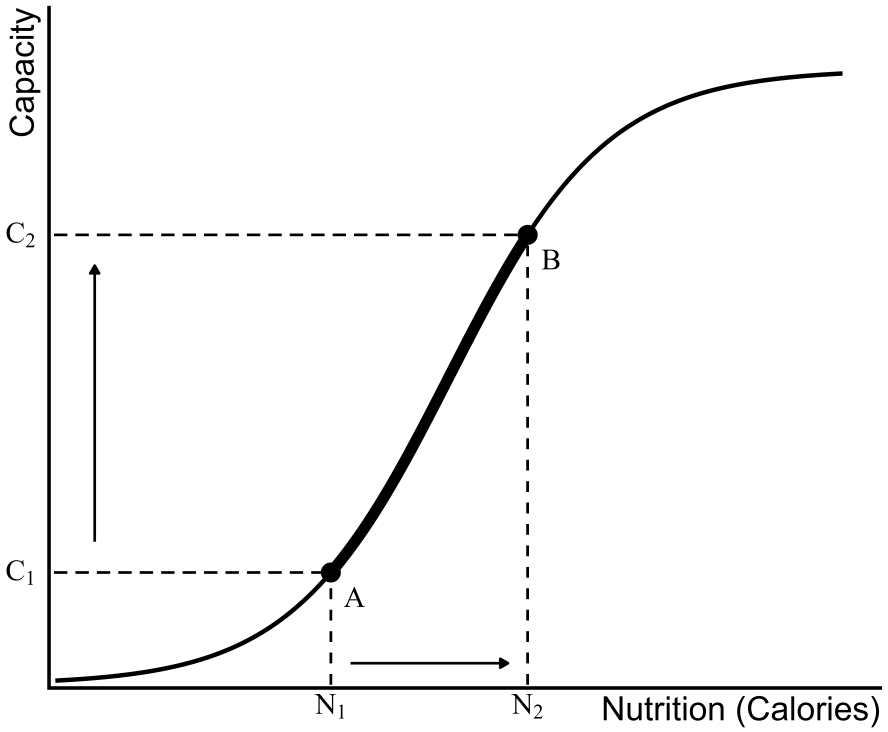


Figure 2: Increase in Nutritional Intake.

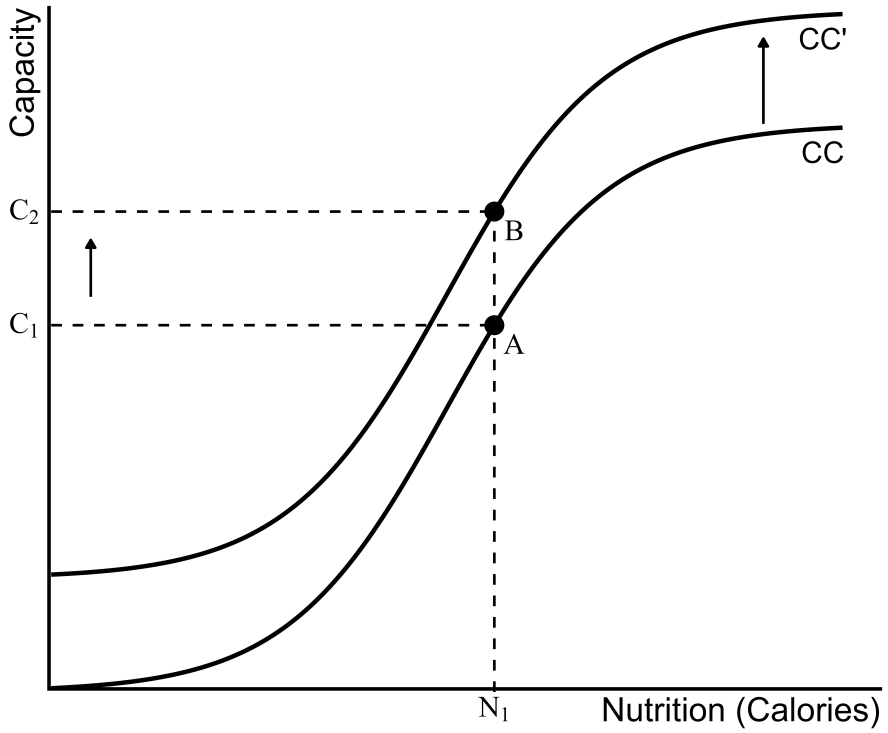


Figure 3: Improvement in Nutritional Intake.

In a similar vein a study by exploiting the staggered implementation of the school meals program across different states in India to ensure that variation in exposure across different birth cohorts is exogenous, indicates that midday meals had a positive effect on

learning achievement accompanied with the improvement in math and reading test scores by approximately 10-20 % (Chakraborty and Jayaraman, 2019).

Literature assessing the effect of shift from monthly provision of free food grains to daily distribution of cooked meals in a rural area in India, provides evidence of a significant impact on the daily participation rates of children particularly in lower grades (Afridi, 2011a). Research analysing the extent of the beneficial effect on children from the mandated school meal program corroborates to the evidence that the intervention led to a significant increase in daily nutrient intake with a subsequent decline in protein, calorie and iron deficiency of primary grade students suggesting substantial effect of the program on reducing malnutrition at school (Afridi, 2011b).

Leveraging longitudinal data from Andhra Pradesh in India with further disaggregation to analyse the heterogeneous effects of the meal transfers by using WHO anthropometric Z scores for nutrition and Peabody Picture Vocabulary Test[4] (PPVT) scores for the impact on learning skills, it has been documented that the scheme led to highly significant gains in both nutrition and learning thereby alluding to the effectiveness of the school meals program in developing countries. The study after controlling for self selection into the program, finds that the meals acted as a cushion for children from deleterious health effects of a severe drought (Singh et al., 2014).

Research conducted in Andhra Pradesh combines the heterogeneity in educational history of children with the staggered implementation of the MDM program with selective targeting of public school students and show that the policy reduced inequalities between children enrolled in the private and public sectors by further employing a Heckman Selection model to account for the school selection (Cavapozzi et al., 2024).

Millets[5] have historically occupied an important place in India's agricultural systems and food culture. These small-grained cereals are well adapted to dry and semi-arid environments because of their ability to withstand relatively harsh climatic conditions and limited water availability.

[4] The Peabody Picture Vocabulary Test (PPVT) is a standardized assessment of receptive vocabulary measuring an individual's ability to understand the meanings of spoken words. It is commonly used to assess language development and verbal ability particularly among children.

[5] Millets are a group of cereal crops that are generally hardy and suited to dry and semi-arid conditions. They include crops such as pearl millet (bajra), finger millet (ragi), sorghum (jowar), foxtail millet, little millet, kodo millet, barnyard millet and proso millet.

Their adaptability makes them particularly relevant to India's diverse agro-climatic landscape. In addition to their agronomic advantages millets are valued for their nutritional properties and potential contribution to a healthy diet. Despite this millet consumption in India has declined over the past several decades accompanied by a gradual shift in dietary preferences towards rice and wheat. More recently due to the growing recognition of their nutritional value and their potential role in climate resilient agriculture has renewed interest in millet production and consumption. The Indian government has introduced several measures to encourage their cultivation and inclusion in diets whereas the United Nations designated 2023 as the International Year of Millets (Kalpe et al., 2023).

In a community level study with nutritional intervention for tribal children in Telangana, India ; millet, pulse and groundnut based nutrient rich formulations were administered for an year. The intervention led to the improvement in health status measured by weight for height Z scores (WHZ) (wasting), height for age Z scores (HAZ) (stunting), weight for age Z scores (WAZ) (underweight) and hemoglobin levels (anaemia)[6] (Mazumdar Saikat et al., 2024). In a similar intervention with deployment of millet-based meals in certain regions of Karnataka schools found significant improvement in body mass index and stunting incidence. Furthermore a sensory evaluation test found broad acceptability of millet-based meals (Anitha et al., 2019).

Eggs can be a valuable addition to MDM because they provide a concentrated source of high-quality easily digestible protein along with several essential micronutrients. A single average-sized egg provides approximately 6–7 g of protein and contains all nine essential amino acids making it a useful complement to cereal and pulse-based meals. This is particularly important because meals may meet calorie requirements without necessarily providing adequate amounts of high-quality protein. Eggs also supply nutrients such as iron, zinc, calcium, vitamin D, vitamin B12 and choline while compounds such as lutein and zeaxanthin contribute to their nutritional value. Choline is especially relevant because of its role in supporting cognitive function. Eggs also have practical advantages

[6] Anthropometric Z-scores are calculated by comparing a child's observed weight or height with the age and sex-specific reference distribution established by the World Health Organization (WHO). WHZ, HAZ and WAZ indicate the number of standard deviations a child's weight-for-height, height-for-age and weight-for-age differs from the corresponding WHO Child Growth Standards.

for mid day meals as they are relatively affordable, widely available, easy to prepare and can be served boiled. Thus incorporating eggs can help improve the nutritional quality and diversity of school meals and support children's growth and overall development (Kate & Tewary, 2025).

The endeavour of this paper is to further analyse the linkage between nutrition and learning outcomes by using data on learning outcomes of school going children. The study incorporates evidence from isolated policy interventions in three different Indian states wisely; alcohol prohibition in the state of Bihar, inclusion of millets-based meals in MDM in Haryana and finally provision of eggs in MDM in backward districts of Karnataka. The study adds to the literature by empirically testing the nutrition-based efficiency-wage hypothesis by corroborating existing findings with evidence from the Indian states. To strengthen the causal pathway, a robustness exercise of pre-trends test which tests the impact of the policy in pre-intervention years as a placebo along with SDID estimates are deployed which uses unit and time weights to create a synthetic control group addressing the balance between treated and control units (Arkhangelsky et al., 2021).

These findings highlight the potential for nutrition-focused policies to contribute to improvements in children's learning outcomes. The evidence from Bihar suggests that changes in household resource allocation following alcohol prohibition may have contributed to improved learning outcomes through increased expenditure on food, highlighting the broader relevance of household consumption patterns for human capital development. The findings from Haryana and Karnataka further indicate that strengthening the nutritional content of school meals can support children's learning. Incorporating nutrient-rich foods such as millets and eggs into MDM programmes may therefore complement conventional investments in education. These results suggest that nutrition-sensitive education policies which combine school-based food provision with broader improvements in household food security can form an important component of strategies aimed at enhancing children's educational development particularly in settings where nutritional deficiencies remain a concern.

The rest of the paper is organised as follows. Section 2 provides the research background of the paper. Section 3 gives data descriptions and Section 4 provides the methodology. Section 5 presents the results and Section 6 concludes.

2 Background

2.1 Alcohol Prohibition in Bihar.

Alcohol Prohibition has been in effect in the Indian state of Bihar since April 2016 . In a different paper analysing the effect of liquor ban on consumption, we have documented that prohibition led to the diversion of household resources towards the consumption of nutritious protein-rich food items like pulses, meat, eggs and fish (Khadgawat and Dharmveer, 2026). In this paper we are extending our findings to document the impact of nutritious food consumption on learning outcomes of school going children. We have compared changes in learning outcomes due to the ban in Bihar with the neighbouring state of Uttar Pradesh (UP) which is our control group for the conparison (Figure 4). Although alternative underlying mechanisms exist impacting the learning outcomes like decline in intimate partner violence and home environment improvement due to alcohol prohibition (Dar et al., 2026), the food productivity pathway cannot be discounted. While acknowledging the effect on learning outcomes through multiple channels as depicted in the conceptual framework (Figure 5), we stress on the impact of nutrition by supplementing our findings with evidence from the other Indian states.

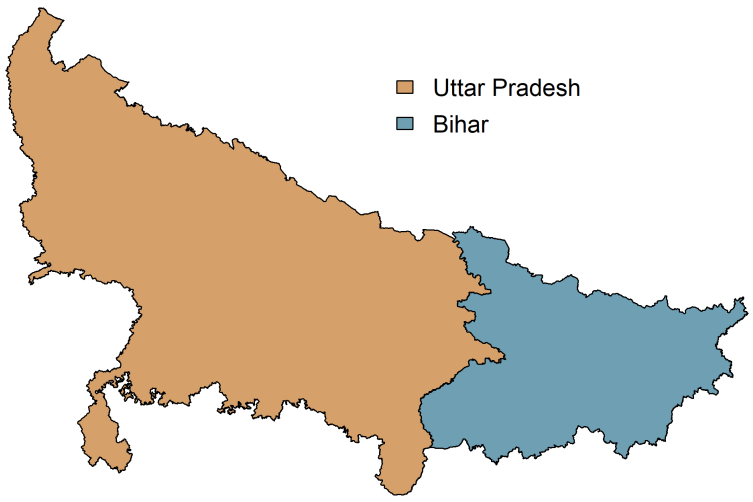


Figure 4: Bihar and Uttar Pradesh.

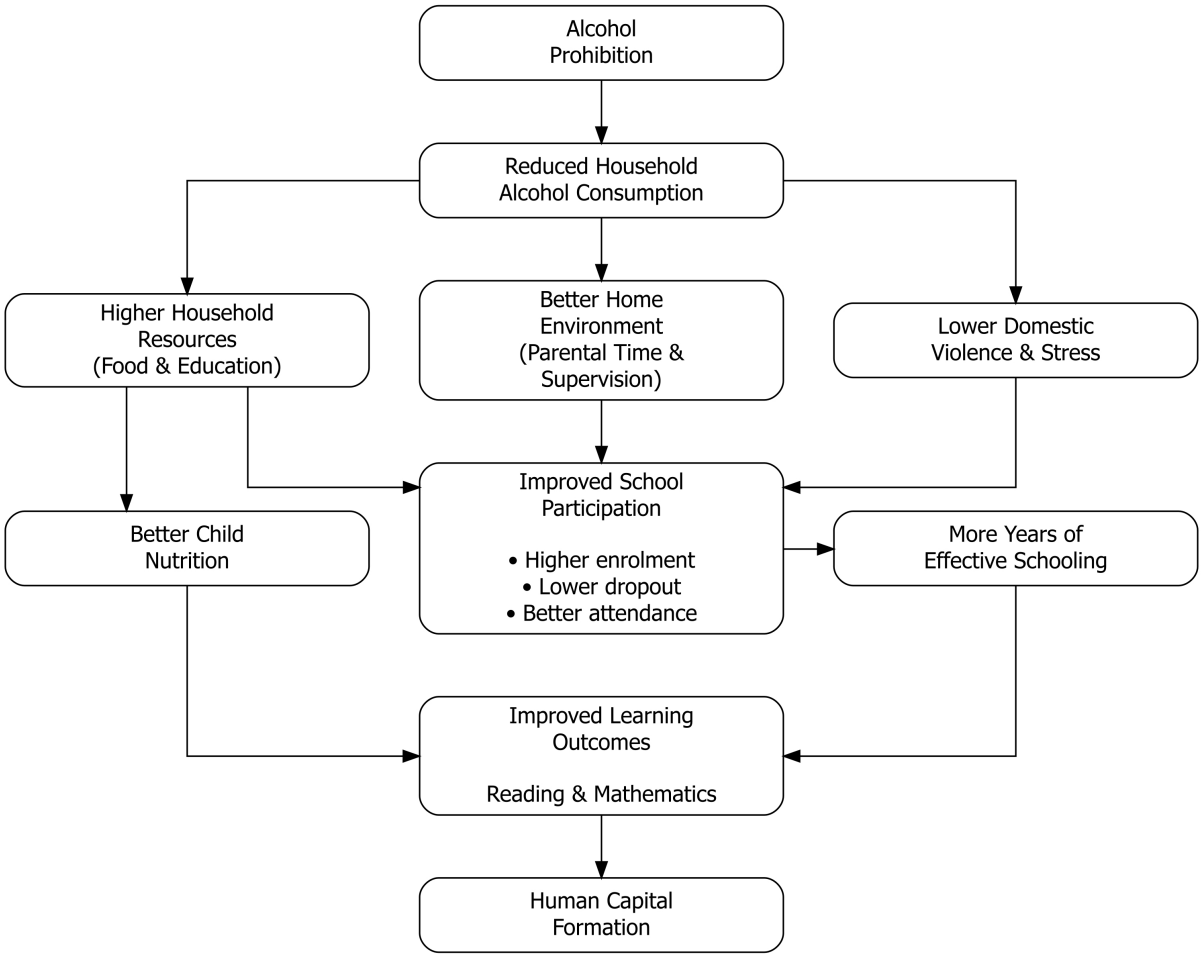


Figure 5: Conceptual Framework.

2.2 Millets in MDM.

The Indian state of Haryana implemented a policy change in 2017 by incorporating millets-based meals in MDM in schools across the state as per the newly enacted Mid Day Meal (Amendment) Rules, 2017. The state government introduced bajra mixtures and fortified elements into school menus along with nutritional supplements such as millet pinni, panjiri and kheer[7]. We have compared learning outcomes pre and post millet introduction in Haryana schools with those of the neighbouring states of Rajasthan and Punjab where no such meal change was implemented (Figure 6). These two states form our control groups for comparison with Haryana as the treated group.

[7] Millet-based preparations such as *pinni*, *panjiri* and *kheer* are traditional Indian foods that can be prepared using millets as a principal ingredient often combined with milk, ghee, nuts or other locally available ingredients.

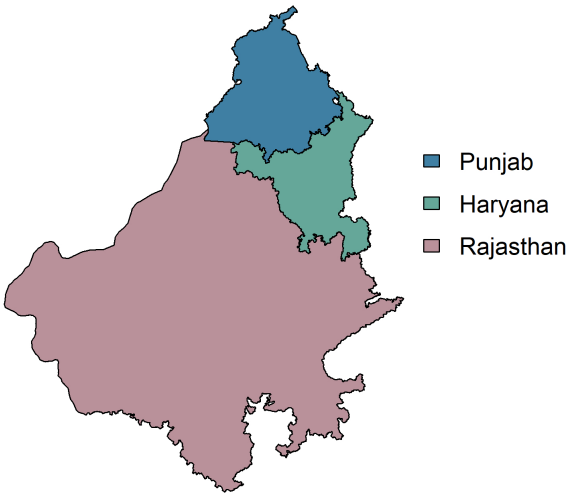


Figure 6: Punjab, Haryana and Rajasthan.

2.3 Eggs in MDM.

Eggs were introduced three days a week as part of MDM in the economically disadvantaged districts of the Indian state of Karnataka in 2021 to address serious malnutrition prevalence in these areas[8]. We have compared learning outcomes pre and post eggs introduction in backward districts of Karnataka which form our treated group with the rest of the districts of the state forming our control group for the analysis (Figure 7).

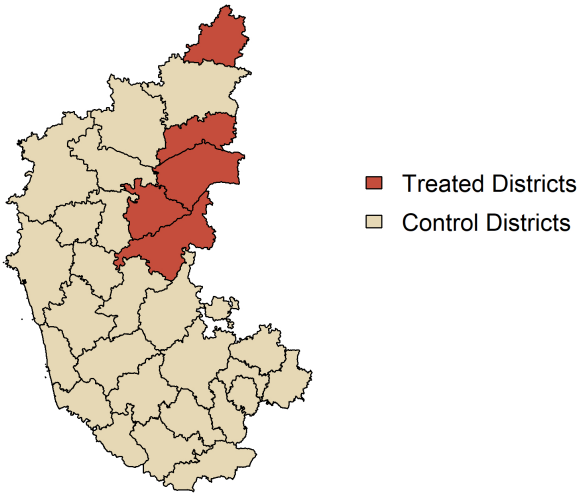


Figure 7: Karnataka - Treated and Control Districts.

[8] These districts are *Bidar, Bellary, Koppal, Raichur and Yadgir.*

3 Data

The study uses data from the Annual Status of Education Report (ASER), a large-scale household survey conducted by ASER Centre under the aegis of the Pratham Education Foundation. ASER provides information on children's schooling status and foundational learning outcomes in rural India. The survey collects schooling information for children aged 3–16 years and assesses basic reading and arithmetic abilities among children aged 5–16 years. Since the survey is household-based, it covers both children attending school and those who are out of school allowing learning outcomes to be examined across different schooling statuses. ASER follows a repeated cross-sectional design rather than tracking the same children or households over time.

The empirical analysis of alcohol prohibition in Bihar considers ASER-2016 data as the post-intervention dataset and ASER-2014 and ASER-2013 as those belonging to the pre-intervention periods. Similarly for the millets inclusion in MDM in Haryana, ASER-2018 is the post-intervention dataset while ASER-2016 and ASER-2014 form the pre-intervention periods. Finally for the eggs provision in MDM in Karnataka districts, ASER-2022 is the post-intervention period and ASER-2018 and ASER-2016 are the pre-intervention periods.

ASER was conducted annually between 2005 and 2014. From 2016 onwards, the survey adopted an alternate-year schedule with the standard survey being conducted in selected years. The 2020 round represented an exception to the usual survey design as the COVID-19 pandemic prevented conventional fieldwork. Thus ASER 2020 was conducted through telephone-based surveys with greater emphasis on children's access to learning opportunities, educational resources and schooling during the period of pandemic-related school closures. In order to ensure the synchronicity across survey rounds this COVID-19 round dataset has been omitted and we incorporate data from the next survey round of 2022 for the Karnataka study.

The child and household-level observations in each survey round are aggregated to the district-year level to obtain measures of learning outcomes for the empirical analysis. The resulting district-level observations form the panel dataset used in the study.

4 Methodology

The analysis uses repeated cross-sectional data from the Annual Status of Education Report (ASER) for the selected districts of treated and control groups. Since the ASER survey observes different households and children in different survey rounds, individual-level observations cannot be treated as a longitudinal panel. To obtain a consistent unit of analysis across survey years, the household and child-level observations are aggregated to the district level. This procedure produces a district-year dataset in which each observation represents the characteristics of a district in a particular survey year.

Several variables in the ASER data are recorded in binary or categorical form. These variables are converted into quantitative district-level measures by constructing weighted proportions or shares. For a binary indicator, the value is coded as one when the specified characteristic is present and zero or NA otherwise. The district-level value is then calculated as the weighted mean of this indicator using the ASER household multiplier as the survey weight[9]. The resulting measure represents the proportion of the relevant population in a district possessing the characteristic[10]. Similarly measures of school participation, reading and mathematics outcomes are computed as district-level shares corresponding to each competency level.

These district-level aggregates are subsequently harmonised across survey rounds and combined by district and year. Restricting the analysis to districts observed consistently across the selected survey years produces a balanced district-level panel constructed from the repeated cross-sectional surveys. This aggregation also transforms individual-level binary outcomes into continuous quantitative measures ranging from zero to one (or zero to 100 when expressed as percentages) allowing them to be used as dependent or explanatory variables in linear regression models. The empirical analysis therefore examines changes in district-level educational outcomes over time while accounting for observable district characteristics and district and time fixed effects.

[9] For district d in year t, the weighted mean is calculated as $\bar{Y}_{dt} = \frac{\sum_{i=1}^{N_{dt}} w_{idt} Y_{idt}}{\sum_{i=1}^{N_{dt}} w_{idt}}$, where Y_{idt} is the individual-level indicator and w_{idt} is the ASER household multiplier.

[10] A district-level value of 0.64 for a binary learning indicator implies that 64 % of the relevant children in that district possess the specified characteristic.

The specification that we use for our analysis is as follows –

$$Y_{it} = \beta(Treat_i \times Post_t) + X'_{it}\theta + \mu_i + \lambda_t + \varepsilon_{it} \tag{1}$$

Y_{it} depicts the average outcome for district i observed in period t which takes various forms like average dropout class, average never entered school proportion, average dropouts and average mathematics scores.

$Treat_i$ is a dummy variable taking a value 1 for districts in the treated group and 0 otherwise.

$Post_t$ is a dummy variable taking a value 1 for the post-intervention period and 0 otherwise.

$Treat_i \times Post_t$ is the interaction of the two dummy variables giving us districts in the treated group in the post-intervention period.

X_{it} are district-level aggregates of household-level controls such as average household members, average child age and average class of father's educational attainment.

μ_i is district fixed effects, λ_t is time fixed effects and ε_{it} denotes the idiosyncratic error term.

The DID interaction coefficient β captures the Intent-to-Treat (ITT) effect of exposure to the policy intervention.

We have deployed Ordinary Least Squares (OLS) for estimation with clustering of standard errors at the district level. The pre-trends analysis estimates the DID specification using only periods preceding the intervention. A statistically insignificant interaction coefficient provides evidence consistent with the absence of differential pre-intervention trends between treated and control districts.

As a complementary estimation strategy, we employ SDID estimator which combines features of synthetic control and DID methods by assigning unit and time weights to improve pre-intervention comparability between treated and control units. The SDID estimates provide a complementary assessment of the treatment effect and serve as a robustness check for the baseline DID results.

5 Results

5.1 Alcohol Prohibition in Bihar.

Table 1 presents the descriptive statistics for the dependent and control variables for Bihar and Uttar Pradesh (UP). These statistics provide an overview of the characteristics of the two groups and facilitate a preliminary comparison between the treated and control states. The descriptive statistics also provide context for interpreting the subsequent regression estimates and the observed changes in learning-related outcomes following the implementation of alcohol prohibition in Bihar.

Table 1: Descriptive Statistics.

	Bihar		**UP**	
Variable	**Mean**	**Variance**	**Mean**	**Variance**
	(1)	(2)	(3)	(4)
Dropout Class	5.3	0.28	6.3	0.55
Never Entered	0.018	0.00007	0.015	0.00013
Maths Scores - 4	0.13	0.0005	0.14	0.0007
Maths Scores - 5	0.29	0.004	0.22	0.004
Members	7.6	0.36	7.8	0.62
Child Age	9.2	0.05	9.5	0.06
Father Class	9	0.6	9.5	0.5

Source: Annual Status of Education Report (2013 - 2016).

Notes: The table reports the mean and variance of learning outcomes and control variables for Bihar and UP calculated as average district values. Maths Scores - 4 and 5 denote the proportion of children able to perform two-digit subtraction and three-digit by one-digit division respectively. All outcome measures are calculated using household survey weights.

Table 2 examines the average class in which students dropped out of school as the dependent variable. The DID specification in Column DID indicates that, following the implementation of alcohol prohibition, the average class at which students dropped out increased by 43.8 percentage points in Bihar relative to the districts of UP with the estimated effect being statistically significant at the 1 % level. The positive coefficient suggests that following the intervention students who eventually dropped out tended to remain in school for a longer period before leaving. Thus the result is consistent with an improvement in school retention associated with the post-prohibition period.

The PT column reports the DID specification using the pre-intervention period and provides a test of whether the treated and control groups exhibited differential trends prior to the intervention. The estimated coefficient is statistically insignificant, providing no evidence of a systematic differential pre-intervention trend between Bihar and UP for this outcome. This supports the plausibility of the parallel-trends assumption underlying the DID specification.

The SDID specification reported in the final column produces an estimated effect of 49.3 percentage points, which is statistically significant at the 1 % level and is consistent in direction and magnitude with the main DID estimate. The similarity between the DID and SDID estimates provides additional evidence that the observed post-intervention change is not driven solely by differences in the composition or pre-treatment trajectories of Bihar and UP.

Figure 8 provides a graphical representation of these results by plotting the evolution of the average dropout class for Bihar and its synthetic control. The figure illustrates the divergence between the observed trajectory of Bihar and the counterfactual trajectory following the intervention. The arrow indicates the estimated effect of the intervention, represented by the gap between the grey line which captures the counterfactual trend in the absence of alcohol prohibition and the blue line which represents the observed post-intervention trajectory.

Table 2: Effect on Dropout Class.

	DID	PT	SDID
Treat × Post	0.438***	-0.0004	0.493***
	(0.158)	(0.159)	(0.182)
Observations	210	210	210
R^2	0.78	0.84	
Adj. R^2	0.54	0.68	
Controls	Yes	Yes	
District FE	Yes	Yes	
Time FE	Yes	Yes	
Inference	Clustered (District)	Clustered (District)	Placebo

Source: Annual Status of Education Report (2013 - 2016).

Notes: The dependent variable is the average dropout class at the district level with average being computed using household survey weights. Bihar is the treated state and the neighbouring state of UP forms the control group. The data for year 2016 is in the post-treatment phase and the year 2014 data is the pre-intervention period for the DID column whereas PT column uses pre-intervention periods 2013 and 2014. District and time fixed effects along with other covariates like average household members, average child age and average class of father's educational attainment are controlled for in the DID and PT specifications. Standard errors are clustered at the district level whereas SDID draws inference by using placebo standard errors. ***, ** and * depict significance at 1 %, 5 % and 10 % respectively.

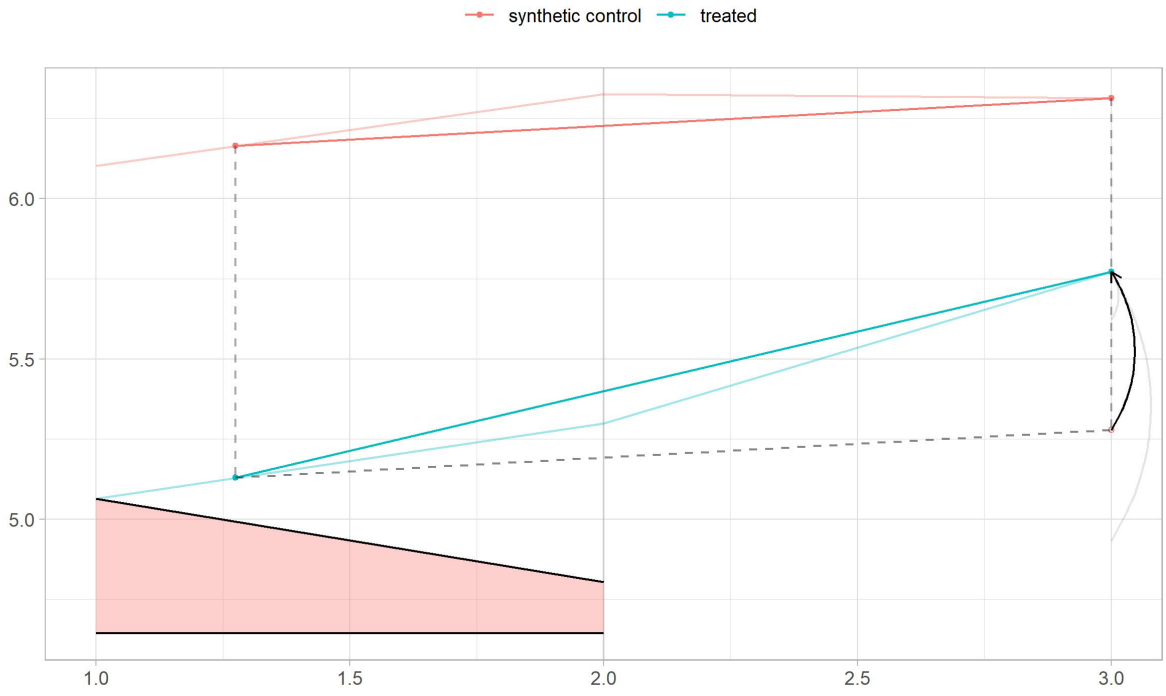


Figure 8: Dropout Class.

Table 3 examines the proportion of children who have never entered school as the dependent variable. The DID estimate in Column DID indicates that, following alcohol prohibition, the proportion of children who never entered school declined by 0.6 percentage points in Bihar relative to UP with the estimate statistically significant at the 1 % level. The negative coefficient indicates a reduction in the share of children who had never enrolled in school suggesting that a greater proportion of children entered formal schooling during the post-intervention period.

As in the previous specification, the PT column estimates the DID model over the pre-intervention period. The coefficient is statistically insignificant, indicating that there is no evidence of a systematic differential trend between Bihar and UP before the implementation of alcohol prohibition. This provides support for the validity of the pre-intervention comparison between the treated and control groups.

The SDID estimate is 0.7 percentage points in magnitude and is statistically significant at the 1 % level, again consistent with the direction and statistical significance of the main DID estimate. The comparable results across the DID and SDID specifications suggest that the decline in the proportion of children who never entered school is robust to an alternative method of constructing the counterfactual trajectory.

Figure 9 complements the regression estimates by presenting the trends in the proportion of children who never entered school for Bihar and its synthetic control. The figure shows the divergence between the observed outcome in Bihar and the estimated counterfactual trajectory following the intervention. The arrow represents the estimated intervention effect measured as the gap between the grey counterfactual line which represents the expected trajectory in the absence of prohibition and the blue observed line which captures the post-intervention trajectory.

Table 3: Effect on Never Entered.

	DID	PT	SDID
Treat × Post	-0.006***	-0.0006	-0.007***
	(0.002)	(0.001)	(0.002)
Observations	210	210	210
R^2	0.81	0.85	
Adj. R^2	0.61	0.69	
Controls	Yes	Yes	
District FE	Yes	Yes	
Time FE	Yes	Yes	
Inference	Clustered (District)	Clustered (District)	Placebo

Source: Annual Status of Education Report (2013 - 2016).

Notes: The dependent variable is the average proportion of children who have never entered school at the district level with average being computed using household survey weights. Bihar is the treated state and the neighbouring state of UP forms the control group. The data for year 2016 is in the post-treatment phase and the year 2014 data is the pre-intervention period for the DID column whereas PT column uses pre-intervention periods 2013 and 2014. District and time fixed effects along with other covariates like average household members, average child age and average class of father's educational attainment are controlled for in the DID and PT specifications. Standard errors are clustered at the district level whereas SDID draws inference by using placebo standard errors. ***, ** and * depict significance at 1 %, 5 % and 10 % respectively.

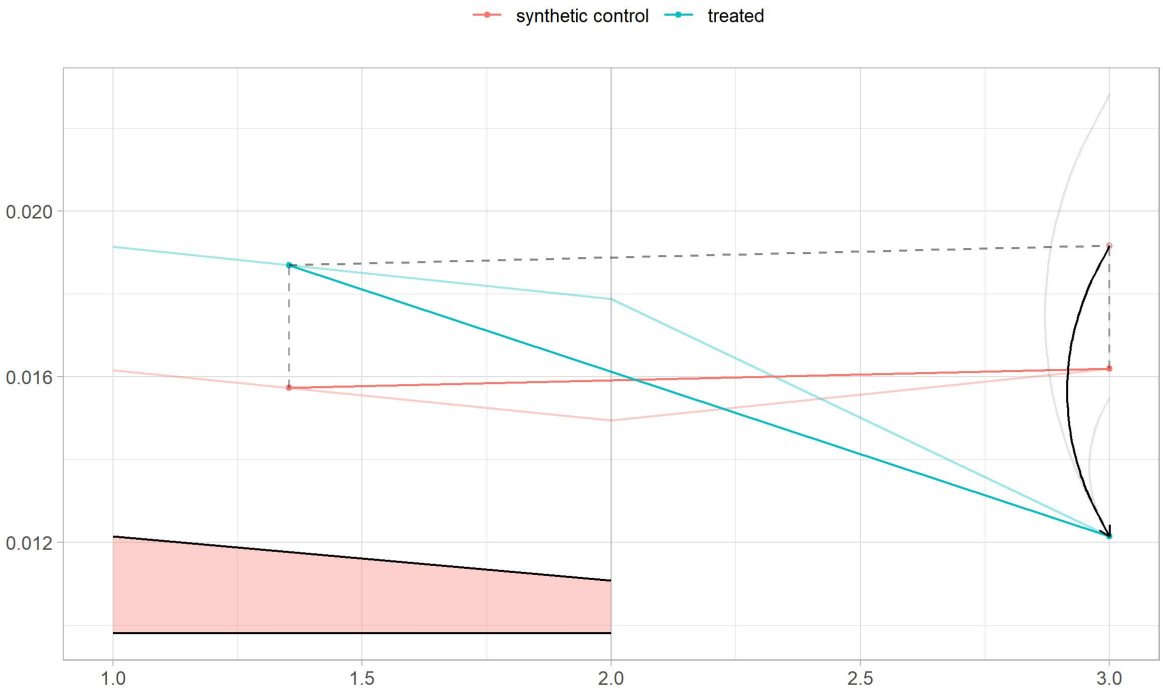


Figure 9: Never Entered.

Table 4 considers Maths Scores – 4 as the dependent variable[11]. The DID estimate in Column DID indicates that, following alcohol prohibition, the average Mathematics Score–4 in Bihar increased by approximately 1 percentage point relative to UP. The estimate is marginally statistically significant at the 10 % level. The positive coefficient is consistent with an improvement in the mathematical performance of students in Bihar following the intervention and suggests a potential improvement in their basic quantitative abilities.

The PT specification produces a statistically insignificant coefficient indicating that there is no evidence of a differential pre-intervention trend between Bihar and UP for Maths Scores – 4. This provides support for the use of the DID framework for estimating the post-intervention difference.

The SDID specification produces an estimated effect of approximately 1 percentage point which is statistically significant at the 5 % level. The SDID estimate therefore reinforces the direction of the DID result while providing stronger statistical evidence of an improvement in Maths Scores – 4.

Figure 10 illustrates these results by comparing the trajectory of Maths Scores – 4 in Bihar with that of its synthetic control. As in the preceding figures the arrow denotes the intervention effect measured by the divergence between the grey counterfactual trajectory in the absence of prohibition and the blue observed trajectory following the intervention.

[11] Maths Scores - 4 refers to the weighted proportion of children in a district who are able to perform a two-digit subtraction, among children for whom the mathematics assessment outcome is recorded.

Table 4: Effect on Maths Scores - 4.

	DID	PT	SDID
Treat × Post	0.01*	-0.007	0.01**
	(0.005)	(0.005)	(0.004)
Observations	210	210	210
R^2	0.70	0.69	
Adj. R^2	0.38	0.35	
Controls	Yes	Yes	
District FE	Yes	Yes	
Time FE	Yes	Yes	
Inference	Clustered (District)	Clustered (District)	Placebo

Source: Annual Status of Education Report (2013 - 2016).

Notes: The dependent variable is the maths scores - 4 which gives the weighted proportion of children in a district who are able to perform a two-digit subtraction, among children for whom the mathematics assessment outcome is recorded. Bihar is the treated state and the neighbouring state of UP forms the control group. The data for year 2016 is in the post-treatment phase and the year 2014 data is the pre-intervention period for the DID column whereas PT column uses pre-intervention periods 2013 and 2014. District and time fixed effects along with other covariates like average household members, average child age and average class of father's educational attainment are controlled for in the DID and PT specifications. Standard errors are clustered at the district level whereas SDID draws inference by using placebo standard errors. ***, ** and * depict significance at 1 %, 5 % and 10 % respectively.

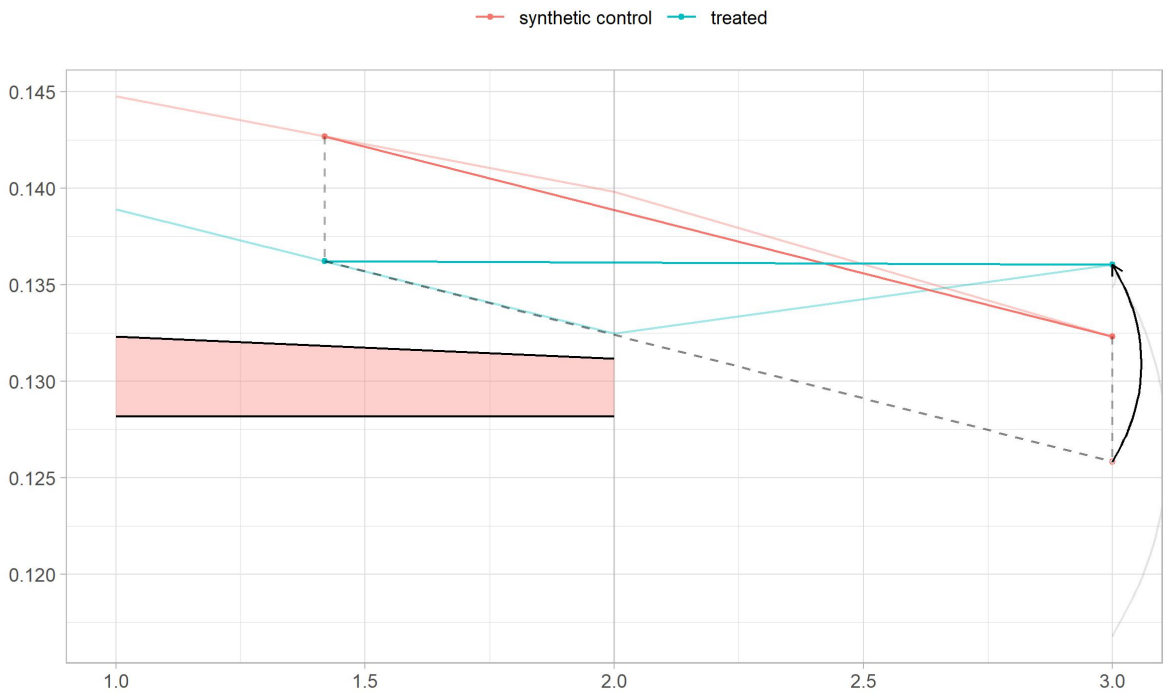


Figure 10: Maths Scores - 4.

Table 5 examines Maths Scores – 5 as the dependent variable[12]. The DID specification shows that following alcohol prohibition the average Maths Scores – 5 increased by 5.3 percentage points in Bihar relative to UP with the estimate statistically significant at the 1 % level. The magnitude and statistical significance of this estimate indicate a sizeable improvement in the mathematical performance of students consistent with an improvement in their quantitative abilities following the intervention.

The PT specification again yields a statistically insignificant coefficient providing no evidence of differential pre-intervention trends between Bihar and UP. This result supports the plausibility of the parallel-trends assumption for this outcome.

The SDID estimate indicates an increase of 5.8 percentage points which is statistically significant at the 1 % level and closely aligns with the direction and magnitude of the main DID estimate. The consistency between the two estimation approaches strengthens the evidence that the post-intervention improvement in Maths Scores – 5 is not simply attributable to differences in the pre-intervention trajectories of the treated and control groups.

Figure 11 graphically presents the corresponding trends in Maths Scores–5 for Bihar and its synthetic control. The figure shows the divergence between Bihar's observed trajectory and the counterfactual trajectory estimated from the synthetic control following the intervention. The arrow represents the estimated intervention effect defined by the gap between the grey counterfactual trend which approximates the trajectory that Bihar would have followed in the absence of alcohol prohibition and the blue observed trend following the intervention.

[12] Maths Scores - 5 refers to the weighted proportion of children in a district who are able to perform a three-digit by one-digit division, among children for whom the mathematics assessment outcome is recorded.

Table 5: Effect on Maths Scores - 5.

	DID	PT	SDID
Treat × Post	0.053***	-0.011	0.058***
	(0.01)	(0.01)	(0.009)
Observations	210	210	210
R^2	0.93	0.92	
Adj. R^2	0.86	0.85	
Controls	Yes	Yes	
District FE	Yes	Yes	
Time FE	Yes	Yes	
Inference	Clustered (District)	Clustered (District)	Placebo

Source: Annual Status of Education Report (2013 - 2016).

Notes: The dependent variable is the maths scores - 5 which gives the weighted proportion of children in a district who are able to perform a three-digit by one-digit division, among children for whom the mathematics assessment outcome is recorded. Bihar is the treated state and the neighbouring state of UP forms the control group. The data for year 2016 is in the post-treatment phase and the year 2014 data is the pre-intervention period for the DID column whereas PT column uses pre-intervention periods 2013 and 2014. District and time fixed effects along with other covariates like average household members, average child age and average class of father's educational attainment are controlled for in the DID and PT specifications. Standard errors are clustered at the district level whereas SDID draws inference by using placebo standard errors. ***, ** and * depict significance at 1 %, 5 % and 10 % respectively.

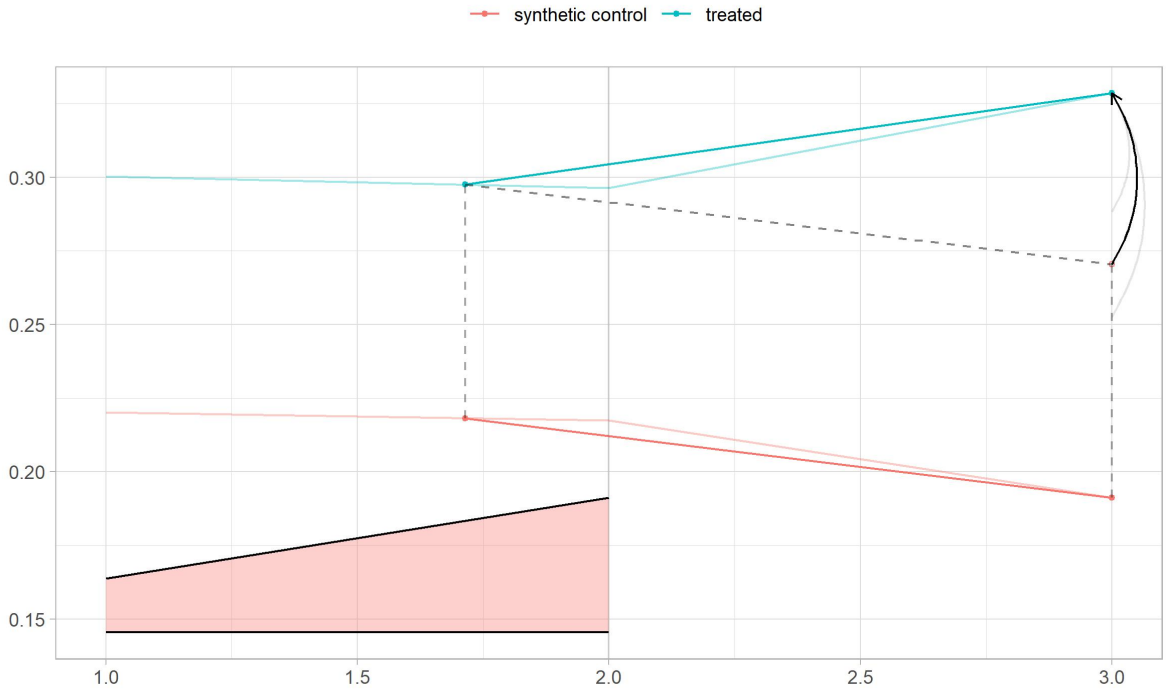


Figure 11: Maths Scores - 5.

Taken together, the results across the four learning-related outcomes indicate that the period following the implementation of alcohol prohibition was associated with improvements in school retention, school entry and mathematical performance in Bihar relative to UP. The results are consistently observed across the DID and SDID specifications while the absence of statistically significant differential pre-intervention trends provides support for the underlying identification strategy. These findings are consistent with the broader mechanism examined in this study whereby changes in household expenditure following alcohol prohibition may have enabled greater allocation of household resources toward nutritious and protein-rich food items potentially contributing to improved conditions for children's learning and educational participation. Since the analysis directly measures household expenditure rather than nutritional intake or cognitive mechanisms however this channel should be interpreted as a plausible mechanism consistent with the observed results rather than as a directly established biological pathway.

5.2 Millets in MDM.

Table 6 presents the descriptive statistics for the dependent and control variables for the treated group (Haryana) and the control group comprising Punjab and Rajasthan. These descriptive statistics provide a summary of the main variables and allow for a preliminary comparison between the treated and control groups prior to examining the regression results.

Table 6: Descriptive Statistics.

	Treated		**Control**	
Variable	**Mean**	**Variance**	**Mean**	**Variance**
	(1)	(2)	(3)	(4)
Never Entered	0.006	0.00018	0.011	0.00015
Members	6.5	0.37	6.4	0.59
Child Age	9.5	0.05	9.7	0.05
Father Class	9.9	0.5	9.1	0.6

Source: Annual Status of Education Report (2014 - 2018).
Notes: The table reports the mean and variance of learning outcomes and control variables for treated (Haryana) and control (Punjab and Rajasthan) groups calculated as average district values. All outcome measures are calculated using household survey weights.

Table 7 examines the district-level proportion of children who have never entered school as the dependent variable. The DID specification in Column DID indicates that following the introduction of millet-based meals under the MDM programme in Haryana, the proportion of children who had never entered school declined by 1 percentage point in the treated districts of Haryana relative to the districts in Punjab and Rajasthan. The estimated coefficient is marginally statistically significant at the 10 % level. The negative coefficient suggests that the introduction of millet-based meals was associated with a reduction in the proportion of children who had never entered the schooling system, indicating an increase in school entry following the intervention.

The PT column estimates the DID specification over the pre-intervention period. The coefficient is statistically insignificant, indicating that there is no evidence of a systematic differential trend between the treated and control groups prior to the introduction of millet-based meals. This provides support for the plausibility of the parallel-trends assumption underlying the DID specification.

The SDID specification reported in the final column produces an estimated effect of 1.5 percentage points, which is statistically significant at the 5 % level and is consistent in direction with the main DID specification. The SDID estimate therefore provides additional evidence of a post-intervention decline in the proportion of children who had never entered school.

Table 7: Effect on Never Entered.

	DID	**PT**	**SDID**
Treat × Post	-0.01*	0.003	-0.015**
	(0.005)	(0.002)	(0.006)
Observations	142	142	142
R^2	0.86	0.91	
Adj. R^2	0.70	0.82	
Controls	Yes	Yes	
District FE	Yes	Yes	
Time FE	Yes	Yes	
Inference	Clustered (District)	Clustered (District)	Placebo

Source: Annual Status of Education Report (2014 - 2018).

Notes: The dependent variable is the average proportion of children who have never entered school at the district level with average being computed using household survey weights. Haryana is the treated state and the neighbouring states of Punjab and Rajasthan form the control group. The data for year 2018 is in the post-treatment phase and the year 2016 data is the pre-intervention period for the DID column whereas PT column uses pre-intervention periods 2014 and 2016. District and time fixed effects along with other covariates like average household members, average child age and average class of father's educational attainment are controlled for in the DID and PT specifications. Standard errors are clustered at the district level whereas SDID draws inference by using placebo standard errors. ***, ** and * depict significance at 1 %, 5 % and 10 % respectively.

Figure 12 provides a graphical representation of the estimated effect by showing the evolution of the proportion of children who had never entered school in Haryana relative to its synthetic control. The figure illustrates the divergence between the observed trajectory of the treated group and the counterfactual trajectory following the intervention. The arrow represents the estimated intervention effect measured as the gap between the grey

line which represents the counterfactual trend in the absence of the millet-based meal intervention and the blue line which represents the observed post-intervention trajectory.

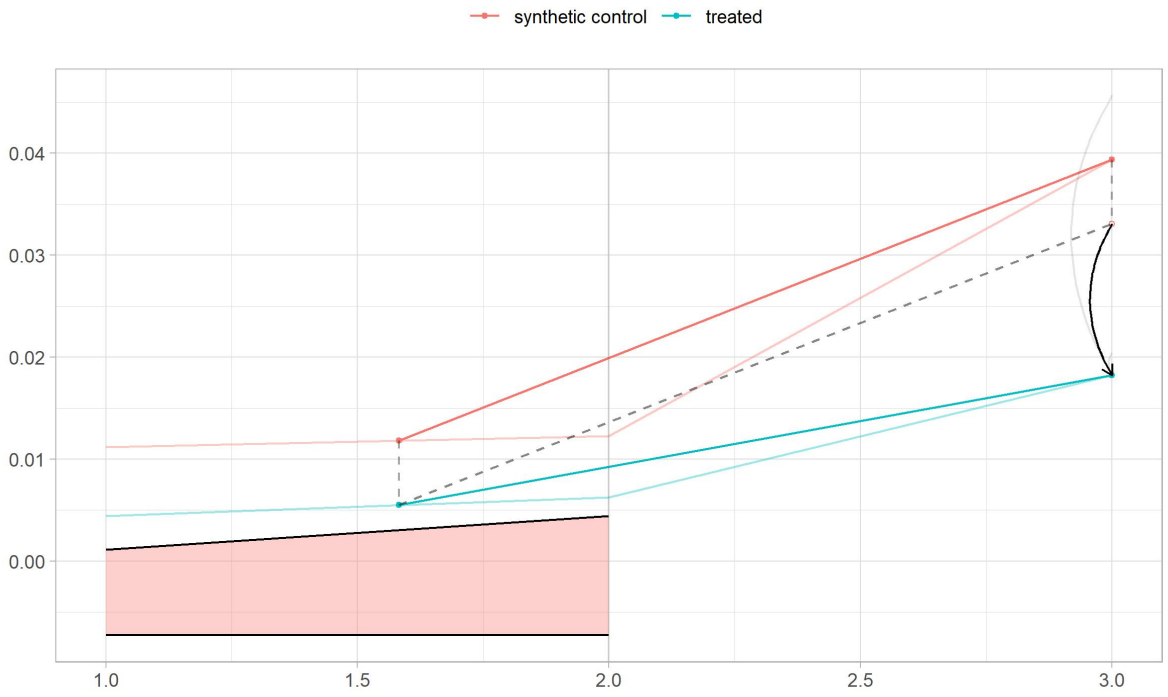


Figure 12: Never Entered.

Overall, the results indicate that the introduction of millet-based meals through the MDM programme in Haryana was associated with a decline in the proportion of children who had never entered school. This suggests that the intervention coincided with greater entry into the schooling system. The finding is consistent with the broader hypothesis examined in this study that improvements in the nutritional content of school meals may be associated with improved educational participation and potentially learning outcomes. However, since the outcome considered in this specification directly captures school entry rather than learning achievement itself the result should primarily be interpreted as evidence of an improvement in educational participation which in turn affects the cognitive abilities of children due to the longer time spent in learning.

5.3 Eggs in MDM.

Table 8 presents the descriptive statistics for the dependent and control variables for the treated and control districts of Karnataka. The table provides a summary of the main characteristics of the two groups and facilitates a preliminary comparison between the districts that received the egg intervention and those that did not.

Table 8: Descriptive Statistics.

	Treated		**Control**	
Variable	**Mean**	**Variance**	**Mean**	**Variance**
	(1)	(2)	(3)	(4)
Dropout Rate	0.023	0.00018	0.008	0.00003
Members	6.5	0.5	5.8	0.6
Child Age	9.7	0.13	9.7	0.05
Father Class	8.3	1.03	8.9	0.4

Source: Annual Status of Education Report (2016 - 2022).
Notes: The table reports the mean and variance of learning outcomes and control variables for treated and control districts of Karnataka calculated as average district values. Treated districts are *Bidar, Bellary, Koppal, Raichur and Yadgir*. All outcome measures are calculated using household survey weights.

Table 9 examines the average dropout as the dependent variable. The DID specification in Column DID indicates that following the inclusion of eggs in the MDM programme the average dropout in the treated districts declined by 1.4 percentage points relative to the control districts of Karnataka. The estimated coefficient is statistically significant at the 1 % level. The negative coefficient indicates that dropouts declined following the introduction of eggs suggesting that students in the treated districts remained in school for longer and were less likely to leave the schooling system.

The PT column reports the DID specification for the pre-intervention period. The estimated coefficient is statistically insignificant indicating that there is no evidence of a

systematic differential trend in dropouts between the treated and control districts before the introduction of eggs. This provides support for the plausibility of the parallel-trends assumption and strengthens the interpretation of the post-intervention DID estimate.

The SDID specification produces an estimated effect of 1.3 percentage points, which is statistically significant at the 5 % level and is consistent in direction with the main DID estimate. The close correspondence between the DID and SDID results provides additional evidence that the decline in dropouts is robust to an alternative construction of the counterfactual trajectory.

Table 9: Effect on Dropouts.

	DID	**PT**	**SDID**
Treat × Post	-0.014***	-0.003	-0.013**
	(0.004)	(0.007)	(0.005)
Observations	60	60	60
R^2	0.88	0.87	
Adj. R^2	0.72	0.69	
Controls	Yes	Yes	
District FE	Yes	Yes	
Time FE	Yes	Yes	
Inference	Clustered (District)	Clustered (District)	Placebo

Source: Annual Status of Education Report (2016 - 2022).

Notes: The dependent variable is the average proportion of children who have dropped out of school at the district level with average being computed using household survey weights. . Treated districts are Bidar, Bellary, Koppal, Raichur and Yadgir whereas rest of the districts of Karnataka form the control group. The data for year 2022 is in the post-treatment phase and the year 2018 data is the pre-intervention period for the DID column whereas PT column uses pre-intervention periods 2016 and 2018. District and time fixed effects along with other covariates like average household members, average child age and average class of father's educational attainment are controlled for in the DID and PT specifications. Standard errors are clustered at the district level whereas SDID draws inference by using placebo standard errors. ***, ** and * depict significance at 1 %, 5 % and 10 % respectively.

Figure 13 graphically presents these results by showing the trends in average dropout for the treated districts and their synthetic control. The arrow represents the estimated intervention effect measured as the gap between the grey counterfactual trajectory which represents the expected trend in the absence of the egg intervention and the blue observed trajectory following the intervention.

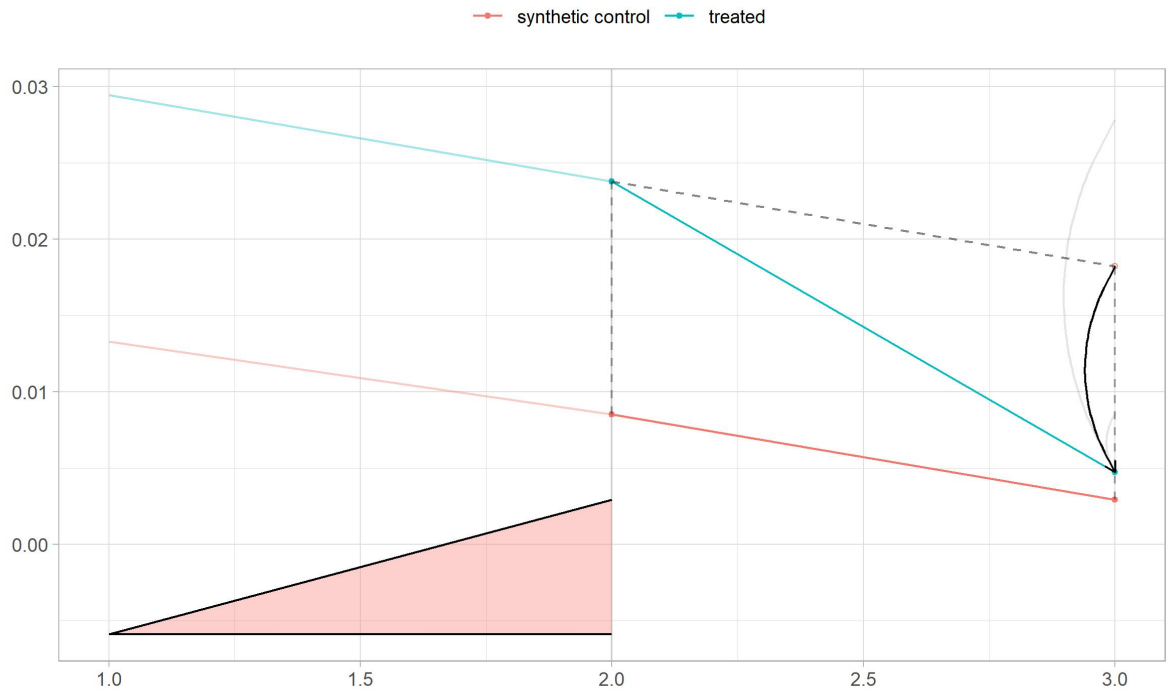


Figure 13: Dropouts.

Taken together the results indicate that the introduction of eggs into the MDM programme in the treated districts of Karnataka was associated with a decline in average dropouts relative to the control districts. The reduction in dropouts is consistent with improved educational participation as students appear to have remained in school for longer following the intervention. More broadly the finding is consistent with the possibility that improvements in the nutritional content of school meals can contribute to better educational participation which has beneficial effects on learning outcomes in line with the literature on time spent in learning.

6 Conclusion

This study examines the relationship between nutrition and learning outcomes by bringing together evidence from three different policy settings in India. While the interventions considered in the study differ in their immediate nature—changes in household resource allocation following alcohol prohibition in Bihar, the introduction of millet-based meals in Haryana and the provision of eggs through the MDM programme in selected districts of Karnataka—they share a common underlying dimension: changes in children's access

to nutritional resources. By examining these settings jointly, the study highlights the importance of looking beyond conventional educational inputs when considering the determinants of children's participation in schooling and their acquisition of learning skills.

The empirical evidence indicates that improvements in nutritional conditions are associated with more favourable educational outcomes. In the Bihar setting, the post-intervention period is characterised by improvements in school participation, retention and mathematical learning relative to the comparison group. The evidence from Haryana and Karnataka complements this finding by showing improvements in educational participation following changes in the nutritional composition of school meals. These findings are obtained across different institutional settings and using different manifestations of educational outcomes. The consistency in the direction of the findings across the baseline DID and complementary SDID specifications together with the absence of systematic differential pre-intervention trends in the analysis provides support for the broader empirical relationship examined in the study.

The findings can be understood within the theoretical framework developed in the paper. The nutrition-based efficiency-wage hypothesis traditionally explains how improved nutritional intake can enhance physical productive capacity particularly in settings where individuals are close to subsistence levels. This study extends this intuition to the domain of learning. Just as nutritional improvements can increase the productivity of labour adequate nutrition may enhance children's capacity to participate in schooling, sustain attention and make productive use of instructional time. Nutrition can therefore be viewed as one of the inputs contributing to learning capacity and human-capital formation.

The conceptual framework also suggests that the relationship need not operate exclusively through the quantity of food consumed. Improvements in the quality and composition of diets may also influence learning capacity. This is particularly relevant for school meal programmes where interventions can modify the nutritional composition of meals without necessarily implying a proportionate increase in total calorie consumption. The inclusion of nutrient-rich foods can therefore potentially improve the nutritional quality of children's diets and through this channel their ability to participate effectively in schooling. The evidence from the school meal interventions is consistent with this broader interpretation.

An important link in this framework is the role of time spent in school. Nutrition may influence learning not only by affecting children's capacity to learn while in the classroom but also by influencing whether children enter school, remain enrolled and attend regularly. The findings from the school meal interventions are particularly relevant in this respect. Improvements in school entry and retention imply greater exposure to instructional time which can itself contribute to skill acquisition. Thus the relationship between nutrition and learning may operate through both the productivity of time spent learning and the amount of time children are able to spend within the schooling system.

The Bihar case further illustrates the importance of considering nutrition within the broader household environment. Changes in household expenditure following alcohol prohibition may have allowed greater allocation of resources towards food and other child-related expenditures. At the same time the study recognises that prohibition can influence children's outcomes through several channels including changes in the home environment and domestic violence. The evidence should therefore not be interpreted as establishing nutrition as the exclusive pathway through which the intervention affected educational outcomes. The Bihar results are therefore consistent with nutrition being one plausible component of a broader household-resource and human-capital mechanism.

The study has several limitations that should be considered when interpreting these findings. First the analysis relies on ASER which follows a repeated cross-sectional design rather than tracking the same children over time. The empirical strategy therefore operates at the district level after aggregating child and household observations using survey weights. While this approach provides a consistent unit of analysis across survey rounds, it does not allow the study to observe individual children's nutritional and educational trajectories directly. Second, the available learning measures differ across the three policy settings. Some analyses capture learning achievement directly whereas others capture school entry or retention which are important determinants of learning but should not themselves be interpreted as measures of cognitive achievement. Third, the study does not directly observe children's nutritional intake, nutritional status or the biological processes through which nutrition may affect learning. The proposed nutrition-learning mechanism is therefore theoretically motivated and empirically consistent with the evidence but cannot be directly established from the available data. Finally, partic-

ularly in the Bihar setting multiple channels may operate simultaneously following the intervention making it difficult to isolate the contribution of nutrition from other changes in household and school environments.

The policy implications of the study stresses that policies aimed at improving educational outcomes can potentially benefit from incorporating nutritional considerations alongside conventional investments in schooling. School meal programmes provide one avenue through which governments can integrate nutritional and educational objectives by improving the quality, diversity and nutritional composition of meals. The experiences examined in this study indicate the potential relevance of nutrient-rich and locally appropriate foods including millets and eggs within such programmes. At the household level policies that strengthen food security and enable households to allocate adequate resources towards children's diets may similarly complement investments in education.

The evidence points towards the value of viewing nutrition and education as complementary dimensions of human-capital formation. Improvements in schooling infrastructure and instructional resources may have limited potential when children face nutritional constraints that affect their ability to participate in and benefit from education. Nutritional interventions may generate greater developmental returns when they operate alongside effective schooling systems. The findings therefore support an integrated perspective in which educational policy and nutrition policy are not treated as separate domains particularly in settings where nutritional deprivation remains an important constraint on children's development.

Future research could strengthen this evidence by combining learning outcomes with direct measures of dietary intake, anthropometric and nutritional status, attendance and household expenditure. Such data would allow the mechanisms suggested by the present study to be examined more directly and would help distinguish improvements in nutritional status from other channels through which household and school-based interventions may affect learning. Overall the study contributes to the growing understanding of human-capital formation by highlighting nutrition as a potentially important complement to schooling and by showing how changes in nutritional conditions can be linked to children's ability to enter, remain within and benefit from the education system.

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