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Discriminatory social norms and early childhood development☆,☆☆

Ashwini Deshpande [a], Rajesh Ramachandran [b,*]

[a] Ashoka University, Department of Economics, Rajiv Gandhi Education City, Sonipat, Haryana 131029, India
[b] Monash University Malaysia, Department of Economics, School of Business, 47500 Subang Jaya, Selangor, Malaysia

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ABSTRACT

This study explores caste-based disparities in childhood stunting in India, focusing on the role of caste-based practices. Using data from the National Family Health Survey, we employ a difference-in-differences (DID) framework to compare stunting rates between dominant and stigmatized caste groups within the same state, across a narrow geographical band on either side of the Vindhyas mountain range—a historical and social boundary associated with greater prevalence of caste-based practices in the north. Our findings reveal that children from stigmatized caste groups north of the Vindhyas exhibit significantly higher stunting rates than their southern counterparts. Validation exercises rule out alternative explanations such as economic disadvantage or disadvantages unrelated to caste. Moderation analyses further show that while socioeconomic and contextual factors partially reduce the stunting gap, they do not explain the persistent north-south divide, underscoring the structural and historical nature of caste-based inequities. These results call for targeted policy interventions addressing both material and structural barriers.

1. Introduction

Child malnutrition is a pressing issue in India, with nearly one-third of children under five classified as stunted—a condition that reflects chronic undernutrition and has far-reaching consequences for human capital development (Karlsson et al., 2021). These outcomes are not uniformly distributed: persistent inequalities in child health outcomes exist along lines of caste and religion, reinforcing cycles of disadvantage (Deshpande and Ramachandran, 2024). Understanding these disparities is critical for designing effective policy interventions to promote health equity.

A first step toward addressing these disparities is to examine the extent of the gap and its geographical distribution. Understanding where inequalities are most pronounced provides a foundation for investigating the mechanisms that sustain them. This paper begins by examining the gaps in child health outcomes by comparing Scheduled Caste (SC) children — historically subject to caste-based discrimination — to the socioeconomically dominant caste groups, the so-called upper-caste Hindus (UC). While the role of

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* Corresponding author.
E-mail addresses: ashwini.deshpande@ashoka.edu.in (A. Deshpande), rajesh.ramachandran@monash.edu (R. Ramachandran).

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socioeconomic factors in shaping child health disparities is well-studied (Van de Poel et al., 2008), there is less clarity on the extent to which these differences can be attributed to structural and historical factors. In the Indian context, caste-based discrimination, for instance, remains a deeply entrenched issue in India, with Scheduled Castes (SCs) historically subjected to exclusionary practices such as untouchability (Barbour et al., 2007). The geographic dimension adds another layer of complexity: the North Central and Central plains of India have higher rates of caste-based practices than the rest of the country (Thorat and Joshi, 2020, p.42). This raises the central research question of this paper: To what extent do caste-based mechanisms, shaped by geographic patterns, contribute to child health inequalities, particularly in terms of childhood stunting?

To address this, we draw on data from the National Family Health Survey-2015-16 (NFHS-IV) for India, and begin by providing a detailed description of the extent and geographical pattern of caste-based gaps in stunting. Our analysis reveals that the gap in child heights is evident across all age profiles (0–60 months) and remains roughly constant at around 0.40 standard deviation units (relative to the world reference median) in favor of UC-Hindu children. In terms of stunting incidence, we find that SC children are approximately 50% more likely to be stunted compared to UC-Hindu children (43% vs. 29%, respectively). The extent of stunting and the magnitude of these gaps are most pronounced in the northern and central plains of India, one of the country's most populous regions. Here, stunting incidence exceeds 40% in 82% of districts for SC children, compared to only 20% of districts for UC-Hindu children. Thus, regions with higher rates of caste-based practices not only exhibit greater overall stunting but also wider caste gaps in child health outcomes.

These descriptive findings motivate our subsequent analysis, which employs a difference-in-differences (DID) framework, leveraging the Vindhyas mountain range as a natural geographic boundary, to disentangle the role of caste-based mechanisms and geography in driving these disparities. The areas to the North of the Vindhyas range comprise the North Central and Central plains, also known as the Indo-Gangetic plain. This was once home to the Indus Valley Civilization around 3000 BCE and was later known as "Aryavarta" during the Vedic period (c. 1500-600 BCE). According to the Manusmṛti[1] (2.22), Aryavarta encompassed the land between the Himalayas and the Vindhyas, stretching from the Bay of Bengal in the east to the Arabian Sea in the west (Gopal, 1961, pg. 70; Cook, 2014, pg. 68). This is what was historically the historical geographical span of Hinduism, bounded to the south by the Vindhyas mountain range (Thapar, 1990; Sharma, 2016).

Drawing on this history, we suggest that the caste system and practices such as untouchability more strongly define the social code of the caste system to the North of the Vindhyas range compared to the South of the Vindhyas range. This is also evident in the higher rates of caste based practices in this part of India (Thorat and Joshi, 2020, p.42). However, Northern and Southern India as broad regions are different in several other ways: language, culture, and socio-economic development indicators. A broad comparison of north and south could be attributable to a multiplicity of factors, not just caste differences. Hence, our empirical strategy is based on a comparison of the SC and UC-Hindu children living in the same state, and within a narrow band to the south and north of the Vindhyas mountain range.[2]

The results indicate that SC children are 21 percentage points (approximately 70%) more likely to be stunted than UC-Hindu children. However, the DID estimates reveal that SC children living within a 100-km band to the south of the Vindhyas range are about eight percentage points less likely to be stunted than their peers living within a 100-km band to the north. This interaction between the SC child dummy and the dummy for living south of the Vindhyas is both economically meaningful and statistically significant. By contrast, the indicator for "South of Vindhyas" is small and statistically insignificant, suggesting that living south of the Vindhyas has no observable effect on stunting outcomes for UC-Hindu children. Taken together, these findings indicate that the benefits of living south of the Vindhyas are not universal but are specific to SC children. This result supports the interpretation that the observed improvements are tied to reduced caste-based discrimination or other caste-related mechanisms in the southern region, rather than being attributable to a general geographic advantage. In addition, we test the robustness of our results by varying the distance from the Vindhyas using optimal bandwidth tests (Calonico et al., 2017). This includes applying different distance cutoffs and excluding areas near the mountain range to account for potential misclassification errors. Our findings remain consistent across these alternative scenarios.

This DID estimate is interpreted as capturing differences in caste-based practices across the Vindhyas range, which we hypothesize as driving the observed disparities in child stunting. To validate this interpretation, we conduct a series of exercises aimed at ruling out alternative explanations for the observed effect. First, we address the concern that the effect could be driven by economic disadvantage, as lower caste groups such as SCs are also economically disadvantaged. By accounting for both caste and economic status simultaneously, we can disentangle their contributions. To do so, we introduce the wealth index factor score of the child's household, interacted with the south of Vindhyas dummy. As expected, wealthier households are significantly less likely to have stunted children, as indicated by the wealth index's strong statistical significance. However, the interaction term between the wealth index and the south of Vindhyas dummy is small and statistically insignificant. Importantly, the SC×South of Vindhyas interaction remains large and significant, ruling out the possibility that the observed effect is solely driven by economic disadvantage.

Next, we examine whether similar patterns emerge for other disadvantaged groups. Specifically, we test for effects among Scheduled Tribes (STs), who share socioeconomic disadvantages with SCs but are not historically subject to caste-based discrimination. Additionally, we analyze two Muslim subgroups: SC-Muslims, who are caste converts from Hinduism, and UC-Muslims, who are not. The results show no significant interaction effects for STs or UC-Muslims, indicating that the benefits of living south of the Vindhyas

[1] Manusmriti or Laws of Manu, is traditionally the most authoritative books of the Hindu code, dating from circa 100 CE. See https://www.britannica.com/topic/Manu-smriti for more details.

[2] The bandwidth is selected using the mean squared error (MSE)–optimal procedure developed by Calonico et al. (2017), implemented via the rdrobust command.

are not generalizable to all disadvantaged groups. For SC-Muslims, however, we observe an economically meaningful reduction in stunting associated with living south of the Vindhyas, though the result is less precise. These findings lend further support to the interpretation that the observed effect is specific to groups historically subject to caste-based discrimination.

Another way to validate our interpretation is through placebo exercises, which test whether the observed effect is unique to the Vindhyas as a historical boundary for caste-based practices. We do this by arbitrarily shifting the boundary line northward or southward, ensuring that the comparisons remain entirely within the north or south regions, such that the Vindhyas line is not crossed. If the observed effect were driven by factors unrelated to the historical significance of the Vindhyas, we would expect to see similar results when using these arbitrary lines. However, our findings show that neither the SC×placebo line interaction nor the placebo boundary itself yields any significant effect. This reinforces the conclusion that the observed divide is tied to the Vindhyas as a historical and social boundary for caste-based practices, rather than reflecting a general north-south difference.

Having established the significant north-south divide in stunting outcomes for SC children and validated the caste-based interpretation of this effect, we now turn to examining the factors that might underlie this gap. To do so, we conduct a moderation exercise, sequentially introducing controls accounting for maternal, child-specific, household, public health, and community-level characteristics. Our findings show that accounting for these covariates significantly reduces the SC dummy from 23 percentage points in the baseline model to about 11 percentage points when all controls are included. This underscores the importance of addressing these factors through targeted policy interventions. For instance, maternal health indicators — such as education, height-for-age Z-scores, and anemia status — emerge as critical determinants, suggesting the need for enhanced prenatal and maternal healthcare programs. Similarly, household socioeconomic status, proxied by the wealth index factor score, and access to improved sanitation — measured through exposure to open defecation — play pivotal roles in reducing disparities. Public health interventions focused on improving sanitation infrastructure could therefore substantially mitigate stunting rates.

However, despite these improvements, the interaction term between SC children and the south of Vindhyas dummy remains large, statistically significant, and robust, decreasing only slightly from 7.7 to 5 percentage points. This persistent gap highlights the enduring influence of caste-based discrimination and exclusionary practices, which socioeconomic and contextual factors alone cannot fully explain. These findings align with patterns observed in racial health disparities in the United States. For example, William et al. (2016) highlight that non-equivalence of socioeconomic status, chronic psychosocial stressors, and persistent discrimination contribute to Black-White health disparities, even when controlling for socioeconomic factors. Translating these insights into the Indian context, it is plausible that SC families in the north face elevated exposure to stressors, such as social exclusion and systemic discrimination, that undermine child health outcomes.

We also examine Height-for-Age Z-scores (HAZ) as an important complementary outcome to stunting, as it captures continuous variation in child growth. In our baseline specification, we find that SC children living south of the Vindhyas are, on average, 0.24 standard deviation units taller (approximately 30%) than their counterparts to the north. Moreover, the dummy for living to the South of Vindhyas is again small and statistically insignificant. Results from additional specifications — including those controlling for breastfeeding, wealth, and other covariates — remain qualitatively similar, though the coefficient loses statistical significance in some cases. This attenuation is largely due to reductions in sample size or increased imprecision, rather than a substantive change in the estimated effect.

Our work relates to a rich body of literature exploring the high rates of stunting in India, motivated by Deaton (2007)'s seminal work on the "Indian stunting puzzle." Deaton highlighted the paradox of India having higher rates of stunting than Sub-Saharan Africa, despite better economic and disease environments. This puzzle has led to various explanations, including the role of birth order effects, as shown by Jayachandran and Pande (2017a), where later-born children, particularly girls, face systematic resource disadvantages, and the prevalence of open defecation (Spears, 2018a). More recently, Von Grafenstein et al. (2023) posit that accounting for sibling size and maternal height explains much of the apparent disadvantage for Indian girls. However, our findings reveal that even when controlling for these factors, the pronounced North-South divide in stunting remains unexplained, pointing to the significance of caste-based social and historical contexts.

Additionally, our findings intersect with a small but significant body of literature examining the role of caste in child stunting. Coffey and Spears (2017) and LoPalo et al. (2019) highlight how caste-based norms, such as untouchability and purity-pollution practices, drive high rates of open defecation and contribute to stunting outcomes across social groups. Extending this line of inquiry, Coffey et al. (2019) demonstrate that in villages with a greater proportion of upper-caste households, children from lower castes experience worse health outcomes, which they attribute to the enforcement of caste hierarchy through social exclusion and limited access to communal resources.

While these studies underscore the importance of caste dynamics at the local level, our work extends this literature by examining caste-based disparities at a regional scale, leveraging the Vindhyas as a historical and cultural boundary. We show that caste diversity at the district level is associated with worse stunting outcomes, consistent with these local-level findings. However, we also demonstrate that these mechanisms fail to account for the persistent North-South divide in stunting among SC children, pointing to the broader structural and historical significance of regional anti-caste movements and cultural shifts in the south. By situating our findings within this broader regional context, our work highlights the enduring influence of caste-based social structures on child health outcomes.

Finally, our paper is also related to the literature on early childhood interventions, which document lasting adverse effects of stunting that shape adult life disparities in cognitive, human capital, health, and material outcomes (Case and Paxson, 2010; Currie and Almond, 2011; Currie and Vogl, 2013; Deshpande and Ramachandran, 2022). The documented findings suggest that SC children are likely to be at a serious disadvantage in adult life, as almost half of them are stunted, leading to multiple forms of disadvantage. This perpetuates a vicious intergenerational cycle, as parental disadvantage gets passed on to their children, who in turn are

chronically undernourished. Our results suggest that tackling early childhood stunting would play a major role in lowering adult-life caste disparities. Recognizing the deadly effects of untouchability and resultant social stigma on early childhood indicators for marginalized groups can pave the way for urgent and appropriate policy responses.

This evidence points to the need for multifaceted strategies that not only address material inequities but also seek to dismantle the deeply entrenched social hierarchies and cultural norms perpetuating these health disparities. Policymakers could draw lessons from global examples, emphasizing the importance of anti-discrimination laws, targeted community programs, and efforts to foster inclusive societal norms. Addressing these structural and psychological barriers is essential to ensure sustained improvements in child health outcomes among marginalized groups.

The remainder of the paper is organized as follows. Section 2 provides the contextual background, introducing the social groups under study and discussing the historical roots of the caste system, particularly the relevance of the North-South divide defined by the Vindhyas. Section 3 presents the data and establishes the extent of caste-based gaps in stunting, as well as their geographical distribution. Section 4 outlines our empirical strategy, while Section 5 presents the main results. Finally, Section 6 concludes with a discussion of the implications and avenues for future research.

2. The context: Caste, discrimination and stunting

This section defines the two primary social groups central to our analysis: UC-Hindus (so-called upper caste Hindus, ranked high in the caste hierarchy) and SCs (Scheduled Castes). We briefly trace the historical roots and geographical span of Hinduism and the caste system, which motivate our empirical strategy (Section 4). Additionally, we present contemporary evidence on the prevalence of caste-based practices, particularly untouchability, with a focus on health-related outcomes. We also highlight the geographical variation in these practices, aligning with the historical descriptions provided in Section 2.2.

2.1. The social groups

The caste system in India comprises of thousands of units called "jatis"[3]. India's affirmative action program targets the most marginalized and historically disadvantaged caste and tribal communities. Thus, data on caste, or more appropriately on social identity, is available for the administrative blocks created for the purpose of affirmative action that club castes, communities and tribes into large groups. There are three such broad groups: the Scheduled Castes (SCs) or Dalits, a collection of jatis historically subject to the stigmatizing practice of untouchability and traditionally at the bottom of the social hierarchy. Distinct from the caste system, India is home to hundreds of aboriginal tribal groups, several of which are included in the category called Scheduled Tribes, or STs.[4] These are also referred to as Adivasis, meaning original inhabitants.

Third is a group of intermediate castes and communities referred to as the Other Backward Classes (OBCs). This includes are jatis that are considered low in the social hierarchy but do not suffer the stigma of untouchability. This group also includes some Muslim and Christian communities.[5] Within the majority religion Hinduism, the residual group of Hindus who do not belong to any of these categories are the so-called upper caste Hindus who are socioeconomically the most advantaged group in the country (Mosse, 2018; Deshpande and Ramachandran, 2019) We refer to this group as the UC-Hindus. Other major religions in India also have caste-like cleavages that we refer to below.

The primary social groups analyzed in this study are the SCs and UC-Hindus. While caste-based population data has not been collected through a national census since 1931, nationally representative surveys estimate UC-Hindus to comprise approximately 14% of the population.

In contrast, SCs, representing around 17% of the population, are among the most socioeconomically disadvantaged groups in India. These castes were traditionally associated with occupations deemed "dirty" or "polluting," leading to their ostracization as outcastes and the stigmatization of untouchability (Deshpande, 2013; Galanter, 1984). The term "Scheduled Castes" originates from administrative classification and refers to a government schedule (list) of several hundred castes (jatis) eligible for affirmative action. Many individuals within these groups identify with the term "Dalit", a Sanskrit word, used in Marathi, meaning oppressed, as a form of self-empowerment and solidarity. Eleanor Zelliot, a leading scholar of caste writes "Dalit became a self-chosen term in 1972 when a group of Bombay youths organized the 'Dalit Panthers', in an effort to encourage the militancy of the American 'black panthers' . Like the word 'black' in the USA, it was used proudly."(Zelliot, 2008).[6]

In addition to SCs and UC-Hindus, we also analyze three other groups to validate our findings. The Scheduled Tribes (STs), comprising around 8% of the population, share many socio-economic disadvantages with SCs (Deshpande and Ramachandran, 2019), but were not traditionally subject to caste-based discrimination or untouchability, as they are outside the folds of the conventional caste system. India's National Commission for Scheduled Tribes lists the following criteria for specification of a community as an

[3] The 1994 K.S. Singh (edited), People of India series, Volume II on "The Scheduled Castes", mentions that 6748 communities were originally identified, of which 4635 communities were identified and studied.

[4] Details about the Scheduled Tribes and various affirmative action and protective measures can be found on the Government of India's Ministry of Tribal Affairs website: www.tribal.nic.in

[5] The full list of OBCs at the Central and State levels can be found at https://ncbc.nic.in

[6] For the origin of the description Dalit as a self-identification, see articles such as this one by the prominent caste scholar and activist Gail Omvedt (https://seekingbegumpura.wordpress.com/2012/07/08/Dalit-or-scheduled-caste-a-terminological-choice/), or thispiece on the history of its usage (https://www.thequint.com/news/india/dalit-history-of-term-political-social-usage#read-more).

ST: "Primitiveness, geographical isolation, shyness and social, educational and economic backwardness due to these reasons are the traits that distinguish Scheduled Tribe communities of our country from other communities"[7].

The other two groups are Muslim subgroups: SC-Muslims, comprising caste converts from Hinduism, and UC-Muslims, representing the socioeconomically dominant Muslim population. In India while overall, the minority Muslim community faces multiple forms of disadvantage (Sachar et al., 2006), there are caste-like cleavages within the Muslim community (Fuller, 1976; Jodhka and Shah, 2010) and several Muslims identify themselves as SC even though Muslim communities are not included in the official SC list. These groups allow us to explore whether the observed north-south differences in stunting are specific to caste-based mechanisms or extend to other disadvantaged groups.

2.2. The historical roots of the caste system

The practice of untouchability entered as one of the codes of the caste system during its evolution on the Indian subcontinent, but the history of the caste system predates the practice of untouchability. Joseph (2018)'s summary of DNA-based research confirms the accounts of historians of ancient India, such as Thapar (1990), from whose work we can establish the following timeline. The north-west of India had a pre-Aryan civilization, the Indus Valley civilization, that started to decline in importance around the 2nd millennium B.C. By 1500 B.C., Indo-Aryan tribes, likely originating from the Iranian plateau or southern Russian steppes, had entered the subcontinent, spreading east and south.

The areas to the north of the Vindhyas range, comprising the North Central and Central plains — also known as the Indo-Gangetic plain — were once home to the Indus Valley Civilization and later became Aryavarta during the Vedic period (c. 1500–600 BCE). Aryavarta, as described in Manusmṛti (2.22), encompassed the land between the Himalayas and the Vindhyas, stretching from the Bay of Bengal in the east to the Arabian Sea in the west (Gopal, 1961, pg. 70; Cook, 2014, pg. 68). This region was the cultural heartland of Hinduism, bounded to the south by the Vindhyas mountain range (Thapar, 1990).

Scholars have further contextualized the significance of this divide. The "Vindhya complex, a continuous chain of mountains, hills, and plateaus which stretches across central India," marked a boundary between Aryavarta and "mleccha desas" or "barbarian lands," where non-Aryan languages were spoken, and Hindu rituals were not observed (Joseph, 2018, 207). *Mlecchas* were people who did not speak Sanskrit and were not Aryans. Manusmṛti, a text composed around the beginning of the Common Era or slightly earlier, laid down the "social obligations and duties of various castes and of individuals in different stages of life" (see Introduction of Doniger and Smith, 1992). It defined Aryavarta as the "country between the Himalayas and the Vindhya mountains, to the east of the Disappearance and to the west of Prayaga."[8] Manusmṛiti included the entire stretch between the eastern and western seas, between the two mountain ranges, as what "the wise men call the Land of the Aryans" (v.22, Chapter 2, Manu, p.27, 1991 edition). However, others, such as Sharma (2016), defined Aryavarta more narrowly as the region between Punjab and Bihar, bounded by the Himalayas in the north and the hills of Malwa in the south, rather than extending all the way to the seas (p. 91).

This historical literature, supported by recent genetic evidence (summarized in Joseph (2018), underscores the importance of the Vindhya mountains as the dividing line between Aryan- and non-Aryan-dominated regions. In its early years, untouchability was not a feature of Aryavarta. On the contrary, Sharma (2016) presents evidence to show that intermixing, intermarriage, and commensality were common social practices among social classes, and manual work was neither stigmatized nor associated with impurity. However, by around 100 C.E., the divisions between *varnas*[9] became rigid, and intermixing ceased. Brahmanical society, which possessed knowledge of metals and agriculture, developed contempt for manual work and extended it to the hands that practiced it. Against the backdrop of the aborigines' low material culture, this growing disdain for manual work, combined with primitive notions of taboo and impurity associated with certain materials, produced the unique social phenomenon of untouchability (Sharma, 2016, pg.146). This practice was most strongly entrenched in the Aryavarta region, whereas religions such as Buddhism and Jainism actively contested it (*ibid.*).

This historical context provides the foundation for our study's hypothesis: caste-based practices, including untouchability, more strongly define social norms in the regions to the north of the Vindhyas than in the south. Consequently, we argue that these practices have a profound influence on caste-based disparities in health outcomes, including childhood stunting. In the next section, we outline contemporary evidence on the prevalence of untouchability-related practices, particularly in health-related services, and their geographical variation consistent with the historical patterns described here.

2.3. The continuing stigma of untouchability and its geography

Despite decades of legal and formal equality between caste groups, discriminatory practices against Dalits remain pervasive and deeply entrenched in Indian society. These include residential segregation, hate crimes, sexual violence (particularly against Dalit women), denial of entry into temples, restrictions on inter-caste marriages, bonded labor, segregation in classrooms, discriminatory treatment by teachers, unequal access to water and irrigation facilities, biased justice systems, and exclusion in public spaces such as streets and marketplaces (Barbour et al., 2007). These practices are manifestations of untouchability, a deeply stigmatizing system

[7] https://ncst.nic.in/content/frequently-asked-questions

[8] The Himalayas and the Vindhyas are two great mountain ranges in Northern and Central India. Prayaga is the city formerly known as Allahabad, now renamed Prayagraj; Vinasana (the Disappearance') is the place where the river Sarasvati disappears.

[9] Varnas are the ancient and original manifestation of the caste system. Over time, the varna system gave way to the contemporary jati system. The same English word, caste, is used to translate both varna and jati.

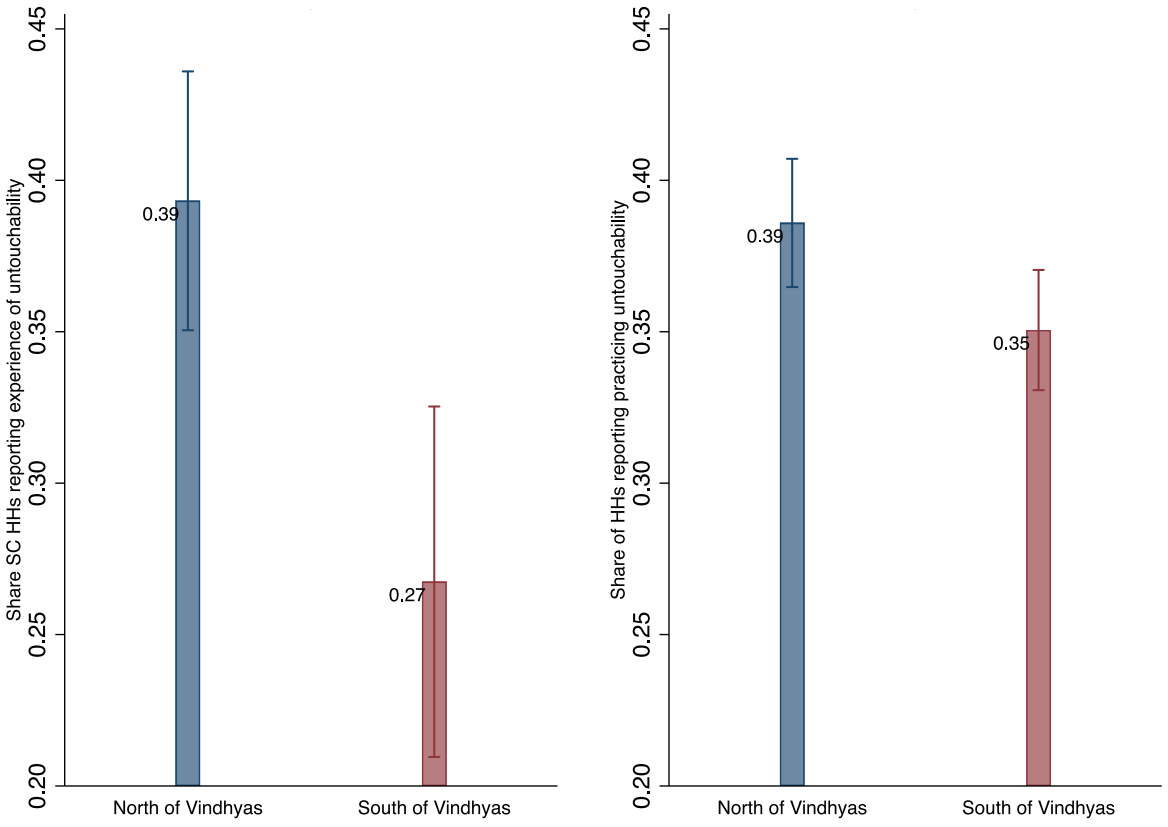

Fig. 1. The prevalence and experience of untouchability.
Notes: The prevalence and experience of untouchability at the district level is calculated from the second round of the Indian Human Development Survey (IHDS) conducted in 2011–12 and is based on self-reports by households on practice and experience. The data is restricted to district lying within 100 kms of either side of the Vindhyas range and restricts it to districts that do not cross the Vindhyas line.

rooted in notions of ritual purity that regard association with waste matter as "impure." Groups engaged in occupations involving contact with human or animal waste — such as manual scavenging, butchery, leather work, and midwifery — have historically been stigmatized as impure. While untouchability was legally abolished and made punishable by law at Independence, both overt and covert instances remain widespread, as discussed below, and seen in Fig. 1.

Discriminatory practices are particularly evident in the sphere of healthcare. Shah et al. (2006, 104), in their study of rural India, report that Dalits were denied entry into private health clinics in 74 out of 348 villages surveyed. Additionally, in 30%–40% of villages, public health workers refused to visit Dalit settlements, and in 15%–20%, Dalits were denied admission to public health clinics. Even when admitted, Dalits faced discriminatory treatment in 10%–15% of the villages. Similarly, Acharya (2010, Table 7.3, 218), based on interviews with 200 Dalit children in Gujarat and Rajasthan, documents widespread caste-based discrimination in rural public health services, including home visits by health professionals, provision of medicines, and diagnostic services. For instance, 91% of Dalit children reported discrimination in receiving medicines, and 87% faced bias during pathological tests. Among grassroots workers, such as Auxiliary Nurse Midwives (ANMs), discriminatory practices were especially pronounced: 94% of respondents reported that ANMs refused to enter Dalit homes, 93% reported that public health workers avoided touching Dalit children while dispensing medicines, and 98% noted that SC children were served food last during mid-day meals. These biases stem from prejudiced views held by healthcare providers, as illustrated by remarks documented by Acharya (2010, 225): "Conventionally, improper drainage, flies and garbage, and consumption of stale food mark their understanding of the Dalits. However, during the group discussions, 'children with running nose, which they keep licking', ill-clad or naked children playing in the dirty streets also emerged as the markers."

The pervasiveness of untouchability is further documented in a study of 1,589 villages in the state of Gujarat, where Davenport et al. (2010) identify 98 distinct practices of untouchability across eight domains, including water access, food and beverage, religion, physical touch, access to public institutions, caste-based occupations, social prohibitions, and private sector discrimination. Relevant to healthcare, they report that in over two-thirds of villages, non-Dalit midwives refused to provide services to Dalit women, and in 10% of villages, even private doctors would not physically touch Dalit patients. In schools, 53% of villages segregated Dalit children during mid-day meals and required them to return home for drinking water. These practices not only perpetuate social exclusion but also exacerbate health inequalities. In a related study of 68 villages in Gujarat, untouchability practices were found

to directly influence health outcomes. For instance, polio vaccination rates among Dalit children were half those of upper-caste children, with untouchability emerging as a significant factor underlying these disparities.[10] These findings underscore the systemic nature of caste-based discrimination and its pervasive impact on health outcomes, particularly for Dalit children.

The widespread practice and experience of untouchability, along with its distinct regional patterns, is evident in one of the few nationally representative data sets that collect such information. The second round of the Indian Human Development Survey (IHDS-II), conducted in 2011–12, surveyed over 42,000 households and posed questions such as "In your household, do some members practice untouchability?" and further inquired, "Would there be a problem if someone who is Scheduled Caste were to enter your kitchen or share utensils?" For Scheduled Caste (SC) households, additional questions explored whether any member had been subjected to untouchability in the past five years.

Analysis by Thorat and Joshi (2020) based on IHDS-II data reveals stark regional disparities in the prevalence of untouchability. Central India and the North-Central Plains report the highest levels of untouchability practices, with nearly 49% and 40% of households, respectively, admitting to such practices. In contrast, these practices are far less prevalent in the southern states, where only 17% of households report practicing untouchability. Similarly, the western and eastern regions exhibit lower prevalence rates, at 13% and 16%, respectively, reflecting significant regional variation in the persistence of caste-based practices.

This geographic variation reflects the historical trajectory of caste practices in India. As discussed earlier, the Vindhyas have historically served as a cultural and social boundary, delineating the Aryavarta region to the north — where caste hierarchies and untouchability-related practices have been more deeply entrenched — from the southern regions, which were less directly influenced by the Indo-Aryan social order. These persistent regional patterns underscore how historical, cultural, and social contexts continue to shape contemporary caste practices.[11]

Fig. 1 provides further evidence on this pattern. Using data from the Indian Human Development Survey (IHDS), we restrict the sample to districts lying within 100 kilometers to the north or south of the Vindhyas. To ensure accuracy, we exclude districts that traverse the Vindhyas line, as the IHDS data is not geocoded. For these selected districts, we calculate two measures: (1) the proportion of households that report practicing untouchability, and (2) the proportion of Scheduled Caste (SC) households that report experiencing untouchability.

The results, presented in Fig. 1, reveal a stark regional contrast. Among SC households, 27% in districts south of the Vindhyas report experiencing untouchability, compared to 39% in districts north of the Vindhyas within the same 100-kilometer range. Similarly, the proportion of households reporting the practice of untouchability is 35% in the south and 39% in the north. While the difference in practicing untouchability is less pronounced than the difference in experiencing untouchability, the overall pattern aligns with the historical evidence highlighting stronger caste-based practices in the north compared to the south. These findings provide a basis for understanding the geographical differences in caste practices and their potential implications for child health outcomes, which are explored in subsequent sections.

3. Data and descriptive statistics

The primary data source for this study is the National Family Health Survey (NFHS-4) conducted in 2015–16. This survey provides anthropometric measurements for a nationally representative sample of 230,898 children under the age of five in India, along with their caste information. For our analysis, we focus on a subsample comprising 45,924 Scheduled Caste (SC) children and 29,132 UC-Hindu children, all aged 0–59 months.

3.1. Height-for-Age-Z-scores and stunting by caste

Panel A and B of Fig. 2 present the height-for-age (HFA) z-scores and the average stunting rates, respectively. The y-axis represents the HFA z-score or stunting rates, while the x-axis shows the child's age in months for the two groups. The graphs reveal three key patterns: (i) at every age, UC-Hindu children are taller and have lower stunting rates than SC children; (ii) HFA z-scores decline sharply, and stunting rates increase significantly for both groups until about 20 months of age, after which they remain relatively stable; and (iii) the time trends in HFA z-scores and stunting rates are similar for both groups.

Panels C and D of Fig. 2 summarize the averages for the two groups. The HFA z-scores for UC-Hindu and SC children aged 0–59 months are −1.12 and −1.64, respectively, indicating that SC children are, on average, more than half a standard deviation shorter than UC-Hindu children. Regarding stunting rates, 29% of UC-Hindu children and 43% of SC children are classified as stunted, meaning SC children are 50% more likely to experience stunting.

To further understand differences by caste group, we construct district-level averages of stunting for SC and UC-Hindu children. The dataset contains information on 585 districts across the country. However, for the groups under consideration, we include only districts where the group has a minimum of 25 observations. This criterion leaves us with 467 districts for SCs and 369 districts for UC-Hindus, respectively.[12]

We classify the districts into five categories based on the average rate of stunting:

[10] See Down To Earth (2011) for more details.

[11] Beyond the historical role of the Vindhyas, southern and southwestern India also witnessed strong anti-caste reform movements. These efforts challenged untouchability, dismantled social hierarchies, and expanded political representation for marginalized groups. Over time, they helped shift societal attitudes and raise awareness of caste inequities—factors that may contribute to the lower prevalence of untouchability in the south.

[12] The average number of observations for SCs and UC-Hindus in these districts is 93 and 73, respectively.

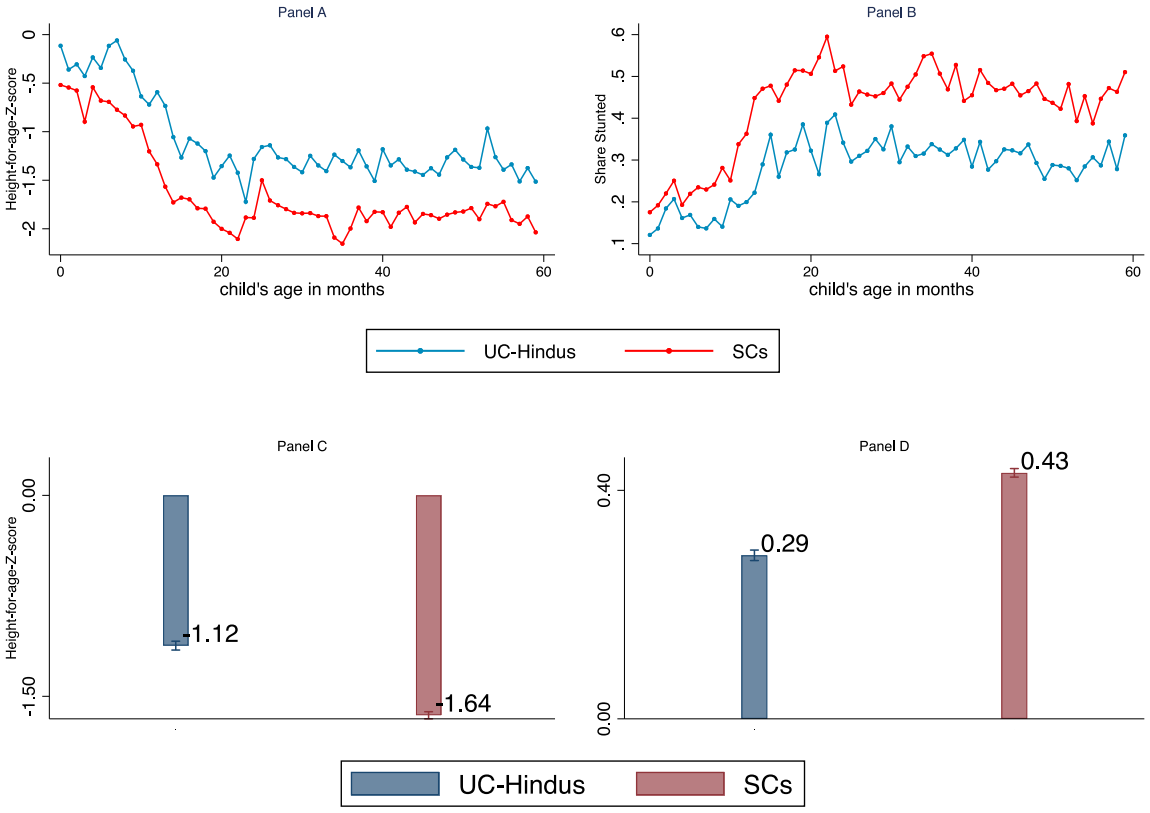

Fig. 2. Height-for-age-Z-score and stunting rates for SC and UC-Hindu children.
Notes: The data is from the Nation Family Health Survey-IV, 2015–16 and consists of a sample of 45,924 and 29,132 SC and UC-Hindu children, respectively.

1. **Category 1:** The average stunting rate lies in the range of 0 to 20%;
2. **Category 2:** The average stunting rate lies in the range of greater than 20% and less than or equal to 30%;
3. **Category 3:** The average stunting rate lies in the range of greater than 30% and less than or equal to 40%;
4. **Category 4:** The average stunting rate lies in the range of greater than 40% and less than or equal to 50%; and
5. **Category 5:** The average stunting rate lies in the range of greater than 50%.

Panel A of Table 1 shows that for SC children, in only 8 districts (1.71%), the average rate of stunting is between 0 and 20%. In 64 districts (13.70%), the average rate of stunting is greater than 20% and less than or equal to 30%; in 139 districts (29.76%), it is greater than 30% and less than or equal to 40%; in 140 districts (29.98%), it is greater than 40% and less than or equal to 50%; and in 116 districts (24.84%), it exceeds 50%.

In contrast, Panel B of Table 1 shows that for UC-Hindu children, in 65 districts (17.62%), the average rate of stunting is between 0 and 20%. In 136 districts (36.86%), the average rate of stunting is greater than 20% and less than or equal to 30%; in 111 districts (30.08%), it is greater than 30% and less than or equal to 40%; in 47 districts (12.74%), it is greater than 40% and less than or equal to 50%; and in 10 districts (2.71%), it exceeds 50%.

In other words, for SC children, stunting rates exceed 40% in 55% of districts, while this is the case in only 15% of districts for UC-Hindu children. Conversely, stunting rates are below 30% in only 15% of districts for SC children, compared to 54% of districts for UC-Hindu children.

3.2. Regional differences in stunting by caste

To shed light on geographical patterns, we plot district-level averages of stunting for SC and UC-Hindu children. Fig. 3 presents color-coded heat maps showing the spatial distribution of the average stunting rates by district and social group. The thin black lines depict district boundaries, while the thick black lines show state boundaries. The prevalence of stunting increases with the intensity of the color.

In terms of regional patterns, Fig. 3 reveals a clear trend: areas with the highest stunting prevalence for SCs are concentrated in

Table 1
Prevalence rates of stunting by category and districts of India.

	No. of districts	Percent
	Panel A - SC children	
0< Share stunted <=20%	8	1.713
20%< Share stunted <=30%	64	13.70
30%< Share stunted <=40%	139	29.76
40%< Share stunted <=50%	140	29.98
Share stunted >50%	116	24.84
Total	467	100
	Panel B - non-SC-ST-OBC-Hindu children	
0< Share stunted <=20%	65	17.62
20%< Share stunted <=30%	136	36.86
30%< Share stunted <=40%	111	30.08
40%< Share stunted <=50%	47	12.74
Share stunted >50%	10	2.710
Total	369	100

Notes: The table presents the prevalence rates of stunting by categories and districts for the SC and UC-Hindu children. Only districts with a minimum of 25 observation for that group are considered, which results in 467 districts for SCs and 369 districts for the UC-Hindus. The average number of SC children in each district is 95 with the median district having 80 observations. For the UC-Hindu children the average number of children in each district is 73 with the median district having 53 observations.

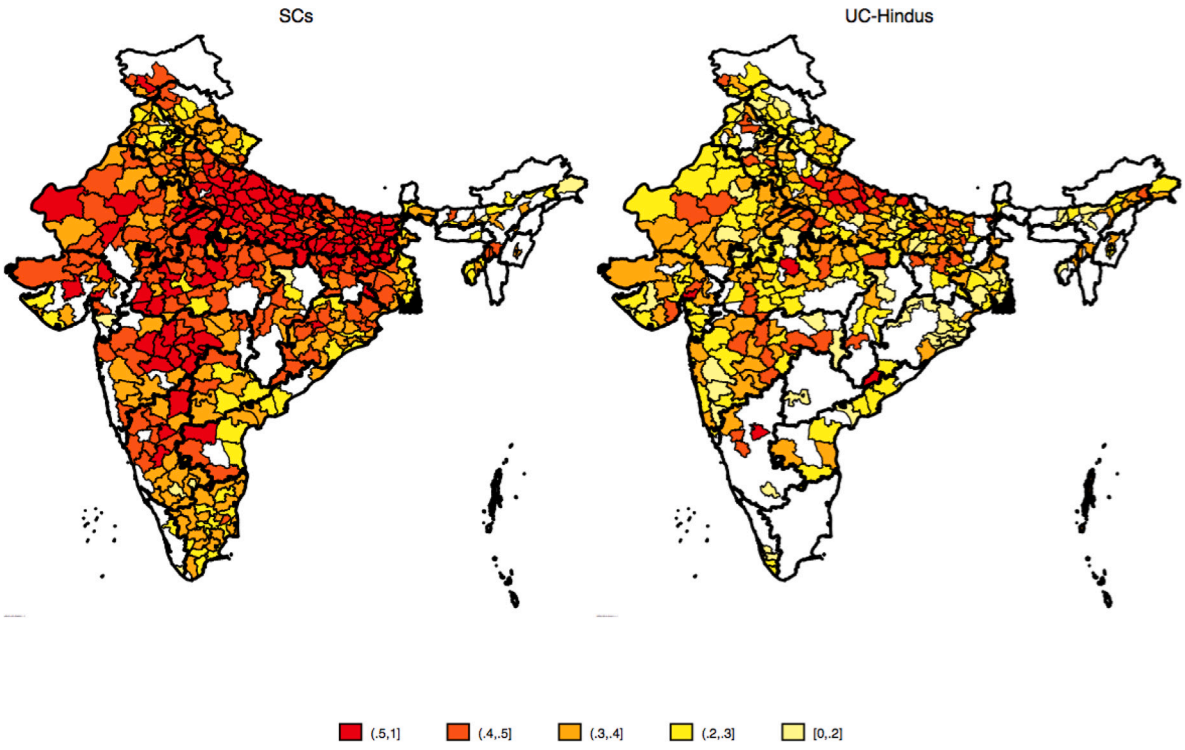

Fig. 3. Stunting prevalence by district for SC and UC-Hindus children aged 0–59 months.
Notes: The data on the on stunting is from the Nation Family Health Survey-IV, 2015–16. Weighted district level averages are shown where the prevalence is increasing in the intensity of the color. The thin and thick black lines refer to district and state boundaries, respectively. Only districts with a minimum of 25 observation are shown. The average number of observation per district is 167. The district wise stunting shares by the two groups for the districts located within 100 kms North and South of Vindhyas is available at https://drive.google.com/file/d/1Qd8S78giHOBtiCTGx95UO9NLmJ-svOwh/view?usp=sharing.

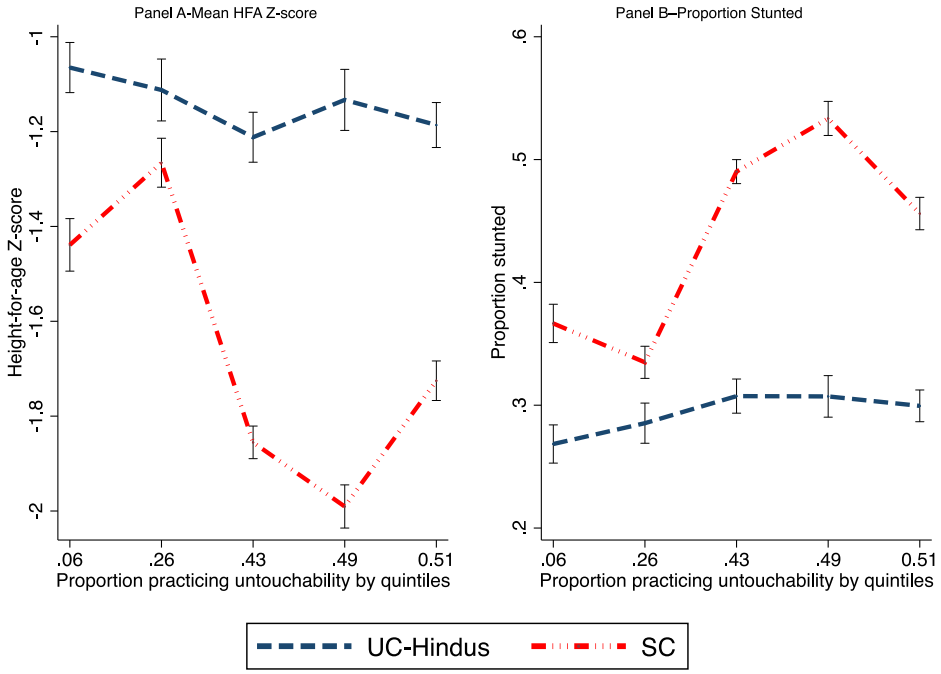

Fig. 4. Practice of untouchability and height-for-age Z-score and stunting.
Notes: The practice of untouchability by households at the state level is calculated from the second round of the Indian Human Development Survey (IHDS) conducted in 2011–12. The above plots the predicted values with the 90 percent confidence intervals arising from a regression estimating the gaps in HFA Z-score and likelihood of being stunted between SC and UC-Hindus at the five quintiles for the practice of untouchability. This data is based on the All-India sample.

the BIMARU states of Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Rajasthan, and Uttar Pradesh. This is visually represented by the northern and central plains being largely red in color. Notably, these regions also exhibit the highest prevalence of untouchability. The BIMARU region is significant due to its large population share, comprising 50.8% of our total sample. Out of the 220 districts in this region, 180 districts (or 82%) report a stunting prevalence greater than 40% for SC children, and in 99 of the 220 districts (or 45%), more than half of the SC children are stunted. By contrast, for UC-Hindu children in the BIMARU region, only 20% of districts show stunting rates greater than 40%, and just 3.61% have stunting rates exceeding 50%.

In contrast, in the southern region, only 24% of districts report a stunting prevalence above 40% for SC children.[13] For UC-Hindu children in the southern region, stunting exceeds 40% in 16% of districts. The eastern and western regions present intermediate patterns.[14] In 34% of districts in the eastern region and 65% in the western region, stunting prevalence exceeds 40% for SC children. However, for UC-Hindu children, only 5% of districts in the eastern region have stunting rates above 40%.

Our estimates indicate that in the BIMARU region of India — home to over 50% of the country's population — not only are stunting rates highest for SC children, but the gap in stunting incidence between SC and UC-Hindu children is also the widest. These regions, primarily located north of the Vindhyas, exhibit the highest rates of untouchability.

To further examine the association between untouchability and child heights, we calculate state-level averages of the proportion of households practicing untouchability, merge this data with the NFHS-IV dataset, and partition the sample into quintiles. We then analyze the relationship between the prevalence of untouchability and child heights, as shown in Fig. 4 for the all-India sample. Panels A and B plot the predicted HFA Z-score and the proportion stunted, respectively, for SC and UC-Hindu children by quintiles of untouchability prevalence. The figure reveals a striking pattern: for SC children, the HFA Z-score decreases sharply (while stunting increases) with higher levels of untouchability. In contrast, for UC-Hindu children, neither height nor stunting appears to be associated with the prevalence of untouchability. These observed patterns motivate our exploration of the role of discrimination in driving caste-based disparities in child height.

We now turn to our method for investigating the role of discrimination in driving these caste-based disparities in child height.

[13] The southern region includes Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, and Telangana.
[14] The eastern region includes Assam, Odisha, and West Bengal and The western region includes Goa, Gujarat, and Maharashtra.

4. Method

4.1. The difference-in-differences estimator

To identify the effect of social practices associated with untouchability on child height, we compare how gaps in anthropometric outcomes vary between UC-Hindu and SC children living north and south of the Vindhyas. Specifically, we estimate a difference-in-differences (DID) model. The motivation for this approach stems from evidence surveyed in Section 2.2, which highlights the historical prevalence of Hinduism being concentrated north of the Vindhyas, where caste-based exclusionary practices such as untouchability have traditionally dominated. Furthermore, as discussed in Section 2.3, these exclusionary practices remain particularly prevalent in the northern regions.

To implement the DID estimator, we proceed as follows: First, we define the Vindhyas mountain range as shown by the black line in Fig. 5, and the blue and the red shaded area shows the principal bandwidth we consider in our analysis.[15] Second, we overlay data from the National Family Health Survey (NFHS-IV), which provides the geographical coordinates for all respondents. Third, we assign each individual a location, categorizing them as living either north or south of the Vindhyas. Finally, we calculate the distance of each respondent from the nearest point on the Vindhya mountain range. We estimate the DID model using the following equation, restricting the comparison to individuals residing within 100 km north and south of the Vindhyas range:

$$O_{isc} = \alpha + \beta_1 SC_i + \beta_2 \text{South of Vindhyas} + \beta_3 SC_i * \text{South of Vindhyas} + \delta_s + \eta_1 X_{sc} + + \eta_2 X_{isc} + f(BD)sc + \epsilon_{isc} \quad (1)$$

Here, O_{isc} denotes the outcome variable, which is either a dummy indicating whether the child is stunted or the HFA-Z-score, for child i residing in state s and cluster c. The coefficient β_1, associated with the SC dummy, captures the difference in stunting rates between SC and UC-Hindu children. The coefficient β_2 captures the effect of living south of the Vindhyas on stunting rates. The key coefficient of interest is β_3, which is associated with the interaction between the SC dummy and the dummy for living south of the Vindhyas. It measures whether living south of the Vindhyas has a differential effect on SC children.

δ_s represents state fixed effects, ensuring comparisons are made among children living within the same state. The function $f(BD)sc$ denotes a second-order RD polynomial of the distance from the centroid of each cluster to the closest point on the Vindhyas range. X_{isc} is a set of individual-level controls, including dummies for age in months, gender, and urban residence. The standard errors, ϵ_{isc}, are clustered at the level of the primary sampling unit to account for spatial correlation.

The Vindhyas act as a natural geographical barrier, implying that geography varies between the regions north and south of the range. To ensure that differences in stunting are not driven by geographic disparities, we include detailed geographical controls at the cluster level from the NFHS. These cluster-level controls, denoted by X_{sc}, include (i) total population for the period 2005–15; (ii) annual precipitation; (iii) aridity; (iv) mean temperature; (v) number of wet days for the period 2005–15; (vi) growing season length; (vii) gross cell production; (viii) absolute latitude; (ix) proximity to water; and (x) proximity to national borders. These factors are included because they potentially influence child height outcomes.

We define the boundary around the Vindhyas using a 100 km bandwidth, chosen based on guidance from the optimal bandwidth literature and common practices in regression discontinuity designs (RDD).[16] This bandwidth allows for a focused comparison of groups residing near the Vindhyas boundary while ensuring a sufficient sample size for reliable estimates. Although the RDD methodology is discussed in detail later, this choice aligns with its principles. In the results section, we test the robustness of this choice by varying the bandwidth.

Fig. 6 shows the raw gaps in stunting rates and HFA-Z-scores for UC-Hindu and SC children living within 100 km to the north and south of the Vindhyas. For UC-Hindu children, the average HFA-Z-score (−1.19 vs. −1.05) and stunting rates (0.30 vs. 0.28) are not statistically different across the two regions, suggesting that living south of the Vindhyas does not provide a generic benefit to child height. In contrast, SC children living south of the Vindhyas show economically significant and statistically meaningful improvements in height and reductions in stunting. Specifically, SC children experience an 8 percentage point (or 17%) reduction in stunting rates when living south of the Vindhyas. The difference-in-differences in stunting rates across the Vindhyas is approximately 6 percentage points, based on raw group averages: while stunting among UC-Hindu children falls by 2 percentage points when moving from the north to the south, the reduction among SC children is 8 percentage points.

While raw averages provide an initial insight, another way to examine these patterns is through a regression discontinuity design (RDD), where the discontinuity is defined at the Vindhyas range. Following Calonico et al. (2017), we implement an RDD estimator for point estimates and robust 95% confidence intervals, using a data-driven bandwidth selection procedure. The results of this exercise are presented in Fig. 7. Similar to the patterns observed in Fig. 6, SC children show statistically significant and economically meaningful improvements in HFA-Z-scores and reductions in stunting rates when crossing the Vindhyas range. For example, the point estimate for stunting is −0.099, with a robust 95% confidence interval of −0.143 to −0.0536, suggesting nearly a 10 percentage

[15] The southern edge of the escarpment is defined as north and parallel to the Narmada River. Further to the east, we use the plains-highland edge (see Fig. 5). Our hypothesis is that Brahminical culture did not diffuse south of the Vindhyas due to their geographic impassibility, characterized by highlands and dense forests. To operationalize this, we use the escarpment edge, which transitions into the Chhota Nagpur plateau in the east. This effectively separates the Indo-Gangetic Plains from the central Indian highlands.

[16] We use the MSE-optimal bandwidth selection method implemented in rdrobust (Calonico et al., 2017), which minimizes the asymptotic mean squared error of the local polynomial estimator. This is a standard approach in regression discontinuity designs and allows for objective, data-driven determination of the optimal window around the discontinuity.

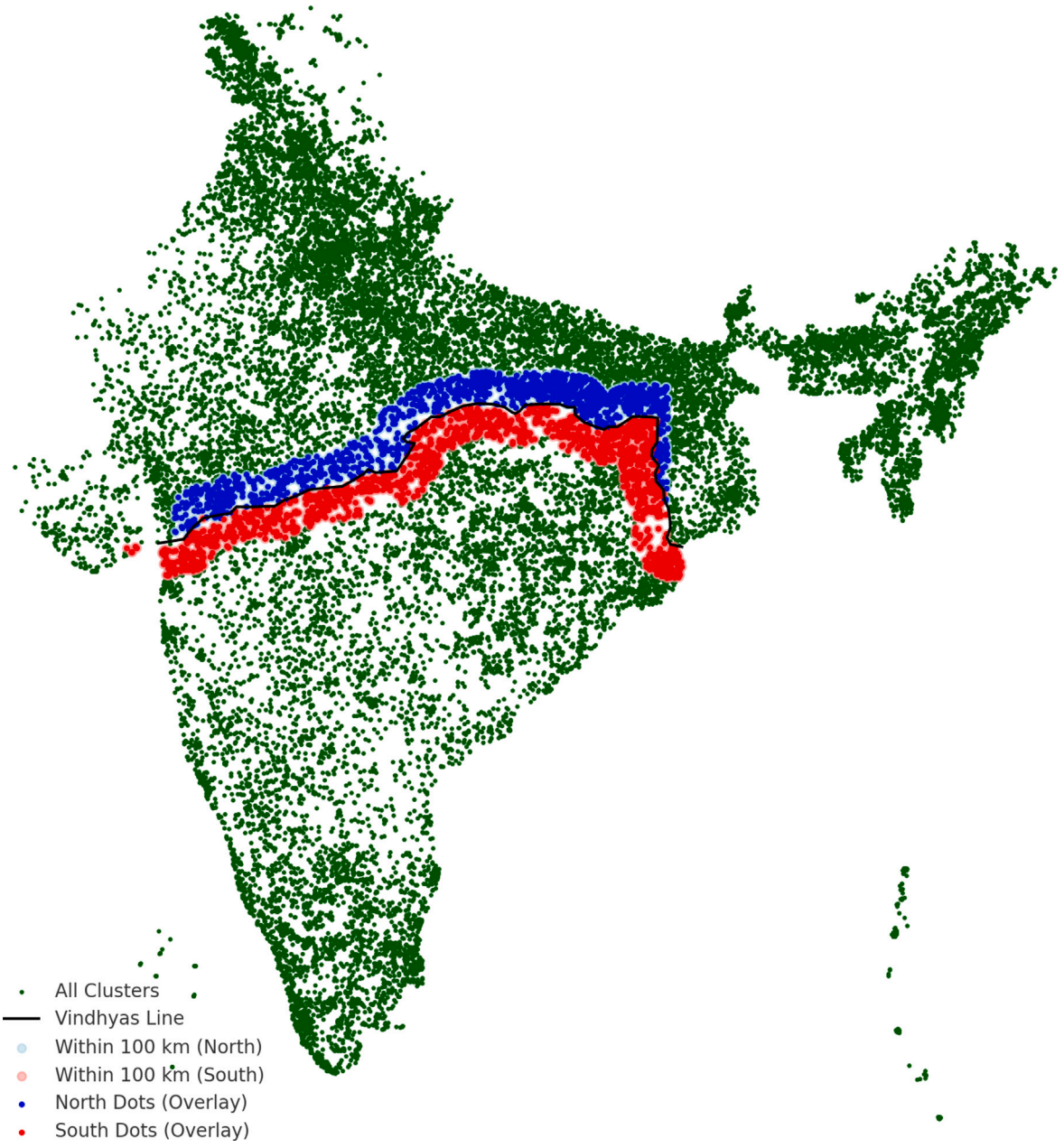

Fig. 5. The map of Vindhyas and the south and north regions.
Notes: The dark shaded line shows the Vindhyas range. The dots show the primary sampling clusters from the NFHS-IV. We in our empirical exercises consider a bandwidth of up to 100 km either side of the Vindhyas range.

point reduction in stunting rates for SC children living south of the Vindhyas. Conversely, for UC-Hindu children, crossing the Vindhyas line has no observable effect on stunting or HFA-Z-scores (e.g., the coefficient for stunting is −0.00069, with a robust 95% confidence interval of −0.048 to 0.047).

While the RDD offers a complementary perspective, its assumptions are stricter than those of the DID. Specifically, the RDD requires that all other factors influencing child height change smoothly across the boundary, with the discontinuity attributed solely to differences in the experience of discrimination. In contrast, the DID approach does not require geography or other contextual factors to remain constant across the regions being compared. Instead, the DID assumes that any differences in these factors have the same effect on stunting for both caste groups. This flexibility makes the DID a more robust method for capturing the differential effects of untouchability on child height.

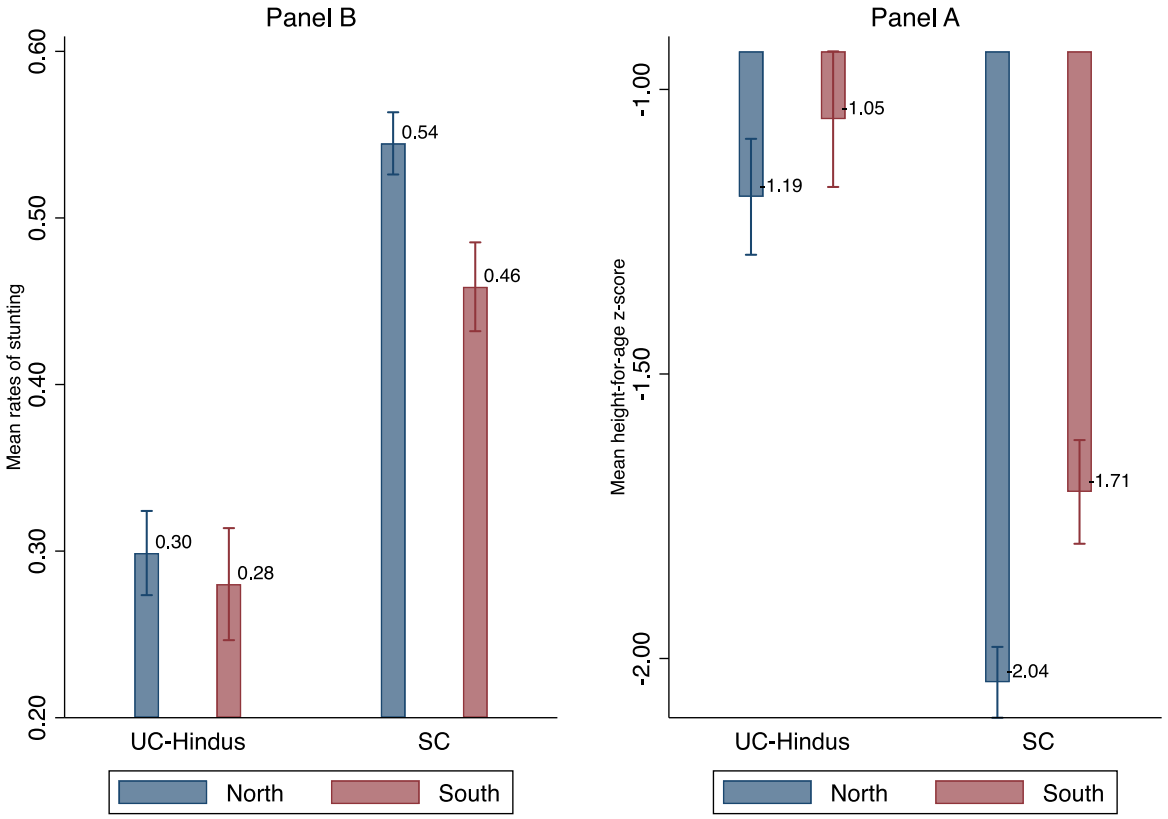

Fig. 6. Average stunting rates and Height-for-age-Z-Scores for UC-Hindus and SC children living 100 km north and south of the Vindhyas.
Notes: The figure plots the raw averages for the height-for-age Z-scores and stunting rates for children living within 100 km to the north and south of the Vindhyas range. The standard errors are calculated accounting for correlation at the primary sampling unit level.

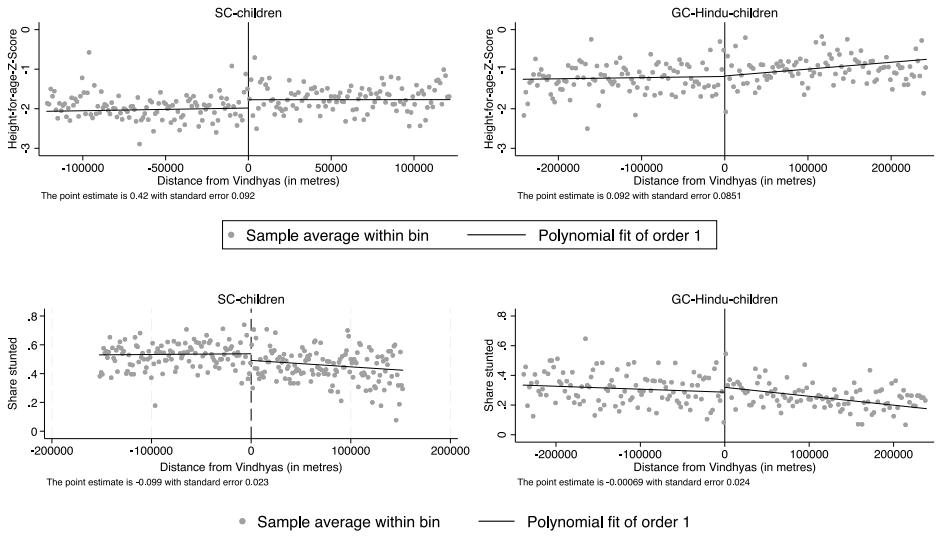

Fig. 7. Regression discontinuity estimates of the north-south Vindhya divide on SCs and UC-Hindus: HFA-Z-Score and Stunting.
Notes: The above plots the results of RDD estimator where the discontinuity is defined at the Vindhyas range. The point estimate, as well as robust 95% confidence intervals, are based on a data-driven bandwidth selection following Calonico et al. (2017).

4.2. Validating the caste-based interpretation of the DID effect

This subsection outlines the analytical approaches we employ to interpret the effect of the DID estimator and validate whether it can be attributed to caste-based discrimination. Specifically, we address the following potential concerns:

Ruling out economic disadvantage. We test whether similar patterns emerge when stratifying by income baselines. If the DID effect were primarily driven by economic disadvantage, we would expect income to explain the observed improvements in anthropometric outcomes across the north-south divide. However, lower caste groups such as SCs are also economically disadvantaged, meaning income indicators may partially capture the effect of caste when considered independently. By accounting for both income and caste effects together, we can disentangle their contributions and determine whether caste, rather than economic disadvantage, is driving the observed patterns.

Testing other disadvantaged groups. We analyze other disadvantaged socioeconomic groups to assess whether the DID estimator can be interpreted as capturing the effect of caste-based discrimination. The first group we consider is the Scheduled Tribes (STs), who are socioeconomically disadvantaged and share similarities with SCs in terms of material outcomes (Deshpande and Ramachandran, 2019). However, STs have traditionally not been part of the caste system. Although they face multiple forms of disadvantage, caste-based discrimination has not historically been one of them. Therefore, if the documented north-south difference for SCs stems from caste-based discrimination, we should observe no such effect for STs.

The second set of groups we examine consists of Muslims, who are a minority religion in India and are disadvantaged as a religious minority along several dimensions (Sachar et al., 2006). The Muslims can be subdivided into those who self-identify as SC-Muslims and those identifying as UC-Muslims.[17] While Islam does not have a formal caste system elsewhere in the world, in the Indian subcontinent, Islam (as well as Christianity) exhibits caste-like divisions. Those at the bottom of this hierarchy often self-identify as SC-Muslims (Jodhka and Shah, 2010). Evidence suggests that SC-Muslims, who are frequently SCs who converted out of Hinduism to escape stigmatization, continue to face caste-related stigma and untouchability-related practices (Trivedi et al., 2016). By contrast, UC-Muslims, though socioeconomically disadvantaged compared to their Hindu counterparts (Sachar et al., 2006), are not former SC converts and do not experience caste-based discrimination. This implies that if caste-based discrimination underlies the north-south divide observed for SCs compared to UC-Hindus, we should observe a similar divide for SC-Muslims but not for UC-Muslims.

Placebo exercise. We conduct a placebo test by arbitrarily shifting the Vindhyas boundary either northward or southward. To ensure that the observed patterns are not artifacts of arbitrary geographic delineations, we modify the comparison framework for these shifted boundaries. Specifically, when the boundary is shifted, comparisons are restricted to individuals residing exclusively to the north or exclusively to the south of the new line. This prevents the analysis from inadvertently capturing the original north-south divide that the true Vindhyas boundary represents. If the observed effects persist with the shifted boundary, this would suggest that the results are not tied to caste-based discrimination. Conversely, if the effects vanish, it strengthens the validity of the true Vindhyas boundary as capturing a meaningful threshold related to caste.

4.3. Exploring moderating factors: Covariates influencing child stunting

To better understand the factors influencing childhood stunting, we examine the role of various moderating factors in the DID framework. These factors, drawn from the literature, are critical determinants of child health and nutritional outcomes.

Maternal characteristics. Maternal health and education are pivotal in determining child health outcomes. Studies have shown that better-educated mothers are more likely to adopt positive health practices and ensure access to healthcare and nutrition for their children (Smith et al., 2003). Maternal height is a key indicator of intergenerational transmission of nutritional status, with shorter mothers more likely to have stunted children (Özaltin et al., 2010). Anemia among mothers, a prevalent issue in many low-income settings, has been linked to adverse pregnancy outcomes and poor child growth (Black et al., 2013).

Child characteristics. Child-specific factors, such as birth order, the number of siblings, and the number of deceased siblings, influence household resource allocation and care practices. Higher birth order is associated with lower investments in early health and nutrition due to resource constraints (Jayachandran and Pande, 2017b). Similarly, the death of siblings can affect household dynamics and caregiving, with potential implications for child health outcomes.[18]

Household socioeconomic status. The wealth index is a composite measure of household living standards and is strongly associated with stunting rates (Li et al., 2020). Wealthier households tend to have better access to healthcare, sanitation, and nutrition, all of which are crucial for child growth and development.

Public health factors. Sanitation and access to clean water are critical determinants of child health. Open defecation contributes to environmental contamination and the transmission of infections, leading to stunting (Spears, 2018b). Improved water sources reduce the risk of waterborne diseases, which impair nutrient absorption and growth (Prüss-Üstün et al., 2002).

[17] These refer to the non-SC, non-ST and non-OBC Muslims.

[18] Sibling death in childhood is linked to higher mortality (Yu et al., 2017), worse cognitive outcomes (Fletcher et al., 2018), reduced caregiving support, and parental distress with long-term health impacts (Song et al., 2010).

Social diversity. Social diversity, particularly in terms of caste and religion, influences access to resources and public goods. Caste diversity has been linked to reduced cooperation and less equitable access to services, affecting health outcomes (Banerjee and Somanathan, 2007). Religious diversity, while less directly studied, may also impact community-level support systems and social cohesion, though its role in child health outcomes remains less well-documented.

Pre- and post-natal care services. Access to pre- and post-natal care is crucial for improving maternal and child health outcomes and mitigating the risk of stunting in early childhood. These services address key vulnerabilities, including maternal nutritional deficiencies, infant feeding practices, and exposure to preventable diseases. In the Indian context, Anganwadi centers and the Integrated Child Development Services (ICDS) program provide a range of maternal and child health services that include prenatal counseling, nutritional supplements, and immunizations[19]. This section examines how variations in access to these services moderate the observed North-South stunting gap, noting that data availability limits the sample size when these controls are introduced.

We focus on three broad components of pre- and post-natal services. First, we explore maternal care and delivery-related factors, such as whether the mother received benefits from Anganwadi/ICDS centers, whether the mother received any form of prenatal care, and whether the child was delivered at home or in a health facility. Institutional deliveries and ICDS engagement are associated with improved maternal and neonatal health outcomes, including lower infant mortality and better growth trajectories (Kandpal, 2011; Bhutta et al., 2013).

Second, we examine breastfeeding practices and dietary diversity. Breastfeeding duration, measured in months, is a key indicator of optimal infant nutrition, linked to better immunity, reduced infections, and healthier growth patterns (Victora et al., 2016). Dietary diversity is measured using the child's intake of key food groups, such as proteins (e.g., eggs, meat, legumes), vitamins (e.g., fruits and vegetables), and micronutrient-rich foods (e.g., dairy products). These factors collectively contribute to the child's immediate nutritional needs and long-term development (Rah et al., 2010).

Finally, we incorporate child immunization coverage as the last component of postnatal services. Vaccination schedules for DPT, polio, and BCG are critical for reducing the prevalence of preventable diseases and improving childhood survival rates (McGovern and Canning, 2015). These vaccines not only provide direct protection to the child but also reduce the overall disease burden in the community, creating a healthier environment for growth.

5. Results

5.1. The baseline DID estimates

Columns (3)–(5) of Table 2 present the results of estimating Equation (1), focusing on the DID analysis. To provide context for these estimates, Columns (1) and (2) report baseline gaps in anthropometric outcomes for SC and UC-Hindu children using simpler comparisons. Panel A uses a dummy variable indicating whether a child is stunted as the dependent variable, while Panel B examines the height-for-age Z-score (HFA-Z-Score) .

Columns (1) and (2) serve as comparison points. Column (1) estimates the stunting gap between SC and UC-Hindu children for the all-India sample, including age-in-month-by-gender controls and state fixed effects. Panel A shows that SC children are 14 percentage points (or 50%) more likely to be stunted than UC-Hindu children, replicating the raw gap shown in Fig. 2. Column (2) restricts the sample to individuals living within 100 km to the north or south of the Vindhyas. For this restricted sample, SC children are 21 percentage points (approximately 70%) more likely to be stunted than UC-Hindu children. The larger gap in Column (2) is expected, as the restricted sample excludes southern states where SC children have better anthropometric outcomes.

Columns (3)–(5) present the main DID estimates. Column (3) shows that the SC dummy is negative and significant, indicating that SC children are 24 percentage points more likely to be stunted than UC-Hindu children. The indicator for "South of Vindhyas" is small and statistically insignificant, suggesting that living south of the Vindhyas has no observable effect on stunting outcomes for UC-Hindu children. The coefficient of interest, β_3, associated with the interaction between the SC indicator and the "South of Vindhyas" indicator, is negative and statistically significant. This is our main DID estimate, which shows that SC children living within 100 km to the south of the Vindhyas are 6.9 percentage points less likely to be stunted compared to SC children living to the north.

The significance of β_3, coupled with the insignificance of the "South of Vindhyas" dummy, suggests that the benefits of living south of the Vindhyas are not universal but specific to SC children. This result reinforces the interpretation that the observed improvements are tied to reduced caste-based discrimination or other caste-related mechanisms in the southern region, rather than being due to a general geographic advantage.

In Column (4), a second-order polynomial for the distance from the Vindhyas is included, and the results remain consistent. Column (5) introduces extensive cluster-level geographical controls, including total population (2005–2015); annual precipitation, aridity, mean temperature, and wet days (2005–2015); growing season length; gross cell production; absolute latitude; proximity to water, national borders, and protected areas; and an urban dummy. The inclusion of these controls slightly increases the magnitude of the reduction in stunting rates for SC children living south of the Vindhyas, while the stunting outcomes of UC-Hindu children remain unaffected. These results suggest that geography does not explain the relative differences in stunting rates across the north and south of the Vindhyas.

[19] https://wcd.delhi.gov.in/wcd/services-under-integrated-child-development-services

Table 2
Difference-in-Differences estimates: Comparing SC and UC-Hindu children to the north and south of the Vindhya mountain range.

	All India Sample	100 kms Bandwidth - North and South of Vindhyas Range			
	(1)	(2)	(3)	(4)	(5)
	Panel A - Dependent variable - Dummy stunted				
SC	0.141***	0.215***	0.238***	0.236***	0.231***
	(0.00581)	(0.0128)	(0.0157)	(0.0157)	(0.0157)
South of Vindhyas			0.0172	0.0131	0.0162
			(0.0242)	(0.0242)	(0.0243)
SC×South of Vindhyas			−0.0694***	−0.0674**	−0.0771***
			(0.0267)	(0.0267)	(0.0264)
Constant	0.288***	0.301***	0.293***	0.305***	1.626***
	(0.00457)	(0.0100)	(0.0135)	(0.0247)	(0.556)
Observations	69,426	10,863	10,863	10,863	10,863
R-squared	0.079	0.118	0.119	0.120	0.124
Mean UC	0.28	0.29	0.29	0.29	0.29
	Panel B - Dependent variable - HFA-Z-Score				
SC	−0.513***	−0.763***	−0.827***	−0.821***	−0.796***
	(0.0209)	(0.0459)	(0.0582)	(0.0582)	(0.0572)
South of Vindhyas			0.00832	0.0229	0.0245
			(0.0919)	(0.0910)	(0.0896)
SC×South of Vindhyas			0.199**	0.192**	0.238**
			(0.0958)	(0.0955)	(0.0952)
Observations	69,426	10,863	10,863	10,863	10,863
R-squared	0.115	0.153	0.155	0.156	0.162
Mean GC	−1.12	−1.13	−1.13	−1.13	−1.13
	Panel C - Controls in Panels A and B				
State fixed effects	Yes	Yes	Yes	Yes	Yes
Gender-age dummies	Yes	Yes	Yes	Yes	Yes
Distance to Vindhyas (2nd Order Polynomial)	No	No	No	Yes	Yes
Geographic Controls	No	No	No	No	Yes

Notes: Column (1) considers the All-India sample of SC and UC-Hindu children, whereas columns (2)–(5) restricts the sample to SC and UC-Hindu children living within 100 km of the Vindhyas range. The geographical controls include total population for the period 2005–15; annual precipitation, aridity, mean temperature, wet days for the period 2005–15; growing season length; gross cell production; absolute latitude; proximity to water; proximity to national borders; proximity to protected areas and an urban dummy. The standard errors are clustered at the level of the primary sampling unit. *p<.05; **p<.01; ***p<.001

Panel B of Table 2 provides results for HFA-Z-Scores instead of the stunting dummy. The pattern of results is similar. In Column (5), which includes age-in-month-by-gender dummies, state fixed effects, a second-order polynomial for distance to the Vindhyas, and geographical controls, SC children are on average 0.80 standard deviation units shorter than UC-Hindu children. The coefficient on "South of Vindhyas" remains small and statistically insignificant. The coefficient of interest associated with the DID estimate shows that SC children living south of the Vindhyas are 0.24 standard deviation units (approximately 30%) taller than their counterparts living to the north.[20]

To test the robustness of the DID estimates, Table 3 varies the distance from the Vindhyas mountain range. Columns (1) and (2) expand the bandwidth to 200 km and 150 km, respectively, and show patterns consistent with those documented in Table 2. Columns (3)–(5) focus on the original 100 km bandwidth but exclude children living within 5 km, 10 km, and 20 km of the Vindhyas range, respectively. This "donut" approach accounts for potential misclassification near the boundary by omitting clusters located very close to the Vindhyas. The results in Columns (3)–(5) are reassuringly similar to the baseline estimates presented in Column (4) of Table 2, further supporting the robustness of our findings.

5.2. Validating the caste-based mechanism of the DID effect

To strengthen the interpretation that the DID effect reflects caste-based mechanisms, we conduct three additional analyses, which are summarized in Table 4.

Ruling out economic disadvantage. Column (1) shows the results of the exercise examining whether the effect is driven by income-based disadvantage by stratifying the sample along income lines. To do this, we include the wealth index value of the household, the

[20] We also examine these patterns using data from NFHS-V, conducted between 2019 and 2021. Data collection during this round was interrupted by the onset of the COVID-19 pandemic, leading to significant temporal variation: some states were surveyed before the pandemic, others afterward, and in certain cases, interviews within the same state spanned multiple years. Given these concerns, our primary analysis relies on NFHS-IV. However, when we replicate Fig. 6 and Table 2 using NFHS-5, we observe qualitatively similar patterns (see Appendix Figure A1 and Table A1).

Table 3
Difference-in-Differences estimates: Comparing SC and UC-Hindu children to the north and south of the Vindhyas range with varying bandwidth and excluding regions close to the line.

	Bandwidth - North and South of Vindhyas Range				
	200 km	150 km	100 km	100 km Excludes areas within	100 km
			5 km	10 km of Vindhyas range	20 km
	(1)	(2)	(3)	(4)	(5)
	Panel A - Dependent variable - HFA-Z-Score				
SC	−0.77***	−0.78***	−0.79***	−0.80***	−0.81***
	(0.043)	(0.047)	(0.058)	(0.059)	(0.061)
South of Vindhyas	0.065	0.13*	0.063	0.046	0.085
	(0.081)	(0.081)	(0.090)	(0.095)	(0.10)
SC×South of Vindhyas	0.21***	0.15*	0.20**	0.21**	0.18*
	(0.079)	(0.082)	(0.096)	(0.099)	(0.11)
Observations	18,826	14,699	10,616	10,194	9,296
R-squared	0.156	0.162	0.165	0.167	0.172
Mean UC	−1.12	−1.13	−1.13	−1.13	−1.13
	Panel B - Dependent variable – Dummy stunted				
SC	0.21***	0.23***	0.23***	0.23***	0.23***
	(0.012)	(0.013)	(0.016)	(0.016)	(0.017)
South of Vindhyas	−0.015	−0.0057	0.0062	0.0062	0.0041
	(0.021)	(0.022)	(0.025)	(0.026)	(0.028)
SC×South of Vindhyas	−0.043**	−0.059**	−0.071***	−0.071**	−0.065**
	(0.020)	(0.023)	(0.027)	(0.028)	(0.030)
Observations	18,826	14,699	10,616	10,194	9,296
R-squared	0.119	0.122	0.124	0.128	0.130
Mean UC	0.29	0.28	0.29	0.29	0.29
	Panel C - Controls in Panels A and B				
State fixed effects	Yes	Yes	Yes	Yes	Yes
Gender-age dummies	Yes	Yes	Yes	Yes	Yes
Distance to Vindhyas (2nd Order Polynomial)	Yes	Yes	Yes	Yes	Yes
Geographic Controls	Yes	Yes	Yes	Yes	Yes

Notes: Column (1) and (2) consider the bandwidth of 200 and 150 km, respectively. Columns (3)–(5) restrict the sample to SC and UC-Hindu children living within 100 km of the Vindhyas range but exclude children living 5 km, 10 km and 20 km, respectively, from the range. The geographical controls include total population for the period 2005–15; annual precipitation, aridity, mean temperature, wet days for the period 2005–15; growing season length; gross cell production; absolute latitude; proximity to water; proximity to national borders; proximity to protected areas and an urban dummy. The standard errors are clustered at the level of the primary sampling unit. *p<.05; **p<.01; ***p<.001

dummy for living south of the Vindhyas, and their interaction term as additional covariates.[21] We observe that, as expected, higher wealth is associated with lower levels of stunting, but the interaction between the wealth index score and the dummy for living south of the Vindhyas is close to zero and statistically insignificant. Moreover, our coefficient of interest "SC×South of Vindhyas" remains large and statistically significant, showing a 6% point benefit for SC children living to the south of the Vindhyas. This result implies that the observed effect is not driven by differences in economic conditions across the north-south divide, reinforcing the argument that caste-based mechanisms are central to the findings.

Testing other disadvantaged groups. Columns (2)–(4) examine whether the North-South Vindhyas divide observed for SC children is also pertinent for other disadvantaged groups. Column (2) introduces an interaction between Scheduled Tribes (STs) and the South of Vindhyas dummy. As noted earlier, STs share a similar socioeconomic profile with SCs but have not traditionally been subject to caste-based discrimination. The results show that ST children are 17 percentage points more likely to be stunted compared to UC-Hindu children. However, the interaction term "ST×South of Vindhyas" is small, positive, and statistically insignificant, suggesting that the benefits observed for SC children do not extend to STs.

Column (3) considers UC-Muslims, who, while socioeconomically disadvantaged compared to UC-Hindus, are not subject to caste-based discrimination. The results indicate that UC Muslims are 7 percentage points more likely to be stunted than UC-Hindus. However, the interaction term "UC Muslims×South of Vindhyas" is negative but statistically insignificant, suggesting that living south of the Vindhyas does not provide significant benefits for this group.

[21] According to the DHS, "The wealth index is a composite measure of a household's cumulative living standard. The wealth index is calculated using easy-to-collect data on a household's ownership of selected assets, such as televisions and bicycles; materials used for housing construction; and types of water access and sanitation facilities." See here for further details.

Table 4
Validating the caste based mechanism of the Difference-in-Differences estimates: Comparing SC and UC-Hindu children to the north and south of the Vindhyas range.

	Bandwidth - 100 km North and South of Vindhyas Range					
	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable - Stunting Dummy					
SC	0.13***	0.23***	0.23***		0.22***	0.11***
	(0.019)	(0.016)	(0.016)		(0.025)	(0.028)
South of Vindhyas	0.0027	0.017	0.017	0.016		
	(0.025)	(0.024)	(0.024)	(0.024)		
SC×South of Vindhyas	−0.059*	−0.077***	−0.079***			
	(0.031)	(0.026)	(0.026)			
Wealth index factor score	−1.0e−06***					
	(1.0e−07)					
Wealth Index Factor Score×South of Vindhyas	−9.5e−08					
	(1.4e−07)					
ST		0.17***				
		(0.024)				
ST×South of Vindhyas		0.015				
		(0.029)				
UC-Muslims			0.069**			
			(0.028)			
UC-Muslims×South of Vindhyas			−0.042			
			(0.053)			
SC-Non-Muslims				0.23***		
				(0.016)		
SC-Non-Muslims×South of Vindhyas				−0.077***		
				(0.026)		
SC-Muslims				0.15**		
				(0.074)		
SC-Muslims×South of Vindhyas				−0.11		
				(0.10)		
Placebo Line 1					−0.033	
					(0.033)	
SC×Placebo Line 1					0.023	
					(0.031)	
Placebo Line 2						−0.024
						(0.045)
SC×Placebo Line 2						0.039
						(0.039)
Observations	10,863	17,928	11,564	10,863	7,029	3,834
R-squared	0.146	0.109	0.122	0.124	0.131	0.154
Mean UC	0.29	0.29	0.29	0.29	0.29	0.29
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Gender-age dummies	Yes	Yes	Yes	Yes	Yes	Yes
Distance to Vindhyas	Yes	Yes	Yes	Yes	Yes	Yes
Geographic Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The geographical controls include total population for the period 2005–15; annual precipitation, aridity, mean temperature, wet days for the period 2005–15; growing season length; gross cell production; absolute latitude; proximity to water; proximity to national borders; proximity to protected areas and an urban dummy. The standard errors are clustered at the level of the primary sampling unit. *p<.05; **p<.01; ***p<.001. For details on the wealth index, see Section 5.2.

Finally, Column (4) distinguishes between SC non-Muslims and SC Muslims, introducing separate interactions for "SC non-Muslims×South of Vindhyas" and "SC Muslims×South of Vindhyas," along with their constituent terms.[22] The results show that SC non-Muslims are 23 percentage points more likely to be stunted compared to UC-Hindus, while SC Muslims are 15 percentage points more likely to be stunted. Interestingly, the interaction term for SC non-Muslims living south of the Vindhyas is −7.7 percentage points and highly statistically significant, indicating a substantial reduction in stunting for this group. For SC Muslims, the interaction term is an even larger effect of −11 percentage points, but it is not statistically significant.

Columns (1)–(4) of Table A2 present results using Height-for-Age Z-scores as the dependent variable. We observe a qualitatively similar pattern to that shown in Table 4. Taken together, these findings suggest that the observed North–South Vindhyas divide is not simply capturing general socioeconomic disadvantage. Rather, the effect appears to be specifically linked to caste-based mechanisms, as comparable benefits are not observed for other disadvantaged groups such as STs or UC-Muslims.

Placebo exercises. Columns (5) and (6) introduce placebo lines to test whether the observed effects are specific to the Vindhyas boundary or arise from random geographical divisions. Column (5) draws an arbitrary line north of the Vindhyas, comparing

[22] SC non-Muslims includes SCs from all other religious groups excluding the Muslims.

individuals living within 0–50 km north of the Vindhyas to those living 50–100 km north. The results show that neither the dummy variable for living 50–100 km north of the Vindhyas nor its interaction with the SC dummy is statistically significant. This suggests that no meaningful differences in stunting outcomes emerge when using a random line within the northern region.

In Column (6), we repeat the placebo exercise with another arbitrary line, this time entirely south of the Vindhyas. Here, the comparison is between individuals living within 0–50 km south of the Vindhyas and those 50–100 km south. Again, the results show that both the dummy for living 50–100 km south of the Vindhyas and its interaction with the SC dummy are statistically insignificant. These findings reinforce that the observed north-south differences in stunting outcomes are not merely driven by geographical proximity to a line but are uniquely tied to the Vindhyas boundary itself. This underscores the importance of crossing the Vindhyas as a meaningful determinant of the observed patterns, further validating the robustness of the DID framework.[23]

5.3. Robustness of the DID estimates: Controlling for covariates

This section examines the robustness of the DID estimates to the inclusion of covariates that might influence childhood stunting.

Mother, child, household, public health and social diversity. For ease of comparison, Column (1) in Table 5 reproduces the baseline specification from Column (5) of the main DID estimates, which indicates that living south of the Vindhyas reduces stunting among SC children by 7.7 percentage points. The discussion focuses on stunting as the dependent variable, while results for height-for-age z-scores, which are shown in Table A3 are also presented and reveal similar qualitative patterns.

In Column (2), we introduce maternal characteristics that are well-documented determinants of child health: the mother's years of education, height-for-age z-score, and anemia status. Maternal education is associated with improved decision-making and access to healthcare, while maternal height reflects intergenerational transmission of nutritional status. Anemia status accounts for maternal health, which is critical for fetal development. As expected, each of these variables is significantly associated with stunting; for example, better maternal health and education reduce the likelihood of child stunting. The interaction term for "SC×South of Vindhyas" remains robust, showing a 6 percentage point reduction in stunting for SC children living south of the Vindhyas.[24]

Column (3) introduces child-specific characteristics, including the total number of siblings, the number of deceased siblings, and the child's birth order, which have been linked to stunting through resource allocation and early life conditions. Their inclusion has little impact on the DID coefficient, which declines only slightly from 7.7 to 7.2 percentage points.

In Column (4), we add the wealth index factor score, capturing household socioeconomic status. Wealthier households are significantly less likely to have stunted children, as expected. Introducing this control reduces the DID coefficient from 7.7 to 5 percentage points, suggesting that wealth accounts for part of the effect but does not fully explain the north-south divide.

Column (5) incorporates household-level public health characteristics, including whether the household defecates in the open, the proportion of households in the primary sampling unit engaging in open defecation, and whether the household has access to an improved water source. Open defecation is strongly associated with higher stunting rates, with children in households practicing open defecation being 11 percentage points more likely to be stunted. Similarly, exposure to open defecation at the community level has a large and statistically significant effect. However, even after accounting for these factors, the DID coefficient for "SC×South of Vindhyas" remains largely unchanged, declining only slightly to 5.6 percentage points.

Column (6) examines the role of social diversity, specifically caste and religious fractionalization, which some literature suggests could influence stunting outcomes. Caste and religious fractionalization are measured at the district level using a fractionalization index derived from the Hirschman–Herfindahl Index (Alesina et al., 2003). This index captures the probability that two randomly selected individuals within a district belong to different caste or religious groups, reflecting the diversity of the population. We find that religious diversity is uncorrelated with stunting, while caste diversity has a large and positive association. Moving from no caste diversity to complete diversity increases the probability of being stunted by 25 percentage points. Despite these strong associations, the DID interaction term remains unaffected and even slightly increases from 7.7 to 7.8 percentage points.

Finally, Column (7) introduces all the covariates simultaneously. Even with this comprehensive specification, the DID coefficient for "SC×South of Vindhyas" only decreases to 5 percentage points. Notably, the south of Vindhyas dummy itself is consistently close to zero and statistically insignificant across all specifications, indicating that there is no generic southward benefit for children regardless of caste.

Turning to the SC dummy, we observe systematic reductions across specifications, indicating that some of the average differences between SC and UC-Hindu children are explained by these covariates. In the baseline comparison (Column 1), SC children are 23

[23] Columns (5)-(6) of Table A2 shows the results when we use the height-for-age-Z-score as the dependent variable, and we again find that the observed effects are specific to the Vindhyas boundary.

[24] To further analyze the effect of maternal education on stunting outcomes, we re-estimate the specification presented in column (5) of Table 2, splitting the sample into two groups: one where mothers have five or fewer years of schooling, and another where mothers have six or more years of schooling. This results in a roughly equal split of the sample, with each group comprising approximately 50% of the observations. The results are displayed in Figure A2. Panel A shows the SC dummy coefficients for each subsample. The average probability of being stunted for SC children is not statistically different across the two groups: SC children are 21 percentage points more likely to be stunted when their mothers have five or fewer years of schooling, and 17 percentage points more likely when their mothers have six or more years of schooling. However, the interaction term for "SC × South of Vindhyas" reveals an intriguing pattern. For mothers with five or fewer years of schooling, the likelihood of stunting decreases by nearly 15 percentage points for SC children living south of the Vindhyas. In contrast, for mothers with six or more years of schooling, this decrease is only about 5 percentage points. One possible explanation for this pattern is that education may serve as a protective shield against discrimination. Discrimination may be more prevalent among individuals with lower levels of education, so the benefits of living in regions with weaker caste-based discriminatory norms are more pronounced for those with less education. This interpretation aligns with the patterns observed in the figure.

Table 5
Difference-in-Differences estimates accounting for moderators: Comparing SC and UC-Hindu children to the north and south of the Vindhyas range.

	Bandwidth - 100 km North and South of Vindhyas Range						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Dependent variable - Stunting Dummy						
SC	0.23***	0.14***	0.22***	0.13***	0.18***	0.23***	0.11***
	(0.016)	(0.016)	(0.016)	(0.018)	(0.017)	(0.016)	(0.018)
South of Vindhyas	0.016	0.014	0.013	−0.0019	−0.0020	0.017	0.0089
	(0.024)	(0.023)	(0.024)	(0.023)	(0.024)	(0.025)	(0.023)
SC×South of Vindhyas	−0.077***	−0.060**	−0.072***	−0.050**	−0.056**	−0.078***	−0.050**
	(0.026)	(0.025)	(0.026)	(0.025)	(0.026)	(0.026)	(0.025)
Mother's HFA-Z-Score		−0.083***					
		(0.0059)					
Years of Education		−0.011***					
		(0.0013)					
Anemia-Severe		0.0050					
		(0.057)					
Anemia-Moderate		0.040**					
		(0.016)					
Anemia-Mild		0.031**					
		(0.012)					
Sibling Size			0.032***				
			(0.012)				
Birth Order			0.0075				
			(0.0058)				
No. of siblings dead			−0.0056				
			(0.012)				
Wealth index factor score				−1.1e−06***			
				(8.6e−08)			
Dummy HH defecates in the open					0.11***		
					(0.015)		
Open defecation at the PSU					0.064**		
					(0.031)		
Improved water source					0.026		
					(0.019)		
District Caste Diversity						0.25**	
						(0.11)	
District Religious Diversity						0.088	
						(0.077)	
Observations	10,863	10,807	10,863	10,863	10,863	10,863	10,815
R-squared	0.124	0.164	0.128	0.145	0.134	0.125	0.151
Mean UC	−1.13	−1.13	−1.13	−1.13	−1.13	−1.13	−1.13
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gender-age dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Distance to Vindhyas	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Geographic Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
All Covariates	No	No	No	No	No	No	Yes

Notes: The geographical controls include total population for the period 2005–15; annual precipitation, aridity, mean temperature, wet days for the period 2005–15; growing season length; gross cell production; absolute latitude; proximity to water; proximity to national borders; proximity to protected areas and an urban dummy. The standard errors are clustered at the level of the primary sampling unit. *p<.05; **p<.01; ***p<.001. For details on the wealth index, see Section 5.2.

percentage points more likely to be stunted than UC-Hindu children. Accounting for maternal characteristics reduces this gap to 14 percentage points, while controlling for wealth reduces it further to 13 percentage points. Including public health factors reduces the gap to 18 percentage points, and with all controls, the SC dummy decreases to 11 percentage points. While this represents a reduction of more than half, a substantial gap remains unexplained by these covariates. Importantly, while the inclusion of additional covariates reduces the point estimate on "SC × South of Vindhyas" from 7.7 to 5 percentage points — approximately a one-third decline — the change is not statistically significant.

Table A3 reproduces Table 5, but uses Height-for-Age Z-scores (HAZ) as the dependent variable. We observe that, when we account for the wealth index factor score (column 3) and include the full set of controls (column 7), the coefficient on "SC×South of Vindhyas" declines from 0.24 to 0.15 and 0.14, respectively, and is no longer statistically significant at conventional levels. Nonetheless, the estimated effect remains substantively large—its magnitude is still over 60% of the baseline specification in column (1). This attenuation in statistical significance is observed only for HAZ; in contrast, the results for stunting — defined as $HAZ < --2$ — remain robust across specifications. This distinction suggests that while the continuous outcome becomes less precisely estimated with additional controls, the main pattern holds when using the commonly employed threshold for identifying growth faltering.

Table 6
Difference-in-Differences estimates accounting for pre and post natal care services: Comparing SC and UC-Hindu children to the north and south of the Vindhyas range.

	Bandwidth - 100 km North and South of Vindhyas Range				
	(1)	(2)	(3)	(4)	(5)
	Dependent variable - Stunting Dummy				
SC	0.23***	0.20***	0.22***	0.22***	0.23***
	(0.016)	(0.017)	(0.017)	(0.019)	(0.020)
South of Vindhyas	0.016	0.032	0.032	0.038	0.039
	(0.024)	(0.024)	(0.025)	(0.031)	(0.033)
SC×South of Vindhyas	−0.077***	−0.092***	−0.099***	−0.090***	−0.090**
	(0.026)	(0.027)	(0.027)	(0.034)	(0.036)
Recd. benefits from anganwadi/icds centre during preg.		0.041***			
		(0.014)			
Prenatal: no care		0.064***			
		(0.016)			
Delivered child at home		0.046***			
		(0.017)			
Months of breastfeeding			0.0021***		
			(0.00066)		
Gave child eggs				−0.13***	
				(0.038)	
Gave child any other fruits				−0.055**	
				(0.026)	
Gave child yogurt				−0.085***	
				(0.029)	
BCG vaccine					0.015
					(0.022)
All DPT vaccines					0.028
					(0.029)
All Polio vaccines					−0.030
					(0.025)
Measles vaccine					−0.012
					(0.024)
Observations	10,863	7,855	8,098	6,396	6,361
R-squared	0.124	0.145	0.140	0.172	0.166
State fixed effects	Yes	Yes	Yes	Yes	Yes
Gender-age dummies	Yes	Yes	Yes	Yes	Yes
Distance to Vindhyas	Yes	Yes	Yes	Yes	Yes
Geographic Controls	Yes	Yes	Yes	Yes	Yes

Notes: The geographical controls include total population for the period 2005–15; annual precipitation, aridity, mean temperature, wet days for the period 2005–15; growing season length; gross cell production; absolute latitude; proximity to water; proximity to national borders; proximity to protected areas and an urban dummy. The standard errors are clustered at the level of the primary sampling unit. *p<.05; **p<.01; ***p<.001

Pre- and post natal care services. Table 6 presents the results of accounting for pre- and postnatal care services.[25] As mentioned earlier, data on these services are not available for the entire sample of SC and UC Hindu children living within 100 kilometers north and south of the Vindhyas. Consequently, the number of observations varies across the columns. Column (1) replicates the baseline results from Column 5 of Table 2 for reference.

In Column (2), we include controls for prenatal care services. These include a dummy for whether the mother received any benefits from an Anganwadi or ICDS center during pregnancy, a dummy for whether the mother received no form of prenatal care (e.g., from a doctor, midwife, auxiliary nurse, community or village health worker, or Anganwadi/ICDS worker), and a dummy for whether the child was delivered at home. Consistent with expectations, having no prenatal care and delivering the child at home are associated with higher levels of stunting. However, these variables have no impact on our principal coefficient of interest, "SC×South of Vindhyas".

Column (3) introduces a control for breastfeeding duration, measured as the total number of months the child was breastfed. Interestingly, while breastfeeding duration is statistically significant, it is positively associated with stunting, which is somewhat counterintuitive.[26] However, again, the "SC×South of Vindhyas" term remains unaffected and, if anything, increases slightly in magnitude.

In Column (4), we include dietary diversity controls to capture the child's diet. These dummies account for whether the child was provided with specific food items such as poultry (e.g., chicken, ducks), bread/noodles, eggs, dark green leafy vegetables, squash or other vegetables, fruits, yogurt, meat, fish/shellfish, or organ meats (e.g., liver or heart). Notably, children who consumed eggs,

[25] Table A4 shows the results when we use the height-for-age-Z-score as the dependent variable.
[26] Table A4 in the Appendix shows that it has no significant relationship with the height-for-age-Z-score.

fruits, or yogurt showed significantly lower probabilities of being stunted. For example, children consuming eggs were 13 percentage points less likely to be stunted, while those consuming yogurt and fruits were 8.5 and 5.5 percentage points less likely, respectively.[27] Importantly, accounting for the dietary improvements, the "SC×South of Vindhyas" term remains unaffected and even increases in magnitude.

Finally, Column (5) includes controls for child immunization status, such as receipt of BCG, DPT, polio, and measles vaccines. Surprisingly, none of these immunization variables show a significant relationship with stunting outcomes. However, the "SC×South of Vindhyas" coefficient remains robust and slightly increases in magnitude.

Table A4 in the Appendix now uses Height-for-Age Z-scores rather than the stunting dummy as the dependent variable and shows a qualitatively similar pattern. One point to note is that in column (3), when we control for months of breastfeeding, the coefficient on "SC×South of Vindhyas" becomes statistically insignificant. However, the estimate remains large in magnitude (0.19 compared to 0.24 in the baseline), and the loss of significance is driven by a substantial drop in sample size, which increases the standard error.

In summary, our results suggest that access to pre- and postnatal care services, dietary diversity, and immunization status do not explain the persistent north–south divide in stunting outcomes between SC and UC Hindu children. These findings underscore the enduring influence of factors beyond material conditions or service delivery in shaping these disparities.

6. Conclusion

Using data from the National Family Health Survey (NFHS-4), we highlight the importance of caste in analyzing early childhood stunting in India. Our study begins by examining the disparities in stunting outcomes between Scheduled Castes (SCs) and the so-called Upper Caste (UC) Hindus, groups positioned at opposite ends of the caste hierarchy. The analysis reveals stark disparities: SC children are significantly shorter on average and are about 50% more likely to be stunted compared to UC children (43% vs. 29%). Furthermore, the gaps persist across all age profiles (0–60 months), with SC children exhibiting an average height deficit of 0.4 standard deviation units compared to the world reference median. These disparities are geographically concentrated, with the Northern and Central Plains — regions characterized by a higher prevalence of caste-based practices — showing the most pronounced stunting rates and gaps.

To understand the mechanisms underlying these disparities, we exploit the Vindhyas mountain range as a natural geographical boundary. Using a difference-in-differences (DID) framework, we find that SC children living to the south of the Vindhyas experience a significant reduction in stunting rates compared to their peers living to the north. Specifically, the DID estimate reveals that SC children in the south are 8 percentage points less likely to be stunted, a result that is both economically meaningful and robust to multiple validations. Notably, this north-south divide does not emerge for other socioeconomically disadvantaged groups, such as Scheduled Tribes (STs) or UC Muslims, who are not traditionally subject to caste-based discrimination. This reinforces the interpretation that the observed effect is tied to caste-related mechanisms rather than general geographic advantages or economic disadvantage.

Further analysis reveals that a broad set of socioeconomic, maternal, and public health factors play an important role in reducing the overall stunting gap between SC and UC children. Maternal health indicators, such as height-for-age z-scores, anemia status, and years of education, are all significantly correlated with childhood stunting. Similarly, household wealth and sanitation practices — measured through the wealth index factor score and open defecation variables — emerge as critical determinants. These factors collectively reduce the average SC-UC gap from 23 to 11 percentage points, highlighting the importance of targeted policy interventions to address these dimensions. However, the inclusion of these controls has a limited effect on the north-south divide for SC children: the DID estimate decreases only marginally from 7.7 to 5 percentage points, and this change is not statistically significant. This persistence in the north-south divide suggests that socioeconomic and public health factors, while important, do not fully account for the disparities observed. Instead, it points to structural and historical factors tied to the differing trajectories of caste reform movements and social attitudes across these regions.

The Northern and Central Plains of India are characterized by a longer and more rigid history of caste hierarchy, where untouchability and caste discrimination were (and in some areas continue to be) institutionalized as part of the social code. Contemporary data, such as from the Indian Human Development Survey (IHDS), reinforce this historical pattern, showing higher prevalence rates of untouchability and caste-based discrimination in these regions. These structural barriers may impede progress and perpetuate stark health disparities even when socioeconomic improvements are achieved.

These patterns of persistence, where historical and structural inequities outlast improvements in material conditions, are not unique to India. Similar findings emerge from research on racial disparities in the United States. Studies on Black and White health disparities, such as those by William et al. (2016), highlight how non-equivalence of socioeconomic status (SES) across racial groups, compounded by ongoing experiences of discrimination and elevated stressors, contribute to worse health outcomes for marginalized communities. Translating these insights into the Indian context, we posit that caste-based hierarchies may exert a similar influence, where the legacy of discrimination and exclusion manifests as psychosocial stressors and barriers to accessing resources, undermining health outcomes for SC children even in regions with better material conditions.

First, the non-equivalence of socioeconomic status across caste groups could mean that the same level of wealth or education does not translate into comparable health benefits for SCs and UCs. This could be due to differential access to networks, healthcare

[27] For brevity, we report only the coefficients of dietary elements significantly associated with stunting.

quality, or societal perceptions of caste. Second, caste-based discrimination itself likely imposes an additional health burden. This may occur both directly—through reduced access to public services or overt acts of exclusion—and indirectly—through chronic stress caused by a lifetime of stigmatization. Third, SC households may face higher exposure to other stressors, such as occupational segregation into hazardous or low-status jobs, or limited political representation, all of which exacerbate health inequities.

These findings underscore the importance of designing policies that go beyond addressing material inequities and also tackle the deeply entrenched social hierarchies perpetuating health disparities. For instance, promoting awareness campaigns, strengthening anti-discrimination laws, and encouraging social inclusion in schools, workplaces, and communities could all play pivotal roles in reducing caste-based health disparities. Furthermore, future research should focus on quantifying the impact of psychosocial stressors and developing interventions to mitigate their effects on health outcomes.

By drawing these connections between the Indian context and broader global patterns of inequity, this study not only sheds light on the enduring impact of caste but also situates these findings within the larger discourse on social exclusion and health disparities worldwide.

Declaration of competing interest

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jebo.2025.107245.

Data availability

Data will be made available on request.

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