From Liquor to LPG: Spillover effects of alcohol prohibition on clean fuel adoption

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ABSTRACT

This paper examines whether Bihar's 2016 alcohol prohibition generated spillover effects on household adoption of LPG as a primary cooking fuel. Although clean cooking lies well outside the policy's intended scope, prohibition may affect fuel choice by altering household expenditure patterns and intra-household dynamics. Using repeated cross-sectional data from the Household Consumption Expenditure Surveys of 2011–12 and 2023–24, we implement a PSM-DID design, comparing Bihar with Jharkhand. We estimate that the prohibition increased primary LPG adoption by 12.8 percentage points. The effect is concentrated in rural areas and is robust to alternative estimators, sample restrictions, and falsification tests. We further discuss that this spillover operates through reduced alcohol spending that relaxes the budget constraint for recurring LPG use and improved women's intra-household agency following prohibition. The results highlight that policies aimed at curbing socially costly consumption can generate broader welfare gains in unexpected domains, including clean energy adoption.

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1 Introduction

Access to clean energy remains one of the most pressing development challenges in South Asia. Clean energy is crucial for addressing the health, economic, and social burdens of widespread use of solid fuel for fundamental needs like lighting, heating, and cooking (Gould and Urpelainen 2018). Clean cooking, in particular, sits at the intersection of public health, gendered time use, and overall household welfare. While there has been significant progress towards achieving the United Nations Sustainable Development Goal 7 of universal access to clean and affordable energy by 2030, persistent inequalities in access to clean energy persist across regions and socioeconomic groups (Astuti et al. 2019; International Energy Agency et al. 2018). In India, despite decades of policy effort, more than 660 million people continue to rely on solid fuels like firewood, dung cakes, crop residue, and coal as their primary source of cooking energy (International Energy Agency 2021).

The epidemiological case for understanding clean cooking adoption is well-established. Balakrishnan et al. (2015) show that solid fuel combustion generates indoor air pollution at levels far above WHO guidelines. Using evidence from Cameroon, Kypridemos et al. (2020) estimate that LPG adoption could avert around 28,000 deaths and 770,000 disability-adjusted life years, underscoring the large welfare gains from clean fuel transitions in low- and middle-income countries. Exposure to indoor air pollution has also been linked to acute lower respiratory infections in children, chronic obstructive pulmonary disease, lung cancer, tuberculosis, and low birth weight (Guarnieri and Balmes 2014; Laumbach and Kipen 2012; Madaniyazi and Xerxes 2021). This is especially salient in India, where the burden of disease and mortality from air pollution is already high and carries substantial economic and social costs (Ali et al. 2021; Balakrishnan et al. 2019). These harms fall disproportionately on women and young children, who spend more time near cooking areas. Beyond health, reliance on solid fuels places heavy time burdens on women through fuel collection, limits their labour market participation, and reinforces energy poverty and broader socioeconomic disadvantage (Maji et al. 2021; Su and Azam 2023). Clean cooking transitions, therefore, reduce both health and time burdens, making energy choice a welfare-enhancing household expenditure.

Yet clean cooking transitions are not simply a matter of awareness or initial access. A large body of evidence links economic development to cleaner household energy choices. The *energy ladder hypothesis* suggests that as household incomes rise, households move toward cleaner and more efficient fuels at the top of the ladder (Hosier and Dowd 1987; Poddar et al. 2021; Song et al. 2018; Van der Kroon et al. 2013). However, Alem et al. (2016), Fentie et al. (2023), Han et al. (2018), and Wassie et al. (2021) questions this linear transition from traditional to modern fuels, documenting that rising income does not necessarily lead households to abandon traditional fuels altogether. Instead, households often *stack* fuels, using modern fuels for some meals while continuing to rely on traditional fuels for others. As a result, even households that obtain LPG connections may not fully switch away from solid fuels. This pattern has persisted despite India's large supply-side push through the Pradhan Mantri Ujjwala Yojana (PMUY) to provide deposit-free LPG connections to poor households.[1] Despite the rapid expansion in connections, adoption of LPG as the *primary* cooking fuel has remained slow. This gap between connection and sustained use points to a binding demand-side income constraint that supply-side programmes alone cannot overcome. Understanding whether a demand-side income shock can shift households toward using LPG as their primary cooking fuel is therefore of direct policy relevance. Increasingly, policy discussions recognize that the key margin is not initial access, but sustained use, which depends on the recurring cost of refills and the household's ability and willingness to allocate liquidity toward LPG amid competing expenditures.

Our paper brings a complementary and underexplored perspective to this debate. We ask whether clean cooking can respond not only to energy-policy initiatives, but also to shocks that reshape household budgets by curbing spending on a 'temptation' or socially costly good. A well-established body of work on household economics highlights that spending on temptation goods or what is classified as 'wasteful expenditure' can crowd out expenditures on welfare-enhancing goods, especially when intra-household preferences diverge, and bargaining power is unequal (Banerjee and Mullainathan 2010; Lundberg and Pollak 1996). In such settings, a policy-induced reduction in spending on temptation goods can operate like a relaxation of the household's liquidity constraint, potentially shifting budgets toward investments with high private and social returns. Building on this idea, we examine whether a sharp reduction in alcohol availability induced by statewide prohibition shifts household budgets in ways that increase investments in welfare-enhancing goods. Specifically, we test whether alcohol prohibition leads to higher use of LPG and higher expenditure on clean fuel.

We study this question in the context of Bihar where a complete prohibition on alcohol was enacted in 2016. Following an initial announcement and rollout, the Bihar Prohibition and Excise Act, 2016 enforced prohibition and regulated enforcement and penalties. The prohibition regime was notified on 2 October 2016, after which the policy environment became more stringent and institutionalized. The ban comprehensively banned the production, sale, and consumption of all alcoholic beverages across the state, enforced through special police units

[1] PMUY was subsequently extended through Ujjwala 2.0 (PMUY Phase-2), launched on 10 August 2021, which sought to cover remaining eligible households and included provisions such as a free first refill and stove for beneficiaries.

and village-level vigilance committees.

Bihar is an especially policy-relevant setting for us because it is both populous and relatively poor, with high baseline reliance on solid fuels for cooking (International Institute for Population Sciences (IIPS) and ICF 2017) and tight household budgets that make expenditure-reallocation mechanisms empirically important. If prohibition reduces alcohol expenditures for a segment of households, either through reduced consumption or through heightened expected costs of purchase, then some of that freed budget may plausibly be reallocated toward goods that improve household well-being, including cooking energy. Concurrently, prohibition could generate substitution toward illicit alcohol, or affect local labor markets and household stress in ways that complicate simple 'freed budget' argument. Such competing possibilities therefore speak to the merit of further empirical investigation of the net effects of an alcohol ban.

Our study also speaks to a growing empirical literature evaluating Bihar's prohibition and its downstream consequences. Bihar's 2016 alcohol prohibition, enacted through the Bihar Excise (Amendment) Act, provides one of the most extensively studied natural experiments in the recent economics literature on prohibition. Existing work has examined impacts on crime and social outcomes leveraging difference-in-differences (DID) framework with neighboring states as comparisons (Chaudhuri et al. 2024; Dar and Sahay 2018; Dar et al. 2024; Falézan 2020; Jha and Sharma 2026; Krishnatri and Vellakkal 2026; Kumar and Prakash 2016; Majeed and Vellakkal 2025). Related studies examine population-level health indicators and domestic violence outcomes around the ban, with suggestive evidence of improvements in women's welfare and empowerment channels when male alcohol consumption declines (Aggarwal et al. 2025; Chakrabarti et al. 2024; Dar and Vellakkal 2024; Dixit and Mukherjee 2025; Mookerjee et al. 2025). While this literature has generated important insights into social harms and health outcomes, much less is known about whether prohibition triggers measurable shifts in household consumption portfolios toward productive inputs, particularly in domains like household energy that matter for health, time use, and women's daily lives.

Empirically, we estimate the effect of Bihar's prohibition on LPG use and LPG expenditure using a DID framework, complemented by a kernel based propensity score matching DID (PSM-DID) approach. Its sudden and comprehensive nature, combined with the availability of pre- and post-ban survey data across comparable states, has made it a near-ideal quasi-experimental setting (Kumar and Prakash 2016). We treat Bihar as the treated state and use Jharkhand as the control state, consistent with a strand of Bihar-focused quasi-experimental research that leverages geographic proximity and similar pre-policy trajectories (Chaudhuri et al. 2024; Dar and Sahay 2018; Dar et al. 2024; Dixit and Mukherjee 2025; Mookerjee et al. 2025).

A recurring finding in this literature is that what changes post-ban is households' financial capacity to act on pre-existing preferences (Jha and Sharma 2026). Besides, the clean cooking literature establishes that income constraints and women's agency are first-order determinants of whether households sustain primary LPG use (Chatterjee and Poddar 2026; Gould et al. 2020; Nandwani and Jain 2024; Zhang et al. 2022). The intersection of these two bodies of evidence points toward a causal pathway from alcohol prohibition to clean cooking transitions although no existing paper has directly estimated its causal effect on LPG adoption as the primary cooking fuel. Falézan (2020) treats energy as part of a broad 'productive expenditure' aggregate. Majeed and Vellakkal (2025) mention increased energy spending in NSSO data but do not disaggregate to LPG specifically or estimate causal effects on cooking fuel choices. Our paper occupies this gap.

A key identification challenge we confront is that clean cooking access expanded nationally over a similar period through PMUY and led to changes in LPG availability and pricing. These nationwide forces could increase LPG adoption across many states irrespective of prohibition. Our design therefore emphasizes relative changes in Bihar versus Jharkhand before and after the alcohol prohibition. Our findings point to a consistent pattern. Bihar's prohibition led to an increase in LPG use by 12.8 percentage points. We note consistently statistically significant results across sub-samples sliced by age and gender of the head of the household, household size, and social groups. Interestingly, the ban has a statistically significant effect on LPG use only for the rural subsample, highlighting the particular significance of such a ban for rural households where clean fuel access is more constrained. Our results survive a series of robustness tests, including an alternative estimation strategy utilizing coarsened exact matching; sample restrictions to exclusion of bordering districts of Bihar and Jharkhand that may have contributed to unregulated movement of people and alcohol; alternative definitions of control groups; augmenting our DID setup to include an additional pre-period round of survey data; and falsification tests. A plausible channel of the effects of alcohol ban on LPG use is improvements in women's agency as already documented in Chatterjee and Poddar (2026), Dixit and Mukherjee (2025), Mookerjee et al. (2025), and Zhang et al. (2022). We provide further evidence of expenditure reallocation as another channel of our impacts. We find an increase in LPG expenditure and a decline in alcohol expenditure in real terms. This is accompanied by a larger increase in LPG connections for the sub-sample that witnessed a greater decline in alcohol expenditure.

Clean cooking concerns are typically framed around energy infrastructure, price subsidies, and behavioral interventions. Our results suggest that policies that reduce expenditures on socially costly goods such as alcohol may also generate spillovers into household investments with large health and welfare returns. Our results ought not to be read as an argument for evaluating prohibition as an energy policy, nor are we downplaying the potential costs of prohibition regimes. Rather, our contribution is to document a concrete channel, i.e., household budget reallocation toward cleaner cooking, that complements existing evidence on health and social benefits of clean cooking fuel. In settings where household air pollution remains a major risk factor, identifying policy initiatives that indirectly relax constraints on sustained clean-fuel use can broaden the interventions considered by policymakers and practitioners.

2 Literature review

2.1 Alcohol consumption, alcohol ban and welfare outcomes

The literature on the household and social effects of alcohol consumption establishes that a ban on alcohol has broad welfare effects operating through two primary channels, i.e., household expenditure reallocation from temptation goods towards productive uses and improvements in women's agency and empowerment (Banerjee and Duflo 2007; Jones et al. 1999; Nayak et al. 2010; Parekh et al. 2022; Tempier et al. 2006; Wu et al. 2021). For India, the economic and social burden of alcohol consumption is crucial, threatening not only individual health but also household stability and cohesion. As such, a policy shock like the Bihar Prohibition Act assumes contextual critical importance. In this context, Falézan (2020) finds that the ban reduced spending on alcohol and broader temptation goods and increased household expenditures on nutritious food and education. In line with this, Krishnatri and Vellakkal (2026) find significant increases in caloric, protein, and fat intake from healthy food sources, accompanied by a decline in fat intake from unhealthy sources as a result of the ban. These effects are attributed to behavioral spillovers from reduced marital conflict, improved household earnings, and reallocation of spending toward items such as pulses, dairy products, and healthy oils.

At the child level, Dar and Vellakkal (2024) document that maternal exposure to the ban reduced the prevalence of stunting and underweight with shifts in reproductive behavior, greater women's autonomy, and increased parental investment in child well-being as the mediating pathways. In addition, Dar et al. (2024) examine the ban's effect on children's cognitive outcomes operating through improvements in the home learning environment resulting from reduced parental alcohol use. Aggarwal et al. (2025) document adverse unintended consequences among young adults, producing additional smokers and drinkers through substitution toward illicit and home-produced alcohol. They also document modest deterioration in mental health, including self-worth and sleep disturbances, and increases in aggressive and risky behaviors, concentrated among poorer households.

Furthermore, Dixit and Mukherjee (2025), Jha and Sharma (2026), and Mookerjee et al. (2025) show direct causal effects of the ban on a host of outcomes identified as mechanisms in Dar et al. (2024), Dar and Vellakkal (2024), and Krishnatri and Vellakkal (2026), including women's agency and decision making, several dimensions of intimate partner violence, measures of women's mobility and medical care access. Most papers also provide evidence of reduced alcohol consumption by husbands. The overall evidence on crime, in general, is contested with Chaudhuri et al. (2024) noting that the ban led to a decline in violent crime attributed to reduced alcohol availability, while Dar and Sahay (2018) reach the opposite conclusion that overall crime increased, with rise in violent and property crime concentrated in districts with higher black-market alcohol prices.

To our knowledge, no existing study has examined whether either channel translates into adoption of clean cooking fuel as the household's primary energy source, the gap our paper addresses.

2.2 Clean Cooking Fuel, LPG Adoption, and Energy Access in India

Over 750 million people in India continue to rely on solid fuels for daily cooking, despite large public investments to promote LPG as a clean alternative (Gould et al. 2020). Existing literature identifies affordability and fuel stacking as the core obstacles to a full transition to clean cooking. Gould and Urpelainen (2018) document that fuel costs from both initial connection charges and the recurring cost of cylinders are the critical obstacle to widespread LPG adoption. In addition, while fuel stacking is the prevailing norm in Indian households, both users and non-users hold strongly positive views of LPG as a clean and convenient cooking fuel. On similar lines, Baquíe and Urpelainen (2017) find that access to LPG is a strong and robust predictor of subjective satisfaction with cooking arrangements, primarily through reductions in smoke and improvements in cooking speed and meal quality. Households assign a high value to the welfare benefits of clean cooking but remain financially constrained from accessing them. In such a setting, an exogenous relaxation of the household budget constraint, such as that provided by the Bihar alcohol prohibition, could plausibly shift the LPG adoption margin. The role of budget constraints in sustaining cooking fuel transitions is also highlighted by Gould et al. (2020), which finds that improved rural incomes and education increased the exclusive use of LPG.

Asharaf and Tol (2024) estimate that the PMUY generated a modest but statistically significant increase in LPG consumption among BPL households. Nandwani and Jain (2024) explicitly examine PMUY's impact on women, finding positive effects on their health, education, employment, and women's agency, driven primarily by the registration of LPG connections in women's names. As such, a key insight from this literature suggests that women's agency is an important determinant of clean cooking fuel adoption, thereby directly connecting the two strands of literature our paper bridges. For instance, Zhang et al. (2022) construct a Women's Empowerment Index (WEI) and find that women in low-empowerment households are significantly less aware of energy services and use less electricity than their spouses. The most direct causal evidence linking empowerment to clean cooking fuel adoption comes from Chatterjee and Poddar (2026) which finds that female empowerment caused an increase in the probability of using modern cooking fuels.

Broader evidence on energy access in India suggests that while geographic remoteness has become less predictive of household electricity access over time, caste-based socioeconomic inequalities remain persistent and salient (Dugoua et al. 2017). Studies using ACCESS data further show that grid electrification improves household appliance ownership and usage intensity with each additional year of electrification (Aklin and Urpelainen 2020; Richmond and Urpelainen 2019), but access does not automatically translate into full energy transition. Even in 2018, 9% of electrified households continued to rely on kerosene as their primary lighting fuel, reflecting fuel-stacking behavior similar to that observed for cooking fuels (Hou and Urpelainen 2020). Consistent with this, Pelz and Urpelainen (2020) emphasize that the quality of electricity access, especially supply availability in hours per day, is a critical determinant of whether households can use energy services. In the cooking domain, Pelz et al. (2021) show that inequalities in Scheduled Castes or Schdeuled Tribes (SC/ST) households' likelihood of obtaining an LPG connection declined by 4.6 percentage points, driven largely by PMUY, although improvements in grid electricity quality for SC/ST households remained more limited than for majority households. This distributional pattern is especially relevant for our setting, as it helps identify which households may be best positioned to benefit from LPG adoption gains following the Bihar alcohol prohibition, particularly given evidence that the ban's welfare effects were concentrated among socially disadvantaged caste groups (Krishnatri and Vellakkal 2026).

3 Background on Bihar Alcohol Ban

Bihar is one of India's largest and poorest states, with a population of approximately 130 million, about 8 percent of the national total, but a per capita income barely one-third of the national average (around USD 1,500 at PPP). The state ranks last on the Human Development Index (HDI), near the bottom in literacy and life expectancy, and second-highest in homicides, accounting for 10.4 percent of all violent crimes in India despite comprising 8.5 percent of the population (Chaudhuri et al. 2024; Dixit and Mukherjee 2025). Gender inequalities are acute with the sex ratio at 882 females per 1,000 males, female literacy of 57 percent against 77 percent for males, and female labor force participation of only 10.7 percent. Alcohol consumption was high and growing. Per capita consumption reached 14.7 liters in 2014 (NSSO), placing Bihar sixth among Indian states, while the number of licensed liquor outlets increased from 2006–07 2012–13, including a 200 percent increase in village-level outlets (Dar and Sahay 2018). By 2015, 29 percent of men in Bihar reported drinking, of whom 14 percent drank almost daily. Domestic violence was pervasive with 59 percent of ever-married women reporting spousal violence in NFHS 2005, and while this fell to 43 percent by 2015, Bihar remained one of the most violent states for women in the country, with alcohol consumption by male partners associated with a 17 percentage point higher probability of physical or sexual violence (Kumar and Prakash 2016).

The political origins of the ban lie in a decade-long shift in Bihar's governance and a mobilized female electorate. The election of Nitish Kumar's government in 2005 marked a turning point. Under the banner of 'Sushasan' (good governance), successive administrations invested in infrastructure, electricity, and education while specifically targeting women's empowerment through quotas (Dar and Sahay 2018). The Bihar Rural Livelihoods Project (BRLP) organized millions of women into self-help groups, converting them into a collective constituency against domestic violence and alcoholism. The proximate trigger came on July 9, 2015, when an SHG leader posed a direct public question to state government demanding action on alcohol-fueled domestic violence. The prohibition accordingly became a central promise in the November 2015 state assembly election campaign, appealing explicitly to the preferences of female voters who had experienced alcohol-related violence, and after Kumar's decisive re-election, the prohibition was formally announced on November 26, 2015 (Chaudhuri et al. 2024; Dixit and Mukherjee 2025; Mookerjee et al. 2025).

The Bihar Prohibition and Excise Act was enacted on March 30, 2016 and came into full force on April 5, 2016, prohibiting the manufacture, transport, sale, and consumption of all alcoholic beverages statewide. This was an expansion from the initially planned country-liquor-only ban. What distinguished Bihar's ban from earlier Indian prohibitions was the severity and breadth of its enforcement apparatus. The law provided for capital punishment in cases of spurious liquor deaths, imprisonment of five to ten years and fines of up to INR 1 million (approximately USD 11,660) for drinking in public, property seizure of entire households, and a toll-free reporting hotline. Police were empowered to raid premises, seize property, and arrest on suspicion without warrant. The fiscal consequences were immediate and substantial. Excise duties had constituted roughly 12 percent of Bihar's internal tax revenue but fell to near zero after the ban (Kumar and Prakash 2016). Prohibition-related offenses surged to constitute more than 76 percent of all crimes recorded in the Bihar State Crime Records Bureau from 2017 to 2021. In July 2018, following political and judicial pressure, the government moderated the most punitive provisions, i.e. bail became available to first-time offenders and the family property confiscation clause was abolished, though the core prohibition remained in place (Chaudhuri et al. 2024; Dixit and Mukherjee 2025).

4 Data

We utilize the unit level data from the 2011-12 and 2023-24 rounds of Household Consumption Expenditure Survey (HCES).[2] The HCES is a nationally representative survey conducted by the National Sample Survey Office (NSSO) under the Ministry of Statistics and Programme Implementation (MoSPI), Government of India. It provides comprehensive information on household-level consumption expenditures across a broad range of goods and services, including energy commodities. The HCES 2011-12 was conducted from July 2011 to June 2012 and surveyed 101,651 households, while HCES 2023-24 was conducted from August 2023 to July 2024 and covered 261,953 households. Both the surveys used a stratified two-stage sampling design covering all states and union territories, except for a few remote villages in the Andaman and Nicobar Islands (See Ministry of Statistics and Programme Implementation and National Statistics Office (2014) and Ministry of Statistics and Programme Implementation and National Statistics Office (2025) for more details on the survey methodology). Both the rounds of the HCES survey are publicly available.[3]

In our baseline analysis, we focus on households from Bihar (treatment state) and Jharkhand (control state). Following the recent literature (Chakrabarti et al. 2024; Dixit and Mukherjee 2025; Kumar and Prakash 2016; Mookerjee et al. 2025), we select Jharkhand as the control state for several reasons. First, Bihar and Jharkhand share a common administrative and socioeconomic history. Jharkhand was carved out of southern Bihar in 2000 and offers substantial institutional and cultural continuity prior to state bifurcation. Second, the two states exhibit comparable baseline development profiles. Both states exhibit a similar trajectory in per capita net state domestic product (Figure 1). They also rank among the lowest on broader social indicators (Mookerjee et al. 2025). Figure 2 presents the trends in the HDI for these states

[2] Following the recommendation of National Statistical Commission, the survey was renamed "Household Consumption Expenditure Survey" from the earlier "Household Consumer Expenditure Survey".

[3] https://microdata.gov.in/NADA/index.php/catalog/CEXP

over time. Third, pre-policy alcohol consumption patterns were broadly similar (Chaudhuri et al. 2024). Finally, while Bihar implemented a statewide alcohol prohibition in 2016, no such policy was introduced in Jharkhand during the study period. This divergence in policy exposure, coupled with structural similarity at baseline, strengthens the plausibility of Jharkhand as an appropriate control state in our empirical framework. As a robustness check, we replace Jharkhand as the control state with neighbouring states including Assam, Chhattisgarh, Madhya Pradesh, and Sikkim that do not share the land border with Bihar. Figure 3 presents the map of states used in this study.

In Bihar and Jharkhand, the HCES 2011-12 and 2023-24 rounds surveyed 7,317 and 23,586 households, respectively. Since LPG is the most widely used clean cooking fuel among households, our analysis focuses specifically on households that report LPG as their primary clean fuel. Accordingly, we exclude 20 households from the pooled dataset that use electricity or biogas as their cooking fuel. Further, we exclude 8 observations due to missing information on variables included in the analysis. Our final analytical sample consists of 30,875 observations. Figure 4 provides a detailed schematic flow of the construction of our analytical sample.

Our outcome variable captures LPG as the household's primary source of energy for cooking. Specifically, the binary indicator *LPG* takes a value 1 if the household reports LPG as its main cooking fuel and 0 if the primary fuel is firewood, dung cakes, kerosene, coke, coal, charcoal, other fuels, or if no formal cooking arrangement is reported. Notably, the survey provides information on the primary cooking fuel only. Therefore, households that use LPG as their main fuel but continue to rely on traditional fuels as secondary sources are also classified as LPG users. This definition aligns with the energy transition literature (Mani et al. 2020), where primary fuel choice is interpreted as the dominant source of household energy.

We control for a comprehensive set of household and household-head characteristics available in the HCES to mitigate confounding. Household head characteristics include age (in years), sex (=1 if male and 0 otherwise), and education level, categorized into illiterate, literate without formal education, below primary schooling, primary schooling, middle schooling, secondary schooling, higher secondary schooling, diploma/certificate course, graduate, post graduate and above. Household-level controls include household size, monthly per-capita expenditure quintiles (poorest, poor, middle, rich, and richest), ownership of the dwelling unit (=1 if yes and 0 otherwise), social group (Scheduled Caste - SC, Scheduled Tribe - ST, Other Backward Class - OBC, others, and missing/not reported), religion (Hindu, Muslim, and others), and place of residence (=1 if rural and 0 otherwise).

Table 1 presents the mean and standard deviation of variables for Bihar and Jharkhand before and after the implementation of the prohibition policy. Examining changes over time, we find limited shifts in household head characteristics in Bihar between 2011–12 and 2023–24, with the notable exception of education. The share of household heads completing graduate-level education has increased by approximately 2 percentage points (pp). In contrast, Jharkhand has experienced a 3.5 pp rise in female-headed households, an increase in the average age of household heads by 2.2 years, and improvements in educational attainment. At the household level, average household size has declined in both states. Dwelling ownership has fallen modestly in Bihar (by 1.5 pp) but risen in Jharkhand (by 3.4 pp). Social composition exhibits marginal shifts over time. The share of OBCs has declined by 4 pp in Bihar, while the proportion of Muslim households has declined by 3 pp in Jharkhand.

5 Empirical framework and Identification strategy

5.1 Difference-in-Differences (DID)

The objective of this study is to empirically estimate the causal impact of the alcohol prohibition policy in Bihar on household-level LPG adoption. We adopt a Difference-in-Differences (DID) estimation framework that compares the change in LPG uptake in Bihar before and after prohibition to the corresponding change in Jharkhand over the same period. This identification strategy exploits cross-state variation in policy exposure, using Jharkhand as a counterfactual to net out common macro-level shocks affecting household energy transitions in both states.

Figure 5 shows that the share of households reporting LPG as their primary cooking fuel in Bihar rose markedly from 11.4% in 2011–12 to 42.4% in 2023-24. However, this raw difference cannot be interpreted as the causal effect of prohibition. The period between the two survey rounds witnessed major contemporaneous policy interventions, most notably the expansion of subsidized LPG access under the PMUY, as well as broader time-varying factors such as rising awareness of the health costs of household air pollution. These concurrent changes may independently influence LPG uptake. As illustrated in 5, LPG adoption in Jharkhand increased by 15.9 pp (from 14.6% in 2011–12 to 30.5% in 2023–24) and reflects the influence of nationwide factors. Under the identifying assumption that, absent prohibition, LPG adoption in Bihar would have followed a trajectory similar to that of Jharkhand (parallel trends), the differential change across the two states provides a preliminary estimate of the policy's impact. Figure 5 indicates that the post-ban unconditional mean of LPG uptake is approximately 15.1 pp higher in Bihar relative to Jharkhand.

We build on this preliminary evidence and use the following DID empirical framework:

$$LPG_{hdst} = \beta_1 Bihar_s * Post_t + \beta_2 Post_t + \beta_3 \mathbb{X}_h + \lambda_d + \epsilon_{hdst} \quad (1)$$

where LPG_{hdst} depicting LPG as the primary cooking fuel of household h residing in district d of state s surveyed at time t. $Bihar_s$ is a dummy variable that takes a value 1 for the state of Bihar and 0 for the state of Jharkhand. $Post_t$ takes the value 1 for the survey round 2023-24 and 0 for the survey round 2011-12. It accounts for unobservable time-variant changes that might have happened in both the states. $\mathbb{X}_h$ is a vector of household and household-head characteristics. λ_d captures the district fixed effects and account for district level time-invariant differences. ϵ_{hsdt} denotes the error term. To account for intra-district correlation in LPG uptake, we cluster the standard errors at the district level. Our coefficient of interest is β_1 and captures the DID estimate of alcohol prohibition on LPG uptake in Bihar.

5.2 Propensity Score Matching Difference-in-Differences (PSM-DID)

A key methodological concern arises from the structure of the underlying data. The empirical strategy draws on repeated cross-sectional surveys rather than a longitudinal panel. Households observed in the 2011–12 survey round are likely to be distinct from those surveyed in 2023–24. In repeated cross-sectional settings of this kind, standard DID estimators may be biased by compositional change if the observable or unobservable attributes of households systematically differ across survey waves. DID estimates of the treatment effect risk conflating true policy impacts with shifts in sample composition (Blundell and Dias 2009; Stuart et al. 2014). The descriptive statistics presented in Table 1 provide preliminary evidence of such compositional drift, recording modest but discernible changes in household characteristics between the pre- and post-intervention periods.

To mitigate this concern and improve the comparability of treatment and control observations, the baseline DID framework is complemented with a kernel-based propensity score matching DID (PSM-DID) estimator. This empirical strategy strengthens internal validity by combining PSM to address observable differences in household and household-head characteristics with the DID framework that accounts for time-invariant unobserved heterogeneity (Krishnatri and Vellakkal 2026). It enables a more credible identification of the impact of alcohol prohibition on LPG adoption.

As a first step, a probit model is estimated to calculate the propensity scores for each observation. Households drawn from the pre-intervention period in Bihar constitute the *treated* group, while observations from the post-intervention period in Bihar and all observations from

Jharkhand, irrespective of survey round, form the *control* pool. The fitted probabilities from the probit model capture each observation's conditional likelihood of belonging to the treated group given a set of household and household-head covariates included in our analysis. Following the approach outlined in (Dixit and Mukherjee 2025), these scores are subsequently employed as kernel weights to rebalance the covariate distributions across *treated* and *control* observations.

Table 2 presents unweighted and propensity-score-weighted descriptive statistics for household and household-head characteristics along with covariate balance diagnostics. Prior to weighting, column (3) reveals statistically significant mean differences across several covariates. Following the application of propensity score weights, these imbalances are substantially attenuated, as shown in column (7). Additional balance diagnostics, including Rubin's B and R statistics corroborates this improvement and confirm that the matching procedure achieves an adequate degree of covariate balance. Of the 30,875 observations in our analytical sample, 30,873 satisfy the common support condition and are retained in the matched sample. Subsequently, we estimate Equation (1) using this matched sample.

Another potential concern is that Bihar's alcohol prohibition was partly driven by political mobilization among women demanding reductions in alcohol-related intimate partner violence (IPV) (Tewary 2015). If such social dynamics were correlated with unobserved changes in household welfare or women's bargaining power, they could independently influence LPG adoption and add a question on exogeneity of the alcohol prohibition policy. However, our PSM-DID framework mitigates this concern by comparing changes in Bihar to those in Jharkhand, a neighboring state with similar socioeconomic characteristics but without prohibition. If broader social trends influencing women's empowerment evolved similarly across the two states, their effects would be absorbed by the PSM-DID framework. Moreover, the recent literature shows that various proxies of women's empowerment (decision making power by Mookerjee et al. (2025) and IPV by Dixit and Mukherjee (2025)) followed parallel trends in Bihar and Jharkhand or Bihar registered a slower growth than Jharkhand before the prohibition was enacted in 2016.

5.3 Validating the Parallel Trends Assumption

The internal validity of the DID estimator rests on the parallel trends assumption. It requires that, in the absence of the 2016 Bihar alcohol prohibition, LPG adoption trajectories in Bihar and Jharkhand would have evolved along a common path. As this counterfactual is inherently unverifiable over the post-policy period, we offer two complementary pieces of indirect evidence in support of this identifying assumption.

First, we construct a long-run graphical comparison of LPG penetration rates for the two states prior to the intervention. Specifically, we compute the ratio of LPG connections to the total number of households in each state using data from the 2001 and 2011 Census rounds. These are supplemented by state-level coverage figures for 2004 and 2006, obtained from parliamentary records of the Rajya Sabha[4]. We present the resulting four pre-intervention data points in Figure 6. It broadly indicates similar trajectories in LPG uptake across Bihar and Jharkhand, lending visual support to the parallel trends assumption. Additionally, we use the 2005–06 and 2015–16 rounds of the National Family Health Survey (NFHS) to estimate the proportion of households relying on LPG or natural gas as their primary cooking fuel.[5] Figure 7 corroborates these findings and show similar trends of clean cooking fuel across the two states.

Second, we conduct a regression based pre-trends test using the HCES rounds of 2004–05 and 2011–12. Both the surveys were conducted before the alcohol-prohibition policy came into effect in Bihar. Treating 2004–05 as the base period and 2011–12 as the comparison period, we re-estimate equation (1) over this window under the maintained assumption that neither state was subject to any treatment. Under the null hypothesis of parallel pre-intervention trends, the coefficient β_1 should be statistically indistinguishable from zero. Table 3 reports these placebo estimates for both the baseline DID specification (column 1) and the PSM-DID specification (column 2). The coefficients are insignificant in both the columns and provide additional evidence for the absence of differential pre-policy trends.

6 Results

Table 4 presents estimates of the effect of Bihar's alcohol prohibition on household LPG adoption, derived from Equation (1). Controls are introduced sequentially across columns (1) to (3) to assess the sensitivity of the estimates to covariate inclusion. Column (1) presents the naive DID estimate. Household head characteristics are added in column (2), followed by household-level attributes in column (3). All the specifications include $Post_t$ dummy and district fixed effects. The treatment coefficient is positive and statistically significant across all three specifications. Specifically, column (3) yields a point estimate of 15.9 percentage points (pp). It shows that that the alcohol prohibition substantially accelerated LPG adoption in Bihar relative to the counterfactual.

Column (4) reports the preferred PSM-DID estimate, which accounts for compositional differences across survey rounds and incorporates the full set of controls. This specification returns a somewhat more conservative estimate of 12.8 pp. It suggests that once pre-existing

[4] The Rajya Sabha is the upper house of the Parliament of India.

[5] Notably, NFHS 2005–06 and NFHS 2015–16 do not report LPG as a separate category of primary cooking fuel.

differences between treated and control observations are adjusted for, the policy effect remains economically large and statistically significant. We treat this as the preferred estimate given its robustness.

7 Robustness

We conduct a battery of checks to assess the robustness of our baseline results where we consider alternative estimation strategy, cross-border spillovers, alternative set of control states, expansion of baseline period, and falsification analysis.

7.1 Alternative Estimation Strategy

While kernel-based PSM provides the basis for our preferred PSM-DID estimate, it relies on an assumption of correctly specified propensity score model. If the probit equation imposes an incorrect functional form, the resulting weights may fail to achieve adequate covariate balance and potentially reintroduce the very confounding the procedure is designed to eliminate (King and Nielsen 2019). Therefore, as an alternative to kernel-based PSM, we use coarsened exact matching (CEM).

CEM directly controls the covariate imbalance that is permitted to enter the estimation instead of estimating a propensity score and weighting observations by their predicted treatment probability. Each covariate is temporarily coarsened into bins and observations are matched exactly on their coarsened values. Within each stratum, observations are assigned weights to restore the original covariate distribution (Blackwell et al. 2009; Iacus et al. 2012). We implement CEM by coarsening each covariate included in our main analysis. Notably, our effective sample size for CEM analysis reduces to 13,558 because it involves exact matching over coarsened covariate values and drops observations outside the coarsened strata. The DID estimator is then re-estimated on the CEM-matched sample using the full set of controls and district fixed effects included in equation (1). Column (1) of Table 5 shows that the alcohol prohibition policy in Bihar increased LPG adoption by 12.6 pp.

7.2 Cross-Border Spillovers

A standard challenge in evaluating the effects of state-level prohibition policies is that enforcement capacity is not uniformly distributed across space. Districts situated along state boundaries occupy a structurally distinct position. Unregulated jurisdictions in the neighboring states lowers the effective cost of cross-border procurement and creates conditions conducive to informal supply networks in the treated state (Chaudhuri et al. 2024). In the context of Bihar's alcohol prohibition, this concern is particularly salient given that Bihar shares land borders with three major states — Uttar Pradesh, Jharkhand, and West Bengal — each of which permits the legal sale of alcohol. The policy-induced reduction in alcohol expenditure may be partially offset due to possibility of cross-border procurement and likely to attenuate the effect of alcohol prohibition on LPG.

To assess the sensitivity of our main estimates to this potential source of attenuation bias, we implement a border-exclusion robustness check. Specifically, we drop all households residing in districts of Bihar that share an administrative boundary with neighboring states. Additionally, we exclude districts of Jharkhand that share a border with Bihar. Figure A1 maps the spatial distribution of interior districts used for this analysis. We re-estimate the preferred PSM-DID specification with the full set of controls and district fixed effects and present the results in column (2) of Table 5. The estimate (14.9 pp) is slightly larger in magnitude than the corresponding estimate from the full sample (12.8 pp). This pattern is consistent with the hypothesis that proximity to state borders weakens the effective reach of prohibition, such that the treatment effect is more precisely identified among households in districts insulated from cross-border supply channels.

7.3 Alternative set of Control States

Our baseline identification strategy uses Jharkhand as the comparison state. Although Jharkhand is an appropriate counterfactual due to its historical and socioeconomic similarities with Bihar, the estimated treatment effect could potentially be sensitive to the choice of control state. To examine this possibility, we replace Jharkhand with a set of neighboring states — Assam, Chhattisgarh, Madhya Pradesh, and Sikkim — that do not share a land border with Bihar. We re-estimate our preferred PSM–DID specification using this set of states as the control group. The direction and statistical significance of the PSM-DID estimate, reported in column (3) of Table 5, remain unchanged. It suggests that our findings are not driven by the specific choice of Jharkhand as the control state and strengthen the credibility of our identification strategy.

7.4 Baseline Period Choice: Incorporating the 2004–05 HCES Round

A potential concern with any two-period DID design is that the estimated treatment effect may be sensitive to the choice of pre-policy baseline. To address this concern, we augment the main estimation sample by incorporating the 2004–05 round of the HCES as an additional pre-treatment period and extend the pre-policy window by approximately seven years. This three-round pooled sample, spanning 2004–05, 2011–12, and 2023–24, allows us to assess whether the estimate of treatment effect remains stable when the identifying variation is drawn from a longer pre-policy baseline.

We re-estimate Equation (1) on this expanded sample where we redefine the post-treatment indicator to take the value of one for the 2023–24 round and zero for both pre-policy rounds (2004–05 and 2011–12). The classification of treatment group and the control group remain unchanged relative to the main specification. The PSM-DID estimate, in column (4) of Table 5, remain positive, statistically significant and comparable in magnitude to the main estimate presented in Table 4.

7.5 Falsification test

Our baseline as well as robustness results consistently show that the alcohol prohibition policy in Bihar increased household LPG adoption. However, a potential concern could be that the effect is spurious in nature and not necessarily that of the alcohol prohibition. Here, we address any concerns of spurious correlation in our findings and provide evidence to generate further confidence in our identification strategy. Following Bharadwaj et al. (2014), we implement a falsification exercise in which the treatment status is randomly reassigned across all households in our analytical sample. We repeat this exercise 1000 times and re-estimate equation (1) for each iteration. This procedure generates an empirical distribution of placebo treatment effects under the null hypothesis that prohibition had no effect on household LPG adoption. Based on this exercise, any estimated treatment effect obtained from the simulated samples would arise purely from a random assignment of treatment status.

Figure 8 shows that distribution of estimated coefficients through these iterations. The simulated coefficients are tightly centered around zero and are substantially smaller in magnitude than the estimate reported in column (4) of Table 4. This pattern suggests that the estimated impact of prohibition on LPG adoption is unlikely to be driven by random chance and provides additional support for the validity of our empirical findings.

7.6 Sub-sample Analysis

Average treatment effects can obscure meaningful variation in policy impacts across household types. To explore this, we estimate the preferred PSM-DID specification on a series of subsamples defined by household head characteristics including *age* (below versus above the sample median of 45 years) and *sex* (male- versus female-headed) and by household-level attributes, including *MPCE quintiles* (bottom two versus top three quintiles), *household size* (below versus above the median size of 5), *social group* (backward vs non-backward), and *area of residence* (rural versus urban). We present the results in Table 6.

The prohibition-induced increase in LPG adoption is positive and statistically significant across the majority of subgroups. The effect is broadly symmetric with respect to the age of the household head, arising in both younger and older household heads. Similarly, the policy appears to have stimulated LPG uptake in male- and female-headed households, and the estimates are comparable in magnitude across the MPCE distribution. It suggests that the welfare gains from the ban are not confined to relatively affluent households. Positive and significant effects are also recorded for both smaller and larger households and across backward and non-backward social groups.

One notable exception concerns area of residence. While the direction of the effect is positive in both rural and urban areas, the estimated coefficient for urban households is attenuated in magnitude and fails to attain statistical significance. This pattern likely reflects the considerably higher baseline rates of LPG penetration in urban areas (61% in comparison to 6% in rural areas) prior to the ban, which may compress the scope for further adoption gains. In contrast, the rural subsample, where clean cooking fuel access remains more constrained, exhibits a larger and more precisely estimated treatment effect.

8 Potential mechanism

We posit that the alcohol prohibition may have raised the probability of LPG adoption as the primary cooking fuel through two channels. The first operates through household expenditure reallocation. By eliminating legal access to alcohol, a temptation good that competes with productive household expenditures, the prohibition releases resources that can be redirected toward recurring clean fuel costs, pushing financially constrained households over the LPG adoption margin. The second operates through intra-household dynamics. This channel suggests that reductions in male alcohol consumption following the prohibition may improve women's well-being and agency within the household. Existing evidence links lower alcohol consumption to reductions in IPV and greater female participation in household decision-making, while a growing literature shows that women's agency is positively associated with the adoption of clean cooking fuels. We provide direct empirical evidence for the first channel and draw on existing literature to motivate the second.

Alcohol is a canonical temptation good[6] whose expenditure comes disproportionately at

[6]Temptation goods are characterised by strong immediate utility but negative long-run welfare consequences

the expense of household-wide public goods (Banerjee and Duflo 2007). When the prohibition eliminates legal access to alcohol, households that previously allocated expenditure to alcohol experience an effective expansion of the budget available for productive uses. In the context of Bihar, Falézan (2020) documents precisely this reallocation and finds reduced spending on temptation good and increased expenditures on food and education following the prohibition. Krishnatri and Vellakkal (2026) corroborate this finding and report significant increases in caloric and macronutrient intake from healthy food sources. They attribute these findings to reduced marital conflict, improved household earnings, and reallocation of spending.

This reallocation maps directly onto the primary barrier identified in the LPG adoption literature. For instance, Gould and Urpelainen (2018) show that the recurring cost of LPG cylinders is the central obstacle to fuel transition in rural India, while Baquíe and Urpelainen (2017) demonstrate that households place high value on the welfare gains from clean cooking but remain financially constrained from accessing them. An exogenous relaxation of the household budget constraint arising from the elimination of alcohol expenditure should therefore translate, at least partially, into greater capacity to meet recurring LPG costs, particularly for households near the adoption margin. It should therefore push financially constrained households over the LPG adoption margin.

To empirically test this channel, we use two strategies. First, we examine separately the effect of the ban on alcohol expenditure and LPG expenditure during the last 30 days. Both, alcohol expenditure as well as LPG expenditure are measured in real terms.[7] We use PSM-DID specification with the full set of covariates and present the results in columns (1) and (2) of Table 7. Column (1) shows that Bihar households in the post-ban period spent approximately INR 153 less in real terms on alcohol relative to their counterparts in Jharkhand. It confirms that the prohibition generated a measurable reduction in alcohol outlays at the household level. Column (2) documents a corresponding increase in real LPG expenditure by approximately INR 150. This estimate also captures the intensive margin effect of the ban on clean cooking fuel use.

Second, we exploit spatial variation in the magnitude of alcohol expenditure decline across Bihar districts to construct alternative test of the mechanism. We classify Bihar districts into two groups based on the percentage reduction in alcohol expenditure between 2011–12 and 2023–24: those recording a decline of 100 percent - *high-decline* and those recording a decline of less than 100 percent - *low-decline*.[8] The Jharkhand districts serve as the comparison group

for the household.

[7] Alcohol expenditure is deflated using the 2012 price index for pan, tobacco, and intoxicants, whereas LPG expenditure is adjusted using the fuel and light price index.

[8] It is important to note that 20 out of 38 districts in Bihar recorded a decline of 100 percent in alcohol

in both cases.

If the expenditure reallocation channel is operative, the treatment effect on LPG adoption should be larger in *high-decline* districts, where the effective income gain from prohibition is more pronounced, than in *low-decline* districts. Columns (3) and (4) of Table 7 report the PSM-DID estimates for these two subsamples. Consistent with the prediction, LPG adoption increased by 20.1 pp in *high-decline* districts, while the effect is substantially attenuated and less precisely estimated in *low-decline* districts. In sum, this gradient in treatment effects across districts categorized by the intensity of the expenditure shock provides direct evidence that the reallocation of freed-up resources toward LPG costs constitutes a meaningful transmission channel from prohibition to clean cooking fuel adoption.

A second pathway through which prohibition may raise LPG adoption operates via changes in intra-household power dynamics. A growing body of evidence establishes that Bihar's alcohol ban substantially improved women's welfare and increased women's participation in household decisions. Dixit and Mukherjee (2025) find large declines across all dimensions of IPV, with overall IPV falling by 0.53 standard deviations, driven by reductions in emotional, physical, sexual, and controlling violence. Complementarily, Mookerjee et al. (2025) document that the ban increased women's household decision-making power by 11.2 to 14.2 pp across domains including health care, large purchases, and management of household earnings, with the primary identified mechanism being a 6.9 pp reduction in male alcohol consumption.

The clean cooking fuel literature establishes a direct link from women's agency to LPG adoption and provides the theoretical bridge between these intra-household changes and LPG uptake. Zhang et al. (2022) show that women in low-empowerment households are significantly less aware of available energy services and use less energy than their spouses, even where access has expanded. It suggests that improvements in women's agency could unlock further clean energy adoption independently of income effects. The most direct causal evidence comes from Chatterjee and Poddar (2026), who find that exposure to India's SABLA adolescent girls' empowerment programme caused an increase in the probability of adopting modern cooking fuels. As such, this body of evidence suggests that if the prohibition raised women's agency, increased LPG adoption may follow through this empowerment channel.

That said, the two channels are not mutually exclusive and may operate simultaneously and reinforce each other. A household that reallocates resources away from alcohol may simultaneously experience a shift in intra-household bargaining toward the woman, whose preferences lean toward a safer and cleaner cooking environment, reinforcing the adoption margin. In

expenditure between 2011–12 and 2023–24

such cases, the income and empowerment effects are complementary. The income effect relaxes the budget constraint that prevents LPG adoption, while the empowerment effect shifts the household's effective preferences toward clean fuel use. The total effect estimated in our PSM-DID specification captures the aggregate impact of these reinforcing pathways and represents the policy-relevant quantity for evaluating the welfare consequences of alcohol prohibition for household energy transitions in the context of Bihar.

9 Conclusion

Solid fuel combustion is among the leading causes of indoor air pollution, with severe health consequences concentrated among women and children. The transition to clean cooking is not merely an energy choice but a welfare and health outcome of first-order importance, particularly for poor rural households in states like Bihar where baseline solid fuel dependence is highest. It is also well documented in the literature that poor households may be caught in a trap where expenditure on goods like alcohol crowds out investment in productive or health-improving goods, and as such, removing access to temptation goods can release this constraint and improve household welfare. Bihar's prohibition acts as an excellent test of this mechanism, and LPG adoption as a primary cooking source is a particularly compelling welfare-improving outcome to examine. This is because it is precisely the kind of expenditure for women (recurrent, health-improving, productivity-enhancing) that theory predicts should benefit from the freed-up income.

With this context in mind, this paper provides the first causal estimates of the effect of a state-wide alcohol prohibition on household adoption of clean cooking fuel. Using Bihar's 2016 ban as a quasi-experimental source of variation and a PSM-DID framework that exploits the temporal contrast between the 2011–12 and 2022–23 rounds of the HCES, we find that prohibition increased the probability of LPG adoption as the primary cooking fuel by 12.8 percentage points (pp). This translates to an economically large effect relative to Bihar's pre-ban baseline of 11.4 percent. This estimate is robust to an alternative matching estimator based on coarsened exact matching (12.6 pp), sample restrictions to interior districts insulated from cross-border alcohol procurement (14.9 pp), the replacement of Jharkhand with a set of non-contiguous comparison states (8.5 pp), the inclusion of the 2004–05 HCES wave as an additional pre-policy period (13.2 pp), and a randomization-based falsification exercise in which simulated treatment effects are tightly clustered around zero.

The treatment effect is broadly uniform across household-head age and sex, MPCE quintiles, household size, and social group, with the notable exception of urban households, for whom the scope for adoption gains is compressed by high baseline LPG penetration. However, we find that the effect is concentrated in rural areas, where access to clean cooking fuel remains most constrained and the potential health returns from transition are largest.

Two reinforcing channels appear to account for these adoption gains. The first operates through household budget reallocation. Bihar households in the post-ban period spent approximately INR 153 less in real terms on alcohol relative to their Jharkhand counterparts, accompanied by a corresponding increase in real LPG expenditure of approximately INR 150. The sub-sample of Bihar districts that experienced the largest proportional declines in alcohol expenditure recorded LPG adoption gains of 20.1 pp, substantially exceeding the estimate for districts with smaller alcohol expenditure reductions.

This pattern is consistent with households near the adoption margin being pushed over it by the effective budget expansion that prohibition generates, which is precisely the mechanism that Gould and Urpelainen (2018) and Baquíe and Urpelainen (2017) identify as the central bottleneck. They note that households with preferences for clean cooking often have insufficient liquidity to sustain recurring refill costs. The second channel operates through improvements in women's agency and intra-household bargaining power. Bihar's prohibition substantially reduced intimate partner violence (Dixit and Mukherjee 2025) and increased women's household decision-making authority (Mookerjee et al. 2025), both of which are causally linked to clean cooking adoption in the broader literature (Chatterjee and Poddar 2026; Zhang et al. 2022). These two channels are complementary rather than competing. The income released from alcohol expenditure may simultaneously shift intra-household bargaining authority toward women whose preferences for clean, time-saving, and smoke-free cooking are well documented, reinforcing the adoption margin effect through a second pathway.

Our findings carry several implications for policy. First, they suggest that household liquidity constraints are a binding bottleneck preventing sustained LPG use even among households that have already obtained connections. While India's flagship PMUY programme dramatically lowered the fixed cost of adoption for BPL households, the transition to LPG as a primary fuel remained incomplete because recurring cylinder costs continued to bind. Our results indicate that demand-side policies that reduce expenditure on socially costly goods can complement supply-side programmes by relieving the recurrent cost constraint that PMUY alone could not address. Second, the rural concentration of the treatment effect is directly policy-relevant as they represent the largest expected welfare gains from a clean cooking transition. Third, our results expand the empirical basis for treating reductions in temptation good expenditure as a pathway to SDG 7 outcomes, not as a substitute for energy policy, but as an indirect mechanism that deserves attention in the design and evaluation of complementary social policies.

That said, it is important to qualify the limitations of our findings. The most immediate challenge is the near-simultaneous launch of PMUY in May 2016, one month after Bihar's alcohol ban in April 2016. Both events raise LPG adoption, and our design cannot fully decompose their independent contributions with the available data. Second, our data are repeated cross-sections rather than a panel, which means we cannot track individual households over time. While PSM-DID addresses observable compositional change across survey rounds, we cannot entirely rule out time-varying unobserved heterogeneity at the household level. Third, the external validity of our estimates is also constrained by Bihar's unusual institutional context. Decades of state investment in women's self-help group mobilization and an exceptionally severe enforcement policy may not be easily replicable elsewhere, and the magnitude of our estimated effects may therefore not transfer directly to other prohibition settings. Additionally, existing evidence documents interesting unintended consequences of the ban, including substitution toward illicit alcohol and home-produced substitutes among certain groups (Aggarwal et al. 2025) and a diversion of law enforcement resources toward prohibition-related arrests (Dar and Sahay 2018). We are unable to capture these costs in our outcome variable, and thus these ought to be weighed against our estimated adoption increase for any full welfare accounting.

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Figures and Tables

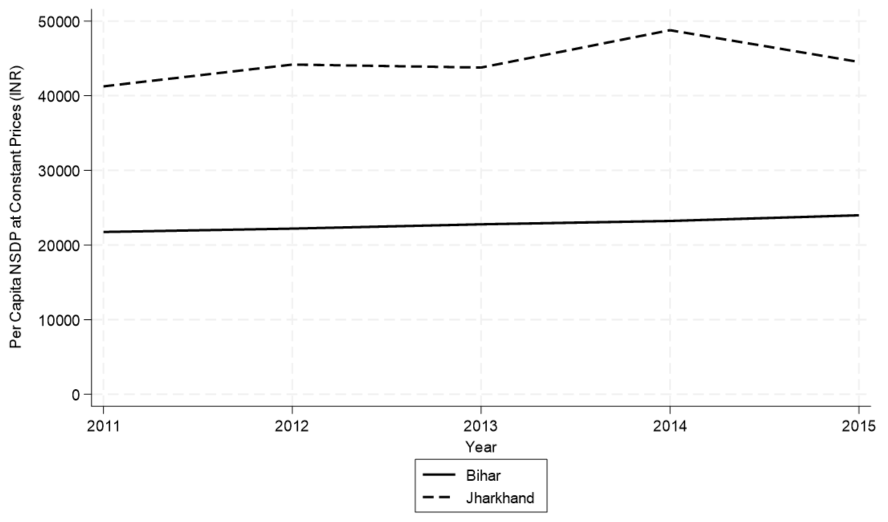

Figure 1: Trends in Net State Domestic Product (NSDP)

Source: Directorate of Economics & Statistics of respective State Governments, Central Statistical Organization

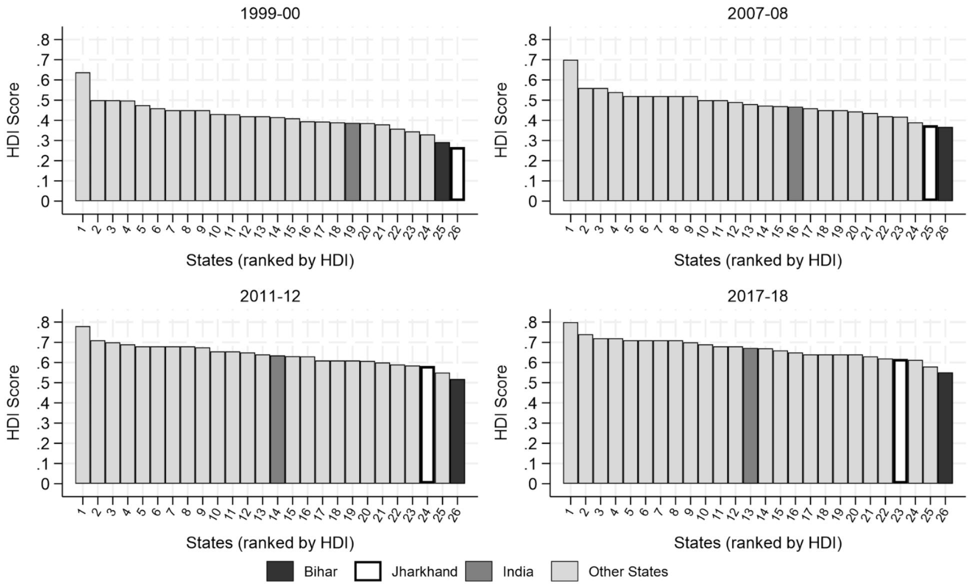

Figure 2: Trends in state rankings in the Human Development Index (HDI)

Source: Ministry of Statistics and Programme Implementation, Government of India (2021) and Planning Commission (2011)

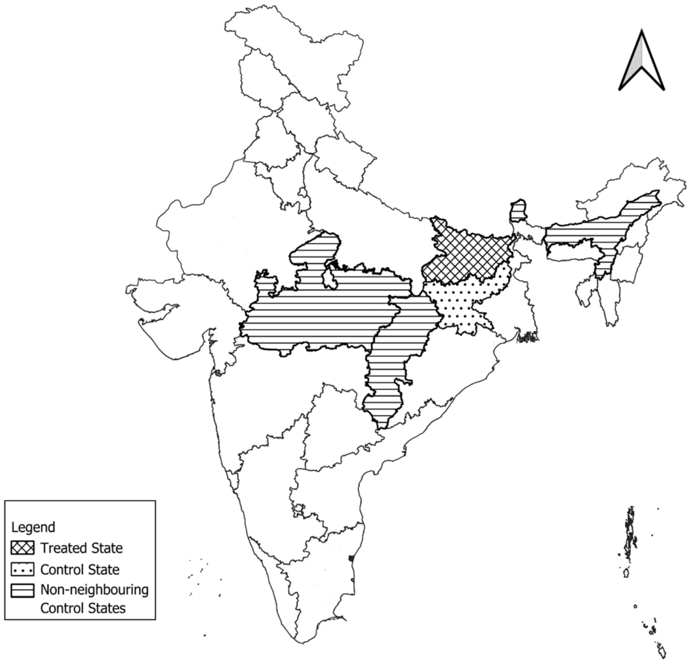

Figure 3: States of India used in the main analysis and robustness checks.

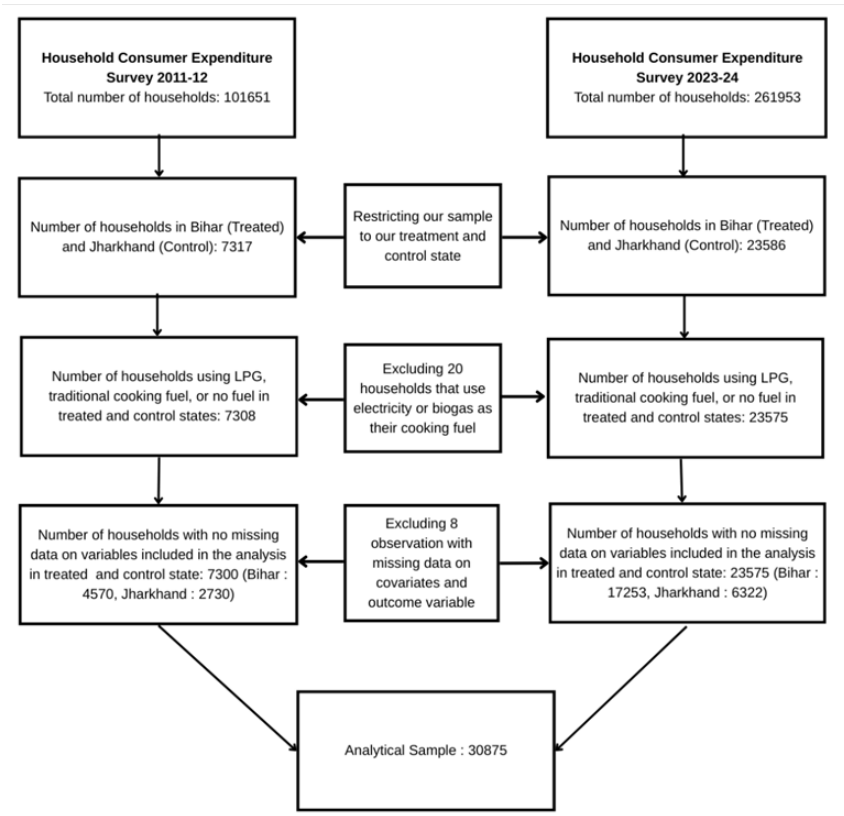

Figure 4: Analytical sample formation

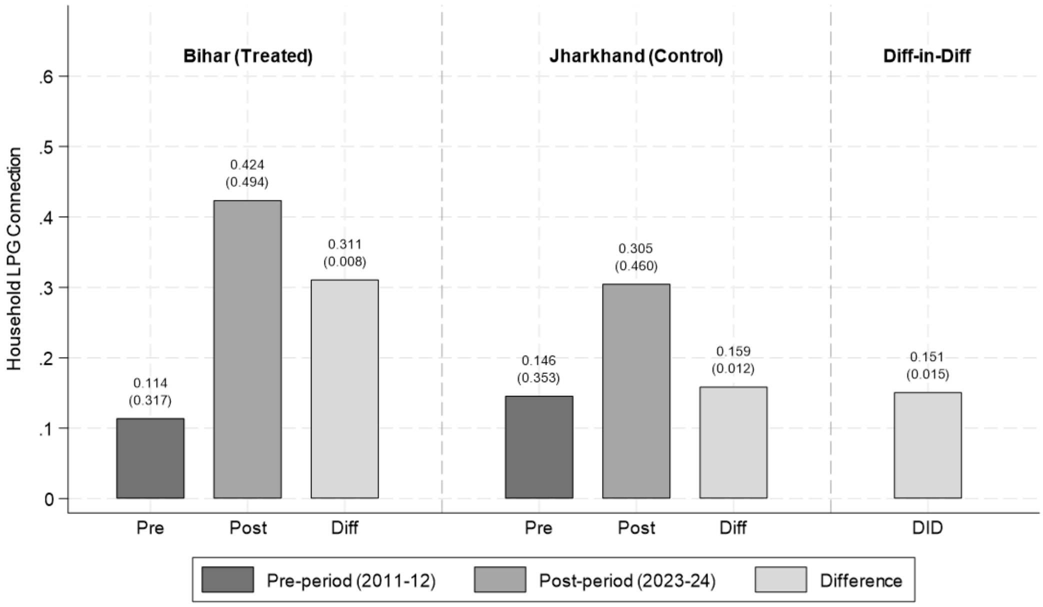

Figure 5: Unconditional means of LPG adoption by rounds and states.

Notes: Standard deviations and standard errors for the mean and the differences are reported in parentheses.

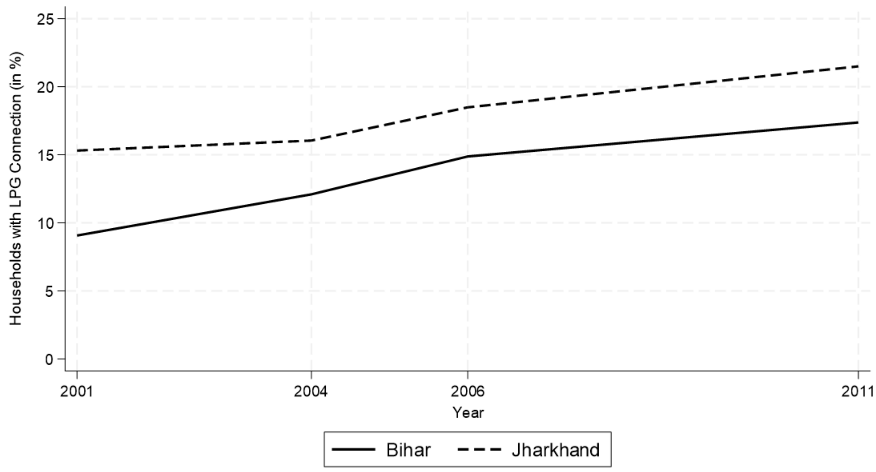

Figure 6: Trends of LPG connection by states.

Source: Census of India (2001, 2011). Parliamentary records of the Rajya Sabha, data accessed via IndiaStat (https://www.indiastat.com).

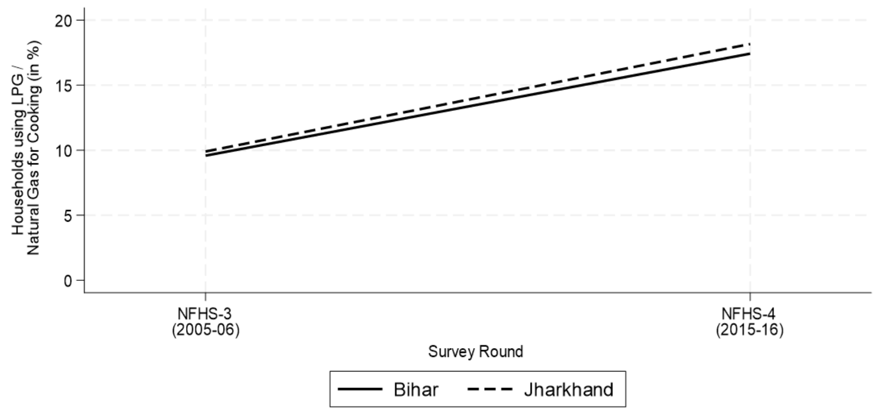

Figure 7: State-Level trends in household use of LPG or natural gas for cooking.

Notes: Percentages are estimated using sampling weights from the National Family Health Surveys (2005–06 and 2015–16).

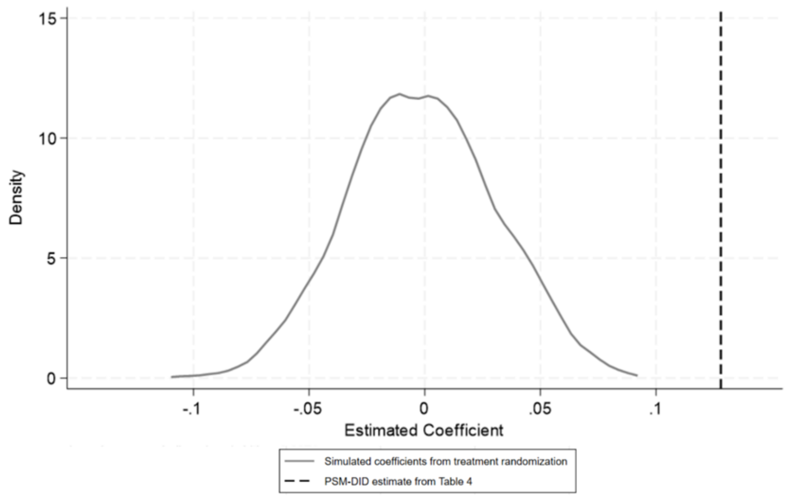

Figure 8: Kernel density of simulated coefficients from treatment randomization.

Table 1: Descriptive Statistics

	Bihar (Treatment State)			Jharkhand (Control State)		
	Pre-period Mean (S.D.)	Post-period Mean (S.D.)	Difference Mean (S.E.)	Pre-period Mean (S.D.)	Post-period Mean (S.D.)	Difference Mean (S.E.)
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Outcome						
LPG Connection	0.114	0.424	0.311***	0.146	0.305	0.159***
	(0.317)	(0.494)	(0.008)	(0.353)	(0.460)	(0.012)
Household Head Characteristics						
Age of Household Head (in years)	44.686	44.783	0.098	43.621	45.839	2.217***
	(12.695)	(13.193)	(0.383)	(13.705)	(13.343)	(0.505)
Sex of Household Head						
Male	0.917	0.911	-0.006	0.900	0.866	-0.035***
	(0.276)	(0.285)	(0.009)	(0.300)	(0.341)	(0.011)
Female	0.083	0.089	0.006	0.100	0.134	0.035***
	(0.276)	(0.285)	(0.009)	(0.300)	(0.341)	(0.011)
Education						
Not Literate	0.404	0.362	-0.042***	0.405	0.295	-0.110***
	(0.491)	(0.481)	(0.015)	(0.491)	(0.456)	(0.018)
Literate without Formal Schooling	0.008	0.052	0.044***	0.022	0.041	0.019***
	(0.090)	(0.222)	(0.003)	(0.148)	(0.199)	(0.006)
Literate but Below Primary	0.125	0.062	-0.062***	0.117	0.073	-0.044***
	(0.330)	(0.242)	(0.010)	(0.322)	(0.261)	(0.011)
Primary School	0.081	0.114	0.033***	0.077	0.147	(0.069***
	(0.273)	(0.317)	(0.008)	(0.267)	(0.354)	(0.010)
Middle School	0.118	0.113	-0.005	0.123	0.148	0.026**
	(0.323)	(0.317)	(0.009)	(0.328)	(0.355)	(0.012)
Secondary School	0.132	0.132	-0.001	0.106	0.131	0.025**
	(0.339)	(0.338)	(0.010)	(0.308)	(0.337)	(0.011)
Higher Secondary School	0.069	0.078	0.009	0.071	0.070	-0.001
	(0.253)	(0.268)	(0.007)	(0.257)	(0.255)	(0.008)
Diploma/Certificate Course	0.002	0.004	0.002**	0.002	0.007	0.005***
	(0.048)	(0.067)	(0.001)	(0.048)	(0.084)	(0.001)
Graduate Course	0.053	0.073	0.020***	0.068	0.074	0.005
	(0.224)	(0.260)	(0.006)	(0.252)	(0.261)	(0.008)
Post Graduate and Above	0.008	0.009	0.001	0.008	0.014	0.006**
	(0.089)	(0.097)	(0.002)	(0.090)	(0.118)	(0.002)
Household Characteristics						
Household Size	5.074	4.899	-0.175***	4.798	4.602	-0.196**
	(2.212)	(2.082)	(0.062)	(2.370)	(2.049)	(0.078)
Monthly Per-Capita Expenditure Quintiles						
Poorest	0.167	0.151	-0.016	0.166	0.152	-0.014
	(0.373)	(0.358)	(0.011)	(0.372)	(0.359)	(0.013)
Poor	0.184	0.174	-0.010	0.176	0.175	-0.001
	(0.387)	(0.379)	(0.012)	(0.381)	(0.380)	(0.014)
Middle	0.181	0.195	0.013	0.196	0.188	-0.008
	(0.385)	(0.396)	(0.012)	(0.397)	(0.391)	(0.014)
Rich	0.215	0.214	-0.001	0.205	0.213	0.008
	(0.411)	(0.410)	(0.012)	(0.404)	(0.409)	(0.014)
Richest	0.253	0.266	0.013	0.257	0.272	0.015
	(0.435)	(0.442)	(0.013)	(0.437)	(0.445)	(0.015)
Ownership of Dwelling Unit						
No	0.032	0.047	0.014***	0.125	0.093	-0.032***
	(0.176)	(0.211)	(0.004)	(0.331)	(0.290)	(0.010)
Yes	0.968	0.953	-0.014***	0.875	0.907	0.032***
	(0.176)	(0.211)	(0.004)	(0.331)	(0.290)	(0.010)
Social Group						
Scheduled Tribe	0.017	0.030	0.013***	0.281	0.299	0.017
	(0.128)	(0.170)	(0.004)	(0.450)	(0.458)	(0.017)
Scheduled Caste	0.191	0.250	0.059***	0.145	0.132	-0.014
	(0.393)	(0.433)	(0.012)	(0.353)	(0.338)	(0.012)
Other Backward Class	0.602	0.561	-0.040***	0.431	0.448	0.018
	(0.490)	(0.496)	(0.015)	(0.495)	(0.497)	(0.017)
Other Groups	0.190	0.157	-0.033***	0.143	0.121	-0.022*
	(0.392)	(0.364)	(0.011)	(0.350)	(0.326)	(0.012)
Missing/Not Reported	0.001	0.001	0.001	0.000	0.000	0.000*
	(0.027)	(0.037)	(0.001)	(0.000)	(0.015)	(0.000)
Religion						
Hindu	0.860	0.859	-0.001	0.741	0.741	0.001
	(0.347)	(0.348)	(0.010)	(0.438)	(0.438)	(0.016)
Muslim	0.137	0.140	0.003	0.154	0.124	-0.031**
	(0.343)	(0.347)	(0.010)	(0.361)	(0.329)	(0.012)
Others	0.004	0.001	-0.002	0.105	0.135	0.030**
	(0.062)	(0.037)	(0.002)	(0.306)	(0.342)	(0.012)
Place of Residence						
Rural	0.900	0.903	0.003	0.772	0.780	0.007
	(0.300)	(0.296)	(0.006)	(0.419)	(0.415)	(0.013)
Urban	0.100	0.097	-0.003	0.228	0.220	-0.007
	(0.300)	(0.296)	(0.006)	(0.419)	(0.415)	(0.013)
Observations	4,570	17,253		2,730	6,332	

Notes: Columns (1) and (2) report the mean and standard deviation for Bihar (treatment state) in the pre-period (2011–12) and post-period (2023–24), respectively. Similarly, columns (4) and (5) report the mean and standard deviation for Jharkhand (control state) in the pre- and post-periods. Columns (3) and (6) present the differences in means between the pre- and post-periods for each state, with standard errors reported in parentheses. Other religions include Christianity, Sikhism, Buddhism, Jainism, Judaism, Zoroastrianism, no religion reported, any other religions, and missing values. *, **, and*** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 2: Balance Of The Covariates: Weighted and Unweighted Samples

Variables	Unmatched				Matched			
	Mean		Bias (%)	t-test	Mean		Bias (%)	t-test
	Treated	Control			Treated	Control		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Household Head Characteristics								
Age of Household Head (in years)	45.486	45.278	1.6	0.980	45.476	45.417	0.4	0.220
Sex of Household Head								
Male	0.920	0.900	7.0***	4.210	0.920	0.919	0.6	0.280
Female	0.080	0.100	-7.0***	-4.210	0.080	0.082	-0.6	-0.280
Education								
Not Literate	0.313	0.319	-1.4	-0.880	0.313	0.321	-1.8	-0.850
Literate without Formal Schooling	0.008	0.044	-22.5***	-11.560	0.008	0.009	-0.5	-0.440
Literate but Below Primary	0.101	0.067	12.5***	8.370	0.101	0.092	3.0	1.330
Primary School	0.073	0.111	-13.2***	-7.750	0.073	0.076	-1.0	-0.510
Middle School	0.115	0.122	-2.2	-1.350	0.115	0.117	-0.8	-0.380
Secondary School	0.165	0.135	8.3***	5.350	0.165	0.162	0.9	0.420
Higher Secondary School	0.102	0.087	5.2***	3.320	0.102	0.099	0.9	0.430
Diploma/Certificate Course	0.005	0.007	-1.9	-1.150	0.005	0.005	-0.2	-0.090
Graduate Course	0.099	0.094	1.7	1.050	0.099	0.099	0.0	0.010
Post Graduate and Above	0.019	0.015	3.5**	2.280	0.019	0.019	0.3	0.120
Household Characteristics								
Household Size	5.239	4.852	16.7***	10.910	5.233	5.149	3.6*	1.660
Monthly Per-Capita Expenditure Quintiles								
Poorest	0.160	0.163	-0.7	-0.450	0.160	0.162	-0.7	-0.310
Poor	0.156	0.176	-5.2***	-3.180	0.156	0.161	-1.2	-0.580
Middle	0.144	0.190	-12.3***	-7.400	0.144	0.148	-0.8	-0.420
Rich	0.215	0.208	1.8	1.100	0.215	0.215	-0.1	-0.050
Richest	0.324	0.264	13.3***	8.510	0.324	0.314	2.3	1.070
Ownership of Dwelling Unit								
No	0.060	0.091	-11.7***	-6.860	0.060	0.063	-1.2	-0.650
Yes	0.940	0.909	11.7***	6.860	0.940	0.937	1.2	0.650
Social Group								
Scheduled Tribe	0.013	0.105	-39.6***	-19.960	0.013	0.017	-1.6	-1.480
Scheduled Caste	0.154	0.201	-12.3***	-7.430	0.154	0.160	-1.6	-0.780
Other Backward Class	0.594	0.531	12.7***	7.870	0.594	0.598	-0.8	-0.380
Other Groups	0.238	0.162	19.0***	12.530	0.238	0.224	3.4	1.550
Missing/Not Reported	0.001	0.001	0.0	0.000	0.001	0.001	-0.1	-0.060
Religion								
Hindu	0.853	0.824	7.9***	4.800	0.853	0.847	1.5	0.760
Muslim	0.144	0.138	1.9	1.220	0.144	0.148	-0.9	-0.420
Others	0.002	0.038	-25.6***	-12.550	0.002	0.005	-1.8**	-2.020
Place of Residence								
Rural	0.723	0.733	-2.2	-1.410	0.723	0.722	0.1	0.040
Urban	0.277	0.267	2.2	1.410	0.277	0.278	-0.1	-0.040
Rubin's B			61.5*				8.5	
Rubin's R			0.350*				0.920	
Observations			30875				30873	

Note: Columns (1) and (2) report mean for the Bihar (treated) and Jharkhand (control) group in the unweighted sample, while columns (5) and (6) report the corresponding means in the weighted sample. Columns (3) and (8) present the standardized bias (in percent) between the treated and control groups before and after weighting the sample, respectively. Columns (4) and (9) report the t-statistics for the differences in mean between the treated and control groups before and after weighting. The Rubin's B and Rubin's R statistics indicate that adequate covariate balance is achieved after weighting. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 3: Pre-trends analysis

	LPG	
	(1)	(2)
Bihar*Post	0.009	0.113
	(0.015)	(0.015)
Post	0.029***	0.25*
	(0.014)	(0.014)
Observations	15,754	15,753
District-fixed effects	Yes	Yes
Household Head's Characteristics	Yes	Yes
Household Characteristics	Yes	Yes
R-squared	0.406	0.450

Notes: This table reports estimates of pre-trends in household LPG adoption using a difference-in-differences (DID) model and a kernel propensity score matching difference-in-differences model (PSM–DID) in columns (1) and (2), respectively. The analysis uses data from the Household Consumer Expenditure Surveys (HCES) 2004–05 and 2011–12. Bihar constitutes the treatment group, while Jharkhand serves as the control group. Households surveyed in 2011–12 are classified as the post-period, and those surveyed in 2004–05 are classified as the pre-period. All specifications include a comprehensive set of household and household-head characteristics. Household-level covariates include household size, social group, monthly per capita expenditure quintiles, religion, ownership of the dwelling unit, and area of residence. Household head characteristics include age, sex, and education. All specifications also include district fixed effects, and standard errors are clustered at the district level. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 4: DID and DID-PSM Analysis : Effect of alcohol prohibition on household LPG adoption.

	LPG			
	DID			PSM-DID
	(1)	(2)	(3)	(4)
Bihar*Post	0.144***	0.094***	0.159***	0.128***
	(0.034)	(0.030)	(0.034)	(0.037)
Post	0.164***	0.139***	0.141***	0.179***
	(0.024)	(0.022)	(0.023)	(0.027)
Observations	30,875	30,875	30,875	30,873
District-fixed effects	Yes	Yes	Yes	Yes
Household Head's Characteristics	No	Yes	Yes	Yes
Household Characteristics	No	No	Yes	Yes
R-squared	0.180	0.278	0.406	0.450

Notes: The analysis uses data from the Household Consumer Expenditure Surveys (HCES) 2011–12 and 2023–24. Columns (1) - (3) present the findings from a difference-in-differences (DID) model, whereas column (4) reports the results from the and a kernel propensity score matching difference-in-differences model (PSM–DID) estimation. Column (1) includes district fixed effects. Household head characteristics are included in column (2), followed by household-level attributes in column (3). In line with column (3), we include all the controls along with the district fixed effects in column (4). Bihar constitutes the treatment group, while Jharkhand serves as the control group. Households surveyed in 2023–24 are classified as the post-period, and those surveyed in 2011–12 are classified as the pre-period. Household-level covariates include household size, social group, monthly per capita expenditure quintiles, religion, ownership of the dwelling unit, and area of residence. Household head characteristics include age, sex, and education. Standard errors are clustered at the district level. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 5: Robustness analysis: Effect of alcohol prohibition on household LPG adoption.

	LPG			
	(1)	(2)	(3)	(4)
Bihar*Post	0.126***	0.149***	0.085***	0.132***
	(0.039)	(0.043)	(0.029)	(0.038)
Post	0.193***	0.154***	0.212***	0.173***
	(0.039)	(0.018)	(0.013)	(0.028)
Observations	26,874	14,245	60,398	39,328
District-fixed effects	Yes	Yes	Yes	Yes
Household Head Characteristics	Yes	Yes	Yes	Yes
Household Characteristics	Yes	Yes	Yes	Yes
Household Characteristics	0.436	0.481	0.467	0.451

Notes: Column (1) present the findings from a coarsened exact matching difference-in-differences (CEM-DID) model, whereas columns (2) to (4) report the results from the kernel propensity score matching difference-in-differences (PSM–DID) estimation. All the districts of Bihar constitutes the treatment group, while all the districts of Jharkhand serve as the control group in columns (1) and (4). Column (2) includes interior districts of Bihar and excludes districts in Jharkhand which share border with Bihar. Column (3) employs an alternative control group comprising the surveyed districts of Assam, Chhattisgarh, Madhya Pradesh, and Sikkim. Households surveyed in 2023–24 are classified as the post-period, and those surveyed in 2011–12 are classified as the pre-period in columns (1) to (3). Column (4) implements an alternative timing specification in which the pre-treatment period includes the 2004–05 as well as 2011–12 rounds of HCES, and the post-treatment period corresponds to the HCES 2023–24. All specifications include a comprehensive set of household-head and household characteristics along with district fixed effects. Household-level covariates include household size, social group, monthly per capita expenditure quintiles, religion, ownership of the dwelling unit, and area of residence. Household head characteristics include age, sex, and education. Standard errors are clustered at the district level. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 6: Sub-sample Analysis: Effect of alcohol prohibition on household LPG adoption.

	LPG											
	Age		Sex of Household Head		MPCE		Household Size		Social Group		Residence	
	Low	High	Male	Female	Poor	Non-poor	Low	High	Backward	Others	Rural	Urban
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Bihar*Post	0.120***	0.137***	0.120***	0.228***	0.120**	0.143***	0.141***	0.116***	0.112***	0.231***	0.135***	0.081
	(0.040)	(0.061)	(0.037)	(0.065)	(0.047)	(0.034)	(0.037)	(0.039)	(0.038)	(0.061)	(0.044)	(0.052)
Post	0.170***	0.187**	0.187***	0.089	0.212***	0.154***	0.157***	0.201***	0.171***	0.218***	0.183***	0.157***
	(0.026)	(0.313)	(0.026)	(0.061)	(0.038)	(0.022)	(0.024)	(0.030)	(0.029)	(0.061)	(0.034)	(0.033)
Observations	14,891	15,982	27,882	2,991	14,868	16,005	13,942	16,931	25,493	5,380	22,576	8,297
District-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household Characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household Head Characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.442	0.472	0.451	0.501	0.473	0.384	0.434	0.489	0.412	0.532	0.317	0.451

Notes: Estimation using a kernel propensity score matching difference-in-differences (PSM–DID). Columns (1) and (2) present results for households with below-median ($<$ 45 years) and above-median ($\geq$ 45 years) age of the household head, respectively. Column (3) includes households headed by males, while column (4) includes households headed by females. Columns (5) and (6) report estimates for households in the bottom two quintiles (poor) and top three quintiles (non-poor) of monthly per capita expenditure (MPCE), respectively. Columns (7) and (8) present results for households with fewer than five members and five or more members, respectively. Column (9) includes households belonging to Scheduled Castes (SC), Scheduled Tribes (ST), or Other Backward Classes (OBC), while column (10) covers other social groups. Columns (11) and (12) report results for rural and urban households, respectively. Bihar constitutes the treatment group, while Jharkhand serves as the control group. Households surveyed in 2023–24 are classified as the post-period, and those surveyed in 2011–12 are classified as the pre-period. All specifications include a comprehensive set of household and household-head characteristics along with the district fixed effects. Standard errors are clustered at the district level. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 7: Possible mechanism analysis

	Alcohol Expenditure	LPG Expenditure	LPG	
			High Alcohol Reduction	Low Alcohol Reduction
	(1)	(2)	(3)	(4)
Bihar*Post	-153.888***	150.084***	0.200***	0.065
	(30.178)	(20.475)	(0.038)	-0.048
Post	130.099***	47.603***	0.181***	0.178***
	(29.868)	(16.976)	(0.028)	(0.025)
Observations	27,196	30,879	19,856	20,068
District-fixed effects	Yes	Yes	Yes	Yes
Household Head Characteristics	Yes	Yes	Yes	Yes
Household Characteristics	Yes	Yes	Yes	Yes
R-squared	0.105	0.457	0.437	0.479

Notes: Estimation are obtained using kernel propensity score matching difference-in-differences (PSM–DID) estimation. The outcome variables in columns (1) and (2) are alcohol expenditure and LPG expenditure, measured in real terms, respectively. LPG adoption is the outcome variable in columns (3) and (4). In columns (1) and (2), all surveyed districts of Bihar constitute the treatment group. In column (3), the treatment group includes districts of Bihar that report a 100 percent reduction in alcohol expenditure between 2011–12 and 2023–24, while column (4) includes districts with less than a 100 percent reduction over the same period. Across all specifications, districts of Jharkhand serve as the control group. Households surveyed in 2023–24 are classified as the post-period, while those surveyed in 2011–12 are classified as the pre-period. All specifications include a comprehensive set of household-head and household characteristics, district fixed effects, and standard errors clustered at the district level. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Appendix

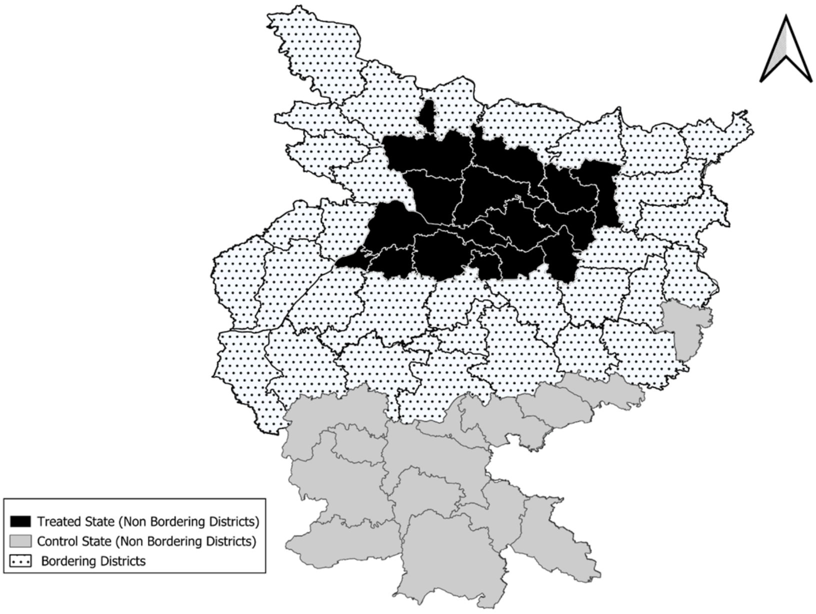

Figure A1: Non-Bordering Districts of Bihar and West Jharkhand