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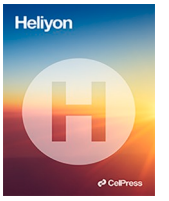

Deepened socioeconomic inequality in clean cooking fuel use in India from 2005-2006 to 2015–2016

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ABSTRACT

Uptake of clean cooking fuels (CCF), such as liquefied petroleum gas (LPG), in place of traditional cooking fuels such as wood, charcoal, and kerosene can improve public health by reducing household air pollution exposures. Though studies have cross-sectionally examined socioeconomic determinants of cooking fuel adoption, little is known about socioeconomic disparities in CCF use over time. Data from the third (2005–06) and fourth (2015–16) rounds of the National Family Health Survey covering 109,041 and 601,509 households, respectively, were used to examine inequities in CCF use in India. While CCF use in India increased nationally from 25% in 2005–06 to 44% in 2015–16, the adoption of CCF varied widely across states and socio-economic groups. Approximately 2% of households in the poorest wealth quintile gained access to LPG during the study period, compared with an increase of 10% or more among households in the middle or richer wealth quintiles; the LPG access gap between the low (0.2%) and middle class (19.2%) was 19% in 2005–06 and nearly doubled to 35% (2.5% vs. 37.4%, respectively) in 2015–16. At the state level, there was a four-fold difference in the uptake of CCF over the two survey periods. The use of CCF increased by less than 10% in Himachal Pradesh, Bihar, Assam, Manipur, Mizoram, and Meghalaya as compared to the increases of at least 30% in Tamil Nadu (42%), undivided Andhra Pradesh (34%), and Kerala (30%). Further, in wealthier states (Delhi, Goa, Punjab, Haryana, Tamil Nadu, Kerala, and undivided Andhra Pradesh), CCF use increased by more than 20% among the poorest individuals compared with less than 1% among the poorest families in lower income states (Tripura, Meghalaya, Madhya Pradesh, Jharkhand, Chhattisgarh, Bihar). To promote a more equitable clean energy transition, poorer and rural Indian households should be prioritized for CCF promotion programs.

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1. Introduction

More than 2.4 billion people, approximately 40% of the global population, primarily use unclean cooking fuels (UCF) including charcoal, firewood, and animal dung [1]. The use of UCF exposes individuals to harmful air pollutants, resulting in an estimated 2.3 million premature deaths annually [1]. In total, health expenditures, productivity losses, and environmental degradation due to the use of UCF cost more than US$ 2 trillion each year [2]. The use of UCF increases health expenditures, which leads to a vicious cycle of fuel and income poverty [3–5]. Access to clean cooking fuels (CCF) such as liquefied petroleum gas (LPG), natural gas, biogas, and electricity for cooking can help break the cycle of fuel poverty [6], leading to better health [7,8], greater educational attainment of children [9], improved gender outcomes [10] and a better standard of living [11]. The inefficient burning of UCF for energy contributes to climate change, and the unsustainable harvesting of trees for wood fuel can result in deforestation and biodiversity loss [2]. Given the social, health, and environmental benefits provided by the use of CCF, universal access to modern energy is one of the UN Sustainable Development Goals (SDG 7: universal access to clean energy) [12].

1.1. Clean cooking fuel in India

India's economic position has improved over the last couple of decades, with higher quality education and healthcare facilities, and better living standards [13,14]. Yet, these benefits have not been uniform across the country and large socioeconomic disparities among the 1.37 billion inhabitants remain consistent [15]. As a result, the gap between the rich and poor has been widening in recent years and is at its highest level since the early 1990s, the richest 10% of the population contain more than three-quarters of the country's wealth, while the bottom 50% account for just 1% [16].

Currently, 41% of households in India exclusively use wood for cooking [17]. This contributed to an estimated 4.8 lakh deaths, a reduction of 1.2 years of life expectancy, and 5% of India's total disease burden in 2016 [18,19]. The Government of India has implemented several programmes to increase access to LPG, which is one of the most rapidly scalable CCF options in the country. LPG schemes promoted in India include the *Rajiv Gandhi Gramin LPG Vitaran Yojana* (RGGLVY) in 2009, *Unnat Chulha Abhiyan* in 2014, *Pratyaksh Hastantrit Labh* (PAHAL) in 2014 and Give it Up in 2015 [20]. Studies have suggested that schemes have disproportionately benefited the middle class, socially advantaged, and urban households [21–23] as the subsidies often did not reach the poor due to a lack of awareness, accessibility, and affordability [22–24]. However, little is known about longitudinal variations in LPG uptake nationally in India across different socioeconomic groups. This paper aims to quantify national and state-level inequities in CCF uptake in India over the decade from 2005-2006 to 2015–2016 by assessing changes in the economic characteristics of individuals.

2. Data and methods

2.1. Data

Data from the third and fourth rounds of the National Family Health Surveys (NFHS), conducted in 2005–06 and 2015–16, respectively, were used [17,25]. The NFHS is a cross-sectional, nationwide survey conducted under the aegis of the Ministry of Health and Family Welfare, which is run by the Government of India. The main objective of the NFHS is to provide data on population and health indicators, including household characteristics, fertility, mortality, maternal and child health, and reproductive health. The NFHS-3 (2005-06) covered a nationally representative sample of 109,041 households and NFHS-4 (2015-16) covered a total of 601, 509 households in India. In the household questionnaire, a question was asked on "type of fuel use by the household for cooking" (primarily) with options of LPG, biogas, electricity, wood, animal dung, agricultural by-product/residue/waste, straw/shrubs/grass, kerosene, coal/lignite, and charcoal.

2.2. Methods

2.2.1. Outcome and predictor variables

The outcome variable was a binary indicator of whether a household primarily cooked with CCF or UCF. The CCF in this study included liquefied petroleum gas (LPG), biogas, and electricity. Households cooking primarily with wood, animal dung, agricultural residue/waste, straw/shrubs/grass, kerosene, coal/lignite, or charcoal were considered to be using UCF.

As the NFHS does not contain information on income, the wealth index was used as a proxy measure of household socio-economic status (SES). The wealth index is a composite score comprising a diverse range of household assets such as land, housing conditions, household amenities, and the presence of domestic servants, etc., further details can be found elsewhere [26]. As the NFHS wealth index includes access to electricity and cooking fuels, we computed a new wealth index excluding electricity and cooking fuels to examine their independent relationship with SES. The wealth index was generated through principal component analysis, grouped into five categories from the poorest (lowest 20%) to the richest (top 20%). Other household-level variables used in this study include the place of residence, educational attainment of the household head, social groups, religion, household size, sex of the household head, access to electricity, and whether the household has a below poverty line (BPL) card (distributed by the Indian government to identify those in need of government help and aid).

2.3. Statistical analyses

The concentration index (CI) was used to quantify changes in levels of inequality in CCF use from 2005- 06 to 2015-16 across states and due to household characteristics. The CI is a measure of the degree of inequality and ranges from −1 to 1. The value −1 indicates pro-poor inequality, while 1 means pro-rich inequality. A value of 0 indicates no inequality [27,28]. The CI is defined as twice the area between the concentration curve and the line of equality. The concentration curve plots the cumulative percentage of the CCF against the cumulative percentage of the sample households ranked by wealth quintile [29]. A concentration curve running below the line of equity would indicate that CCF use is higher among wealthier households and vice-versa. Similarly, a negative CI value reflects a higher use of CCF among poorer households while a positive CI value indicates higher CCF use among wealthier households.

The relative contribution of different socioeconomic and demographic characteristics in the change of using CCF from 2005-06 to 2015–16 was estimated by applying the Oaxaca decomposition model [30,31]. All analyses were conducted using STATA 15.1. The weighting of responses due to the sampling strategy of the NFHS was accounted for using the 'Svyset' command in STATA [32].

3. Results

One quarter (26%) of households in India used CCF in 2005–06 compared with 44% in 2015–16 (Table 1). The prevalence of electricity access increased by a similar amount (20%) during the study period, from 68% in 2005–06 to 88% in 2015–16. The percentage of household heads with education increased slightly from 62% in 2005–06 to 69% in 2015–16. Family size slightly decreased

Table 1
Sample distribution by background characteristics, NFHS-3 (2005-06) and NFHS-4 (2015-16).

Background Characteristics	2005–06		2015–16	
	Percentage (%)	n	Percentage (%)	n
Cooking fuel				
Unclean cooking fuels	74.5	69,278	56.0	372,976
Clean cooking fuels	25.5	39,763	44.0	228,533
Place of residence				
Rural	67.4	50,236	65.1	425,563
Urban	32.6	58,805	34.9	175,946
Wealth index				
Poorest	29.2	21,809	18.6	120,302
Poorer	23.0	21,808	19.0	120,302
Middle	18.0	21,808	19.8	120,302
Richer	15.9	21,808	21.6	120,302
Richest	13.9	21,808	21.0	120,301
Household head's education				
No education[a]	37.7	34,373	30.9	189,082
Primary	18.6	19,593	18.3	111,907
Secondary	34.9	42,197	40.6	244,906
Higher	8.8	12,878	10.2	55,614
Social groups				
Scheduled tribes	8.4	14,708	9.2	114,100
Scheduled castes	19.2	18,251	20.6	108,434
Other backward classes	39.6	34,428	42.2	226,010
Other castes[b]	32.7	41,654	28.0	152,965
Religion				
Muslim	12.5	13,354	12.5	73,067
Hindu	81.6	80,020	81.4	448,411
Christian	2.7	10,042	2.7	49,111
Other[c]	3.2	5625	3.3	30,920
Household size				
1-4 persons	47.6	53,287	52.7	303,199
5-6 persons	31.0	33,782	30.9	192,183
7+ persons	21.4	21,972	16.4	106,127
Sex of household head				
Male	85.6	93,332	85.4	514,128
Female	14.4	15,709	14.6	87,381
BPL card				
No	72.7	85,178	61.4	371,627
Yes	27.3	23,863	38.6	229,882
Access to electricity				
No	32.1	23,204	11.8	71,810
Yes	67.9	85,837	88.2	529,699
Number	109,041	109,041	601,509	601,509

[b] No education also includes don't know.
[c] Other caste also includes missing values of the variable.
[d] Other religion includes Sikh, Buddhist, Jain, Jewish, Parsi, Other and no religion.

over the study period. Over half (53%) of households had a family size of 1–4 persons in 2015–16 i.e., an increase from 48% in 2005–06. About two-thirds of sampled households were from rural areas in both survey rounds.

3.1. Economic inequalities in households gaining access to CCF

While wood (49%) was the predominant primary cooking fuel used by households in 2005–06, its prevalence declined to 41% in 2015–16. It was surpassed by LPG (42%) as the most common primary cooking fuel (Table 2, Table S1). The use of CCF rose from 26% in 2005–06 to 44% in 2015–16. Less than 1% of CCF used were fuels other than LPG (biogas or electricity).

The increase in CCF use in India between the two surveys varied by SES. Approximately 2.3% of households in the poorest wealth quintile gained access to LPG during the study period, compared with an increase in access of 10% or more among households in the middle or richer wealth quintiles (Table 2). These changes resulted in a widening gap in LPG use between the poorest and middle class. Households in the middle quintile had a 19% higher prevalence of LPG use than the poorest households in 2005–06 compared with a 35% difference in primary LPG use in 2015–16 (Table S1). Accordingly, two-thirds of households in the poorest wealth quintile used wood as their primary cooking fuel in 2015–16, as compared to 10% increase in the richest wealth quintile (Figure S1). The prevalence of electricity and biogas cooking fuels remained largely unchanged during the study period (Table 2).

Among the poorest households in India, there was a slight decrease in the prevalence of the most polluting cooking fuels (e.g., animal dung, grass) (Table 2). However, the use of other polluting fuels such as wood, coal, agricultural crops and kerosene increased among households in the poorest quintile, while decreasing across almost all other wealth quintiles (Table 2).

The increase in CCF use between survey rounds was lower among rural households, those in which the household head did not receive an education, larger member households, scheduled tribes, households having below poverty line (BPL) cards, and households with no access to electricity (Table 3). For instance, the use of CCF increased by 21% (60%–81%) from 2005-06 to 2015–16 in urban areas, while rising by 15% (9%–24%) in rural areas during the same period.

The urban-rural gap in the use of CCF also widened between surveys, from 57% in 2005–06 to 63% in 2015–16 (Table 3). Between rural and urban families over the study period, there was a gradient of disparities in gains in CCF access according to income quintile; differences of 15%, 24%, and 12% in the increased usage of CCF were uncovered among middle (rural: 18%; urban: 32%), poorer (rural: 8%; urban: 32%) and poorest quantiles (rural: 2% & urban: 14%), respectively (Table 3).

Among households in the poorest quintile, the increase in CCF use monotonically increased with higher household education levels (Table 3). The CCF access gap between the poorest and wealthiest households decreased among the highest educated households, from 96% in 2005–06 to 87% in 2015–16, while a widening disparity was observed between the poorest and richest wealth quintiles among the lowest education households, from 64% in 2005–06 to 67% in 2015–16 (Table S2).

The resulting change in CI between survey periods due to CCF access was a minimal reduction (−0.04) (Table 3).

Economic inequities in CCF use were most evident among households with a lack of access to electricity (CI: 0.76), belonging to certain social groups (CI among scheduled tribes: 0.69), and with the household head having received no formal education (0.67) (Table S2).

3.2. Use of CCF across states of India

State-level differences emerged in the uptake of CCF over the study period. The prevalence of CCF use rose by over 25% percentage in wealthier states such as Tamil Nadu (42%), Kerala (30%), and Punjab (26%) (Fig. 1). Contrastingly, in poorer states, including Jharkhand and Odisha (9%), Himachal Pradesh (8%), Bihar (8%), Assam (2%), and Meghalaya (1%), less than 10% of households gained access to CCF between surveys (Fig. 1).

Among the poorest income quintiles, the prevalence of CCF use rapidly expanded between 2005–06 and 2015–16 in a few of the wealthier states, namely Delhi (67%), Goa (45%), and Punjab (32%) (Table 4). Comparingly, the uptake of CCF among households in

Table 2
Change in percent of households using cooking fuels by wealth quintiles in India from 2005-06 to 2015-16.

Fuel types	Change (%) 2015–16 to 2005-06					
	Poorest	Poorer	Middle	Richer	Richest	Total
LPG, natural gas	2.3	10.6	18.2	11.2	−0.3	17.6
Biogas	0.1	0.2	0.3	0.4	0.2	0.3
Electricity	0.1	0.3	0.2	0.2	−0.1	0.2
Any Clean Fuel	2.4	11.1	18.7	11.8	−0.3	18.3
Wood	0.1	−3.6	−4.3	−2.4	1.9	−8.2
Animal dung	−0.9	−3.7	−3.7	−1.5	−0.1	−3.4
Agricultural crop	0.7	0.2	−0.9	−1.5	−0.6	−0.9
Straw/shrubs/grass	−4.0	−1.9	−1.2	−0.4	−0.2	−2.8
Kerosene	0.5	−1.8	−5.9	−3.4	−0.3	−2.0
Coal, lignite	0.4	−0.9	−2.6	−1.9	−0.4	−1.0
Charcoal	0.5	0.5	0.1	−0.1	0.0	0.2
Other	0.3	−0.1	−0.3	−0.3	0.0	−0.1
Any Unclean Fuel	−2.4	−11.1	−18.7	−11.7	0.2	−18.2

Table 3
Change in percentage of households using clean cooking fuels from 2005-06 and 2015-16 by background characteristics according to wealth quintiles in India.

Background Characteristics	Change (%) 2015–16 to 2005-06						
	Poorest	Poorer	Middle	Richer	Richest	Total	CI
Place of residence							
Rural	1.9	8.2	17.5	15.7	7.2	15.4	−0.16
Urban	13.5	32.3	32.3	14.0	0.1	20.9	−0.11
Household head's education							
No education	2.4	10.8	21.7	18.5	5.4	16.5	−0.12
Primary	3.2	9.3	17.2	14.0	6.8	17.6	−0.08
Secondary	4.0	12.7	17.9	10.9	0.9	16.7	−0.02
Higher	8.5	19.4	22.5	10.2	0.1	6.3	0.04
Social groups							
Scheduled tribes	1.1	4.6	6.5	0.7	−5.1	9.4	−0.02
Scheduled castes	2.6	12.0	19.4	10.9	−3.5	19.3	−0.10
Other backward classes	3.5	12.9	22.1	12.1	−2.1	22.8	−0.12
Other castes	4.4	12.3	18.2	14.3	3.1	18.2	−0.07
Religion							
Muslim	3.3	11.5	22.4	20.1	6.4	23.9	−0.12
Hindu	2.8	11.4	18.3	10.2	−1.4	17.7	−0.04
Christian	5.1	15.2	23.9	14.1	0.6	19.2	0.00
Others	2.1	7.9	15.1	14.0	4.9	15.5	−0.09
Household size							
1-4 persons	4.0	14.5	21.0	9.6	−0.9	19.9	−0.05
5-6 persons	1.7	9.0	15.8	9.8	−2.6	16.2	−0.04
7+ persons	1.1	5.3	12.4	12.3	1.6	14.1	−0.05
Sex of household head							
Male	2.8	11.1	18.3	11.3	−0.4	18.3	−0.04
Female	3.0	13.5	23.0	15.3	2.0	19.1	−0.06
BPL card							
No	3.5	13.2	19.8	11.6	0.2	21.2	−0.07
Yes	2.4	9.8	20.2	19.9	2.8	−6.6	−0.12
Access to electricity							
No	1.7	7.1	18.3	34.6	50.3	4.8	−0.12
Yes	3.5	11.1	17.2	10.9	−0.4	12.0	0.01
Total	2.9	11.5	19.0	11.9	−0.2	18.5	−0.04

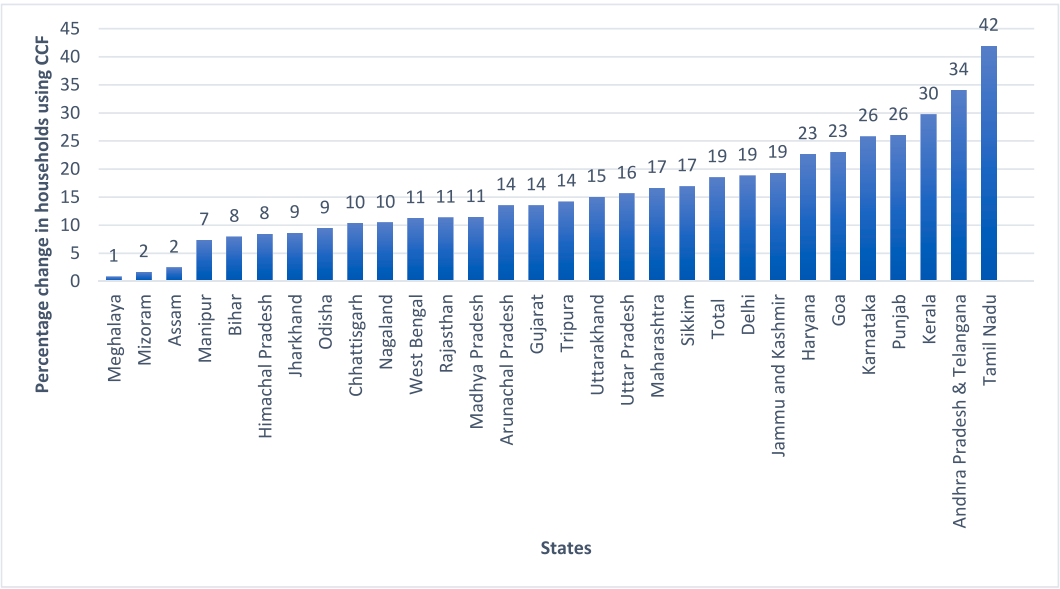

Fig. 1. Percentage in change of households using CCF from 2005-06 to 2015-16 across the states in India.

Table 4
State-level percent change in households gaining access to clean cooking fuels in India between 2005–06 and 2015-16 according to wealth quintile.

States	Change (%) 2015–16 to 2005-06						
	Poorest	Poorer	Middle	Richer	Richest	Total	CI
Andhra Pradesh & Telangana	20.9	35.0	31.0	8.9	−0.1	34.0	−0.17
Arunachal Pradesh	2.6	13.0	18.6	9.8	3.9	13.5	−0.10
Assam	1.0	1.6	0.6	−11.6	−8.3	2.4	0.05
Bihar	0.3	1.6	4.1	6.1	2.2	7.9	−0.01
Chhattisgarh	0.8	2.0	5.6	19.0	2.8	10.3	−0.09
Goa	44.6	42.7	20.0	7.7	3.6	23.0	−0.20
Gujarat	4.6	11.3	12.3	14.2	0.8	13.5	−0.05
Haryana	29.6	32.7	31.0	22.8	3.8	22.6	−0.27
Himachal Pradesh	14.6	11.8	−0.2	−8.4	−7.6	8.4	−0.16
Jammu and Kashmir	9.5	24.0	17.9	11.0	−1.1	19.3	−0.13
Jharkhand	0.6	0.7	3.6	11.1	5.8	8.6	−0.06
Karnataka	6.6	21.1	36.0	34.7	6.4	25.8	−0.21
Kerala	22.0	39.5	34.8	27.5	15.4	29.7	−0.27
Madhya Pradesh	0.6	2.2	3.6	−8.8	−9.3	11.4	0.08
Maharashtra	8.7	11.5	−1.1	−5.4	−2.1	16.6	0.03
Manipur	2.7	3.8	5.7	−4.4	−3.6	7.3	0.00
Meghalaya	0.3	2.5	0.9	−11.7	−12.9	0.8	0.06
Mizoram	4.5	1.5	−4.2	−6.4	−1.8	1.6	0.02
Nagaland	1.2	2.6	4.9	1.9	4.2	10.4	0.05
Delhi	66.6	36.0	11.3	1.9	0.7	18.8	−0.23
Odisha	0.7	1.5	5.4	15.0	10.4	9.4	−0.08
Punjab	32.4	32.1	31.7	20.4	13.1	26.0	−0.23
Rajasthan	2.0	8.9	20.5	16.5	−5.3	11.3	−0.16
Sikkim	17.8	25.4	−4.8	2.8	2.2	16.9	−0.04
Tamil Nadu	25.9	56.6	60.6	33.1	4.4	41.9	−0.34
Tripura	1.0	3.6	11.9	23.2	15.3	14.2	−0.10
Uttar Pradesh	2.1	7.4	15.1	14.5	2.8	15.6	−0.11
Uttarakhand	8.1	17.7	20.2	7.1	−2.3	15.0	−0.10
West Bengal	1.1	2.5	2.4	−2.6	−8.6	11.2	0.01
Andhra Pradesh*	23.9	46.1	64.9	80.9	96.2	62.4	0.31
Telangana*	20.5	45.9	68.7	87.5	98.4	67.6	0.32
Total	9.9	16.2	17.8	11.9	1.4	18.5	−0.04

Note- CI refers to Concentration index, Union territories not shown here, *shows value for 2015–16 only.

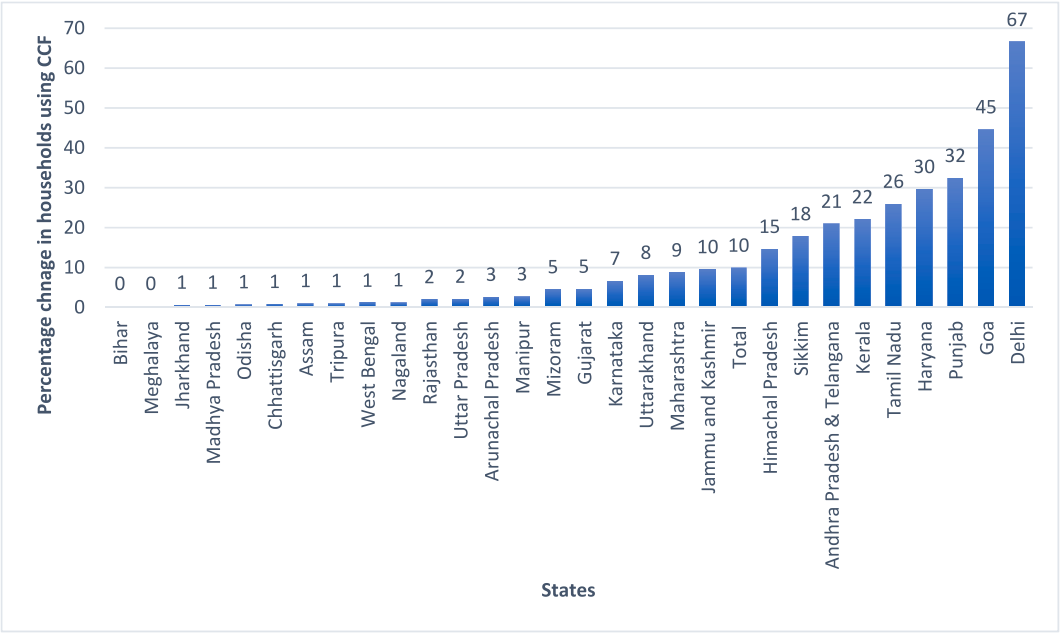

Fig. 2. Change in percentage of households using CCF from 2005-06 to 2015-16 among households in the poorest income quintile across Indian states.

the poorest income quintile during the study period was less than 5% in most of the north-eastern states, including Rajasthan, Madhya Pradesh, Uttar Pradesh and Gujarat. The expansion of CCF use was less than 1% in other poorer states (Tripura, Meghalaya, Madhya Pradesh, Jharkhand, Chhattisgarh, Bihar) (Fig. 2). In 2015–16, the gap in the use of CCF between the poorest and richest wealth quintiles remained over 80% in the states of Arunachal Pradesh, Manipur, Mizoram, Tripura, Gujarat, Maharashtra, Karnataka, Madhya Pradesh, Uttar Pradesh, and Uttarakhand (Table S3). However, four states (Punjab, Kerala, Haryana, Himachal Pradesh) achieved noticeably larger reductions in SES inequities in CCF use (Fig. 3). This equated to large variations in CI at a state level in 2015–16, from 0.53 in Himachal Pradesh to 0.93 in Tripura. Fig. 4 demonstrates that there has been no change in the overall level of inequality in the use of CCF from 2005-2006. This was also seen in some other states, such as Gujarat, although there was a drop in the usage of CCF at that time in Kerala, while the inequality increased in West Bengal.

3.3. Relative contribution of socio-demographic factors in the change of CCF use

The decomposition analysis revealed that household characteristics included in the NFHS explained 40% of the change (19%) in CCF use from 2005-06 to 2015–16. Household income was by far (63%) the largest predictor of changes in CCF use between surveys (Table 5). Access to electricity (21%), household size (8%), urbanicity (6%), and education level of the household head (5%) were also significant determinants of the transition to CCF during the study period. Religion and sex of the household head were not strongly associated with gaining access to CCF from 2005-06 to 2015–16.

4. Discussion

As a large, nationally representative study examining SES determinants of CCF uptake in India, our results show a widening state-level, urban-rural and rich-poor divide in the use of CCF. The largest increase in the use of CCF fuel from 2005-06 to 2015–16 was observed among households in the middle wealth quintiles and wealthier states from northern and southern regions in India. This led to a much higher CI value for CCF use in the less wealthy states of eastern India in 2015–16 (Table 3). The rural-urban gap in the use of CCF during the study period similarly differed according to household wealth quintile; the rural-urban divide in CCF access increased substantially among the poorest 60% of households while declining among the richest 40% of households. For instance, the prevalence of CCF use among urban households in the lowest income quintile was 2.5% higher than that of rural households in 2005–06, but the same is 14% higher in 2015–16. Contrastingly, the use of CCF was 38% higher in urban households compared to rural households in the wealthiest quintile in 2005–06; this disparity decreased to 31% in 2015–16 (Table S2).

Large disparities in CCF use in 2015–16 remained according to education level, household size, household possession of a BPL card, and electricity access (Table 3).

The increased use of CCF among poorer households in urban areas may be attributed to the higher availability and accessibility of LPG, due to a higher density of LPG distributors, improved infrastructure, and better awareness of subsidies and the health benefits of using CCF [33–35]. The low use of CCF in rural areas may be attributed to easier access to cheap, freely available UCF, such as firewood in forest-rich areas of Madhya Pradesh, Odisha, and other north-eastern states and agricultural crop residue and animal dung in the Indo-Gangetic plain [36,37]. To increase the use of CCF in rural areas, increasing the supply of CCF and reducing the distance to the nearest LPG retailer by increasing the density of LPG sellers is critical [38]. Free delivery of LPG cylinders and better road connectivity to villages can also increase the use of LPG [36,39,40].

Following this study period, the Indian government instated the Pradhan Mantri Ujjwala Yojana (PMUY) program in 2016 to remove the initial LPG equipment cost barrier to improve CCF access among low-income households [41]. However, studies suggest that the use of LPG is low among Ujjwala beneficiaries as refilling LPG cost is too high to bear [37,42,43]. Thus, the Indian Government should consider further subsidies on cylinder refill costs for rural and poor households. Such subsidies have been successful in expanding the uptake of LPG among poor households in Tamil Nadu [44].

5. Strength and Limitations

This study importantly documented heightened inequities in the use of CCF over time as opposed to characterizing determinants of CCF adoption at a single point in time. However, several limitations exist. The NFHS does not collect information on secondary cooking fuel type, precluding an investigation of drivers of exclusive versus partial use of CCF. This analysis was limited to household SES determinants of CCF adoption and was unable to capture community-level drivers (availability) and also the nuance of decision-making regarding the use of CCF. Things include the impact of other cultural and supply-demand side factors that impact CCF use [34,38,45,46]. Lastly, the study period occurred before the implementation of the wide-reaching PMUY program, which has the potential to greatly influence the degree of inequities in CCF in the period following 2016 [41]. Investigation into LPG access beyond 2016 is needed to update our understanding of the status of inequities in CCF access in India.

6. Conclusion

From 2005-2006 to 2015–2016, inequitable gains in CCF use occurred with respect to household income and urbanicity. Policies must be implemented that specifically target access to CCF among harder-to-reach poorer households and rural areas of India. Some states may wish to replicate the successful introduction of the ‘Fully subsidized LPG to poor households’ programme in 2006 by the Tamil Nadu Government [44] (GoTN, 2006). Several large-scale studies have shown that providing subsidies for LPG refills for rural

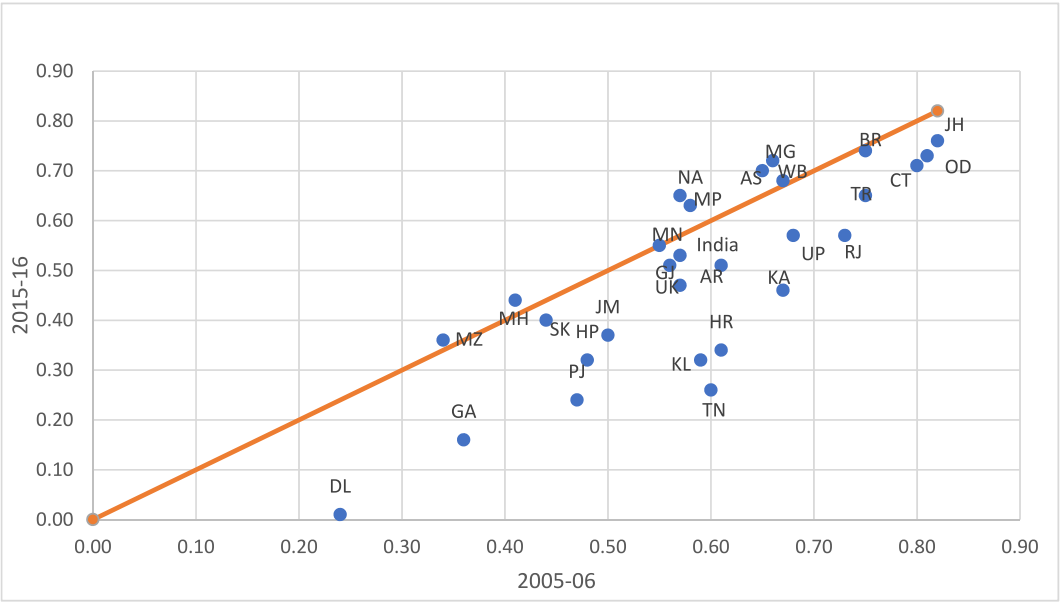

Fig. 3. Concentration index in use of clean cooking fuels across states of India, 2005-06 and 2015-16.

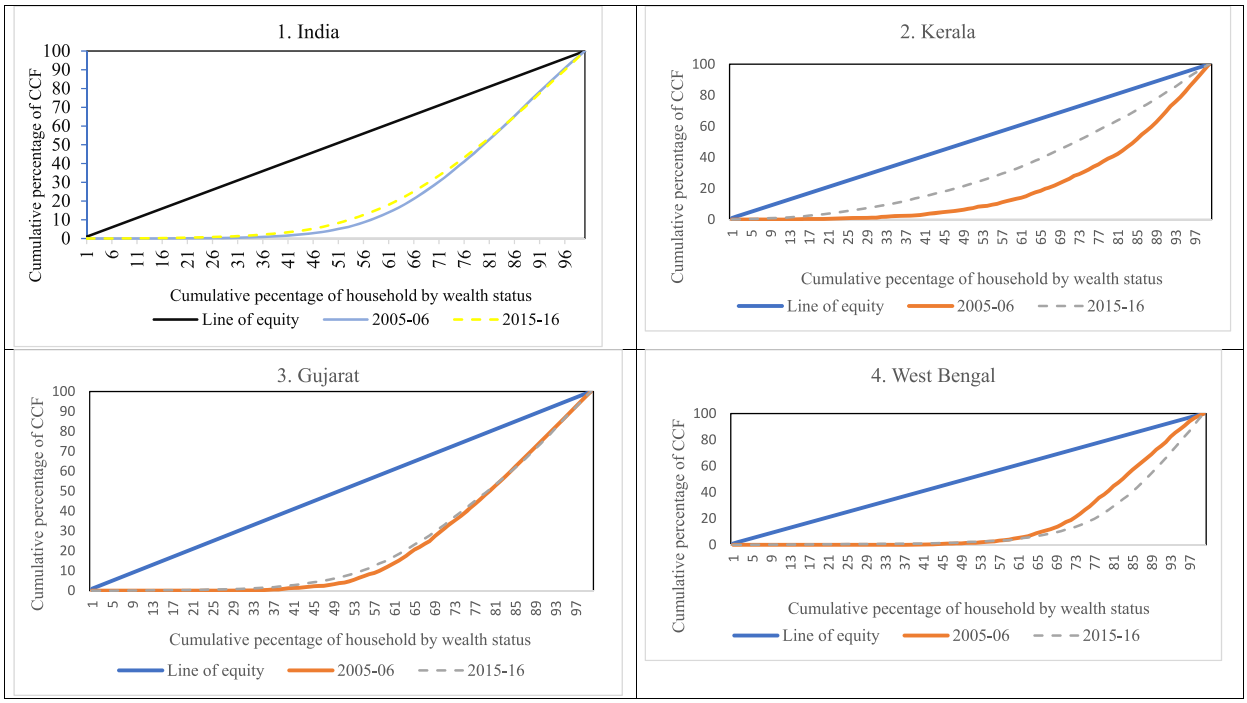

Fig. 4. Concentration curve of the use of clean cooking for India and selected states of Kerala, Gujarat, and West Bengal, 2005–06 and 2015-16.

and poorer households, increasing the density of LPG retailers, providing access to cylinder home deliveries, and allowing for more flexible fuel payment structures are policies that can lead to a more equitable increase in CCF use [36,39,40,47].

Data Availability statement

Data are publicly available and can be accessed by registering at https://dhsprogram.com/data/.
Data will be made available to the researchers meeting the criteria for access to confidential data.

Table 5
Factors contributing to change in use of clean cooking fuels between 2005–06 and 2015–16 in India.

Variable	% Variance explained	*P*-value
Wealth Index	62.6	0.00
BPL card	−0.4	0.01
Access to electricity	20.5	0.00
Household head's education	5.2	0.00
Religion	0.0	0.30
Social groups	−1.5	0.00
Household size	7.5	0.00
Sex of household head	0.1	0.02
Urbanicity	6.0	0.00

Ethical considerations

Our study base on secondary dataset, is available in public domain for research use. Hence, no ethical approval was required from any institutional review board.

Consent for publication

Not applicable.

Author contributions

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Investigation: Samarul Islam.
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Software: Samarul Islam.
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Visualization: Samarul Islam, Md Juel Rana, Matthew Shupler.
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Writing – review & editing: Samarul Islam, Md Juel Rana, Matthew Shupler.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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